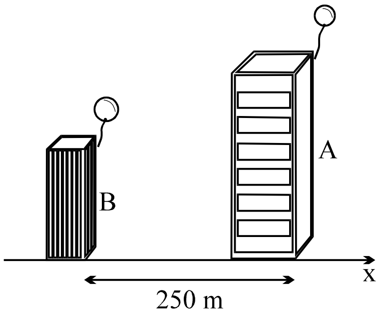
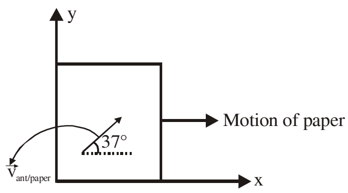
PHYSICS GR # 1 **KINEMATICS**

1. Two balloons are simultaneously released from two buildings A and B. Balloon from A rises with constant velocity 10 ms^{-1}, while the other one rises with constant velocity of 20 ms^{-1}. Due to wind the balloons gather horizontal velocity $V_x = 0.5$ y, where 'y' is the height from the point of release. The buildings are at a distance of 250 m & after some time 't' the balloons collide.



(A) t = 5 sec.
(B) difference in height of buildings is 100 m
(C) difference in height of buildings is 500 m
(D) t = 10 sec

2. An ant is scampering on a paper with velocity 10 m/s. Now you begin to pull the paper with velocity 10 m/s along x-axis as shown in figure. Coordinate system has origin fixed to ground as shown in figure. The initially position of ant is (0, 0). Select the correct alternative(s)



(A) Velocity of ant in ground frame is $\left(18\hat{i} + 6\hat{j}\right)$ m/s

(B) Position vector of ant with respect to ground after 3 sec. is $\left(54\hat{i} + 18\hat{j}\right)$ m.

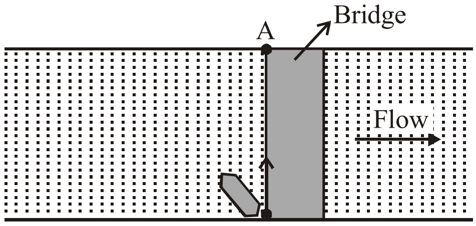
(C) In ground frame, velocity vector of ant is at an angle $\theta < 37°$

(D) In ground frame velocity vector of ant is at an angle $\theta > 37°$.

3. A ball is projected on level ground such that its range is 20 m. An observer moving parallel to the plane of projection observes a range of 10 m relative to himself. If the ball has an initial velocity of $10\sqrt{2}$ m/s, what can be the velocity of the observer.

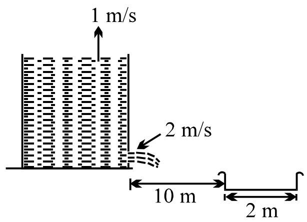
(A) 10 m/s
(B) 5 m/s
(C) 20 m/s
(D) 15 m/s

4. A cyclist moves across a bridge and a boat is rowed in a river as shown in figure. Both the cyclist and boat start at same instant from same point. Both reach point A across the river simultaneously. A person on a floating raft in river sees both of them moving 127° with flow and crossing 40 m wide river in 10 second. Mark the correct statement(s) :

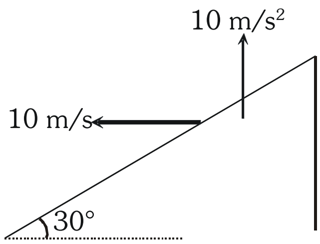


(A) River flow is 4 m/s
(B) Speed of cyclist is 4 m/s
(C) Speed of boat relative to water is 5 m/s
(D) Speed of raft is 3 m/s

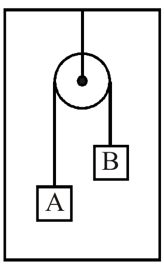
5. A tank filled with water moves vertically with uniform velocity 1 m/s. There is a hole in its wall near bottom from which water comes out with constant relative velocity of 2 m/s in horizontal direction. If there is a tray which is 2m wide kept at 10 m from initial position of tank on floor find for what duration will the water be falling in the tray. ($g = 10\ m/s^2$)



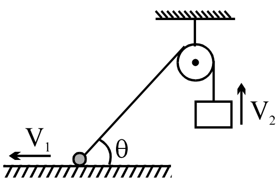
6. A particle is projected horizontally with velocity 10 m/s from an inclined plane. Incline plane starts moving with acceleration $10\ m/s^2$ vertically upward as shown. The time (in second) after which particle will land on the plane is given by $\frac{1}{\sqrt{n}}s$. Find the value of n. ($g = 10\ m/s^2$)



7. An atwood machine is setup in an elevator moving upward at 5 m/s and slowing down at $2\ m/s^2$. The initial velocity of block B is 2 m/s upward and the acceleration of block A is $3\ m/s^2$ downwards. Find the time (in sec.) at which block B will return to its initial position. Assume the string remains taut and the acceleration of the elevator does not change during the required time interval.

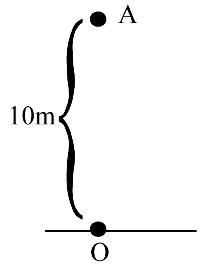


8. In the figure, a ball and a block are joined together with an inextensible string. The ball can slide on a smooth horizontal surface. If v_1 and v_2 are the respective speeds of the ball and the block, then determine the constraint relation between the two.



9. Projectile 1 is fired with velocity 20 m/s, at an angle 37° with the positive x-axis, from the origin of x-y coordinates. X-axis is horizontal while the Y-axis is vertically up. Another projectile is fired from the point (20 m, 0) with an initial velocity 30 m/s, at an angle 127° with positive x-axis. Both projectiles are fired simultaneously. Find the locus of 2 as seen by 1 and the minimum distance between the two during their flights.

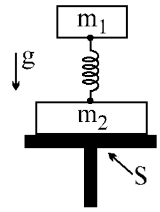
10. A helicopter is moving vertically upwards with a velocity 5 m/s. When the helicopter is at a height 10m from ground. A stone is thrown with a velocity $(3\hat{i} + 4\hat{j})$ m/s from the helicopter w.r.t. the man in it. Considering the point on ground vertically below the helicopter as the origin of coordinates, and the ground below as xy plane, find the coordinates of the point where the stone will fall. Its distance from origin & the distance between the helicopter & the stone, at the instant the stone strikes the ground, assuming helicopter moves upwards with constant velocity.



GR # KINEMATICS			ANSWER KEY
1. Ans. (B, D)	**2. Ans. (A, B, C)**	**3. Ans. (B, D)**	**4. Ans. (B,C,D)**
5. Ans. 55 sec			
6. Ans. 3	**7. Ans.** 4 sec.	**8. Ans.** $v_2 = v_1 \cos\theta$	
9. Ans. straight line, $24/\sqrt{13}$ m			
10. Ans. (6,8,0), 10 m, $10\sqrt{5}$ m			

NEWTON'S LAW

1. The system of two weights with masses m_1 and m_2 are connected with weightless spring as shown. The system is resting on the support S. The support S is quickly removed. The accelerations of each of the weights right after the support S is removed are.



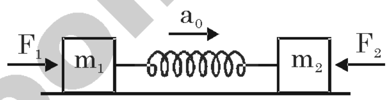
(A) $a_1 = 0$, $a_2 = \frac{(m_1+m_2)g}{m_2}$

(B) $a_1 = 0$, $a_2 = \frac{(m_1+m_2)g}{m_1}$

(C) $a_1 = \frac{(m_1+m_2)g}{m_1}$, $a_2 = 0$

(D) $a_1 = 0$, $a_2 = 0$

2. Two blocks m_1 and m_2 are connected with a compressed spring and placed on a smooth horizontal surface as shown in figure. Force constant of spring is k. Under the influence of forces F_1 and F_2, at an instant blocks move with common acceleration a_0. At that instant force F_2 is suddenly withdrawn. Mark **CORRECT** option.



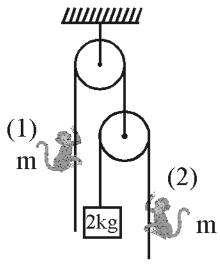
(A) Instantaneous acceleration of m_1 is $a_0 - \frac{F_1}{m_1}$

(B) Instantaneous acceleration of m_2 is $a_2 = a_0 + \frac{F_2}{m_2}$

(C) Instantaneous acceleration of m_1 is $a_1 = a_0$

(D) Spring force is $F_{spring} = m_2a_0 + F_2$

3. Two monkeys (1) & (2) of same mass m = 1kg are hanging on the strings such that block of mass 2 kg remains at rest and it is given that monkey (2) is just holding the string. Then which of the following statement(s) are **CORRECT** ($g = 10\ m/s^2$):-



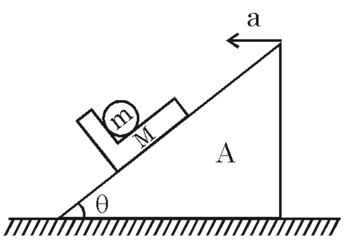
(A) Acceleration of monkey (2) is $10\ m/s^2$ upwards.

(B) Acceleration of monkey (1) is $30\ m/s^2$ upwards.

(C) Acceleration of monkey (1) with respect to his rope is $35\ m/s^2$ upwards.

(D) Acceleration of monkey (2) with respect to his rope is $50\ m/s^2$ upwards.

4. A ball of mass m is placed on a sledge of mass M. The sledge moves on an inclined plane A of angle of inclination θ. Inclined plane A is moving with constant horizontal acceleration 'a' towards left (Neglect friction everywhere)



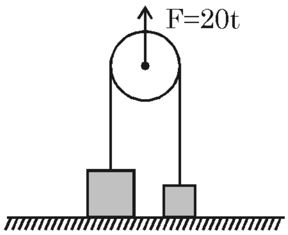
(A) Normal reaction force between m & M is $m(g\cos\theta + a\sin\theta)$

(B) Normal reaction force between A & M is $(M+m)(g\cos\theta + a\sin\theta)$

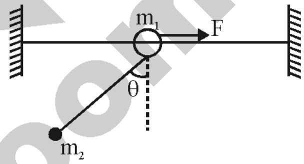
(C) $a_{M/A} = a_{m/A} = (g\sin\theta - a\cos\theta)$

(D) $a_M = a_m = \sin\theta\sqrt{g^2 + a^2}$

5. Two blocks A and B of mass 1 kg and 2kg respectively are connected by a string, passing over a light frictionless pulley. Both the blocks are resting on a horizontal floor and the pulley is held such that string remains just taut. At moment t=0, a force F=20t newton starts acting on the pulley along vertically upward direction, as in Fig. Calculate (a) velocity of A when B loses contact with the floor (b) height raised by the pulley upto that instant and (c) work done by the force F upto that instant.



6. A horizontal force F is applied on a ring of mass m_1 constrained to move on a horizontal smooth wire. The hanging mass m_2 is connected to ring with a massless rod and it maintains a constant angle with vertical. Mark **CORRECT** option :-



(A) Force on m_1 by wire is less than $(m_1 + m_2)g$

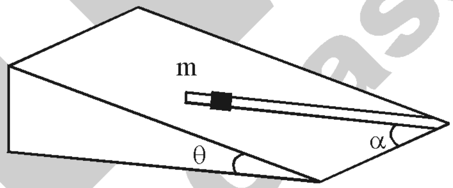
(B) Net force on m_2 is $\dfrac{m_2F}{m_1 + m_2}$

(C) Tension in rod is $m_2g \sec\theta$

(D) $F = (m_1 + m_2)\, g \tan\theta$

FRICTION

7. Figure shows a fixed wedge with a groove in it. A small block lies inside groove just filling it.



(A) If groove is smooth the acceleration of block along groove is $g \sin\theta \sin\alpha$

(B) If friction acts from side walls only the minimum coefficient of friction required to hold block stationary is $\tan\alpha$

(C) If friction acts on base of block only the minimum coefficient of friction required to hold block stationary is $\mu = \tan\theta$.

(D) If groove is smooth the acceleration of block along groove is $g \sin\theta \cos\alpha$.

Paragraph for question no. 8 and 9

Friction is a force that aids us daily, in fact so much so that we don't even pause to appreciate its importance. We would not be able to wear pants or jeans without friction. We would have to live like naked in the jungle. The shirt is supported at our shoulders. But if we stand up the weight of our jeans is to be supported by a vertical force. The surface of our waist and thighs can be approximated to be like curved surface of a vertical cylinder. The force of friction acting between this curved surface and jeans balances the weight of the jeans. To understand this mathematically, let us consider a vertical man whose waist is a rigid cylinder having a circumference of 90 cm. He wears a jeans of mass 500 gm using an elastic massless belt which can be assumed to be on elastic string of force constant 500N/m and circumference 85cm when not extended. The coefficient of friction between waist and jeans is 0.5.

8. What is the friction force acting between the man's waist and jeans?

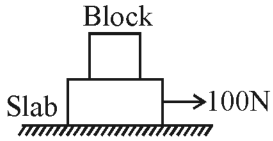
(A) 5N (B) 12.5 N (C) 7.5 N (D) 25 N

9. When the man stands in an elevator going up with a high acceleration, his jeans start sliding down. What can be the minimum acceleration of the elevator?

(A) 147 m/s^2 (B) 288 m/s^2 (C) 87 m/s^2 (D) 24 m/s^2

Paragraph for Questions 10 to 12

In the figure, a horizontal force of 100N is to be applied to a 10kg slab that is initially stationary on a frictionless surface. A 10kg block lies on the top of the slab, there is no information about friction and coefficient of friction between the block and the slab.



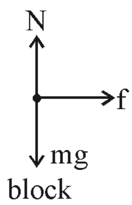
10. What can not be a possible value of the acceleration of the slab ?

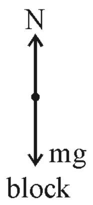
(A) 7 m/s^2 (B) 10 m/s^2 (C) 2 m/s^2 (D) 9 m/s^2

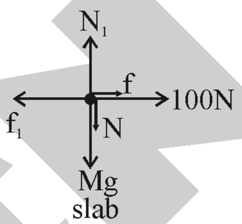
11. What can not be a possible value of the acceleration of the block ?

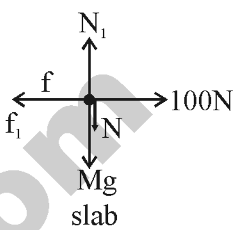
(A) 4 m/s^2 (B) 3 m/s^2 (C) 10 m/s^2 (D) zero

12. If the ground and the top surface of the slab both are rough, which of the following can not be a possible free body diagram ? f is friction between block and slab, N is normal between block and slab, f_1 is friction between slab and ground, N_1 is normal between slab and ground.

(A) 

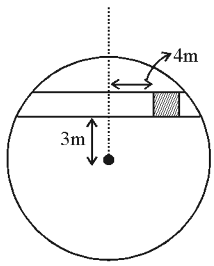
(B) 

(C) 

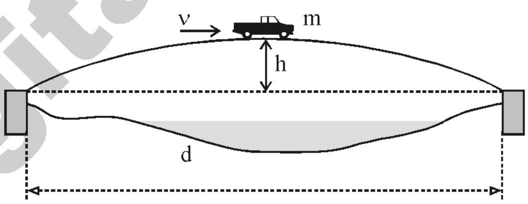
(D) 

CIRCULAR MOTION

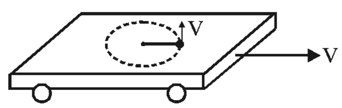
13. A small cubical block of mass 1 kg is placed inside a rough rectangular groove made in a circular rough table as shown in the figure. Coefficient of friction for all the rough surfaces is $\mu = 0.5$. The table starts rotating clockwise with angular acceleration 1 rad/sec^2 in a horizontal plane about its axis. Find the time (in sec) after which the block will start motion with respect to table. Assume the size of block slightly smaller then the width of groove.



14. There is a parabolic-shaped bridge across a river of width 100m. The highest point of bridge is 5m above the level of the banks. A car of mass 1000 kg is crossing the bridge at a constant speed of 20 ms^{-1}. Using the notation indicated in the figure, the force exerted on the bridge by the car when it is : at the highest point of the bridge is (1200x) N. Find x (Ignore air resistance and take g as 10 ms^{-2})



15. On a train moving along east with a constant speed v, a boy revolves a bob with string of length ℓ on smooth surface of a train, with equal constant speed v relative to train. Mark the correct option(s).



(A) Maximum speed of bob is 2 v in ground frame.

(B) Tension in string connecting bob is $\dfrac{4mv^2}{\ell}$ at an instant.

(C) Tension in string is $\dfrac{mv^2}{\ell}$ at all the moments.

(D) Minimum speed of bob is zero in ground frame.

16. A car is moving with constant speed on a rough banked road.

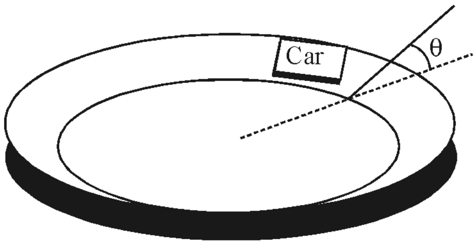
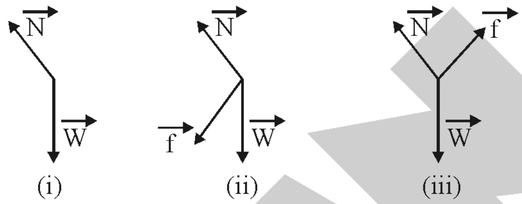


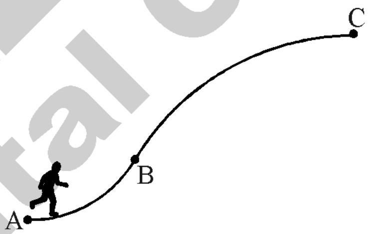
Figure (i), (ii) and (iii) show the free body diagram of car A, B & C respectively:-



(A) Car A has more speed than car C
(B) Car A has less speed than car B
(C) FBD for car A is not possible
(D) If $\mu > \tan\theta$ the FBD for car C is not possible

Paragraph for question nos. 17 to 19

An athelete of mass 80 kg is running on a rough track whose cross-section is shown below. The lower part AB of track is a cylindrical valley of radius 100 m and upper part BC is a cylindrical hill of radius 200 m. The two parts join such that there is no sudden change of slope of the track. The speed of the athelete on the track is always 5m/s. A is the lowest point of the valley, B is the point at which valley ends and hill starts and C is the top of the hill. While moving from A to C, the athelete travels a horizontal distance of 150 m.

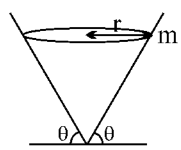


17. Find the time taken by the athelete in going from A to C
(A) 5π sec (B) 10π sec (C) 15π sec (D) 20π sec

18. The correct order of normal force experienced by athelete is :
(A) $N_A > N_B > N_C$ (B) $N_A < N_B < N_C$ (C) $N_A > N_C > N_B$ (D) $N_C > N_A > N_B$

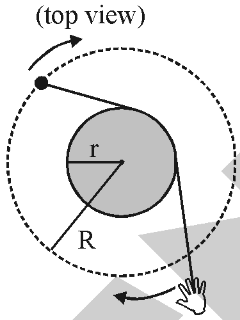
19. The magnitude of friction force experienced by the athelete is :
(A) zero throughout
(B) decreases continuously during motion from A to C
(C) increases continuously from A to C
(D) attains a maximum value at B

20. A ball of mass 'm' is rotating in a circle of radius 'r' with speed v inside a smooth cone as shown in figure. Let N be the normal reaction on the ball by the cone, then choose the correct option.



(A) $N = mg\cos\theta$
(B) $g\sin\theta = \dfrac{v^2}{r}\cos\theta$
(C) $N\sin\theta - \dfrac{mv^2}{r} = 0$
(D) none of these

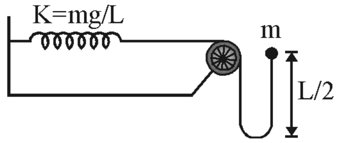
21. A mass m = 1kg, which is free to move on a horizontal frictionless surface, is attached to one end of a massless string that wraps partially around a frictionless vertical pole of radius r (see the top view in figure). You hold on to the other end of the string. At t = 0, the mass has speed v_0 in the tangential direction along the dotted circle of radius R shown. Your task is to pull on the string so that the mass keeps moving along the circular path of radius R. If at any instant 't' force applied by hand on string is $f_0 = 2N$ then find out centripetal acceleration (in m/s^2) of mass. (Given : $R = \frac{2r}{\sqrt{3}}$)



ANSWER KEY			NLM+CIRCULAR MOTION
1. Ans. (A)	**2. Ans. (B,C,D)**	**3. Ans. (A,B,C)**	**4. Ans. (A,B,C,D)**
5. Ans. 5 m/s, 5/6 m, 175/6 J	**6. Ans. (B,C,D)**	**7. Ans. (A,B)**	**8. Ans. (A)**
9. Ans. (A)	**10. Ans. (C)**	**11. Ans. (C)**	**12. Ans. (C)**
13. Ans. 2	**14. Ans. 7**	**15. Ans. (ACD)**	**16. Ans. (A, B)**
17. Ans. (B)	**18. Ans. (C)**	**19. Ans. (D)**	**20. Ans. (B, C)**
21. Ans. 1			

WORK POWER ENERGY

1. In the given figure a ball of mass m is connected to an elastic spring of force constant K = mg/L through an inextensible string as shown. Now the ball is released from rest.



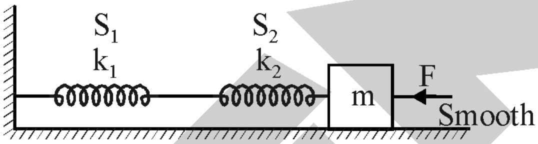
(A) The maximum velocity of mass m during fall is $\sqrt{3gL}$

(B) The maximum velocity of mass m during fall is $\sqrt{2gL}$

(C) The maximum potential energy stored in the spring during the fall is mgL [2 + $\sqrt{3}$]

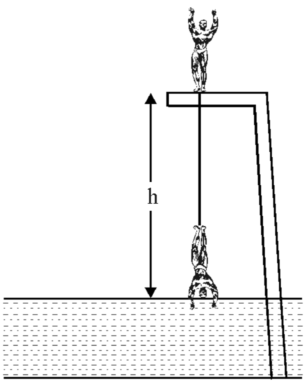
(D) The maximum potential energy stored in the spring during the fall is mgL [3 + $\sqrt{2}$]

2. Initially spring are in natural length. An application of external varying force F causes the block to move slowly distance x towards wall on smooth floor :

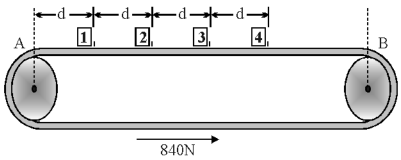


	Column-I		**Column-II**
(A)	Work done by S_2 on block	(P)	zero
(B)	Work done by S_2 on S_1	(Q)	$-\frac{1}{2}\left(\frac{k_1k_2}{k_1+k_2}\right)x^2$
(C)	Work done by F on block	(R)	$\frac{1}{2}\left(\frac{k_1k_2}{k_1+k_2}\right)x^2$
(D)	Work done by S_1 on wall	(S)	$\frac{1}{2}\frac{k_1k_2^2x^2}{(k_1+k_2)^2}$

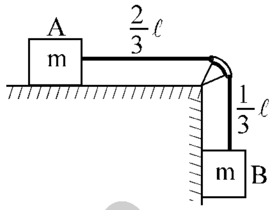
3. A man of height h_0 = 2m is bungee jumping from a platform situated at a height h = 25m above a lake. One end of an elastic rope is attached to his foot and the other end is fixed to the platform. He starts falling from rest in vertical position. The length and elastic properties of the rope are chosen so that his speed will have been reduced to zero at instant when his head reaches the surface of water. Ultimately the jumper is hanging from the rope with his head 8m above the water. Find the maximum acceleration acheived during the jump in m/s^2 (take g = 10 m/s^2)



4. Guide angles have been attached to a conveyor belt at equal distances d = 200 mm. Four packages, each having a mass of 4 kg, are placed as shown on the belt, which is at rest. If a constant force of magnitude 840 N is applied to the belt, determine the velocity of package 2 as it falls off the belt at point A. Assume that the mass of the belt and pulleys is small compared with the mass of the packages. Assume that the radius of pulley is negligible in comparison with d.



5. Two objects A and B of mass m are connected with a uniform rope of length $l = 0.3$ m and mass m as shown in the figure. The rope can slide in a tube which forms a quarter of a circle, and which is fixed to the edge of the table. Initially 1/3 of the rope hangs vertically. Friction is negligible. If the system is released from rest, and B descends a distance of $l/3$, what is the speed (in m/s) of B?

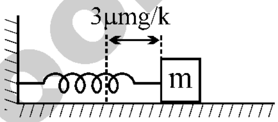


6. A spring block system is placed on a rough horizontal surface having coefficient of friction μ. Spring is given initial elongation $3\mu mg/k$ (where m = mass of block and k = spring constant) and the block is released from rest. For the subsequent motion find

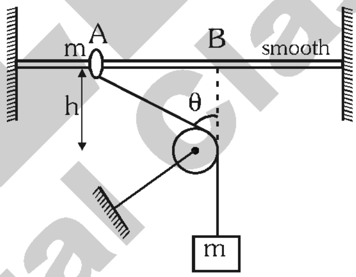
(a) initial acceleration of block

(b) maximum compression in spring

(c) maximum speed of the block



7. A ring of mass m slide from rest on the smooth rod as shown in the figure, due to the block of mass m. Pully and string are massless. Then find the speed of ring when the string become straight. (Given $\theta = 60°$)



(A) $4\sqrt{gh}$ (B) $\sqrt{2gh}$ (C) $2\sqrt{2gh}$ (D) $8\sqrt{gh}$

POTENTIAL ENERGY

Paragraph for question nos. 8 to 10

The potential energy at a point, relative to the reference point is defined as the negative of work done by the conservative force as the object moves from the reference point to the point considered. The value of potential energy at the reference point itself can be set equal to zero because we are always concerned only with differences of potential energy between two points and the associated change of kinetic energy. A particle A is fixed at origin of a fixed coordinate system. Another particle B which is free to move experiences an force $\vec{F} = \left(-\frac{2\alpha}{r^3} + \frac{\beta}{r^2}\right)\hat{r}$ due to particle A where $\vec{r}$ is the position vector of particle B relative to A. It is given that the force is conservative in nature and potential energy at infinity is zero. If B has to be removed from the influence of A, energy has to be supplied for such a process. The ionization energy E_0 is work that has to be done by an external agent to move the particle from a distance r_0 to infinity slowly. Here r_0 is the equilibrium position of the particle.

8. What is potential energy function of particle as function of r.

(A) $\frac{\alpha}{r^2}-\frac{\beta}{r}$ (B) $-\frac{\alpha}{r^2}+\frac{\beta}{r}$ (C) $-\frac{\alpha}{r^2}-\frac{\beta}{r}$ (D) $\frac{\alpha}{r^2}+\frac{\beta}{r}$

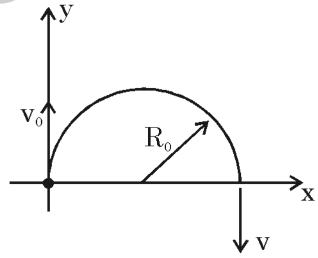
9. Find the ionization energy E_0 of the particle B.

(A) $\frac{\beta^2}{2\alpha}$ (B) $\frac{2\beta^2}{\alpha}$ (C) $\frac{\beta^2}{4\alpha}$ (D) $\frac{\beta^2}{\alpha}$

10. If particle B is transfered slowly from point $P_1\left(\sqrt{2}\,r_0, \sqrt{2}\,r_0\right)$ to point $P_2\left(\frac{r_0}{\sqrt{2}}, \frac{r_0}{\sqrt{2}}\right)$ in the xy-plane by an external agent, calculate work required to be done by it in the process.

(A) $\frac{9\beta^2}{64\alpha}$ (B) $\frac{\beta^2}{16\alpha}$ (C) $\frac{\beta^2}{64\alpha}$ (D) None of these

11. A bead slides on a fixed frictionless wire bent into a horizontal semicircle of radius R_0 as shown in figure. In addition to any normal forces exerted by the wire, the bead is subjected to an external force that points directly away from origin and depends on distance r from the origin according to the formula $\vec{F}=F_0\left(\frac{r}{R_0}\right)^2\hat{r}$:-



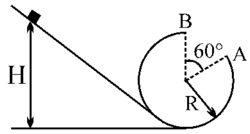
(A) Given external force is a central force.
(B) Given external force is a conservative force.
(C) Normal reaction by wire as bead leaves the wire is $\frac{16F_0}{3}$.
(D) Speed of bead as it leaves the wire is $\sqrt{v_0^2+\frac{16F_0R_0}{3m}}$.

12. A particle moves from the origin to the point x = 3m, y = 6m along the curve $y = ax^2 - bx$ where $a = 2m^{-1}$ and b = 4. It is subject to a force $\overline{F} = cxy\,\hat{i} + d\,\hat{j}$ where c = 10 N/m² and d = 15 N. Calculate the workdone (in J) by force.

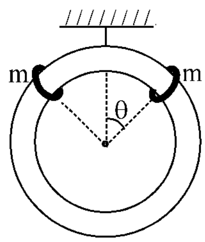
13. The combined frictional and air resistance on a bicyclist has the force F = aV, where V is his velocity and a = 4 newton-sec/m. At maximum effort, the cyclist can generate 400 watts propulsive power. What is his maximum speed (in m/s) on level ground with no wind ?

MOTION IN A VERTICAL CIRCLE

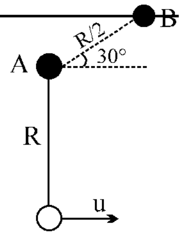
14. A small particle slides from height H = 45 cm as shown and then loops inside the vertical loop of radius R from where a section of angle θ = 60° has been removed. Find R (in cm) such that after losing contact at A and flying through the air, the particle will reach at the point B. Neglect friction everywhere.



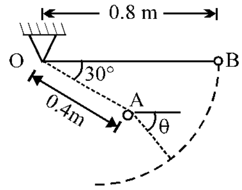
15. A massless ring hangs from a thread and two beads of mass m slide on it without friction. The beads are released simultaneously from the top of the ring and slide down opposite sides. If the angle from vertical at which tension in the thread becomes zero for the first time is θ. Find secθ.



16. A ball is hanging vertically by a string of length R form peg A. There is another peg B at a distance R/2 at an angle of 30° with the horizontal as shown in the figure. Find the minimum horizontal velocity given at the lowest position so that the ball strikes the peg A. Assume string as always taut.



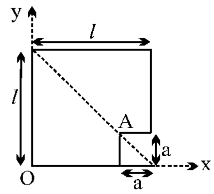
17. A small sphere B of mass m = 1 kg is released from rest in the position shown and swings freely in a vertical plane, first about O and then about the peg A after the cord comes in contact with the peg. Determine the tension in the cord.
(a) just before the sphere comes in contact with the peg,
(b) just after it comes in contact with the peg.



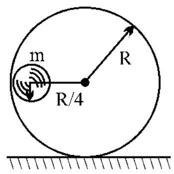
ANSWER KEY	WEP+POTENTIAL ENERGY+MOTION IN A VERTICAL CIRCLE		
1. Ans. (A, C)	**2. Ans. (A)-Q (B)-S (C)-R (D)-P**		**3. Ans. 40**
4. Ans. 7 m/s	**5. Ans. 1**	**6. Ans. (a) 2μg, (b) μmg/k, (c) 2μg$\sqrt{\frac{m}{k}}$**	
7. Ans. (B)	**8. Ans. (B)**	**9. Ans. (C)**	**10. Ans. (B)**
11. Ans. (A,B,D)	**12. Ans. 135 J**	**13. Ans. 10**	**14. Ans. 20**
15. Ans. 1.50	**16. Ans.** $2\sqrt{gR}$	**17. Ans. (a) 15 N, (b) 25 N**	

CENTRE OF MASS

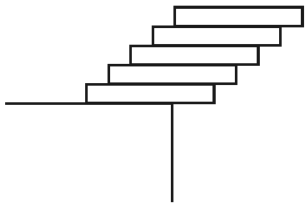
1. The figure shows a square metal plate of side l from which a square plate of side a has been cut as shown in the figure. Find the ratio (a/l) so that the centre of mass of the remaining L-shaped plate coincides with the point A.



2. Inside a smooth spherical shell of the radius R a ball of the same mass is released from the shown position (Fig.) Find the distance travelled by the shell on the horizontal floor when the ball comes to the lowest point of the shell.



3. Some identical bricks are placed on top of each other at the edge of table as shown. It is possible to slide them horizontally on each other in such a way that the projection of the top most one is completely outside the table. What is the least number of bricks needed?

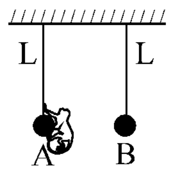


4. A plate in the form of a semicircle of radius R has a mass per unit area of kr where k is a constant and r is the distance from the centre of the straight edge. By dividing the plate into semicircular rings find the distance of the centre of mass of the plate from the centre of its straight edge.

(A) $\frac{4R}{3\pi}$ (B) $\frac{2R}{\pi}$ (C) $\frac{3R}{2\pi}$ (D) $\frac{3R}{4\pi}$

MOMENTUM CONSERVATION

5. A monkey jumps from ball A onto ball B which are suspended from inextensible light strings each of length L. The mass of each ball & monkey is same. What should be the minimum relative velocity of jump w.r.t. ball, if both the balls manage to complete the circle?



(A) $\sqrt{5gL}$ (B) $\sqrt{20gL}$ (C) $4\sqrt{5gL}$ (D) none

6. A man of mass m on an initially stationary boat gets off of the boat by leaping to the left in an exactly horizontal direction. Immediately after the leap, the boat of mass M, is observed to be moving to the right at speed v.

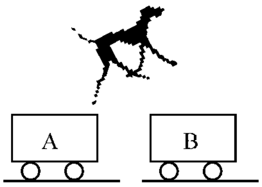
(A) Work done by man on boat is $\frac{1}{2}(m)v^2$.

(B) Increase in the mechanical energy of system of man and boat is $\frac{1}{2}\left(\frac{M^2}{m}+M\right)v^2$.

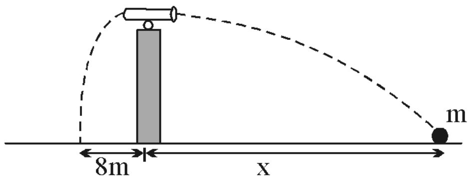
(C) Velocity of centre of mass of system is v.

(D) Increase in kinetic energy of man is $\frac{1}{2}\frac{M^2}{m}v^2$.

7. In a circus act, a 4kg dog is trained to jump from B cart to A and then immediately back to the B cart. The carts each have a mass of 20kg and they are initially at rest. In both cases the dog jumps at 6m/s relative to the cart. If the cart moves along the same line with negligible friction calculate the final velocity of each cart with respect to the floor.

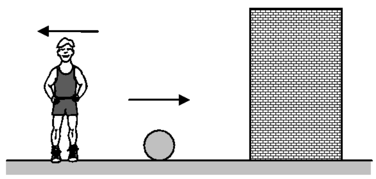


8. A cannon of mass M = 200 kg is positioned a top a narrow wall as shown. It fires a ball of mass m = 2kg horizontally across a plane. Unfortunately the gunners forgot to lock the frictionless wheels of the cannon and it immediately rolls backwards off the wall, landing a distance 8 m from the wall as shown. Neglecting air friction, at what distance x (in meters) from the base of the wall does the ball land ?



IMPULSE

9. A man of mass M is carrying a ball of the mass M/2. The man is initially in the state of rest at a distance D from fixed vertical wall. He throws the ball along the floor towards the wall with a velocity v with respect to earth at t = 0. Because of throwing, the man also starts moving backwards. The ball rebounds elastically from the wall. The man finally collects the ball. Assume friction is absent.



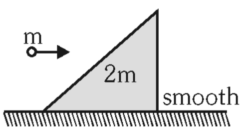
(A) The velocity of the man + ball system after the man has collected the ball is $\frac{2v}{3}$

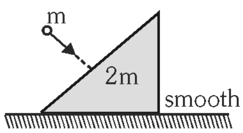
(B) Linear impulse by ball on man is $\frac{Mv}{3}$

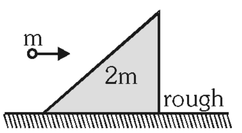
(C) Total linear impulse by ball on man is $\frac{Mv}{6}$

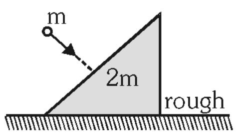
(D) He collects the ball at $t = \frac{4D}{v}$

10. In which of the following system (s) linear momentum cannot be conserved during collision along horizontal line (parallel to base) ?

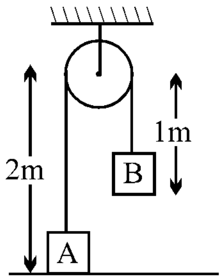
(A) 

(B) 

(C) 

(D) 

11. Two masses A & B each of 5 kg are suspended by a light inextensible string passing over a smooth massless pulley such that mass A rest on smooth table & B is held at the position shown. Mass B is now gently lifted up to the pulley and allowed to fall from rest. Determine up to what height will A rise for the ensuing motion.



12. A projectile of 2 kg is launched from ground at an angle of 30° from horizontal. At the highest point of its trajectory the radius of curvature is 16 km.

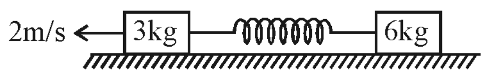
(a) Find its speed at highest point.

(b) Calculate its range on level ground

(c) Calculate impulse due to gravity during total time of flight.

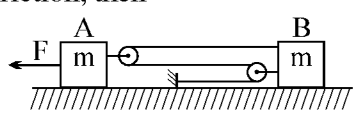
COM FRAME OF REFERENCE

13. Two blocks of masses 3 kg and 6 kg are connected by an ideal spring and are placed on a frictionless horizontal surface. The 3 kg block is imparted a speed of 2 m/s towards left.



Column-I	Column-II
(A) When the speed of 3 kg block is $\frac{2}{3}$ m/s	(P) Velocity of centre of mass is $\frac{2}{3}$ m/s.
(B) When the speed of 6 kg block is $\frac{2}{3}$ m/s	(Q) Deformation of the spring is zero.
(C) When the speed of 3 kg block is maximum	(R) Deformation of the spring is maximum
(D) When the speed of 6 kg block is minimum	(S) Both the blocks are at rest with respect to each other.
	(T) Both the blocks are at rest with respect to ground

14. Two blocks A and B of equal mass are connected by a light inextensible taut string passing over two light smooth pulleys fixed to the blocks. The parts of the string not in contact with the pulleys are horizontal. A horizontal force F is applied to the block A as shown. There is no friction, then



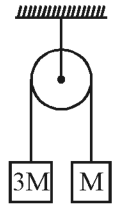
(A) the acceleration of A will be more that of B

(B) the acceleration of A will be less than that of B

(C) the sum of rate of changes of momentum of A and B is greater than the magnitude of F.

(D) the sum of rate of changes of momentum of A and B is equal to the magnitude of F.

15. Two blocks of mass M and 3 M are connected by a light cord which passes over a light frictionless pulley as shown in the figure. The blocks are released from rest and are at the same height at t = 0.



(A) Tension in string connecting masses is $\frac{3Mg}{4}$

(B) The acceleration of both masses is $\frac{g}{2}$ in magnitude

(C) The centre of mass accelerates down.

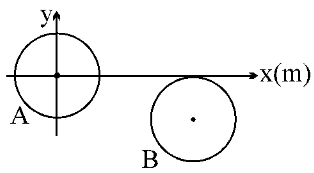
(D) The net force on system having M and 3M is zero.

COLLISION

16. Two balls A & B mass 1 kg & 2 kg are moving with speeds 21 m/s & 4 m/s respectively in opposite direction collide head on. After collision A moves with speed 1 m/s in its initial direction. Which is /are correct ?
(A) Velocity of B after collision is 6 m/s opposite to its direction before collision
(B) e = 0.2
(C) Loss of kinetic energy due to collision is 200J
(D) Impulse of force between 2 balls is 400 N-s

17. A particle moving with kinetic energy = 3J makes an elastic head–on collision with a stationary particle which has twice its mass. During the impact–
(A) the minimum kinetic energy of the system is 1 J.
(B) the maximum elastic potential energy of the system is 2J.
(C) momentum and total energy are conserved at every instant.
(D) All of the above are correct

18. Two smooth balls A and B, each of mass m and radius R, have their centres at (0,0,R) and at (5R,–R,R) respectively, in a coordinate system as shown. Ball A, moving along positive x axis, collides with ball B. Just before the collision, speed of ball A is 4 m/s and ball B is stationary. The collision between the balls is elastic.



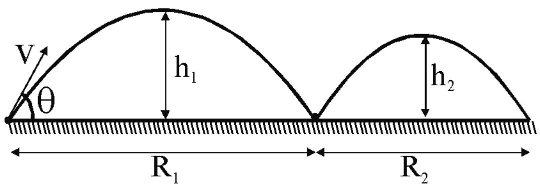
(A) Velocity of the ball A just after the collision is $(\hat{i} + \sqrt{3}\hat{j})$ m/s

(B) Velocity of B just after collision is zero.

(C) Impulse of the force exerted by A on B during the collision, is equal to $(3m\hat{i} - \sqrt{3}m\hat{j})$ kg-m/s

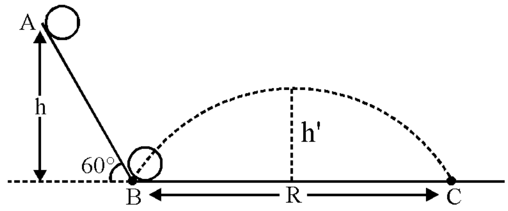
(D) Impulse of the force exerted by A on B is $(4m\hat{i})$ kg-m/s.

19. A ball is projected with velocity V at an angle θ with horizontal. Its maximum height is h_1, range R_1 and time of flight T_1. It collides the ground and collision have coefficient of restitution e = 1/2, then



(A) $h_2 = \frac{1}{2}h_1$ (B) $R_2 = \frac{1}{2}R_1$ (C) $T_2 = \frac{1}{2}T_1$ (D) $R_2 = \frac{1}{4}R_1$

20. In the figure shown, a ball is released from the smooth track. If the ball strikes the horizontal surface of the track and bounces off, it again strikes the horizontal surface at some distance R from B and rises to a height maximum of h' above the surface (If the coefficient of restitution for the collision is e) :-



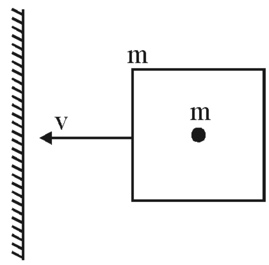
(A) R is maximum for $e = \frac{1}{\sqrt{3}}$

(B) R is maximum for e = 1

(C) $h' \le \frac{3h}{4}$ for all values of e

(D) h' = h for e = 1

21. In the middle of a box of mass m is a weight of the same mass m. The whole structure is moving at a speed v in the horizontal plane toward the wall (see figure). Friction is absent everywhere, all the collision are absolutely elastic. Choose the correct option:



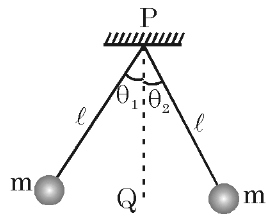
(A) There will be a total of three collisions

(B) Finally the box will be moving towards right with speed v.

(C) Finally the weight will be at the edge of the box.

(D) The weight will oscillate back and forth relative to the box after the collision with the wall is over.

22. Two simple pendulums of equal lengths and equal bob masses are hung from same point. When strings of pendulums are displaced from vertical positions, by angles θ_1 and θ_2 and released, they make elastic collisions with each other in subsequent motion. Neglecting sizes of bobs of pendulums and assuming θ_1 and θ_2 are small enough to hold approximation $\sin\theta = \theta$, mark the **CORRECT** alternative.



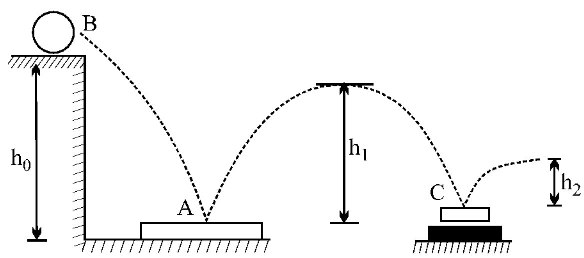
(A) If $\theta_1 > \theta_2$, collision will take place to the left of line PQ.

(B) If $\theta_2 > \theta_1$, time period of oscillation is $2\pi\sqrt{\frac{\ell}{g}}$.

(C) If $\theta_1 > \theta_2$, time period of oscillation is $2\pi\sqrt{\frac{\ell}{g}}$.

(D) If $\theta_1 = \theta_2$, time period of oscillation is $\pi\sqrt{\frac{\ell}{g}}$.

23. A 70g ball B droped from a height $h_0 = 9$ m reaches a height $h_2 = 0.25$m after bouncing twice from identical 210g plates. Plate A rests directly on hard ground, while plate C rests on a foam-rubber mat. Determine



(a) the coefficient of resitution between the ball and the plates,

(b) the height h_1 of the ball's first bounce.

VARIABLE MASS

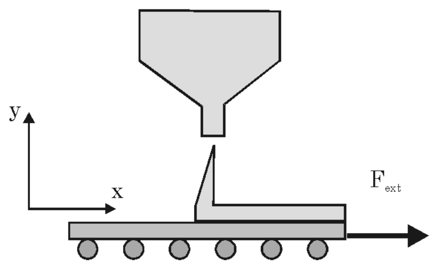
24. A rocket ascends from rest in a uniform gravitational field g by ejecting exhaust with a uniform relative speed u. Assume that the rate at which mass is expelled is given by $\left|\frac{dm}{dt}\right| = km$ where m is the instantaneous mass of the rocket & k is a constant & that the rocket is retarded by air resistance with a force mbv where b is a constant & v is instantaneous velocity of rocket.

(a) Find the acceleration of rocket as a function of time.

(b) Find the velocity of rocket as a function of time

(c) What will be its velocity after a long time.

25. Sand from a stationary hopper falls onto a moving conveyor belt at a rate of 5.00 kg/s as shown in the figure. The conveyor belt is supported by frictionless rollers and moves at a constant speed of 0.750 m/s under the action of a constant horizontal external force F_{ext} supplied by the motor that drives the belt.



(A) The force of friction exerted by the belt on the sand is 3.75 N.

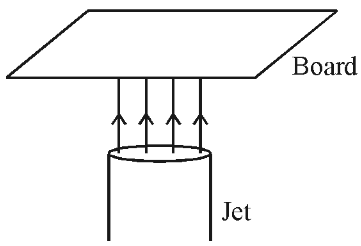
(B) The external force F_{ext} is 3.75 N.

(C) The work done by F_{ext} in 1 sec is 2.81 J.

(D) The kinetic energy acquired by the falling sand each second due to the change in its horizontal motion is 1.41 J.

Paragraph for Question No 26 and 27

A jet shoots a stream of water vertically upward. The water leaves the jet with a velocity v_0 and at a mass rate R kg/s. A horizontal board with mass m faces the water stream as shown. Water jet strikes the board normally and then bounces off sideways. Assume area of cross-section of water stream, does not change as it goes up.



26. When board is placed vary close to the jet and then released, it stays in equilibrium. What is the value of m?

(A) $\frac{2Rv_0}{g}$ (B) $\frac{Rv_0}{g}$ (C) $\frac{Rv_0}{2g}$ (D) $\frac{Rv_0}{4g}$

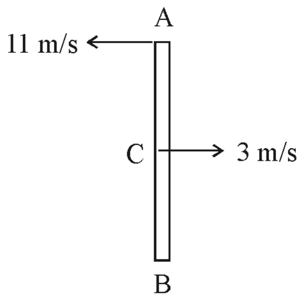
27. If we break the board into half so that its mass is $\frac{m}{2}$, how high from jet, should the board be placed so that it remains in equilibrium.

(A) $\frac{v_0^2}{2g}$ (B) $\frac{2v_0^2}{5g}$ (C) $\frac{3v_0^2}{7g}$ (D) $\frac{3v_0^2}{8g}$

ANSWER KEY		CENTRE OF MASS & COLLISION	
1. Ans. 0.62 = $\frac{\sqrt{5}-1}{2}$	**2. Ans. 3R/8**	**3. Ans. 4**	**4. Ans. (C)**
5. Ans. (C)	**6. Ans. (B, D)**	**7. Ans. v_B = 55/36m/s, v_A = 11/6 m/s, solved**	
8. Ans. 0800.00	**9. Ans. (A,D)**	**10. Ans. (C,D)**	**11. Ans. 1.25 m**
12. Ans. 400m/s, $\frac{32000}{\sqrt{3}}m$, $\frac{1600}{\sqrt{3}}kg-m/s$		**13. Ans. (A)-P,Q,R,S; (B)-P,R,S; (C)-P,Q; (D)-P,Q**	
14. Ans. (A, C)	**15. Ans. (B, C)**	**16. Ans. (A,B,C)**	**17. Ans. (A,B,C,D)**
18. Ans. (A,C)	**19. Ans. (B,C)**	**20. Ans. (B, C)**	**21. Ans. (A,B)**
22. Ans. (B,C,D)	**23. Ans. (a) 0.66, (b) 4 m**		
24. Ans. (a) (ku – g)e^{-bt} (b) [{(ku – g)/b}(1 – e^{-bt})], (c) (ku – g)/b			**25. Ans. (A,B,C,D)**
26. Ans. (B)	**27. Ans. (D)**		

KINEMATICS

1. A uniform rod AB of length 7m is undergoing combined rotational and translational motion on smooth horizontal surface such that, at some instant of time, velocities of its end point A and centre C are both perpendicular to the rod and opposite in direction, having magnitude 11 m/s and 3 m/s respectively as shown in the fig. Now consider that no external force and torque is acting on the rod. Then select **CORRECT** options.



(A) acceleration of point A is 56 m/s^2

(B) acceleration of point B is 56 m/s^2

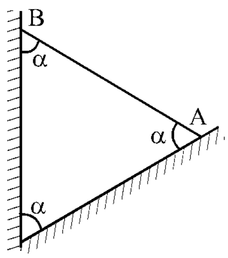
(C) at the instant shown in the figure acceleration of point C is zero.

(D) angular velocity of the rod is 4 rad/s

2. A ring of radius R is rolling purely on the outer surface of a pipe of radius 4R. At some instant, the center of the ring has a constant speed = v. Then , the acceleration of the point on the ring which is in contact with the surface of the pipe is :

(A) $4v^2/5R$ (B) $3v^2/5R$ (C) $v^2/4R$ (D) zero

3. In the figure shown, the end A of the rod AB of length L is being pushed down parallel to the inclined surface with a velocity = v. Let the velocity of end B = u and the angular velocity of the rod = ω. Then,



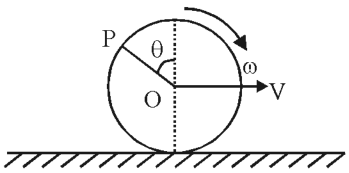
(A) $u = v\cos\alpha$, upward

(B) $u = v$, downwards

(C) $\omega = v \sin\alpha/L$

(D) $\omega = 2v\sin\alpha/L$

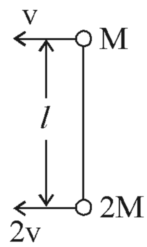
4. A disc of radius R rolls on a horizontal surface with linear velocity V and angular velocity ω. There is a point P on circumference of disc at angle θ with upward vertical diameter measured anticlockwise (see figure), which has a vertical velocity. Here θ is equal to



(A) $\pi + \sin^{-1}\dfrac{V}{R\omega}$ (B) $\dfrac{\pi}{2} - \sin^{-1}\dfrac{V}{R\omega}$

(C) $\pi - \cos^{-1}\dfrac{V}{R\omega}$ (D) $\pi + \cos^{-1}\dfrac{V}{R\omega}$

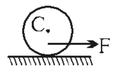
5. On a smooth level ground we keep a light rod to which two masses M & 2M are attached. The velocities of these massess at the moment is shown here. Choose the correct statements.

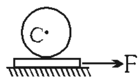


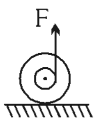
(A) The velocities of masses remain constant.
(B) The angular velocity of the rod is V/L clockwise
(C) The rod is under tension
(D) The centre of mass will move in a straight line.

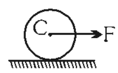
DYNAMICS OF ROLLING

6. In which of the following, correct direction of friction force acting on the cylinder, which is pulled on a rough surface by a constant force F(as shown) is towards LEFT ?

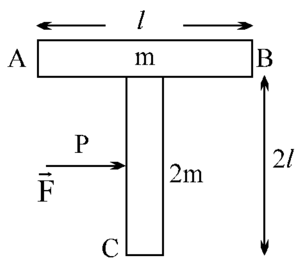
(A) Force (F) acting at a point below the centre of mass of the cylinder 

(B) Rough plank which in turn is placed on a smooth surface. 

(C) A spool is pulled vertically by a constant force F (< Mg) 

(D) A cylinder of mass M and radius R is pulled horizontally by a force F. 

7. A T shaped object with dimensions shown in the figure is lying on a smooth floor. A force $\vec{F}$ is applied at the point P parallel to AB such that the object has only the translational motion without rotation. Find the location of P with respect to C.



(A) $(3/4)l$ (B) l (C) $(4/3)l$ (D) $(3/2)l$

8. A uniform solid cylinder of mass m and radius R is released from rest on a sufficiently rough inclined plane. During its downward journey along the incline, the cylinder moves distance ℓ along the incline. The angle of inclination from horizontal is α. Mark **CORRECT** statements :-

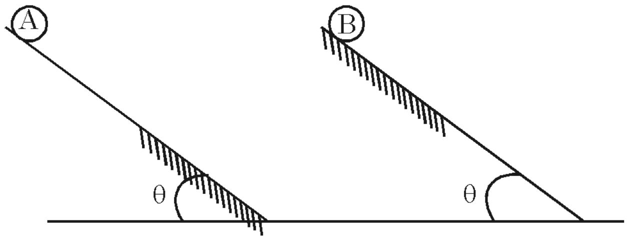
(A) The acceleration of centre of mass of cylinder is $\frac{2g\sin\alpha}{3}$.

(B) The final angular speed of cylinder is $\sqrt{\frac{4}{3}\frac{g\ell\sin\alpha}{R^2}}$.

(C) The minimum coefficient of friction required so that there is no slipping is $\frac{\tan\alpha}{3}$.

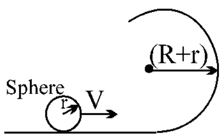
(D) If released from rest cylinder will undergo pure rolling even on smooth inclined plane.

9. Two balls are released simultaneously from top of two different inclined planes as shown. First half length of incline A is smooth while second half length of incline B is smooth as shown in figure. When ball reaches the lowest point of the incline. (Assume friction is sufficient for pure rolling in both cases)

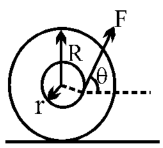


(A) Ball B reaches down with a higher kinetic energy compared to ball A.
(B) Angular momentum of both balls is conserved about any point on incline plane.
(C) Friction is static in nature in both cases.
(D) Work done by friction is negative in A and positive in B.

10. A sphere of mass m and radius r is pushed onto the fixed horizontal surface such that it rolls without slipping from the beginning. Determine the minimum speed V of its mass centre at the bottom so that it rolls completely around the loop of radius (R + r) without leaving the track in between.



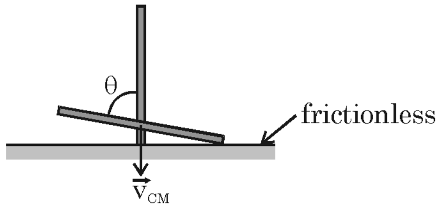
11. The spool shown in figure is placed on rough horizontal surface and has inner radius r and outer radius R. The angle θ between the applied force and the horizontal can be varied. The critical angle (θ) for which the spool does not roll and remains stationary is given by



(A) $\theta = \cos^{-1}\left(\frac{r}{R}\right)$ (B) $\theta = \cos^{-1}\left(\frac{2r}{R}\right)$ (C) $\theta = \cos^{-1}\sqrt{\frac{r}{R}}$ (D) $\theta = \sin^{-1}\left(\frac{r}{R}\right)$

12. A thin uniform stick of mass M and length ℓ is positioned vertically, with its tip on a frictionless table. It is released and allowed to fall. Determine the speed of its CM just before it hits the table (see figure).

If your answer is $\sqrt{\frac{Xg\ell}{Y}}$ then fill value of X + Y, where X and Y are smallest positive integer.



ANGULAR MOMENTUM IN ROLLING

13. A uniform rod of length l and mass 2m rests on a smooth horizontal table. A point mass m moving horizontally at right angle to the rod with velocity v collides with one end of the rod and sticks to it, then

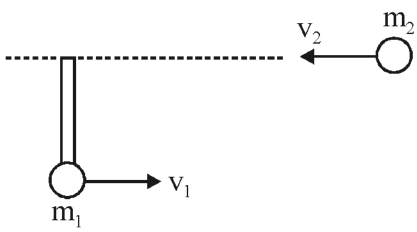
(A) angular velocity of the system after collision is v/l.

(B) angular velocity of the system after collision is $v/2l$.

(C) the loss in kinetic energy of the system as a whole as a result of the collision is $mv^2/6$.

(D) the loss in kinetic energy of the system as a whole as a result of the collision is $7mv^2/24$.

14. Two girls Sita and Gita are skating towards each other on smooth ice along parallel lines as shown in figure. The distance between the lines is ℓ. The mass of two girls are m_1 and m_2 ($m_1 < m_2$) and their respective velocity are v_1 and v_2 ($v_2 > v_1$). One of the girls holds a stick of length ℓ and negligible mass. When the girls pass each other, second girl grasps the stick and the girls move together, each of them on either side of the stick. Mark the correct statements



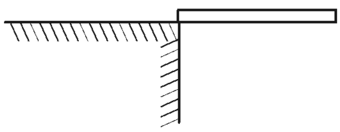
(A) In the centre of mass reference frame of system both the girls have momentum of equal magnitude.

(B) Angular momentum of system about centre of mass increases.

(C) If the girls start moving towards each other by pulling the stick, angular velocity of system will increase.

(D) After the girl has grabbed the rod, system rotates in anticlockwise sense while centre of mass translates towards left.

15. A uniform rod of length l is falling down with a velocity v_0 when one of its end hits a fixed edge as shown.



(A) If the collision is elastic, the centre of mass may have upwards velocity just after the collision

(B) If the collision is partially elastic, the centre of mass may come to rest just after the collision

(C) If the collision is perfectly inelastic, the centre of mass has a downward velocity just after the collision

(D) If the collision is elastic, the centre of mass has a downward velocity just after the collision

16. A hollow massless sphere of radius R is fully filled with non viscous water of mass m. It is rolled down a horizontal plane such that its centre of mass moves with a velocity v. If it purely rolls

(A) Kinetic energy of the sphere is $1/2\ mv^2$

(B) Kinetic energy of the sphere is $14/5mv^2$

(C) Angular momentum of the sphere about a fixed point on ground is mvR

(D) Angular momentum of the sphere about a fixed point on ground is 14/5 mvR

17. Suppose a solid disk having radius R is put on a rough horizontal surface and given an angular speed ω_0 about an axis through it's centre and released. If coefficient of friction between disc and surface is μ then:

(A) Time interval before rolling motion starts is $\frac{R\omega_0}{3\mu g}$.

(B) Distance travelled by disc before pure rolling starts is $\frac{R^2\omega_0^2}{18\mu g}$.

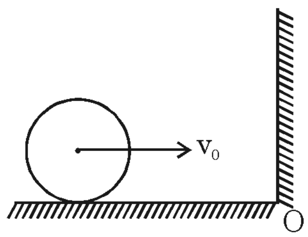
(C) Rolling motion doesn't occur

(D) Time interval before rolling motion starts is $\frac{2R\omega_0}{3\mu g}$.

18. (a) A hoop of radius r and mass m is rolling without slipping with velocity v towards a step of height b (< r) on a horizontal surface. Assume that the hoop does not rebound and no slipping occurs at the point of contact when the hoop rolls up. What is the minimum velocity v needed for the hoop to roll up the step?

(b) If the hoop is sliding without rolling towards the step, what must be the minimum velocity v for it to roll up the step?

19. Consider a sphere of mass 'm' radius 'R' doing pure rolling motion on a rough surface with velocity $\vec{v}_0$ as shown in the figure. It makes an elastic impact with the smooth wall and moves back and starts pure rolling after some time again :-



(A) Change in angular momentum about 'O' in the entire motion equals $2mv_0R$ in magnitude.

(B) Moment of impulse provided by the wall during impact about O equals $2mv_0R$ in magnitude.

(C) Final velocity of ball will be $\frac{3}{7}\vec{v}_0$

(D) Final velocity of ball will be $-\frac{3}{7}\vec{v}_0$.

ANSWER KEY		RIGID BODY DYNAMICS-02	
1. Ans. (A,B,C,D)	**2. Ans. (A)**	**3. Ans. (D)**	**4. Ans. (C,D)**
5. Ans. (B,C,D)	**6. Ans. (A,C,D)**	**7. Ans. (C)**	**8. Ans. (A, B, C)**
9. Ans. (A)	**10. Ans.** $V = \sqrt{\frac{27}{7}gR}$	**11. Ans. (A)**	**12. Ans. 7**
13. Ans. (A,C)	**14. Ans. (A,C,D)**	**15. Ans. (C,D)**	**16. Ans. (A, C)**
17. Ans. (A, B)	**18. Ans. (a)** $v_{min} = \frac{2r\sqrt{gb}}{(2r-b)}$, **(b)** $v_{min} = \frac{2r\sqrt{gb}}{(r-b)}$	**19. Ans. (A,B,D)**	

1. Two spherical bodies of masses M and 2M and radii R and 2R, respectively, start approaching each other at time t = 0 from rest, due to mutual gravitational attraction. They were initially very far away from each other. They collide at time t = T.

(A) Distance travelled by their COM till time t = T is zero (COM–centre of mass)

(B) Their relative velocity at time t = T is $\frac{1}{3}\sqrt{\frac{2GM}{R}}$

(C) PE of the system decreases as the bodies approach each other

(D) In COM frame, speeds of the bodies are always equal

2. The difference between the time periods (in sec) of a seconds pendulum at a depth of 64 km from Earth's surface and on earth surface is ΔT ? Fill the value of $100\Delta T$ in OMR sheet.

3. Two tunnels are dug from one side of the earth's surface to the other side, one along a diameter and the other along a chord. Now two particle are dropped from one end of each of the tunnels. Both the particles oscillate simple harmonically along the tunnels. Let T_1 and T_2 be the time period, v_1 and v_2 be the maximum speed of the particle in the two tunnels. Then :-

(A) $T_1 = T_2$ (B) $T_1 > T_2$ (C) $v_1 = v_2$ (D) $v_1 > v_2$

4. A particle at a distance r from the centre of a uniform spherical planet of mass M radius R (< r) has a velocity of magnitude v.

(A) for $0 < v < \sqrt{\frac{GM}{r}}$ trajectory may be ellipse

(B) for $v = \sqrt{\frac{GM}{r}}$ trajectory may be ellipse

(C) for $\sqrt{\frac{GM}{r}} < v < \sqrt{\frac{2GM}{r}}$ trajectory may be ellipse.

(D) for $v = \sqrt{\frac{GM}{r}}$ trajectory may be circle

5. Two Earth's satellites move in a common plane along circular obrits in the same sense. The orbital radius of one satellite is r while that of the other satellite is r – Δr (Here Δr << r).

(A) Time interval separates the periodic approaches of the satellites to each other over the minimum distance is $\frac{4\pi r^{5/2}}{3(GM)^{1/2}\Delta r}$.

(B) Time interval separates the periodic approaches of the satellites to each other over the minimum distance is $\frac{2\pi r^{5/2}}{3(GM)^{1/2}\Delta r}$.

(C) Angular velocity of approach between two setellites is $\frac{3(GM)^{1/2}\Delta r}{r^{5/2}}$.

(D) Angular velocity of approach between two setellites is $\frac{3(GM)^{1/2}\Delta r}{2r^{5/2}}$.

6. You are at a distance of $R = 1.5 \times 10^6$ m from the centre of an unknown planet. You notice that if you throw a ball horizontally it goes completely around the planet hitting you in the back 90,000 seconds later with exactly the same speed that you originally threw it. If the length of semi major axis of ball is 2R, what is the mass of the planet. Express in scientific notation $(a \times 10^b)$ kg and fill (a + b) in OMR sheet. [Take $G = \frac{20}{3} \times 10^{-11}$ Nm²/kg², $\pi^2 = 10$]

7. Given a thin homogeneous disc of radius a and mass m_1. A particle of mass m_2 is placed at a distance l from the disc on its axis of symmetry. Initially both are motionless in free space but they ultimately collide because of gravitational attraction. Assuming $a << l$, find the relative velocity at the time of collision.

ANSWER KEY	GRAVITATION

1. Ans. (A,C) **2. Ans.** 1 **3. Ans.** (A, D) **4. Ans.** (A,B,C,D)

5. Ans. (A,D) **6. Ans.** 23 **7. Ans.** $\left[2G(m_1+m_2)\left(\frac{2}{a}-\frac{1}{l}\right)\right]^{1/2}$

SHM

1. A particle of mass 1 kg, executing simple harmonic motion of period 20 s, crosses the mean position at t = 0 with velocity π cm/s.
(A) the maximum acceleration of the particle is 10 cm/s^2
(B) when it is 4 cm from the mean position, its velocity is $6\pi/10$ cm/s
(C) the kinetic energy of the particle when its displacement is 5 cm from the mean position is $\frac{3\pi^2}{8\times10^6}$ J
(D) its velocity at displacement 6 cm from the mean position is $8\pi/10$ cm/s

2. Two particles are in SHM with same amplitude A and same angular frequency ω. At time t=0, one is at $x = +\frac{A}{2}$ and other is at $x = -\frac{A}{2}$. Both are moving in same direction.
(A) Phase difference between the two particle is $\frac{\pi}{3}$
(B) Phase difference between the two particle is $\frac{2\pi}{3}$
(C) They will collide after time $t = \frac{\pi}{2\omega}$
(D) They will collide after time $t = \frac{3\pi}{\omega}$

3. A particle is performing SHM with its position given as $x = 2 + 5\sin\left(\pi t + \frac{\pi}{6}\right)$ where x (in m) & t (in sec). Which of the following is/are correct :-
(A) Equilibrium position is at x = 2m
(B) Maximum speed of particle is 5π m/s
(C) At t = 0 particle is 2.5 m away from mean position moving in negative direction
(D) At t = 0, x = 4.5 m; acceleration of particle is $-\pi^2(4.5)$ m/s^2

4. Two particles 'A' and 'B' start SHM at t = 0. Their positions as a function of time are given by $X_A = A\sin\omega t$; $X_B = A\sin(\omega t + \pi/3)$

	Column-I		Column-II
(A)	Minimum time when x is same	(P)	$\frac{5\pi}{6\omega}$
(B)	Minimum time when velocity is same	(Q)	$\frac{\pi}{3\omega}$
(C)	Minimum time after which $v_A < 0$ and $v_B < 0$	(R)	$\frac{\pi}{\omega}$
(D)	Minimum time after which $x_A < 0$ and $x_B < 0$	(S)	$\frac{\pi}{2\omega}$

5. A particle of mass 2 kg moves in a straight line. If v is the velocity at a distance x from a fixed point on the line and $v^2 = 3 - 4x^2$ then-

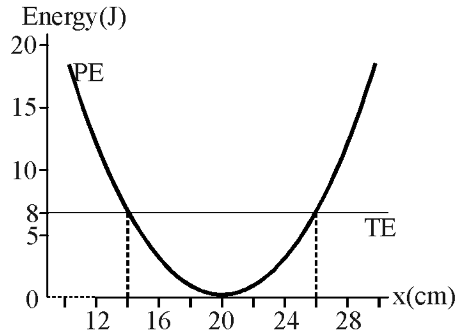
(A) The motion continues along the positive x-direction only.

(B) The motion is simple harmonic

(C) The oscillation frequency is 2 units ($\omega = 2$)

(D) The total energy of the particle is 3 units

6. Figure shows the potential-energy diagram and the total energy line of a particle oscillating on a spring.



(A) the amplitude of oscillation of particle is 6 cm.

(B) the spring constant is 4.44 kN/m.

(C) the mass of particle is 1kg.

(D) the maximum kinetic energy of particle is at x = 20 cm.

7. Acceleration of a particle which is at rest at x = 0 is $\vec{a} = (4 - 2x)\hat{i}$. Select the correct alternatives(s)-

(A) particle further comes to rest at x = 4

(B) particle oscillates about x = 2

(C) maximum speed of particle is 4 units

(D) all of the above

8. A linear harmonic oscillator of force constant $2 \times 10^6 \text{Nm}^{-1}$ and amplitude 0.01 m has a total mechanical energy of 160 J. Its

(A) maximum potential energy is 100 J

(B) maximum kinetic energy is 100 J

(C) maximum potential energy is 160 J

(D) minimum potential energy is zero.

9. A body is performing S.H.M., then its

(A) average total energy of SHM per cycle is equal to its maximum kinetic energy.

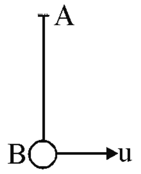
(B) average kinetic energy per cycle is equal to half of its maximum kinetic energy.

(C) mean velocity over a complete cycle is equal to $2/\pi$ times of its maximum velocity.

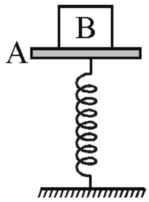
(D) root mean square velocity is $1/\sqrt{2}$ times of its maximum velocity

10. **Column I**

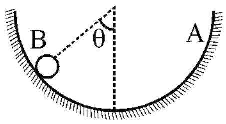
(A) A bob B hanging from a light string A of length 3 m is projected to left with a speed of 10 m/s.



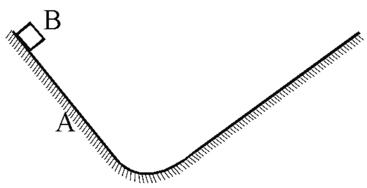
(B) The light platform with block B is pushed down by a distance $2x_0$ below mean position & released.
[x_0 is compression in mean position]



(C) A spherical solid ball B is released on a perfectly rough spherical surface A as shown $\left[\theta = \frac{\pi}{3}\right]$.



(D) Block B is released on a smooth track A as shown.



Column II

(P) The acceleration of centre of mass of B at some time can be equal to g.

(Q) The force exerted by A on B can be zero at some point.

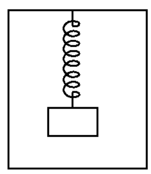
(R) the speed of the body B varies sinusoidally with time when force exerted by A on B is not zero.

(S) The motion of B is oscillatory.

(T) The motion of B is periodic.

DYNAMICS OF SHM

11. A spring mass system is hanging from the ceiling of an elevator in equilibrium. Elongation of spring is l. The elevator suddenly starts accelerating downwards with acceleration g/3 find



(a) the frequency and

(b) the amplitude of the resulting SHM.

12. The potential energy of a particle of mass 0.1 kg, moving along the x-axis, is given by $U = 5x(x-4)$J, where x is in metres. It can be concluded that :

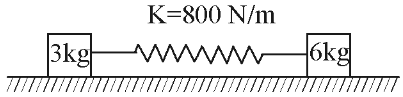
(A) the particle is acted upon by a constant force.

(B) the speed of the particle is maximum at x = 2 m.

(C) the particle executes simple harmonic motion

(D) the period of oscillation of the particle is $\pi/5$ s.

13. The system shown in the figure can move on a smooth surface. The spring is initially compressed by 6 cm and then released.



(A) the particles perform SHM with time period $\frac{\pi}{10}$ sec

(B) the block of mass 3 kg perform SHM with amplitude 4 cm

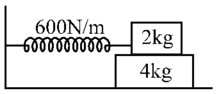
(C) the block of mass 6 kg will have maximum momentum 2.40 kg m/s

(D) none of these

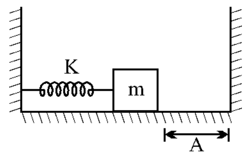
14. In the arrangement shown, the spring of force constant 600N/m is in the unstretched position. The coefficient of friction between the two blocks is 0.4 and that between the lower block & ground surface is zero. If both the blocks are displaced slightly and released, the system executes SHM.

(a) Find time period of their oscillation if they do not slip w.r.t. each other.

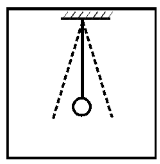
(b) What is the maximum amplitude of the oscillation for which sliding between them does not occur.



15. In the figure shown the spring is relaxed. The spring is compressed by 2 A and released. Mass m attached with the spring collides with the wall & loses two third of its kinetic energy & returns. Find the time after which the spring will have maximum compression first time after releasing. (Neglect Friction)



16. A simple pendulum is oscillating in a stationary lift with a time period T and an angular amplitude θ_0. When it is passing through the mean position, the lift starts accelerating upwards.



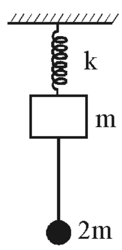
(A) The time period of its oscillation will increase

(B) Its angular amplitude would increase.

(C) The time period of its oscillation would decrease

(D) Its angular amplitude would decrease.

17. A bob of mass 2m hangs by a string attached to the block of mass m of a spring block system. The whole arrangement is in a state of equilibrium. The bob of mass 2m is pulled down slowly by a distance x_0 and released.



(A) For $x_0 = \frac{3mg}{k}$ maximum tension in string is 4mg

(B) For $x_0 > \frac{3mg}{k}$, minimum tension in string is mg

(C) Frequency of oscillation of system is $\frac{1}{2\pi}\sqrt{\frac{k}{3m}}$, for all non-zero values of x_0

(D) The motion will remain simple harmonic for $x_0 \le \frac{3mg}{k}$

18. Consider a spring that exerts the following restoring force

$F = -kx$ for $x > 0$

$F = -4kx$ for $x < 0$

A mass m on a frictionless surface is attached to the spring displaced to x = A by stretching the spring and released :

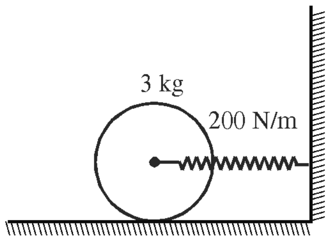
(A) The period of motion will be $T = \frac{3}{2}\pi\sqrt{\frac{m}{k}}$

(B) the most negative value the mass m can reach will be $x = -\frac{A}{2}$

(C) The time taken to move from x = A to $x = -\frac{A}{\sqrt{2}}$, straight away will be equal to $\frac{5\pi}{8}\sqrt{\frac{m}{k}}$

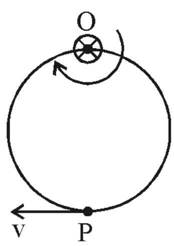
(D) The total energy of oscillations will be $\frac{5}{2}kA^2$

19. The uniform solid cylinder rolls without slipping in the system shown. If the maximum compression in spring is 15cm, the possible friction force acting on the cylinder during its motion is :



(A) 4N (B) 10N (C) 12N (D) 15N

20. A ring of mass m, radius r can oscillate in a vertical plane about is top most point 'O' as shown. Axis is normal to the plane of ring. Maximum speed of lowest point 'P' of ring is v.



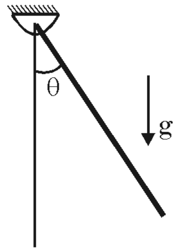
(A) Time period of SHM for small amplitudes is $2\pi\sqrt{\frac{2r}{g}}$

(B) Acceleration of centre of mass of ring at lowest position is zero.

(C) Hinge force when centre of mass is at lowest point is $\frac{mv^2}{4r}$

(D) Mechanical energy of oscillation is $\frac{mv^2}{4}$ (when potential energy at mean position is taken as zero.)

21. An uniform rod of mass m and length ℓ is pivoted at top and it can perform angular SHM in vertical plane according to equation $\theta = \theta_0 \sin \omega t$. At time $t = \frac{2\pi}{\omega}$ a point mass m (at rest) sticks to lowest end of rod.



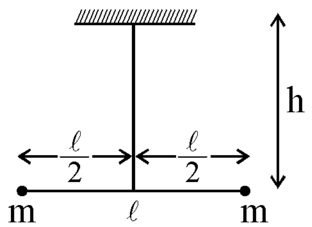
(A) New time period of rod will be $\frac{2}{\sqrt{3}}$ times of the time period before collision.

(B) New angular amplitude is $\frac{\theta_0}{\sqrt{12}}$

(C) New angular amplitude is $\frac{\theta_0}{4}$

(D) There will always be loss of kinetic energy of rod, irrespective of time at which mass sticks to rod.

22. Figure shows two particles connected with a light rod and entire arrangement hangs on a elastic wire. Neglect any gravitational effect, θ_0 = maximum angular displacement of the particles, C = torsional stiffness of wire. Mark the **CORRECT** statements :-



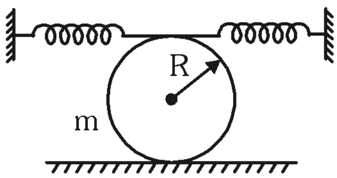
(A) Time period of oscillation is $\pi\ell\sqrt{\frac{2m}{C}}$

(B) Maximum tension in the rod is $\frac{C\theta_0^2}{\ell}$

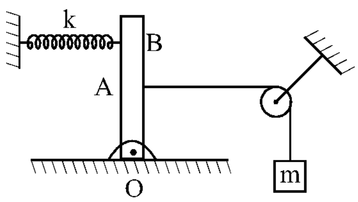
(C) The energy of oscillation is $\frac{1}{2}C\theta_0^2$

(D) The maximum tangential acceleration of particle is $\frac{C\theta_0}{m\ell}$

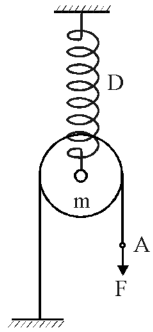
23. A solid uniform cylinder of mass m performs small oscillations due to the action of two springs combined stiffness equal to k (figure). The period of these oscillations in the absence of sliding is $T = \pi\sqrt{\frac{xm}{2k}}$. Then find x :



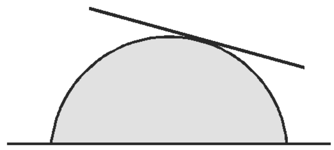
24. A massless rod is hinged at O. A string carrying a mass *m* at one end is attached to point A on the rod so that OA = a. At another point B (OB= b) of the rod, a horizontal spring of force constant *k* is attached as shown. Find the period of small vertical oscillations of mass *m* around its equilibrium position.



25. The axle of a pulley of mass m = 1 kg is attached to the end of a spring of spring constant k = 200 N/m whose other end is fixed to the ceiling. A rope of negligible mass is placed on the pulley such that its left end is fixed to the ground and its right end is hanging freely from the pulley which is at rest in equilibrium. We begin to pull the endpoint A at the right end of the rope by a constant vertical force of F = 15 N. Friction can be neglected between the rope and the pulley. Find the maximum displacement of point A after applying F. Express your answer in cm.



26. A uniform rod of length 2ℓ rocks to and fro on the top of a rough semicircular fixed cylinder of radius a. The period of small oscillations, of rod is



(A) $\dfrac{2\pi\ell}{\sqrt{3ga}}$ (B) $2\pi\sqrt{\dfrac{\ell}{3g}}$

(C) $2\pi\sqrt{\dfrac{a}{3g}}$ (D) $\dfrac{\pi\ell}{\sqrt{3ga}}$

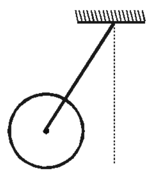
27. A metal rod of length 'L' and mass 'm' is pivoted at one end. A thin disk of mass 'M' and radius 'R' (<L) is attached at its center to the free end of the rod. Consider two ways the disc is attached: (case A). The disc is not free to rotate about its center and (case B) the disc is free to rotated about its center. The rod-disc system performs SHM in vertical plane after being released from the same displaced position. Which of the following statement(s) is(are) true?

(A) Restoring torque in case A = Restoring torque in case B

(B) Restoring torque in case A < Restoring torque in case B

(C) Angular frequency for case A> Angular frequency for case B

(D) Angular frequency for case A< Angular frequency for case B

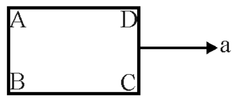


* * * * *

ANSWER KEY			SHM
1. Ans. (D)	**2. Ans. (A,C)**	**3. Ans. (A, B)**	
4. Ans. (A)-Q, (B)-P, (C)-S, (D)-R]		**5. Ans. (B,C,D)**	**6. Ans. (A,B,D)**
7. Ans. (A, B)	**8. Ans. (B,C)**	**9. Ans. (A,B,D)**	
10. Ans. (A) PQ (B) PQRST (C) ST (D) ST		**11. Ans. (a)** $\frac{1}{T}=\frac{1}{2\pi}\sqrt{\frac{g}{L}}$, **(b)** $\frac{L}{3}$	
12. Ans. (B,C,D)	**13. Ans. (A,B,C)**	**14. Ans: (a) π/5, (b) 2cm**	**15. Ans.** $\frac{17\pi}{12}\sqrt{\frac{m}{K}}$
16. Ans. (C,D)	**17. Ans. (A,D)**	**18. Ans. (AB)**	**19. Ans. (A,B)**
20. Ans. (A, D)	**21. Ans. (A, B)**	**22. Ans. (A, B, C, D)**	**23. Ans. 3**
24. Ans. $(2\pi a/b)(m/k)^{1/2}$	**25. Ans. 60**	**26. Ans. (A)**	**27. Ans. (A,D)**

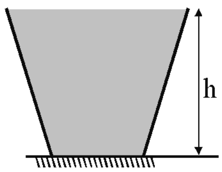
HYDROSTATIC PRESSURE

1. A closed rectangular tank is completely filled with water and is accelerated horizontally with an acceleration towards right. Pressure is (i) maximum at, and (ii) minimum at



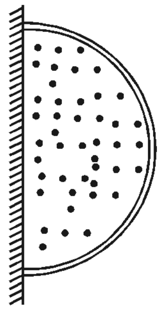
(A) (i) B (ii) D
(B) (i) C (ii) D
(C) (i) B (ii) C
(D) (i) B (ii) A

2. M gm of a liquid of density ρ is filled in a light beaker and kept on a horizontal table as shown in the figure. The height of the liquid in the beaker is h. The beaker is wider on top than at its base and the cross-sectional area of the base is A. Neglect the effect of atmospheric pressure. Now, choose the **CORRECT** statement(s) from the following.



(A) The pressure of liquid at the bottom surface is ρgh.
(B) The normal reaction exerted by the table on the beaker is ρghA.
(C) The pressure of the liquid at the bottom surface is $\frac{Mg}{A}$.
(D) The normal reaction exerted by the table on the beaker is Mg.

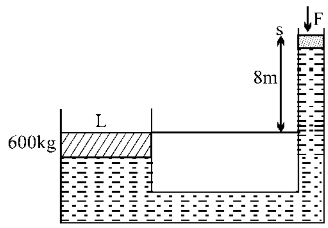
3. A thin walled hemispherical shell of mass m and radius R is pressed against a smooth vertical wall. Through a very small aperture at its top water of density ρ is filled in it completely. Minimum magnitude of force is to be applied to the shell for liquid not to escape from it. Weight of hemispherical shell is mg and total mass of water is $M = \frac{2}{3}\pi R^3\rho$:-



(A) Horizontal component of net force is $\frac{1}{2}\pi R^3\rho g$
(B) Net external force is $Mg\sqrt{\frac{9}{4}+\left(1+\frac{m}{M}\right)^2}$
(C) Vertical component of force is (M + m)g
(D) Direction of net force is given by θ = arc tan $\frac{(m+M)}{3M}$, where θ is from horizontal direction.

4. A cubical block is floating in a liquid with one third of its volume immersed in the liquid. When the whole system accelerates upwards with acceleration of g/2 :-
(A) the fraction of volume immersed in the liquid will change.
(B) the buoyancy force on the block will change.
(C) the buoyancy force will increase by 50 percent.
(D) the pressure in the liquid will increased.

5 For the system shown in the figure, the cylinder on the left at L has a mass of 600kg and a cross sectional area of 800 cm^2. The piston on the right, at S, has cross sectional area 25cm^2 and negligible weight. If the apparatus is filled with oil.(ρ = 0.75 gm/cm^3) Find the force F required to hold the system in equilibrium.



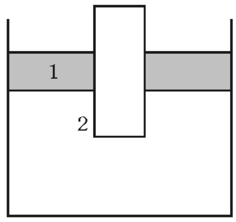
6. A mercury barometer is defective. (It contains some air in the space above the mercury). When an accurate baromete reads 770mm, the defective one reads 760mm. When the accurate one reads 750mm the defective one reads 742mm. What is the length of the air column, when the accurate barometer reads 760mm? What is the reading of the accurate barometer when the defective one reads 752mm? Assume that the temperature remains constant.

BUOYANCY

7. A wax candle floats vertically in a liquid of density twice that of wax. The candle burns at the rate of $4cm/hr$. Then, with respect to the surface of the liquid the upper end of the candle will

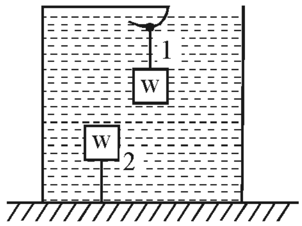
(A) fall at the rate of $4cm/hr$
(B) fall at the rate of $2cm/hr$
(C) rise at the rate of $2cm/hr$
(D) remain at the same height

8. A cylinder is floating in two liquids as shown in figure.
Choose the correct options



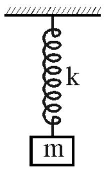
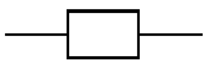
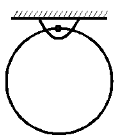
(A) net force on cylinder by liquid 1 is zero.
(B) net force on cylinder by liquid 1 is non-zero.
(C) net force on cylinder by liquid 2 is equal to the upthrust.
(D) net force on cylinder by liquid 2 is more than the upthrust.

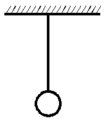
9. An iron block and a wooden block are positioned in a vessel containing water as shown in the figure. The iron block (1) hangs from a massless string with a rigid support from the top while the wooden block (2) floats being tied to the bottom through a massless string. If now the vessel starts acceleration towards right.



(A) iron block gets deflected towards right.
(B) wooden block gets deflected towards right.
(C) iron block gets deflected towards left.
(D) wooden block gets deflected towards left.

10. Assume initially all are in equilibrium

Column-I	Column-II
(A)  A block connected to an ideal spring.	(P) In the situation shown, the gravitational potential energy of the system is minimum.
(B)  A wooden block floating on water surface	(Q) On small appropriate displacement, body can execute SHM.
(C)  A uniform disc free to rotate in a vertical plane.	(R) For body to execute SHM, amplitude should be sufficiently small.

(D) 

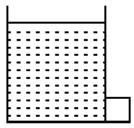
A pendulum bob.

(S) If the mass of body increases without changing its size, its time period of oscillation can change.

(T) If the size of body increases without increasing mass, its time period of oscillation can change.

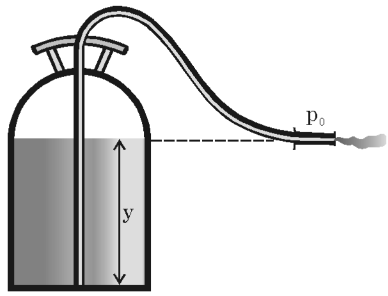
BERNOULLI'S THEOREM

11. A stopper is used to block a small hole at the base of a vessel. Force exerted by liquid on stopper is F_1. The stopper is then removed. Force experienced by vessel due to issuing liquid now is F_2 neglect atmospheric pressure, F_1/F_2 = ?



(A) 1 (B) 2 (C) 1/2 (D) 4

12. A certain fire extinguisher consists of a large sealed tank with a thin tube leading from the bottom of the tank to an exit nozzle; the air above the liquid in the tank is at an overpressure p_{tank} with respect to atmospheric pressure p_0. The exit nozzle is at the same level as the top of the liquid; both are a distance y above the bottom of the tank (see figure). The liquid has density ρ. Find an expression for the speed of the stream of liquid emerging from the nozzle.



(A) $\sqrt{\frac{2(p_{tank}+p_0)}{\rho}}$ (B) $\sqrt{\frac{2p_{tank}}{\rho}}$ (C) $\sqrt{\frac{(p_{tank}+p_0)}{2\rho}}$ (D) $\sqrt{\frac{p_{tank}}{\rho}}$

13. A tank full of water has a small hole at its bottom. Let t_1 be the time taken to empty first one third of the tank and t_2 be the time taken to empty second one third of the tank and t_3 be the time taken to empty rest of the tank then

(A) $t_1 = t_2 = t_3$ (B) $t_1 > t_2 > t_3$ (C) $t_1 < t_2 < t_3$ (D) $t_1 > t_2 < t_3$

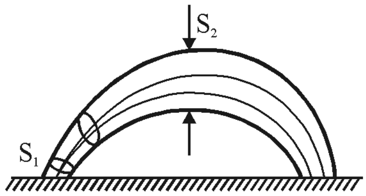
14. Water jet is projected at an angle to the horizontal. At the point of projection, the area of the jet is S_1 and at the highest point, the area of the jet is S_2. The initial velocity of projection is u.

(A) The angle of projection is $\cos^{-1}\left(\frac{S_1}{S_2}\right)$

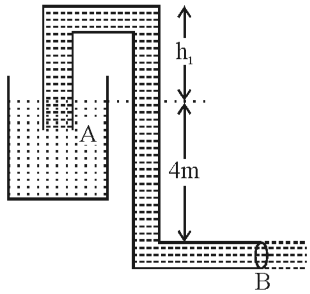
(B) The range on the level ground is $\frac{2u^2}{g}\frac{S_1}{S_2}\sqrt{1-\frac{S_1^2}{S_2^2}}$

(C) The maximum height reached from the ground is $\frac{2u^2}{g}\left(1-\frac{S_1^2}{S_2^2}\right)$

(D) The rate of volume flow is S_2u

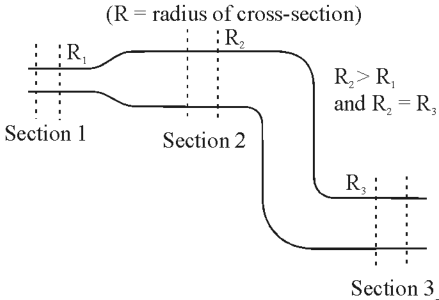


15. A tube of small uniform cross section is used to siphon the water from the vessel. Then choose correct alternative(s) :
($\rho_{water} = 10^3$ kg/m^3, g = 10 m/s^2, $P_{atm} = 10^5$ Pa)



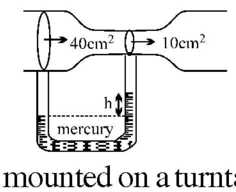
(A) Water will come out from section B with a velocity of $\sqrt{80}$ m/s
(B) Water will come out from section B with a velocity of $10\sqrt{2}$ m/s
(C) The greatest value of h_1 for which the siphon will work is 10 m
(D) The greatest value of h_1 for which the siphon will work is 6 m

16. An arrangement of the pipes of circular cross-section is shown in the figure. The flow of water (incompressible and nonviscous) through the pipes is steady in nature. Three sections of the pipe are marked in which section 1 and section 2 are at same horizontal level, while being at a greater height than section 3. Correctly match order of the different physical parameter with the options given. In column-I certain statements are given and numbers given in column-II represent the section shown in figure. Match the statements in column-I with corresponding ranking in column-II

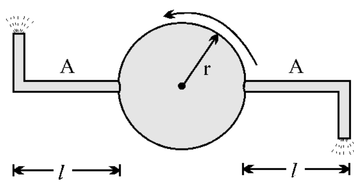


	Column-I		**Column-II**
(A)	Order of volume flow rate in section	(P)	1 > 2 > 3
(B)	Order of total energy of unit weight while flowing through sections.	(Q)	3 > 2 > 1
(C)	Order of pressure in the sections.	(R)	1 > 2 = 3
(D)	Order of flow speed in sections	(S)	1 = 2 = 3
		(T)	1 = 2 > 3

17. The horizontal pipe shown in the diagram has a cross sectional area of 40cm^2 at the wider position and 10cm^2 at the narrow poriton. A liquid of specific gravity 1.6 is flowing in the pipe with volume flow rate equal to 5×10^{-3} m^3/s. Find the difference in the heights h between the mercury column in the manometer tube.($\rho_{\mu g} = 13.6 \times 10^3$ kg/m^3) (g = 10 m/s^2)



18. Shows the top view of a cylindrical can mounted on a turntable. The can is filled with water. At a depth h below the water surface are two horizontal tubes of length *l* and cross-sectional area a, with right-angle bends at their ends. Show that, as the water jets emerge from the tubes, there is a torque τ exerted on the system given by the expression t = 4ρgh (r + *l*)a, where ρ is the density of the water.

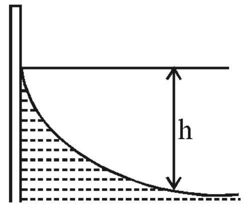


SURFACE TENSION

19. Two soap bubbles with radii r_1 and r_2 ($r_1 > r_2$) come in contact. Their common surface has a radius of curvature r.

(A) $r = \frac{r_1 + r_2}{2}$ (B) $r = \frac{r_1 r_2}{r_1 - r_2}$ (C) $r = \frac{r_1 r_2}{r_1 + r_2}$ (D) $r = \sqrt{r_1 r_2}$

20. Water of density ρ in a clean aquarium forms a meniscus, as illustrated in the figure. Calculate the difference in height h between the centre and the edge of the meniscus. The surface tension of water is γ.



(A) $\sqrt{\frac{2\gamma}{\rho g}}$ (B) $\sqrt{\frac{\gamma}{\rho g}}$

(C) $\frac{1}{2}\sqrt{\frac{\gamma}{\rho g}}$ (D) $2\sqrt{\frac{\gamma}{\rho g}}$

21. Figure (a) and (b) show water drop and mercury drop in two identical conical glass pipes, then

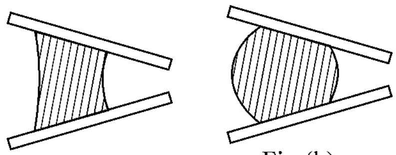
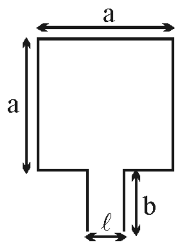


Fig.(a) Fig.(b)

(A) The water drop tends to move towards narrow end and mercury drop towards wide end.
(B) The water drop tends to move towards wide end and mercury drop towards narrow end.
(C) both tend to move towards wide end.
(D) both tend to move towards narrow end.

22. A light open rigid wire frame floats on the surface of water as shown in figure. What force will act on the frame, immediately after some soap solution is dropped inside it? α_1 and α_2 are the surface tensions of water and soap respectively ($\alpha_1 > \alpha_2$)

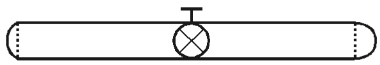


(A) zero
(B) $(\alpha_1 - \alpha_2)\,\ell$
(C) $(\alpha_1 + \alpha_2)\,(4a + 2b + \ell)$
(D) $(\alpha_1 - \alpha_2)\,(4a + 2b - \ell)$

23. If a drop of liquid breaks into smaller droplets, it results in lowering of temperature of the droplets. Let a drop of radius *R*, break into *N* small droplets each of radius *r*. Estimate the change in temperature.

(A) $\frac{2T}{\rho s}\left(\frac{1}{R}+\frac{1}{r}\right)$ (B) $\frac{4T}{\rho s}\left(\frac{1}{R}-\frac{1}{r}\right)$ (C) $\frac{3T}{\rho s}\left(\frac{1}{R}-\frac{1}{r}\right)$ (D) $\frac{2T}{\rho s}\left(\frac{1}{R}-\frac{1}{r}\right)$

24. A glass tube of uniform internal radius (r) has a valve separating the two identical ends. Initially, the valve is in a tightly closed position. End 1 has a hemispherical soap bubble of radius r. End 2 has sub-hemisperical soap bubble as shown in figure. Just after opening the valve :-

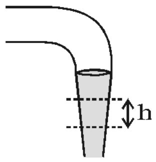


(A) Air from end (1) flows towards end (2) & finally bubble (1) disappear.
(B) Air from end (2) flows towards end (1) & finally bubble (2) disappear.
(C) Air from end (1) flows towards end (2) & finally process stops when curvature radius of both bubble become same.
(D) Air from end (2) flows towards end (1) & finally process stops when curvature radius of both bubble become same.

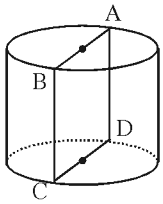
25. A drop of water volume 0.05 cm^3 is pressed between two glass-plates, as a consequence of which, it spreads between the plates. The area of contact with each plate is 40 cm^2. If the surface tension of water is 70 dyne/cm, the minimum normal force required to seperate out the two glass plates in newton is approximately (assuming angle of contact is zero) :

(A) 45 N (B) 100 N (C) 90 N (D) None of these

26. From a water tap, liquid comes out in form of cylinder. As water moves down, radius of that cylinder decreases. Consider, a very small element of height h and radius R (due to small height radius is assumed to be constant)



This element is given in the diagram. An imaginary cross-section ABCD divides this element in two equal semi cylinders. S is surface tension of liquid. Now choose correct statement(s)



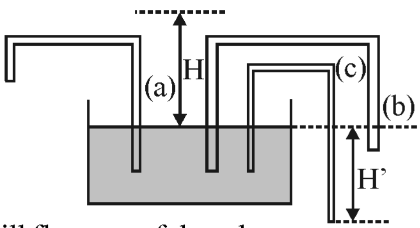
(A) Surface energy of this elementary cylinder is $S[2\pi Rh + 2\pi R^2]$

(B) Pressure inside the cylinder is more than atmospheric pressure by $\frac{2S}{R}$

(C) Force exerted by one half cylinder on another half cylinder due to surface tension is 2Sh.

(D) Surface energy of this elementary cylinder is $S \times 2\pi Rh$

27. Water which wets the walls of a vertical capillary tube rises to a height H within it. Three 'gallows', (a), (b) and (c), are made from the same tubing, and one end of each is placed into a large dish filled with water, as shown in the figure. (H' > H) then



(A) In case a water cannot flow out of the tube.

(B) In case b water cannot flow out of the tube.

(C) In case c water cannot flow out of the tube. (D) In case c water will flow out of the tube.

28. A long capillary of radius r is immersed in liquid of surface tension T. The tube is slowly pulled out of the liquid vertically. Find the length of liquid column left in the capillary tube when it is out of liquid. (ρ density of liquid) g acceleration due to gravity. Assume liquid wets the capillary completely.

VISCOSITY

29. A sphere is dropped into a viscous liquid of viscosity η from some height. If the density of material and liquid are ρ and σ respectively ($\rho > \sigma$) then which of the following is incorrect.

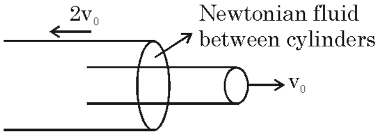
(A) the acceleration of the sphere just after entering the liquid is $g\left(\frac{\rho - \sigma}{\rho}\right)$

(B) Time taken to attain terminal speed $t \propto \rho^0$

(C) At terminal speed, the viscous force is maximum

(D) At terminal speed, the net force acting on the sphere is zero

30. Consider a situation in which there is a Newtonian fluid between two long coaxial uniformly moving cylinders of radius R and 2R.



(A) Force per unit length required to keep the inner cylinder moving is $4\pi\eta v_0$

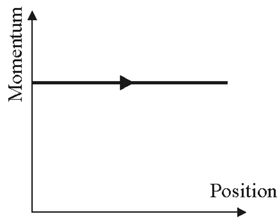
(B) Force per unit length required to keep the inner cylinder moving is $\frac{6\pi\eta v_0}{\ell n 2}$.

(C) Distance of the point from the axis at which speed of fluid is zero is $2^{1/3}R$.

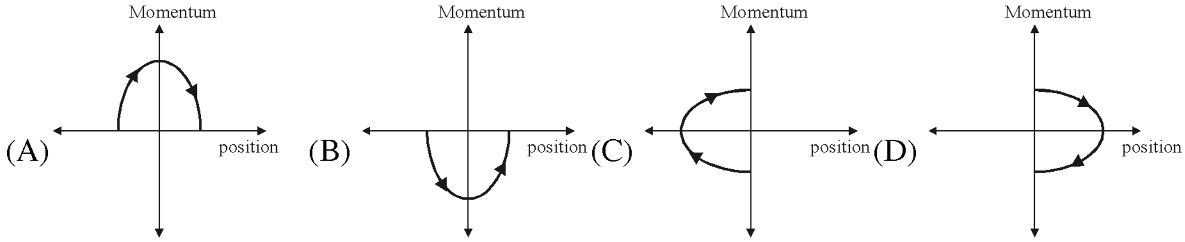
(D) Distance of the point from the axis at which speed of fluid is zero is $\sqrt{2}R$.

Paragraph for Questions Nos. 31 to 33

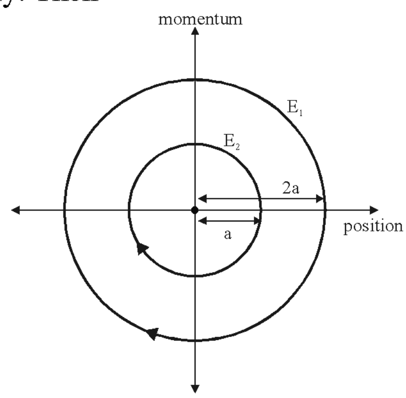
Phase space diagrams are useful tools in analyzing all kinds of dynamical problems. They are especially useful in studying the changes in motion as initial position and momentum are changed. Here we consider some simple dynamical systems in one-dimension. For such systems, phase space is a plane in which position is plotted along horizontal axis and momentum is plotted along vertical axis. The phase space diagram is x(t) vs. p(t) curve in this plane. The arrow on the curve indicates the time flow. For example, the phase space diagram for a particle moving with constant velocity is a straight line as shown in the figure. We use the sign convention in which position or momentum upwards (or to right) is positive and downwards (or to left) is negative.



31. The phase space diagram for a ball thrown vertically up from ground is

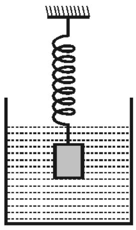


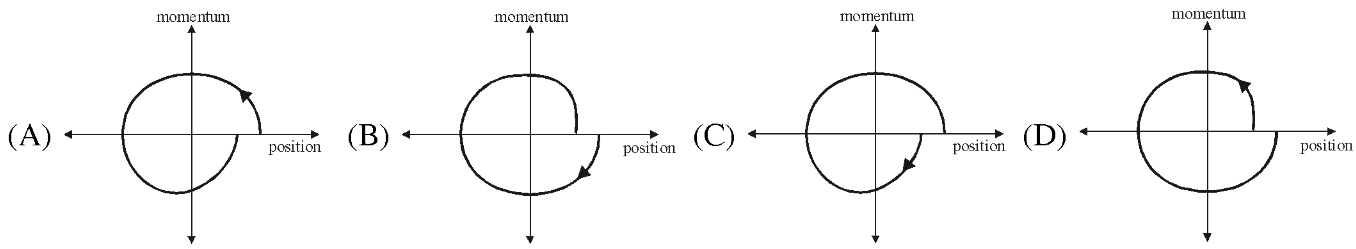
32. The phase space diagram for simple harmonic motion is a circle centered at the origin. In the figure, the two circles represent the same oscillator but for different initial conditions, and E_1 and E_2 are the total mechanical energies respectively. Then



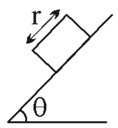
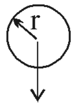
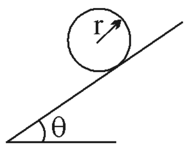
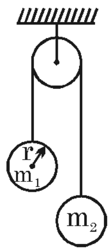
(A) $E_1 = \sqrt{2}E_2$ (B) $E_1=2E_2$ (C) $E_1=4E_2$ (D) $E_1=16E_2$

33. Consider the spring-mass system, with the mass submerged in water, as shown in the figure. The phase space diagram for one cycle of this system is





34.

	Column I		Column II
(A)	Body is a block lying on a rough inclined plane. Angle of inclination $\theta <$ angle of repose. A is inclined surface 	(P)	Force exerted by A on body can be equal to it's weight in magnitude.
(B)	Body is a ball falling in liquid with terminal velocity. A is liquid. 	(Q)	If density of body is somehow increased without changing r, it's state of motion (constant acceleration / constant velocity) or equilibrium position will be disturbed.
(C)	Body is a spherical ball rolling purely on inclined plane; inclined at an angle equal to angle of repose. The inclined surface is A. 	(R)	Work done by the force exerted by A on the body is zero.
(D)	Body is m_1 hanging on an ideal pulley system. A is string $m_1 < m_2$. 	(S)	Mechanical energy of body is constant as time passes.
		(T)	The kinetic energy of body is constant as time passes

35. The velocity distribution in a viscous flow over a plate is given by $u = 4y - y^2$ for $y \le 2m$ where u is velocity in m/s at a point which is at a distance y from the plate. If the coefficient of dynamic viscosity is 1.5 in SI units. Determine the shear stress at y = 0 in N/m^2.

* * * * *

ANSWER KEY			FLUID
1. Ans. (A)	**2. Ans. (A,D)**	**3. Ans. (B, C)**	**4. Ans. (B,C,D)**
5 Ans. 37.5 N	**6. Ans. 76.7 mm, 756.5 mm**		**7. Ans. (B)**
8. Ans. (A,D)	**9. Ans. (B, C)**		
10. Ans. (A) Q,R,S (B) P,Q,R,S,T (C) P,Q,R,T (D) P,Q,R,T			**11. Ans. (C)**
12. Ans. (B)	**13 Ans. (C)**	**14. Ans. (A, B)**	**15. Ans. (A, D)**
16. **Ans. (A)-S; (B)-S; (C)-Q; (D)-R**		**17. Ans. 15.75 cm**	**19. Ans. (B)**
20. Ans. (A)	**21. Ans. (A)**	**22. Ans. (B)**	**23. Ans. (C)**
24. Ans. (C)	**25. Ans. (A)**	**26. Ans. (C,D)**	**27. Ans. (A,B,D)**
28. Ans. $h = \frac{4T}{r\rho g}$	**29. Ans. (A,B,C)**	**30. Ans. (B,C)**	**31. Ans. (D)**
32. Ans. (C)	**33. Ans. (B)**		
34. Ans. (A) P, R,S, T ; (B) P, Q, T ; (C) R, S (D) Q			**35. Ans. 6**

WAVE EQUATION FOR WAVE ON STRING

1. The figures represent two snaps of a travelling wave on a string of mass per unit length, $\mu = 0.25$ kg/m. The two snaps are taken at time t = 0 and at $t = \frac{1}{24}$ s. Then the possible solution for wave are :

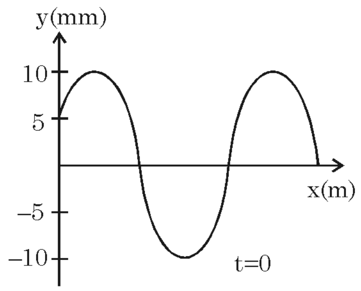


Figure-1

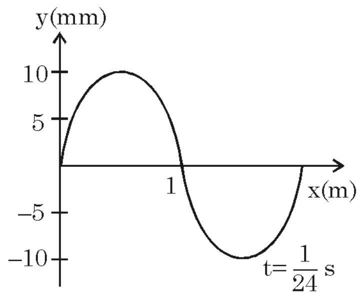


Figure-2

(A) speed of wave is 4 m/s.

(B) the tension in the string is 4 N

(C) the equation of the wave is $y = 10 \sin\left(\pi x - 4\pi t + \frac{\pi}{6}\right)$

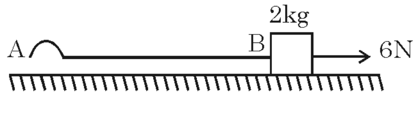
(D) the maximum velocity of the particle $= \frac{\pi}{25}$ m / s

2. y (x, t) = $0.8/[(4x + 5t)^2 + 5]$ represents a moving pulse, where x & y are in meter and t in second . Then:

(A) pulse is moving in +x direction
(B) in 2s it will travel a distance of 2.5 m
(C) its maximum displacement is 0.16 m
(D) it is a symmetric pulse.

SPEED OF WAVE IN STRING

3. A string of mass 1kg length 1m connected to a block of mass 2kg. Block is pulled by a force of 6N. There is no friction anywhere. A pulse is generated at rear end A of string. Then.



(A) Time taken by pulse to reach from A to B is $\sqrt{2}$ sec.

(B) Motion of pulse is non-uniformly accelerated w.r.t ground frame of reference.

(C) Time taken by pulse to move from A to B and then from B to A are equal.

(D) If two pulses are generated simultaneously at A and B they will meet at 0.25 m from A.

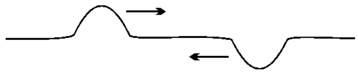
SUPERPOSITION OF WAVES

4. A traveling wave is of the form $y(x,t) = A\cos(kx - \omega t) + B\sin(kx - \omega t)$, which can also be written as

$y(x,t) = D\sin(kx - \omega t - \phi)$ where

(A) $D = A + B$ (B) $D = |A + B|$ (C) $D^2 = A^2 + B^2$ (D) $D = A - B$

5. Two symmetric, identical pulses of opposite amplitude travel along a stretched string in opposite directions as shown in the figure below. Which one of the following statements most fully describes the situation ?



(A) There is an instant when the string is straight

(B) When the two pulses interfere completely, the energy of the wave is zero

(C) There is a point on the string that does not move up or down

(D) Both A and C

6. A thin string with linear density μ is joined to a thick string with linear density 2μ. A incident pulse is sent down the thin string toward the thick string and eventually creates reflected and transmitted pulses. Which of the following is true ?

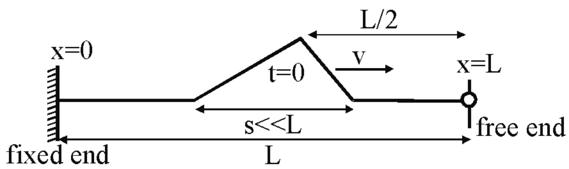
(A) The reflected and transmitted pulses are both inverted.

(B) Neither the reflected nor transmitted pulses are inverted.

(C) The reflected pulse is inverted, but the transmitted pulse is not inverted.

(D) The transmitted pulse is inverted, but the reflected pulse is not inverted.

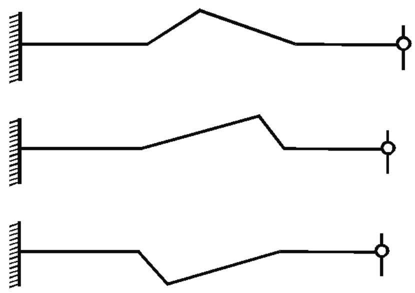
7. A small pulse travelling with speed v in a string is shown at t=0, moving towards free end. Which of these is **NOT CORRECTLY** matched.



(i) $t = \dfrac{L}{v}$ (P)

(ii) $t = \dfrac{2L}{v}$ (Q)

(iii) $t = \dfrac{3L}{v}$ (R)



(A) (i) (B) (ii) (C) (iii) (D) None of these

STANDING WAVES

8. A string of mass 0.2 kg and length 2m is tied at two ends to fixed supports under a tension of 10 N. A point P on the string is found to travel from one extreme to other in 0.1s. Taking one end as x = 0 and the other end x = 2m and t = 0 as the time when P is at rest. (Position of P is x)

The ***CORRECT*** statements will be

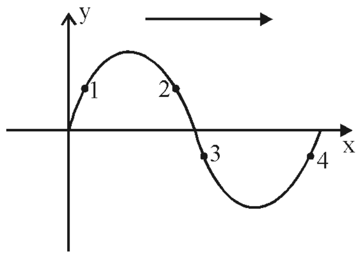
(A) For $0 < t < 0.1$ s, energy flows across P in positive x-direction for $0 < x < 1$ m

(B) For $0 < t < 0.05$ s, energy flows across P in negative x-drection for $0 < x < 1$ m

(C) At $t = 0.05$ s, rate of energy flow through P is zero for $x = 0.5$ m

(D) At $t = 0.1$s, rate of energy flow through P for all values of x is zero

9. Figure shows a snapshot of a string it may be a travelling wave or a standing wave. If it is standing wave the particles are to be considered at extreme.



	Column-I		**Column-II**
(A)	Point–1	(P)	Power transmitted across given point is towards right just after the instant shown for a travelling wave
(B)	Point–2	(Q)	Power transmitted across given point is towards right just after the instant shown for a standing wave
(C)	Point–3	(R)	Speed of given point is increasing for a travelling wave
(D)	Point–4	(S)	Speed of given point is increasing for a standing wave
		(T)	Potential energy is decreasing for a standing wave

10. String of length L whose one end is at $x = 0$, vibrates according to the relations given by different equations. Choose the **CORRECT** statement(s).

(A) $y = A\sin\frac{\pi x}{L}\sin\omega t$ has 1 antinodes, 2 nodes

(B) $y = A\cos\frac{\pi x}{L}\sin\omega t$ has 2 antinodes, 1 nodes

(C) $y = A\sin\frac{2\pi x}{L}\sin\omega t$ has 3 nodes, 2 antinodes

(D) $y = A\cos\frac{2\pi x}{L}\sin\omega t$ has 3 antinodes, 2 nodes

11. A wave disturbance in a medium is described by

$$y(x, t) = 0.02\cos(50\pi t + \pi/2)\cos(10\pi x),$$

where x and y are in metres and t in seconds.

(A) A node occurs at x = 0.15 m
(B) An antinode occurs at x = 0.3 m
(C) The speed of the wave is 5.0 m/s
(D) The wavelength is 0.2 m

12. A waveform : $y_1 = A\sin\left(2x - 4t + \frac{\pi}{3}\right)$ is superposed with a second waveform, to produce a standing wave with a node at x = 0. The equation of the second waveform can be :-

(A) $y_2 = A\sin\left(2x + 4t + \frac{5\pi}{3}\right)$
(B) $y_2 = A\sin\left(2x - 4t + \frac{\pi}{3}\right)$
(C) $y_2 = A\sin\left(2x + 4t - \frac{\pi}{3}\right)$
(D) $y_2 = A\sin\left(2x + 4t + \frac{\pi}{3}\right)$

13. A string fixed at both ends and under tension T vibrates in its 1^{st} overtone with an amplitude A at the antinodes. The total energy of the string is E and the maximum possible speed of a particle of the string is v. If the same string were to vibrate in its fundamental mode under a tension 4T and with an amplitude A at the antinode then :-
(A) The total energy of the string will be E
(B) The total energy of the string will be 2E
(C) The maximum possible speed of a particle on the string is v
(D) The maximum possible speed of a particle on the string is 2v

14. A long wire ABC is made by joining two wires AB and BC of equal cross-sectional area. AB has length 4.80 m and mass 0.12 kg. BC has length 2.56 m and mass 0.4 kg. The wire ABC is under a tension of 160 N. A sinusoidal wave y = 5.6 (cm) sin (ωt – kx) is sent along the wire ABC from the end A. No power dissipates during the propagation of the wave.

(A) The amplitude of the reflected wave is 2.4 cm
(B) The amplitude of transmitted wave is 3.2. cm
(C) The maximum displacement of the nodes of the stationary wave in the wire AB is 3.2 cm
(D) The fraction of power transmitted from the junction B is approximately 0.816

15. The equation of a standing wave in a string is given by y = A sin ωt sin kx. Distance between two points having amplitude A/2 may be:

(A) $\frac{5\pi}{6k}$ (B) $\frac{2\pi}{3k}$ (C) $\frac{7\pi}{6k}$ (D) $\frac{5\pi}{3k}$

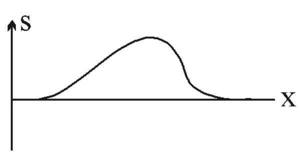
16. A string will break apart if it is placed under too much tensile stress. One type of steel has density. $\rho_{steel} = 10^4$ kg/m^3 and breaking stress $\sigma = 9 \times 10^8$ N/m^2. We make a guitar string from (4π) gram of this type of steel. It should be able to withstand (900 π)N without breaking. What is highest possible fundamental frequency (in Hz) of standing waves on the string if the entire length of the string vibrates.

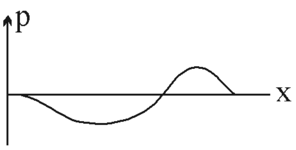
SOUND WAVES

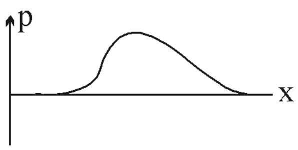
17. The speed of sound in neon (Ne) at a certain temperature is V ms^{-1}. The speed of sound in hydrogen (H_2) at the same temperature will be (assume both gases to be ideal)

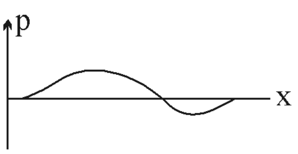
(A) $V\sqrt{\frac{42}{5}}$ ms^{-1} (B) $V\sqrt{\frac{5}{42}}$ ms^{-1} (C) $V\sqrt{5}$ ms^{-1} (D) $\frac{V}{\sqrt{5}}$ ms^{-1}

18. For displacement(s)-x graph shown for a sound wave, select appropriate excess pressure(p)-x graph.



(A)


(B)


(C)


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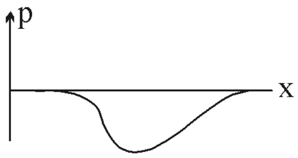


19. A small source of sound operates at 1kHz, 24πW emitting sound uniformly in all directions. The speed of sound is 360m/s in air and density of air is 1.2kg/m^3.

(A) The intensity of sound at a distance 10m from the source is 0.06W/m^2

(B) The intensity of sound at a distance 10m from the source is 0.24W/m^2

(C) The pressure amplitude at distance 10m is 7.2 Pa

(D) The pressure amplitude at distance 10m is 28.8 Pa

20. A point isotropic sonic source of sound power 1 milli watts emits sound of frequency 170 Hz in all directions.

(a) Find the distance of a point from the source where the loudness level is 60 dB. [Take v_s = 340 m/s]

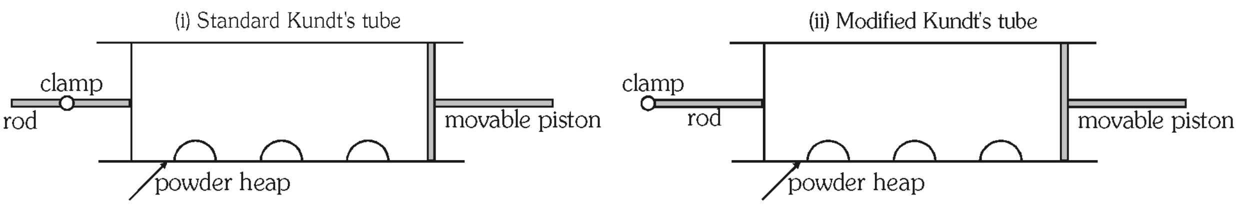
(b) It is known that at some moment t = 0, the displacement of air particles at a certain point 4 m away from the source is A. The amplitude of oscillation at this point is known to be 2A. Find the displacement of air particles in terms of A, at a point 55 m away from the source at the moment t = 0. Consider displacement of particles to be positive if it is away from the source.

STANDING WAVES IN SOUND

21. In a resonance column experiment, the length of air column at 1st resonance is measured to be 13.1 cm with a possible indeterminate error of 0.1 cm. With the same scale, the 2nd resonance occurs at 39.2 cm. The possible wavelength of the sound can be

(A) 52.2 cm (B) 52.4 cm (C) 52.5 cm (D) 51. 9 cm

22. In the Kundts tube experiment (shown in fig. (i)), the rod is clamped at the end instead of clamping it at the center as shown in fig. (ii). It is known that speed of sound in air is 330 m/s, powder piles up at successive distance of 0.6 m and length of rod used is 1m, speed of sound in rod is



(A) 550 m/s (B) 1100 m/s (C) 1200 m/s (D) 600 m/s

23. A narrow steel rod of length 'L' is rigidly clamped at its mid-point and transverse standing waves of frequency 'f' are set up in it. The speed of transverse waves in the rod is 'c'. Then,

(A) The free ends of the rod must be antinodes.

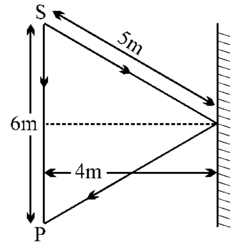
(B) The fundamental frequency of the rod is c/(L)

(C) The second overtone frequency of the rod is 5c/(2L)

(D) 'f' can be any integral multiple of the fundamental frequency.

INTERFERENCE OF SOUND WAVES

24. A person standing at a distance of 6 m from a source of sound receives sound wave in two ways, one directly from the source and other after reflection from a rigid boundary as shown in the figure. The maximum wavelength for which, the person will receive maximum sound intensity, is



(A) 4 m (B) $\frac{16}{3}$ m

(C) 2 m (D) $\frac{8}{3}$ m

25. Sound of wavelength λ passes through a Quincke's tube, which is adjusted to give a maximum intensity I_0. Find the distance through the sliding tube should be moved to give an intensity $I_0/2$.

26. A, B and C are three tuning forks. Frequency of A is 350Hz. Beats produced by A and B are 5 per second and by B and C are 4 per second. When a wax is put on A beat frequency between A and B is 2Hz and between A and C is 6Hz. Then, find the frequency of B and C respectively.

27. Two sound waves of frequencies 100 Hz and 102 Hz and having same amplitude 'A' are interfering. A detector which can detect waves of amplitude greater than or equal to A is kept at rest. In a time interval of 12 seconds, find the total duration (in sec) in which detector is active.

DOPPLER'S EFFECT

28. A car moves towards a hill with speed v_C. It blows a horn of frequency f which is heared by an observer following the car with speed v_0. The speed of sound in air is v.

(A) The wavelength of sound reaching the hill is $\frac{v}{f}$

(B) The wavelength of sound reaching the hill is $\frac{v - v_C}{f}$

(C) The beat frequency observed by the observer is $\left(\frac{v + v_0}{v - v_0}\right)f$

(D) The beat frequency observed by the observer is $\frac{2v_C(v + v_0)f}{v^2 - v_C^2}$

29. A train, standing in a yard, blows a whistle of frequency 400 Hz in still air. The wind starts blowing from yard to platform with a speed of 10m/s. Given that the speed of sound in still air is 340m/s,

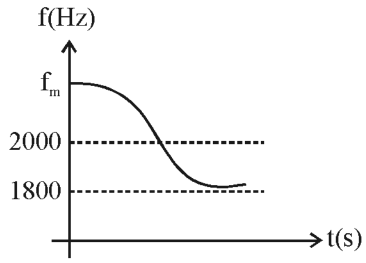
(A) the frequency of sound as heard by an observer standing on the platform is 400Hz.

(B) the speed of sound for the observer standing on the platform is 350m/s.

(C) the frequency of sound as heard by the observer standing on the platform will increase.

(D) the frequency of sound as heard by the observer standing on the platform will decrease.

30. A stationary observer receives a sound of frequency $f_0 = 2000$ Hz when the source is at rest. When the source starts moving with a constant velocity starting from a large distance, the apparent frequency f varies with time as shown in figure. Speed of sound = 300 m/s. Choose the **CORRECT** alternative (s):-



(A) Speed of source is 66.7 m/s.

(B) f_m shown in figure can be 2500 Hz.

(C) Speed of source is 33.33 m/s.

(D) f_m shown in figure cannot be greater than 2250 Hz.

* * * * *

ANSWER KEY			STRING WAVE & SOUND WAVE
1. Ans. (A,B,C,D)	**2. Ans. (B, C, D)**	**3. Ans. (A,C,D)**	**4. Ans. (C)**
5. Ans. (D)	**6. Ans. (C)**	**7. Ans. (B)**	**8. Ans. (C,D)**
9. Ans. A-P,Q,R,S,T; B-P,S,T; C-P,Q,R,S,T; D-P,S,T			**10. Ans. (A,B,C,D)**
11. Ans. (A, B, C, D)	**12. Ans. (A, C)**	**13. Ans. (A, C)**	**14. Ans. (A,B,C,D)**
15. Ans. (B, D)	**16. Ans. 375**	**17. Ans. (A)**	**18. Ans. (A)**
19. Ans. (A, C)	**20. Ans.** (a) $r = \sqrt{\frac{250}{\pi}}$ m, (b) $-\frac{4A}{55}$		**21. Ans. (A, B, C, D)**
22. Ans. (B)	**23. Ans. (A,C)**	**24. Ans. (A)**	**25. Ans.** $\lambda/8$
26. Ans. 345, 341 or 349 Hz		**27. Ans. 8**	**28. Ans. (B,D)**
29. Ans. (A,B)	**30. Ans. (C,D)**		

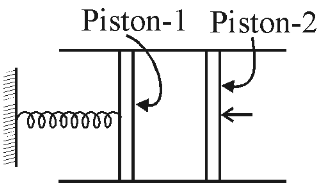
KINETIC THEORY OF GASES

1. A closed vessel contains a mixture of two diatomic gases A and B. Molar mass of A is 16 times that of B and mass of gas A, contained in the vessel is 2 times that of B.
(A) Average translational kinetic energy per molecule of gas A is equal to that of gas B
(B) Root mean square value of translational velocity of gas B is four times that of A
(C) Pressure exerted by gas B is eight times of that exerted by gas A
(D) Number of molecules of gas B in the cylinder is eight times that of gas A

2. A gas consists of particles moving around in random directions. Air molecules move with an average speed of 500 m/s at room temperature. In a balloon filled with hydrogen gas at the same room temperature, the hydrogen molecules would have the same average kinetic energy as the air molecules.
Average relative molecular mass of air molecule = 29
Relative molecular mass of hydrogen molecule = 2.0
Choose the correct options.
(A) Average speed of a hydrogen molecule is $500\sqrt{\frac{29}{2}}$
(B) The average velocity of the hydrogen molecules in the balloon is zero.
(C) If the mass of all the molecules of the hydrogen gas in the balloon is 1.0 g, the sum of the kinetic energies of all the molecules in the balloon is 1812.5 J
(D) If one of the hydrogen molecule was directed upwards from the surface of a planet which had no atmosphere, but was similar in size and mass to the earth and had the same gravitational field strength, height the molecule would go is nearly 95 km

3. A gas of temperature T is enclosed in a container whose walls are (initially) at temperature T_1.
(A) The gas exert a higher pressure on the walls of the container when $T_1 < T$.
(B) The gas exert a higher pressure on the walls of the container when $T_1 > T$.
(C) The gas exert same pressure in both cases.
(D) None of the above.

4. A long container has air enclosed inside at room temperature and atmospheric pressure (10^5 pa). It has a volume of 20,000 cc. The area of cross section is 100 cm^2 and force constant of spring is k_{spring} = 1000N/m. We push the right piston isothermally and slowly till it reaches the original position of the left piston which is movable. What is the final length of air column in m. Assume that spring is initially relaxed.



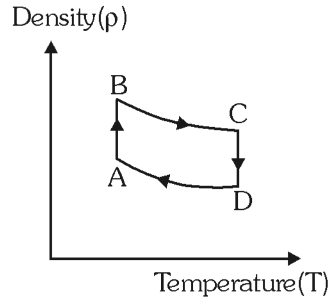
5. A cubical box of side of 1 meter contains helium gas (atomic weight 4) at a pressure of 100 N/m^2. During an observation time of 1 second, an atom traveling with the root-mean-square speed parallel to one of the edges of the cube, was found to make 500 hits with a particular wall, without any collision with other atoms. Take R = 25/3 J/mol-K and k = 1.38×10^{-23} J/K. Evaluate the temperature (in K) of the gas

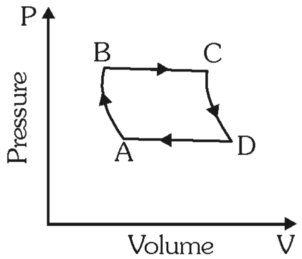
6. A mercury barometer (which is basically a vertical tube whose one end is open and dipped in mercury, the other end of the tube is closed) whose scale is on the stand behind the glass tube, reads 740 mm. Because of the low reading, it is suspected that some air is present in the space above the mercury. The space is 60 mm long. The open end of the barometer is lowered farther into the mercury reservoir. When the barometer reading is 730 mm, the space above the mercury is 40 mm long. What is the true atmospheric pressure? If your answer is N (mm of Hg) fill value of $\left(\frac{N+80}{120}\right)$.

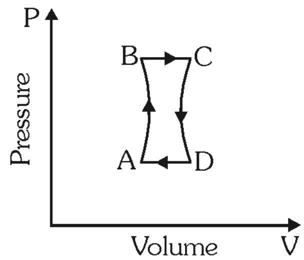
7. A long closed cylinder of length L and area A stands upright in uniform gravitational field g. It is filled with N molecules of a diatomic gas at uniform temperature T. Mass of each molecule is m. Find the pressure at both ends of the tube.

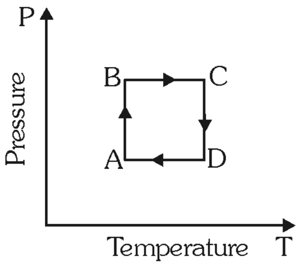
FIRST LAW OF THERMODYNAMICS

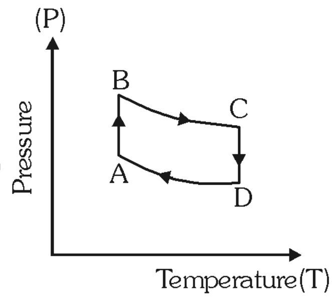
8. Density (ρ) versus temperature (T) graph of a thermodynamic cycle of an ideal gas is as shown. If BC and AD are the part of rectangular hyperbola then which of the following graphs will represent the same thermodynamic cycle ?



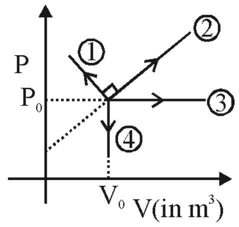
(A)


(B)


(C)


(D)


9. A monatomic ideal gas at pressure P_0 & volume V_0 can be made to undergo 4 different process on PV diagram as shown. For each of the processes, match with entries in column-II. (Symbols have their usual meanings).



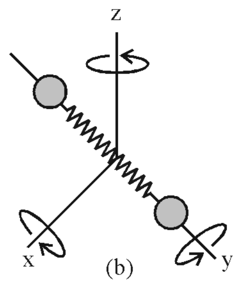
Column-I		**Column-II**	
(A)	Process–1	(P)	ΔQ + ve
(B)	Process-2	(Q)	ΔU + ve
(C)	Process-3	(R)	W –ve
(D)	Process-4	(S)	Temperature decreases
		(T)	ΔQ – ve

10. Certain amount of an ideal gas is contained in a closed vessel. The vessel is moving with constant velocity v. The rise in temperature of the gas when vessel is suddenly stopped is (M is molecular weight of the gas and $\gamma = \frac{C_P}{C_V}$, R is gas constant)

(A) $\frac{Mv^2}{2R}(\gamma-1)$ (B) $\frac{Mv^2}{2R}(\gamma+1)$ (C) $\frac{Mv^2}{2R\gamma}$ (D) $\frac{Mv^2}{2R(\gamma+1)}$

Paragraph for Question no 11 and 12

Let us consider a diatomic gas whose molecules have the shape of a dumbbell. In this model, the center of mass of the molecule can translate in the x, y, and z directions. In addition, the molecule can rotate about three mutually perpendicular axes. We can neglect the rotation about the y-axis because the moment of inertia I_y and the rotational energy $\frac{1}{2}I_y\omega^2$ about this axis are negligible compared with those associated with the x and z axes. (If the two atoms are taken to be point masses, then I_y is identically zero). Thus, there are five degrees of freedom : three associated with the translational motion and two associated with the rotational motion. Because each degree of freedom contributes, on the average, $\frac{1}{2}k_BT$ of energy per molecule, the total internal energy for a system of N molecules is :



(b)

$$E_{int} = 3N\left(\frac{1}{2}k_BT\right) + 2N\left(\frac{1}{2}k_BT\right) = \frac{5}{2}Nk_BT = \frac{5}{2}nRT \quad ....(1)$$

We can use this result to find the molar specific heat at constant volume :

$$C_V = \frac{1}{n}\frac{dE_{int}}{dT} = \frac{1}{n}\frac{d}{dT}\left(\frac{5}{2}nRT\right) = \frac{5}{2}R \quad ....(2)$$

From equation (1) and (2), we find that

$$C_P = C_V + R = \frac{7}{2}R$$

$$\gamma = \frac{C_P}{C_V} = \frac{7/2R}{5/2R} = \frac{7}{5} = 1.40$$

In the vibratory model, the two atoms are joined by an imaginary spring. The vibrational motion adds two more degrees of freedom, which correspond to the kinetic energy and the potential energy associated with vibrations along the length of the molecule about its centre of mass.

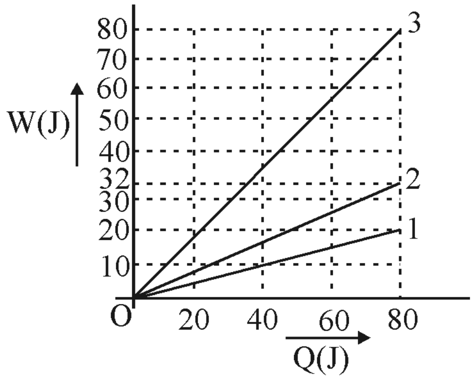
11. The root mean square angular velocity of a diatomic molecule (with each atom of mass m and interatomic distance a) is given by :-

(A) $\sqrt{\frac{4k_BT}{ma^2}}$ (B) $\sqrt{\frac{2k_BT}{ma^2}}$ (C) $\sqrt{\frac{k_BT}{ma^2}}$ (D) $\sqrt{\frac{k_BT}{2ma^2}}$

12. A diatomic molecule is moving without rotation or vibration with velocity v_{rms} such that it is oriented along x-axis. It strikes a wall in yz-plane while moving in +ve x direction. The spring constant can be assumed to be K and time of collision is negligible. After all collision are over :-

(A) The molecule is moving along –ve x-direction and oscillating about its centre of mass
(B) The molecule is moving along –ve x-direction, but not oscillating about its centre of mass
(C) The molecule is oscillating about its centre of mass but not moving at all.
(D) The molecule is neither rotating nor moving at all

13. In the figure shown, the amount of heat supplied to one mole of an ideal gas is plotted on the horizontal axis and the amount of work performed by the gas is drawn on the vertical axis. One of the straight lines in the figure is an isotherm and the other two are isobars of two gases. The initial states of both gases are same. Mark the **CORRECT** statement(s).

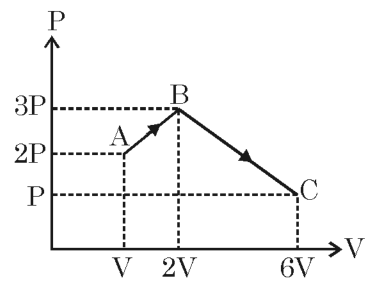


(A) Curve 3 corresponds to isothermal process
(B) Curve 1 corresponds to a polyatomic gas
(C) Curve 2 corresponds to a monatomic gas
(D) Process 1 and 2 are isobaric process.

14. During experiment, an ideal gas is found to obey a condition $\frac{P^2}{\rho}$ = constant [ρ = density of the gas]. The gas is initially at temperature T, pressure P and density ρ. The gas expands such that density changes to $\frac{\rho}{2}$

(A) The pressure of the gas changes to $\sqrt{2}$ P
(B) The temperature of the gas changes to $\sqrt{2}$ T
(C) The graph of the above process on the P–T diagram is parabola
(D) The graph of the above process on the P–T diagram is hyperbola

15. A monoatomic ideal gas undergoes a process ABC:



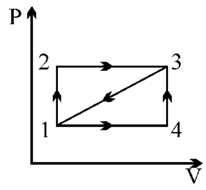
(A) Heat given to the gas is $\frac{33PV}{2}$.

(B) Heat given to the gas is $\frac{35PV}{2}$.

(C) Maximum temperature of the gas during the process is $\frac{8PV}{nR}$.

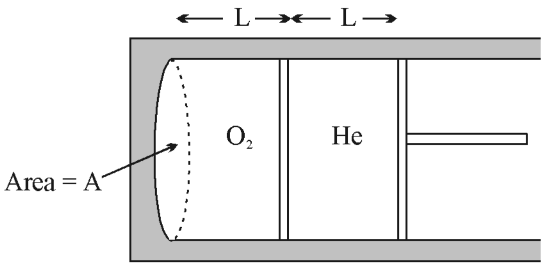
(D) Maximum temperature of the gas during the process is $\frac{4PV}{nR}$.

16. Figure shows an indicator diagram. During path 1-2-3, 100 cal are given to the system and 40 cal work is done. During path 1-4-3, the work done is 10 cal.



(A) Heat given to the system during path 1-4-3 is 70 cal
(B) If the system is brought from 3 to 1 along straight line path 3-1, work done on the gas is 25 cal
(C) Along straight line path 3-1, the heat ejected by the system is 85 cal
(D) The internal energy of the system in state 3 is 140 cal above that in state 1.

17. An insulating cylinder contains equal volumes of He and O_2 separated by a massless freely moving adiabatic piston as shown. The gas is compressed by moving the insulating piston so that volume of He becomes half. Select the correct alternative(s).



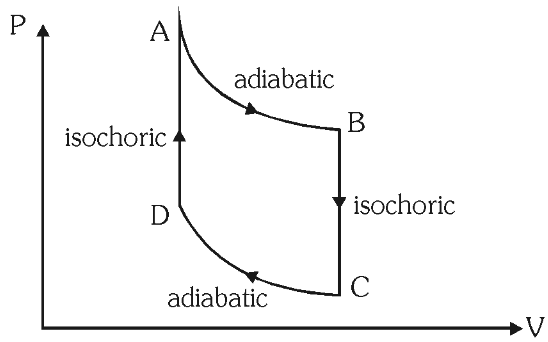
(A) Pressure in He chamber will be equal to pressure in O_2 chamber
(B) Pressure in He chamber will be less then pressure in O_2 chamber
(C) Volume of He chamber will be equal to volume of O_2 chamber
(D) Volume of O_2 chamber will be $\dfrac{(LA)}{(2)^{25/21}}$.

MOLAR HEAT CAPACITY

18. An ideal gas undergoes a process such that $P \propto \dfrac{1}{T}$. The molar heat capacity of this process is 33.24 J/mol K.

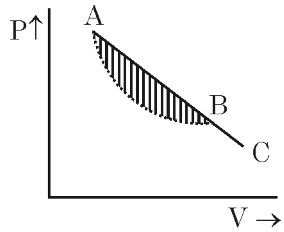
(A) The work done by the gas is $2R\Delta T$.
(B) Degree of freedom of the gas is 4.
(C) Degree of freedom of the gas is 3.
(D) $\gamma = \left(\dfrac{C_P}{C_V}\right)$ for the gas is 1.5.

19. Two moles of helium gas is taken through the cycle ABCDA as shown in the figure. If $T_A = 1000$ K, $2P_A = 3P_B = 6P_C$.



(A) work done by the gas in the process A to B is 3741 J.
(B) heat lost by the gas in the process B to C is 10600 J.
(C) temperature T_D is 2000 K.
(D) none of these

20. A certain amount of ideal gas expands along the straight line path ABC on P-V diagram as shown in the figure. The dotted curve represents the adiabatic for the same gas. Along the straight line path :



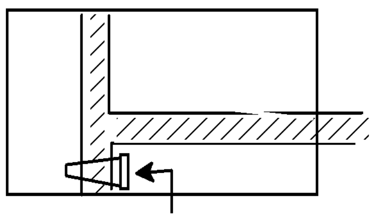
(A) As a net process A → B, the gas absorbs heat
(B) In process B → C, the gas rejects heat
(C) As a net in process A → B, the gas rejects heat
(D) In process A → B, the heat absorbed/rejected by gas is represented by shaded area in figure.

21. A block is given a initial push along rough horizontal fixed table surface and after some time it stops due to friction. For the system of block and table,
(A) temperature increase
(B) heat supplied is positive
(C) heat supplied is negative
(D) total energy decreases

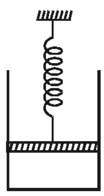
22. 2 moles of He are mixed with 2 moles of H_2 in a closed adiabatic container. Initially the mixture occupies 3 liters at 27°C. The volume is suddenly decreased to (3/2) liters. Choose the correct option(s) (H_2 & He can be treated as ideal gases) :
(A) γ for mixture is 3/2
(B) final temperature = $300\sqrt{2}$ K
(C) C_P for mixture is 2R
(D) Work done in compression is totally converted into internal energy

23. A diatomic gas is kept in a closed container of constant volume. Due to increase in temperature some molecules dissociates into atoms. Neglecting vibrational degrees of freedom :-
(A) Specific heat capacity of mixture will increase.
(B) Specific heat capacity of mixture will decrease
(C) Specific heat capacity of mixture can change by a maximum value of 8%.
(D) Specific heat capacity of mixture can change by a maximum value of 20%.

24. A cylinder of volume 0.6 m^3 is provided with a piston, the wall of which has a stop cock. The left part of the cylinder contains 10 mol of a gas (γ = 1.5) at a temperature of 300 K; the right chamber is evacuated. Initially the gas occupies one third of the total volume of the cylinder. The walls of the cylinder are adiabatic. The piston is moved quassi-statically so that the volume of the gas is doubled. The valve in the piston is then opened so that the gas fills the entire volume. Calculate the final pressure and temperature of the gas , work done and change in internal energy.



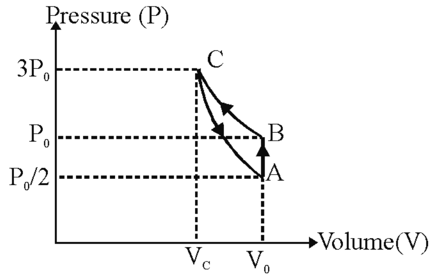
25. An ideal monoatomic gas is enclosed in a vertical cylinder of cross section area A and length ℓ, under frictionless piston connected to spring of spring constant K. Atmosphere pressure is such that in absence of gas under the piston, equilibrium of piston is achieved when piston just touches the bottom of the cylinder and spring is in stretched configuation. Q amount of heat is supplied to gas slowly to move piston to the upper edge. Initially volume occupied by gas is $\frac{1}{3}$rd of the volume of cylinder. If $Q = 2\lambda\frac{K\ell^2}{9}$, find λ, (through the motion of the piston spring is in stretched configuration)



26. A solid object has density ρ, mass M, and coefficient of linear expansion α. At pressure P the heat capacities C_p (at constant pressure) and C_v (at constant volume) are related by $C_p - C_v = \eta(\alpha MP/\rho)$. Fill the value of η in your OMR sheet.

CYCLIC PROCESS

27. One mole of an ideal gas is carried through a thermodynamic cycle as shown in the figure. The cycle consists of an isochoric, an isothermal and an adiabatic processes. The adiabatic exponent of the gas is γ. Choose the correct option(s).



(A) $\gamma = \frac{\ln 6}{\ln 3}$ (B) $\gamma = \frac{\ln 5}{\ln 3}$ (C) BC is adiabatic (D) AC is adiabatic

28. An electric freezer is turned on inside a tent for a long time. It is 0 °C outside the tent, +1 °C inside the tent, and –13 °C inside the freezer. What would be the equilibrium temperature inside the tent if another identical freezer is turned on inside the tent? The outside temperature remains the same. The freezers are identical and follow the Carnot cycle. If your answer is 'α'; fill the approximate value of '2α' in OMR sheet.

* * * * *

ANSWER KEY			KTG & THERMODYNAMICS
1. Ans. (A,B,C,D)	**2. Ans. (A,B)**	**3. Ans. (B)**	**4. Ans. 1**
5. Ans. 160	**6. Ans. 7**	**7. Ans.** $P_0 = \frac{Nmg}{A}\frac{e^{\frac{mgL}{kT}}}{e^{\frac{mgL}{kT}}-1}$, $P_L = \frac{Nmg}{A}\frac{1}{e^{\frac{mgL}{kT}}-1}$	
8. Ans. (A,C)	**9. Ans. (A) → (R) ; (B) → (P, Q) ; (C) → (P, Q) ; (D) → (S, T)**		
10. Ans. (A)	**11. Ans. (B)**	**12. Ans. (B)**	**13. Ans. (A,B,C,D)**
14. Ans. (B, D)	**15. Ans. (A,C)**	**16. Ans. (A,B,C)**	**17. Ans. (A, D)**
18. Ans. (B,D)	**19. Ans. (AB)**	**20. Ans. (A,B,D)**	**21. Ans. (A,C,D)**
22. Ans. (A, B, D)	**23. Ans. (B,D)**		
24. Ans. $3.2 \times 10^4 N/m^2$, 226K, $1.52 \times 10^4 J$, $-1.52 \times 10^4 J$			**25. Ans. 8**
26. Ans. 3	**27. Ans. (AD)**	**28. Ans. 4**	

SHM

1. A particle of mass 1 kg, executing simple harmonic motion of period 20 s, crosses the mean position at t = 0 with velocity π cm/s.
(A) the maximum acceleration of the particle is 10 cm/s^2
(B) when it is 4 cm from the mean position, its velocity is $6\pi/10$ cm/s
(C) the kinetic energy of the particle when its displacement is 5 cm from the mean position is $\frac{3\pi^2}{8\times10^6}$ J
(D) its velocity at displacement 6 cm from the mean position is $8\pi/10$ cm/s

2. Two particles are in SHM with same amplitude A and same angular frequency ω. At time t=0, one is at $x = +\frac{A}{2}$ and other is at $x = -\frac{A}{2}$. Both are moving in same direction.
(A) Phase difference between the two particle is $\frac{\pi}{3}$
(B) Phase difference between the two particle is $\frac{2\pi}{3}$
(C) They will collide after time $t = \frac{\pi}{2\omega}$
(D) They will collide after time $t = \frac{3\pi}{\omega}$

3. A particle is performing SHM with its position given as $x = 2 + 5\sin\left(\pi t + \frac{\pi}{6}\right)$ where x (in m) & t (in sec). Which of the following is/are correct :-
(A) Equilibrium position is at x = 2m
(B) Maximum speed of particle is 5π m/s
(C) At t = 0 particle is 2.5 m away from mean position moving in negative direction
(D) At t = 0, x = 4.5 m; acceleration of particle is $-\pi^2(4.5)$ m/s^2

4. Two particles 'A' and 'B' start SHM at t = 0. Their positions as a function of time are given by $X_A = A\sin\omega t$; $X_B = A\sin(\omega t + \pi/3)$

	Column-I		Column-II
(A)	Minimum time when x is same	(P)	$\frac{5\pi}{6\omega}$
(B)	Minimum time when velocity is same	(Q)	$\frac{\pi}{3\omega}$
(C)	Minimum time after which $v_A < 0$ and $v_B < 0$	(R)	$\frac{\pi}{\omega}$
(D)	Minimum time after which $x_A < 0$ and $x_B < 0$	(S)	$\frac{\pi}{2\omega}$

5. A particle of mass 2 kg moves in a straight line. If v is the velocity at a distance x from a fixed point on the line and $v^2 = 3-4x^2$ then-

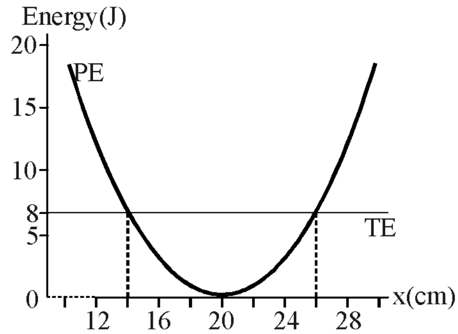
(A) The motion continues along the positive x-direction only.

(B) The motion is simple harmonic

(C) The oscillation frequency is 2 units ($\omega = 2$)

(D) The total energy of the particle is 3 units

6. Figure shows the potential-energy diagram and the total energy line of a particle oscillating on a spring.



(A) the amplitude of oscillation of particle is 6 cm.

(B) the spring constant is 4.44 kN/m.

(C) the mass of particle is 1kg.

(D) the maximum kinetic energy of particle is at x = 20 cm.

7. Acceleration of a particle which is at rest at x = 0 is $\vec{a} = (4-2x)\hat{i}$. Select the correct alternatives(s)-

(A) particle further comes to rest at x = 4

(B) particle oscillates about x = 2

(C) maximum speed of particle is 4 units

(D) all of the above

8. A linear harmonic oscillator of force constant $2 \times 10^6 Nm^{-1}$ and amplitude 0.01 m has a total mechanical energy of 160 J. Its

(A) maximum potential energy is 100 J

(B) maximum kinetic energy is 100 J

(C) maximum potential energy is 160 J

(D) minimum potential energy is zero.

9. A body is performing S.H.M., then its

(A) average total energy of SHM per cycle is equal to its maximum kinetic energy.

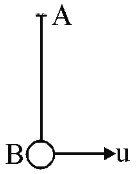
(B) average kinetic energy per cycle is equal to half of its maximum kinetic energy.

(C) mean velocity over a complete cycle is equal to $2/\pi$ times of its maximum velocity.

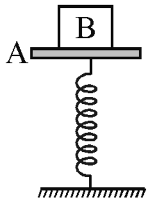
(D) root mean square velocity is $1/\sqrt{2}$ times of its maximum velocity

10. **Column I**

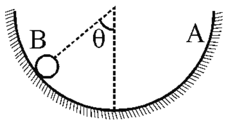
(A) A bob B hanging from a light string A of length 3 m is projected to left with a speed of 10 m/s.



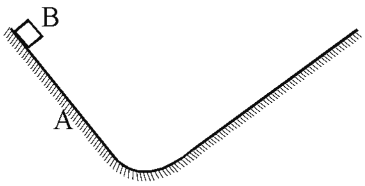
(B) The light platform with block B is pushed down by a distance $2x_0$ below mean position & released.
[x_0 is compression in mean position]



(C) A spherical solid ball B is released on a perfectly rough spherical surface A as shown $\left[\theta = \dfrac{\pi}{3}\right]$.



(D) Block B is released on a smooth track A as shown.



Column II

(P) The acceleration of centre of mass of B at some time can be equal to g.

(Q) The force exerted by A on B can be zero at some point.

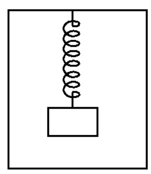
(R) the speed of the body B varies sinusoidally with time when force exerted by A on B is not zero.

(S) The motion of B is oscillatory.

(T) The motion of B is periodic.

DYNAMICS OF SHM

11. A spring mass system is hanging from the ceiling of an elevator in equilibrium. Elongation of spring is l. The elevator suddenly starts accelerating downwards with acceleration g/3 find



(a) the frequency and

(b) the amplitude of the resulting SHM.

12. The potential energy of a particle of mass 0.1 kg, moving along the x-axis, is given by $U = 5x(x-4)$J, where x is in metres. It can be concluded that :

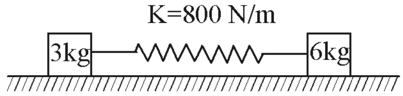
(A) the particle is acted upon by a constant force.

(B) the speed of the particle is maximum at x = 2 m.

(C) the particle executes simple harmonic motion

(D) the period of oscillation of the particle is $\pi/5$ s.

13. The system shown in the figure can move on a smooth surface. The spring is initially compressed by 6 cm and then released .



(A) the particles perform SHM with time period $\frac{\pi}{10}$ sec

(B) the block of mass 3 kg perform SHM with amplitude 4 cm

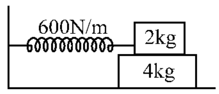
(C) the block of mass 6 kg will have maximum momentum 2.40 kg m/s

(D) none of these

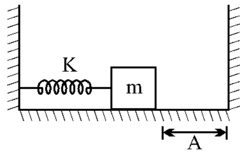
14. In the arrangement shown, the spring of force constant 600N/m is in the unstretched position. The coefficient of friction between the two blocks is 0.4 and that between the lower block & ground surface is zero. If both the blocks are displaced slightly and released, the system executes SHM.

(a) Find time period of their oscillation if they do not slip w.r.t. each other.

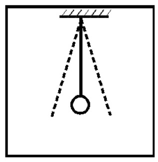
(b) What is the maximum amplitude of the oscillation for which sliding between them does not occur.



15. In the figure shown the spring is relaxed. The spring is compressed by 2 A and released. Mass m attached with the spring collides with the wall & loses two third of its kinetic energy & returns. Find the time after which the spring will have maximum compression first time after releasing. (Neglect Friction)



16. A simple pendulum is oscillating in a stationary lift with a time period T and an angular amplitude θ_0. When it is passing through the mean position, the lift starts accelerating upwards.



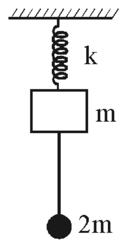
(A) The time period of its oscillation will increase

(B) Its angular amplitude would increase.

(C) The time period of its oscillation would decrease

(D) Its angular amplitude would decrease.

17. A bob of mass 2m hangs by a string attached to the block of mass m of a spring block system. The whole arrangement is in a state of equilibrium. The bob of mass 2m is pulled down slowly by a distance x_0 and released.



(A) For $x_0 = \frac{3mg}{k}$ maximum tension in string is 4mg

(B) For $x_0 > \frac{3mg}{k}$, minimum tension in string is mg

(C) Frequency of oscillation of system is $\frac{1}{2\pi}\sqrt{\frac{k}{3m}}$, for all non-zero values of x_0

(D) The motion will remain simple harmonic for $x_0 \leq \frac{3mg}{k}$

18. Consider a spring that exerts the following restoring force

F = – kx for x > 0

F = – 4kx for x < 0

A mass m on a frictionless surface is attached to the spring displaced to x = A by stretching the spring and released :

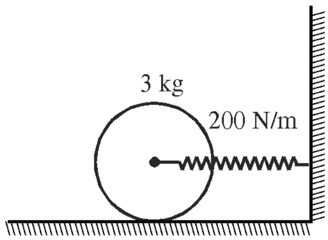
(A) The period of motion will be $T = \frac{3}{2}\pi\sqrt{\frac{m}{k}}$

(B) the most negative value the mass m can reach will be $x = -\frac{A}{2}$

(C) The time taken to move from x = A to $x = -\frac{A}{\sqrt{2}}$, straight away will be equal to $\frac{5\pi}{8}\sqrt{\frac{m}{k}}$

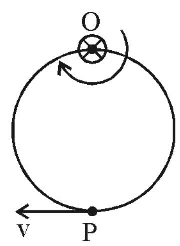
(D) The total energy of oscillations will be $\frac{5}{2}kA^2$

19. The uniform solid cylinder rolls without slipping in the system shown. If the maximum compression in spring is 15cm, the possible friction force acting on the cylinder during its motion is :



(A) 4N (B) 10N (C) 12N (D) 15N

20. A ring of mass m, radius r can oscillate in a vertical plane about is top most point 'O' as shown. Axis is normal to the plane of ring. Maximum speed of lowest point 'P' of ring is v.



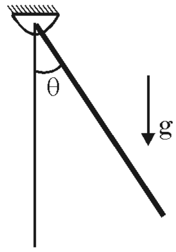
(A) Time period of SHM for small amplitudes is $2\pi\sqrt{\frac{2r}{g}}$

(B) Acceleration of centre of mass of ring at lowest position is zero.

(C) Hinge force when centre of mass is at lowest point is $\frac{mv^2}{4r}$

(D) Mechanical energy of oscillation is $\frac{mv^2}{4}$ (when potential energy at mean position is taken as zero.)

21. An uniform rod of mass m and length ℓ is pivoted at top and it can perform angular SHM in vertical plane according to equation $\theta = \theta_0 \sin \omega t$. At time $t = \frac{2\pi}{\omega}$ a point mass m (at rest) sticks to lowest end of rod.



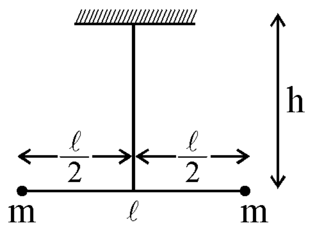
(A) New time period of rod will be $\frac{2}{\sqrt{3}}$ times of the time period before collision.

(B) New angular amplitude is $\frac{\theta_0}{\sqrt{12}}$

(C) New angular amplitude is $\frac{\theta_0}{4}$

(D) There will always be loss of kinetic energy of rod, irrespective of time at which mass sticks to rod.

22. Figure shows two particles connected with a light rod and entire arrangement hangs on a elastic wire. Neglect any gravitational effect, θ_0 = maximum angular displacement of the particles, C = torsional stiffness of wire. Mark the **CORRECT** statements :-



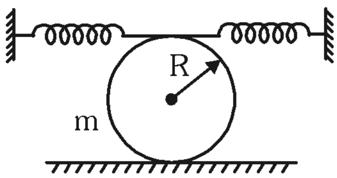
(A) Time period of oscillation is $\pi\ell\sqrt{\frac{2m}{C}}$

(B) Maximum tension in the rod is $\frac{C\theta_0^2}{\ell}$

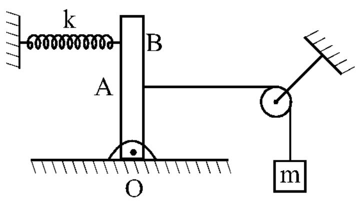
(C) The energy of oscillation is $\frac{1}{2}C\theta_0^2$

(D) The maximum tangential acceleration of particle is $\frac{C\theta_0}{m\ell}$

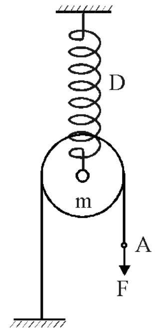
23. A solid uniform cylinder of mass m performs small oscillations due to the action of two springs combined stiffness equal to k (figure). The period of these oscillations in the absence of sliding is $T = \pi\sqrt{\frac{xm}{2k}}$. Then find x :



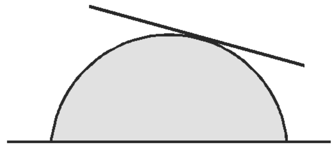
24. A massless rod is hinged at O. A string carrying a mass *m* at one end is attached to point A on the rod so that OA = a. At another point B (OB= b) of the rod, a horizontal spring of force constant *k* is attached as shown. Find the period of small vertical oscillations of mass *m* around its equilibrium position.



25. The axle of a pulley of mass m = 1 kg is attached to the end of a spring of spring constant k = 200 N/m whose other end is fixed to the ceiling. A rope of negligible mass is placed on the pulley such that its left end is fixed to the ground and its right end is hanging freely from the pulley which is at rest in equilibrium. We begin to pull the endpoint A at the right end of the rope by a constant vertical force of F = 15 N. Friction can be neglected between the rope and the pulley. Find the maximum displacement of point A after applying F. Express your answer in cm.



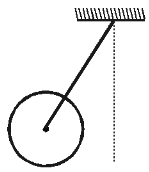
26. A uniform rod of length 2ℓ rocks to and fro on the top of a rough semicircular fixed cylinder of radius a. The period of small oscillations, of rod is



(A) $\frac{2\pi\ell}{\sqrt{3ga}}$ (B) $2\pi\sqrt{\frac{\ell}{3g}}$

(C) $2\pi\sqrt{\frac{a}{3g}}$ (D) $\frac{\pi\ell}{\sqrt{3ga}}$

27. A metal rod of length 'L' and mass 'm' is pivoted at one end. A thin disk of mass 'M' and radius 'R' (<L) is attached at its center to the free end of the rod. Consider two ways the disc is attached: (case A). The disc is not free to rotate about its center and (case B) the disc is free to rotated about its center. The rod-disc system performs SHM in vertical plane after being released from the same displaced position. Which of the following statement(s) is(are) true?



(A) Restoring torque in case A = Restoring torque in case B
(B) Restoring torque in case A < Restoring torque in case B
(C) Angular frequency for case A> Angular frequency for case B
(D) Angular frequency for case A< Angular frequency for case B

* * * * *

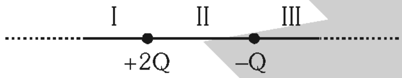
ANSWER KEY			SHM
1. Ans. (D)	**2. Ans. (A,C)**	**3. Ans. (A, B)**	
4. Ans. (A)-Q, (B)-P, (C)-S, (D)-R]		**5. Ans. (B,C,D)**	**6. Ans. (A,B,D)**
7. Ans. (A, B)	**8. Ans. (B,C)**	**9. Ans. (A,B,D)**	
10. Ans. (A) PQ (B) PQRST (C) ST (D) ST		**11. Ans. (a)** $\frac{1}{T}=\frac{1}{2\pi}\sqrt{\frac{g}{L}}$, **(b)** $\frac{L}{3}$	
12. Ans. (B,C,D)	**13. Ans. (A,B,C)**	**14. Ans: (a) π/5, (b) 2cm**	**15. Ans.** $\frac{17\pi}{12}\sqrt{\frac{m}{K}}$
16. Ans. (C,D)	**17. Ans. (A,D)**	**18. Ans. (AB)**	**19. Ans. (A,B)**
20. Ans. (A, D)	**21. Ans. (A, B)**	**22. Ans. (A, B, C, D)**	**23. Ans. 3**
24. Ans. $(2\pi a/b)(m/k)^{1/2}$	**25. Ans. 60**	**26. Ans. (A)**	**27. Ans. (A,D)**

COULOMB'S LAW

1. Two small spheres have mass m_1 and m_2 and hanging from massless insulating threads of lengths ℓ_1 and ℓ_2. Two sphere carry charges q_1 and q_2 respectively. The spheres hang such that they are on the same horizontal level and the threads are inclined to the vertical at angle θ_1 and θ_2 respectively. Which of the following condition is true if $m_1 = m_2$.

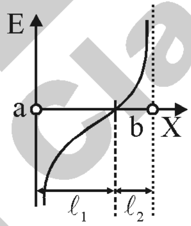
(A) $\theta_1 = \theta_2$ (B) $q_1 = q_2$ (C) $\frac{\ell_1}{\tan\theta_1} = \frac{\ell_2}{\tan\theta_2}$ (D) $\frac{q_1}{\tan\theta_1} = \frac{q_2}{\tan\theta_2}$

2. The figure shows, two point charges $q_1 = 2Q$ (>0) and $q_2 = -Q$. The charges divide the line joining them in three parts I, II and III



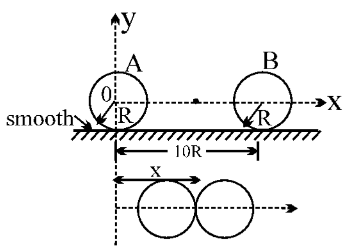
(A) Region III has a local maxima of electric field
(B) Region I has a local minima of electric field
(C) equilibiurm position for a test charge lies in region II
(D) The equilibrium for constrained motion along the line joining the charges is stable for a positive test charge

3. Two point charges are placed at a and b at a certain distance from each other. Assuming the field strength is positive in the direction coinciding with the positive direction of the x axis ($\ell_1 > \ell_2$) :-



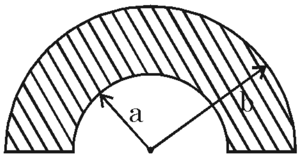
(A) Charge at a is positive and at b negative
(B) Magnitude of charge at a is greater than that of charge at b
(C) Both charges at a and b are negative
(D) Magnitude of charge at b is greater than that of charge at a

4. Two uniform non conducting balls A & B have identical size having radius R but made of different density material (density of A = 2 density of B). The ball A is +vely charged & ball B is –vely charged. The balls are released on the horizontal smooth surface at the separation 10R as shown in figure. Because of mutual attraction the balls start moving towards each other. They will collide at a point.



(A) $x = \frac{10R}{3}$ (B) $x = \frac{11R}{3}$ (C) x = 5R (D) $x = \frac{7R}{5}$

5. A non conducting semicircular disc (as shown in figure) has a uniform surface charge density σ. The electric field intensity at the centre of the disc



(A) $\dfrac{\sigma(b-a)}{4\pi\varepsilon_0}$ (B) $\dfrac{\sigma(b-a)}{2\pi\varepsilon_0}$ (C) $\dfrac{\sigma\ln(b-a)}{2\pi\varepsilon_0(b-a)}$ (D) $\dfrac{\sigma}{2\pi\varepsilon_0}\ln\left(\dfrac{b}{a}\right)$

6. A particle of mass 2 Kg and charge 1mC is projected vertically with a velocity 10 ms^{-1}. There is a uniform horizontal electric field of 10^4N/C.

(A) the horizontal range of the particle is 10m (B) the time of flight of the particle is 2s

(C) the maximum height reached is 5m (D) the horizontal range of the particle is 0.

7. Electric field in a region is given as $\vec{E} = (10-5x)\hat{i}$. A charge particle of mass 5kg and charge Q (= 1C) is situated at origin and free to move in given electric field. Then choose the correct options (Neglect gravity) :-

(A) Motion of charge particle is Oscillatory

(B) Maximum displacement of charge particle from origin is 4 SI units

(C) Maximum velocity gain by charge particle is 2 SI units

(D) The position of charge particle, when velocity gained by particle is maximum, is 2 SI units

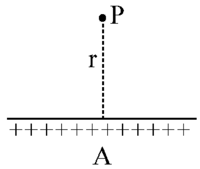
8. Electric field, due to an infinite line of charge, as shown in figure at a point P at a distance r from the line is E. If one half of the line of charge is removed from either side of point A, then

(A) electric field at P will have magnitude E/2

(B) electric field at P in x direction will be E/2

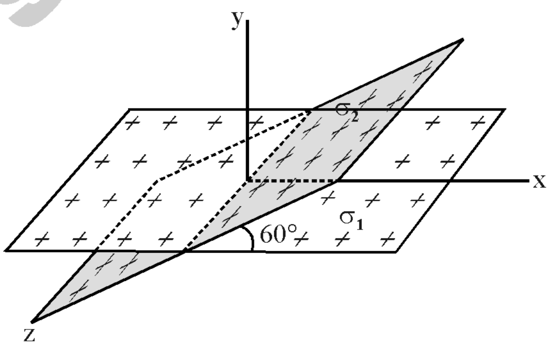
(C) electric field at P in y-direction will be E/2

(D) none of these



GAUSS' LAW

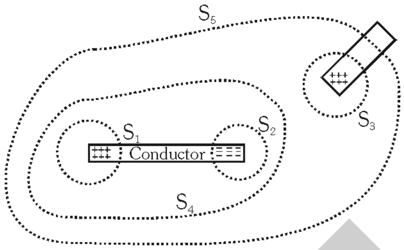
9. An infinite plane in the xz plane carries a uniform surface charge density σ_1 = 8.85 nC/m^2. A second infinite plane carrying a uniform charge density σ_2 = 17.7 nC/m^2 intersects the xz plane at the z axis and makes an angle of 60° with the xz plane as shown in figure. The electric field in the xy plane.



(A) at x = 6m, y = 2m is $500\sqrt{3}$ N/C (B) at x = –5m, y = 0 is $500\sqrt{3}$ N/C

(C) at x = 2m, y = 6 m is $500\sqrt{7}$ N/C (D) at x = –1m, y = –1m is $500\sqrt{7}$ N/C

10. A rod containing charge +Q is brought near an initially uncharged isolated conducting rod as shown. Regions with total surface charge +Q and –Q are induced in the conductor as shown in the figure. The only regions where the net charge in this configuration is non–zero are indicated by the "+" and "–" signs. Let us denote the total flux of electric field outward through closed surface S_1 as ϕ_1, through S_2 as ϕ_2, etc. Which of the following is necessarily false.

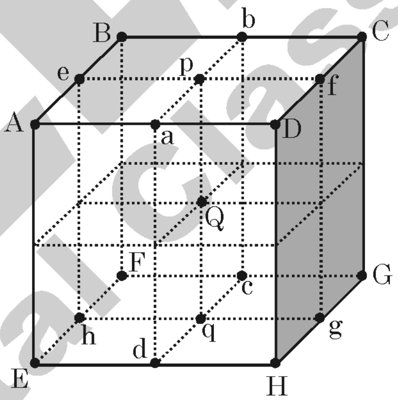


(A) $\phi_1 > 0$ (B) $\phi_2 = \phi_1$ (C) $\phi_3 = \phi_1$ (D) $\phi_4 = 0$

11. $\vec{E} = x\hat{i} + y\hat{j} + z\hat{k}$ exists in space then choose **INCORRECT** statement(s) :

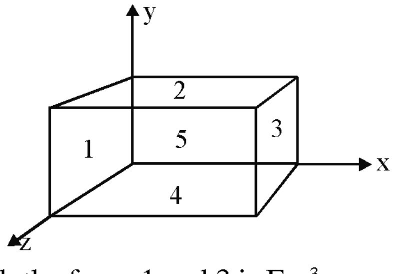
(A) This electric field is not possible
(B) Volume charge density is non uniform.
(C) If a charge particle goes from (3, 4, 5) to (5, 3, 4) then work done by electric force on charge will be positive
(D) Charge enclosed in sphere of unit radius and centered at origin is $4\pi\epsilon_0$.

12. The following figure shows a charge Q kept at the centre of a cube. Let ϕ represent the flux of field due to the charge Q, the correct options are :



(A) $\phi_{ABCD} = \frac{Q}{6\varepsilon_0}$ (B) $\phi_{Cbpf} = \frac{Q}{24\varepsilon_0}$ (C) $\phi_{abcd} = 0$ (D) $\phi_{abcd} = \frac{Q}{2\varepsilon_0}$

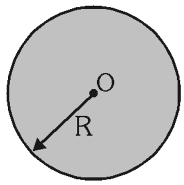
13. In a region of space, the electric field $\vec{E} = E_0 x\hat{i} + E_0 y\hat{j}$. Consider an imaginary cubical volume of edge 'a' with its edges parallel to the axes of coordinates. Now,



(A) the total electric flux through the faces 1 and 3 is E_0a^3
(B) the charge inside the cubical volume is $2\varepsilon_0E_0a^3$
(C) the total electric flux through the faces 2 and 4 is $2E_0a^3$
(D) the charge inside the cubical volume is $\varepsilon_0E_0a^3$

ELECTRIC POTENTIAL

14. Volume charge density of a non–conducting sphere is varying as $\rho = \rho_0 r$ where ρ_0 is a constant and r is the distance from centre of sphere. If potential at r=2R is zero then potential at infinity will be



(A) $\frac{\rho_0 R^3}{8 \epsilon_0}$ (B) $-\frac{\rho_0 R^3}{8 \epsilon_0}$ (C) $-\frac{\rho_0 R^3}{4 \epsilon_0}$ (D) Data insufficient

15. An electron is placed in a electric field. Choose the correct statement(s)
(A) It will move from high potential energy to low potential energy
(B) It will move from low potential to high potential
(C) It may move from region having denser electric lines to region having rarer electric lines
(D) It may move from region having rarer electric lines to region having denser electric lines

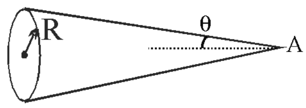
16. Four identical charges are placed at the points (1, 0, 0), (0, 1, 0), (–1, 0, 0) and (0, –1, 0) :-
(A) The potential at the origin is zero.
(B) The field at the origin is zero.
(C) The potential at all points on the z-axis, other than the origin, is zero.
(D) The field at all points on the z-axis, other than the origin acts along the z-axis.

17. In a uniform electric field, the potential is 10V at the origin of coordinates, and 8V at each of the points (1, 0, 0), (0, 1, 0) and (0, 0, 1). The potential at the point (1, 1, 1) will be
(A) 0 (B) 4 V (C) 8 V (D) 10 V

18. A point charge exist at origin. If potential of point charge A & B seperated by radial distance 2 m having potentials 2 V & 1 V respectively, what is the magnitude of $\vec{E}$ (in volt/m) at point A. (A & B lies in same quadrant).

19. A circular ring of radius a with uniform charge density λ is in the xy plane with centre at origin. A particle of mass m and charge q is projected from P (0, 0, a$\sqrt{3}$) on +z-axis towards origin with initial velocity u. The minimum value of the velocity so that the particle does not return to P is $\sqrt{\frac{\lambda q}{x\varepsilon_0 m}}$. Find 'x' (neglect gravity).

20. A cone made of insulating material has a total charge Q = 3mC spread uniformly over its sloping surface. Calculate the energy (in Joule) required to take a charge q = 5μC from infinity to apex A of cone. (Given : half cone angle $\theta = 37°$, R = 2m)



21. A small point charge (+q = 1μC, m = 3 kg) is started from a very long distance towards a fixed point charge (+Q = 1 mC). The initial line of motion of q is at a ⊥ distance of d = 1m from the line passing from the centre of Q, (as shown in figure). Take V_0 = 2 m/s. Determine the least distance between the two point charges (in m)

22. A stationary electric dipole $\vec{\phi} = p\hat{k}$ is situated at origin. A positive charge q, mass m executes circular motion of radius s at constant speed in the field of the dipole. Characterize the plane of orbit is :-

(A) The speed of charge particle is $v = \frac{1}{s}\sqrt{\frac{2qp}{\sqrt{3}\pi \in_0 m}}$

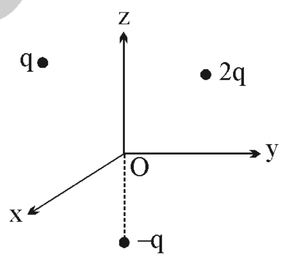
(B) The speed of charge particle is $v = \frac{1}{s}\sqrt{\frac{qp}{3\sqrt{3}\pi \in_0 m}}$

(C) Angular momentum of charge is $L = \sqrt{\frac{2qpm}{\sqrt{3}\pi \in_0}}$

(D) Angular momentum of charge is $L = \sqrt{\frac{qpm}{3\sqrt{3}\pi \in_0}}$

DIPOLE MOMENT

23. Three point charges **2q, –q and –q** are located respectively at (0, a, a), (0, – a, a) and (0, 0, – a) as shown. The dipole moment of this distribution is :-



(A) 2qa in the yoz plane at $\tan^{-1}\left(\frac{1}{4}\right)$ with z-axis

(B) $\sqrt{17}qa$ in the yoz plane at $\tan^{-1}\left(\frac{1}{4}\right)$ with z-axis

(C) $\sqrt{5}qa$ in the xoy plane at $\tan^{-1}(4)$ with γ-axis

(D) 4qa in the xoy plane at $\tan^{-1}(4)$ with γ-axis

24. Two short dipoles $p\left(\hat{i}+\hat{k}\right)$ & $4p\hat{k}$ are located at (0, 0, 0) & (1 m, 0, 2 m) respectively. The resultant electric field due to the two dipoles at the point (1 m, 0, 0) is :

(A) $\frac{p}{\pi \in_0}$ (B) $\frac{p}{2\pi \in_0}$ (C) $\frac{p}{\sqrt{2}\pi \in_0}$ (D) $\frac{\sqrt{2}p}{\pi \in_0}$

25. A dipole of dipole moment 10^{-9} Cm $\hat{i}$ is kept at the origin of coordinates. At which of the following points can the electric field be $\frac{2}{3}$ V/m $\hat{i}$:

(A) (3, 0) (B) (–6, 0) (C) (0, 3) (D) (0, –6)

26. An electric dipole moment $\vec{P} = (2.0\hat{i}+3.0\hat{j})\ \mu Cm$ is placed in a uniform electric field $\vec{E} = (3.0\hat{i}+2.0\hat{k})\times 10^5 NC^{-1}$.

(A) The torque that $\vec{E}$ exerts on P is $(0.6\hat{i}-0.4\hat{j}-0.9\hat{k})$ Nm

(B) The potential energy of the dipole is 0.6 J

(C) The potential energy of the dipole is – 0.6 J

(D) If the dipole is rotated in the electric field, the maximum potential energy of the dipole is 1.3 J

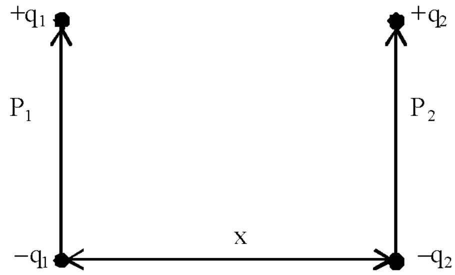
27. Figure shows two dipole moments parallel to each other and placed at a distance x apart x is very large, then :

(A) they will repel each other

(B) they will attract each other

(C) force of interaction is of magnitude of $\frac{3P_1P_2}{4\pi\varepsilon_0 x^4}$

(D) force of interaction is of magnitude of $\frac{6P_1P_2}{4\pi\varepsilon_0 x^4}$



CONDUCTORS

28. A long thin straight wire with linear charge density λ runs along axis of a thin hollow metal cylinder of radius R. The cylinder has a net linear charge density 2λ. Assume λ is positive. Mark correct options:-

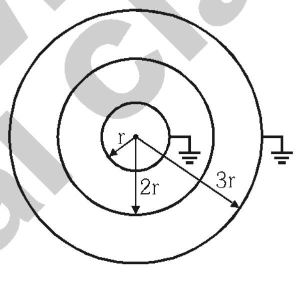
(A) $\vec{E}(r > R) = \frac{3\lambda}{2\pi\epsilon_0}\frac{\hat{r}}{r}$

(B) $\vec{E}(r < R) = \frac{3\lambda}{2\pi\epsilon_0}\frac{\hat{r}}{r}$

(C) Linear charge density on inner surface of cylinder is –λ

(D) Linear charge density on outer surface of cylinder is 3λ

29. Three concentric conducting spherical shells have radii r, 2r and 3r respectively. In the state shown charges are q_1, q_2 and q_3 are present on innermost, middle and outermost shells respectively. Then select correct alternative(s).



(A) $q_1 + q_3 = -q_2$ (B) $q_1 = -\frac{q_2}{4}$ (C) $\frac{q_3}{q_1} = 3$ (D) $\frac{q_3}{q_2} = -\frac{1}{3}$

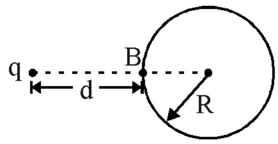
30. For the situation shown in the figure below, mark out the correct statement(s)

(A) Potential of the conductor is $\frac{q}{4\pi\varepsilon_0(d+R)}$

(B) Potential of the conductor is $\frac{q}{4\pi\varepsilon_0 d}$

(C) Potential of the conductor can't be determined as nature of distribution of induced charges is not known

(D) Potential at point B due to induced charges is $\frac{-qR}{4\pi\varepsilon_0(d+R)d}$



Hollow neutral conductor

31. A spherical soap bubble of radius R has uniformly distributed charge over its surface with surface charge density σ then [T = surface tension of the soap solution]

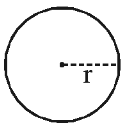
(A) excess pressure inside the bubble is $\frac{4T}{R}-\frac{\sigma^2}{2\varepsilon_0}$

(B) excess pressure inside the bubble is $\frac{4T}{R}+\frac{\sigma^2}{2\varepsilon_0}$

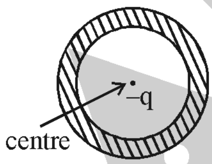
(C) excess pressure inside the bubble is $\frac{4T}{R}$

(D) electrostatic pressure is $\frac{\sigma^2}{2\varepsilon_0}$

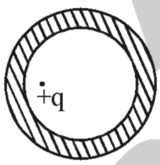
32. In which of the cases we will get uniform charge distribution of (+q) on external spherical surface. Given every object is a conductor :

(A) 

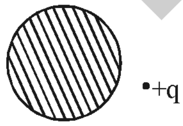
thin shell having net charge +q

(B) 

thick shell having net charge zero

(C) 

thick shell having net charge zero

(D) 

solid sphere having net charge +q

33. A conductor A is given a charge of amount +Q and then placed inside an uncharged deep metal can B, without touching it.

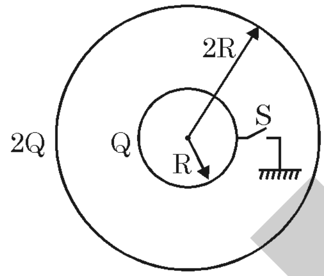
(A) The potential of A does not change when it is placed inside B.

(B) if B is earthed, +Q amount of charge flows from it into the earth.

(C) if B is earthed, the potential of A is reduced.

(D) if B is earthed, the potential of A and B both becomes zero.

34. Two conducting spherical shell of radii R & 2R given charges Q and 2Q respectively. Inner shell is provided with a switch which can ground the inner shell, as shown. Switch is initially open and energy stored in the system is U_1. After the switch is closed, energy stored in the system is found to be U_2. Find $\frac{U_1}{U_2}$.



* * * * *

ELECTROSTATICS			ANSWER KEY
1. Ans. (A)	**2. Ans. (A)**	**3. Ans. (B,C)**	**4. Ans. (B)**
5. Ans. (D)	**6. Ans. (A, B, C)**	**7. Ans. (A,B,C,D)**	**8. Ans. (B,C)**
9. Ans. (A,C)	**10. Ans. (B)**	**11. Ans. (A, B, C)**	**12. Ans. (A,B,C)**
13. Ans. (A,B)	**14. Ans. (B)**	**15. Ans. (A,B,C,D)**	**16. Ans. (B,D)**
17. Ans. (B)	**18. Ans. 1**	**19. Ans. 2**	**20. Ans. 81**
21. Ans. 2	**22. Ans. (B, D)**	**23. Ans. (B)**	**24. Ans. (B)**
25. Ans. (A)	**26. Ans. (A,C, D)**	**27. Ans. (A,C)**	**28. Ans. (A, C, D)**
29. Ans. (A,B,C)	**30. Ans. (A,D)**	**31. Ans. (A,D)**	**32. Ans. (A,C)**
33. Ans. (A,C)	**34. Ans. 5**		

1. In Post office box experiment, to avoid misleading deflection in galvanometer due to self induced current [back emf/back current] one should press

(A) both the cell key & galvanometer key simultaneously

(B) first cell key & then galvanometer key with delay of 2 to 3 second

(C) first galvanometer key & then cell key with delay of 2 to 3 second

(D) any of the manner mentioned above

2. We can compensate backlash error by

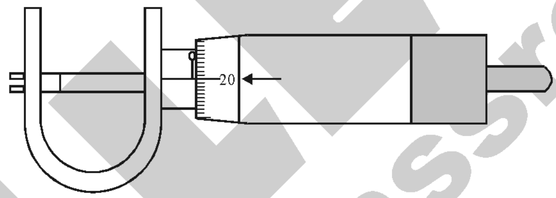
(A) Measuring the objects in ascending order of their sizes.

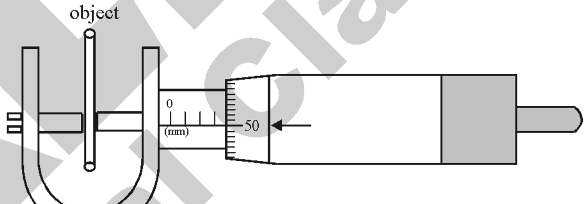
(B) Measuring the objects in descending order of their sizes.

(C) Either (A) or (B)

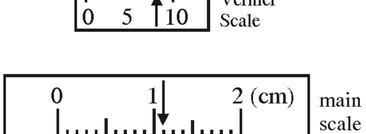
(D) It is not possible as it is random error.

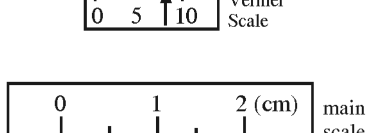
3. When a piece of wire is held diametrically in a screw gauge [pitch = 1mm, number of division on circular scale = 100]. The readings obtained are as shown:

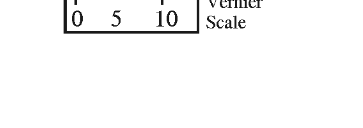


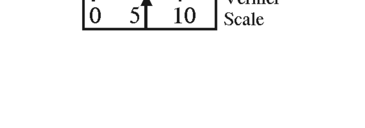


Now if we measure the same with help of vernier callipers [1 MSD = 1mm, 10 divisions of vernier coinciding with 9 divisions of main scale] having a negative zero error of 0.5 mm, then find which of the following figures correctly represents the reading.

(A)


(B)


(C)


(D)


4. Column I shows various practical errors/corrections and column II shows the experimental setups. Choose the correct matching.

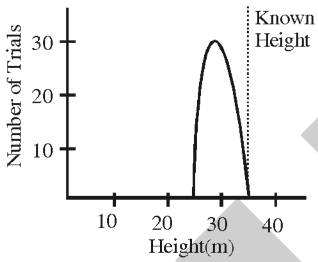
1.	Radiation correction	(i)	Optical bench
2.	End correction	(ii)	Joule's calorimeter
3.	Backlash error	(iii)	Searle's apparatus
4.	Index error	(iv)	Meter bridge

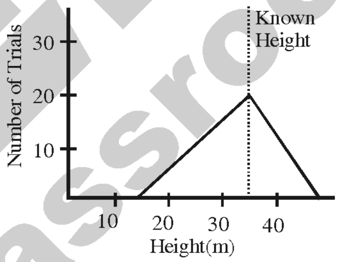
(A) 1 (iii), 2. (i), 3. (iv), 4. (ii) (B) 1. (ii), 2. (iv), 3. (i), 4. (iii)
(C) 1. (ii) 2. (iv), 3. (iii), 4. (i) (D) 1. (ii), 2. (iii), 3. (i), 4. (iv)

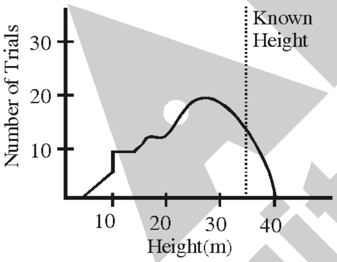
5. If $a = 8 \pm 0.08$ and $b = 6 \pm 0.06$, Let $x = a + b$, $y = a - b$, $z = a \times b$. The correct order of % error in x,y and z is

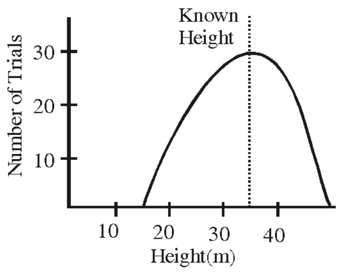
(A) $x = y < z$ (B) $x = y > z$ (C) $x < z < y$ (D) $x > z < y$

6. Students of four classes measure the height of a building. Each class uses a different method and each measures the height many different times. The data for each class are plotted below. Which class made the most precise measurement?

(A)


(B)


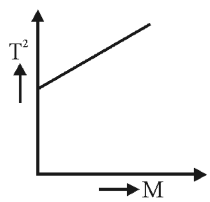
(C)


(D)


7. In a Searle's experiment for determination of Young's Modulus, when a load of 50 kg is added to a 3 meter long wire micrometer screw having pitch 1 mm needs to be given a quarter turn in order to restore the horizontal position of spirit level. Young's modulus of the wire if its cross sectional area is 10^{-5} m^2 is :-

(A) 6×10^{11} N/m^2 (B) 1.5×10^{11} N/m^2
(C) 3×10^{11} N/m^2 (D) None

8. The graph shown was obtained from experimental measurement of the square of period of oscillations T^2 for different masses M placed in the scale pan on the lower end of the spring balance. The most likely reason for the line not passing through the origin is that the-



(A) Spring did not obey Hooke's Law
(B) Amplitude of the oscillations was too large
(C) Clock used needed regulating
(D) Mass of the pan was not negligible

9. The length of the string of a simple pendulum is measured with a meter scale to be 63.5 cm, the radius of the bob plus the hook is measured with the help of vernier caliper to be 1.55 cm. Select the incorrect statement :-

(A) Least count of meter scale is 0.1 cm (B) Least count of vernier caliper is 0.01 cm
(C) Effective length of pendulum is 65.1 cm (D) Effective length of pendulum is 65.2 cm

10. A recent high precision method of determining g has quoted an error of 6 parts in 10^9. The increase in height at the surface due to change in g equal to this error is (Take radius of earth as 6400 km)

(A) 38.4 mm (B) 19.2 mm (C) 3.84 mm (D) 1.92 mm

11. The volume of a sphere of radius 3.1 cm correct to significant digits is

(A) 1.2478×10^2 cm^3 (B) 1.2×10^2 cm^3 (C) 1.25×10^2 cm^3 (D) 1.3×10^2 cm^3

12. A vernier callipers used by student has 20 divisions in 1 cm on main scale. 10 vernier divisions coincide with 9 main scale divisions. When jaws are closed, zero of main scale is on left of zero of vernier scale and 6th division of vernier scale coincides with any of main scale divisions. He places a wooden cylinder in between the jaws and measures the length. The zero of vernier scale is on right of 3.20 cm and 8th vernier division coincides with any main scale division. When he measures thickness of cylinder he finds that zero of vernier scale lies on right of 1.50 cm mark of main scale and 6th division of vernier scale coincides with any main scale division. The correct values of measured length and diameter are respectively:-

(A) 3.21 cm, 1.50 cm (B) 3.210 cm, 1.500 cm
(C) 3.27 cm, 1.93 cm (D) 3.270 cm, 1.560 cm

13. The length of a rectangular plate is measured by a meter scale and is found to be 10.0 cm. Its width is measured by vernier callipers as 1.00 cm. The least count of the meter scale and vernier callipers are 0.1cm and 0.01 cm respectively (Obviously). Maximum permissible error in area measurement is :-

(A) ± 0.2 cm^2 (B) ± 0.1 cm^2 (C) ± 0.3 cm^2 (D) 0

14. The external and internal diameters of a hollow cylinder are measured to be (4.24 ± 0.01) cm and (3.89 ± 0.01) cm. The thickness of the wall of the cylinder is :-

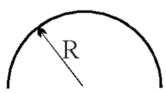
(A) (0.34 ± 0.02) cm (B) (0.17 ± 0.02) cm (C) (0.17 ± 0.01) cm (D) (0.34 ± 0.01) cm

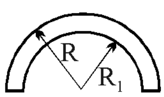
Paragraph for question nos. 15 to 17

Physics is a science which deals with practical life. As such, in most of the situations we are not concerned with exact values but approximate values. While studying theory, we often deal with approximations which can be taken to nearly represent the real situations. Rigorous analysis has shown that a given approximation can be said to be correct if the error in the quantity concerned is less than or equal to 5%. The error is defined as

$$\delta = \frac{A_{ideal} - A_{real}}{A_{ideal}} \times 100$$

A_{ideal} is the value of the quantity in ideal situation and A_{real} is the value of the quantity in real situation.

e.g. we say that the centre of mass of a semicircular ring is at $\frac{2R}{\pi}$ 

. This $\frac{2R}{\pi}$ is A_{ideal}. But in reality, ring is an annular disc. 

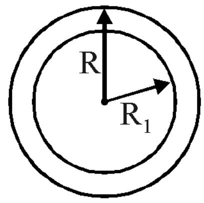
Its centre of mass can be found to be at $\frac{4(R_1^2 + R_1R + R^2)}{3\pi(R_1 + R)}$.

This is A_{real}. In a given situation, we can find error in estimation of centre of mass of the ring.

15. What should be the inner radius/outer radius so that error is just acceptable ?

(A) $\frac{17+\sqrt{3009}}{80}$ (B) $\frac{28+\sqrt{459}}{60}$ (C) $\frac{23+\sqrt{1083}}{70}$ (D) None of these

16. We want to find moment of inertia of an annular disc. For what ratio of $\frac{R}{R_1}$ can we approximate it to be a ring having the same mass.



(A) $\sqrt{\frac{10}{9}}$ (B) $\sqrt{\frac{9}{8}}$

(C) $\sqrt{\frac{8}{7}}$ (D) $\sqrt{\frac{6}{5}}$

17. A charged wire is 20 cm long. At what maximum distance from the wire (on points lying on its perpendicular erected at the middle) can the electric field be regarded as the field of an infinitely charged wire ?

(A) $\frac{10}{19}\sqrt{39}$ cm (B) $\frac{5}{17}\sqrt{37}$ cm (C) $\frac{5}{12}\sqrt{42}$ cm (D) $\frac{7}{15}\sqrt{63}$ cm

Paragraph for Question Nos. 18 & 19

A car has its wheel's circumference of 1 m, which is measured through the meter scale having least count 0.1 cm. In Alto K-10 car there is speed-o- meter where digital meter reading instrument (DMRI) is available. You can set initial reading zero for measuring the distance for milage calculation. Suppose one complete rotation of wheel of car gives DMRI's least count & patrol tank of car is filled at filling station where filling instrument having least count 1ml. Car patrol tank have capacity is 35 lit. Assuming for this car there is no slipping between wheel & grounds.

18. If car goes Allen-Sakar Building to Dakniya railway station, where initial reading of DMRI is zero & final reading is 1 km, then find % error in measurement of distance.

(A)0.1 (B) 0.2 (C) 0.11 (D) 1.1

19. If car starts from Allen Kota & goes to Allen Chandigarh its initial reading is 70.384 km & its final reading is 700.384 km. Initially tank was full & finally empty. If maximum 2% fuel of a car may evaporate & radius of a wheels may change up to 2% then the % error in milage of car is :-

(A) 1 (B) 2 (C) 4 (D) 4.1

20. Match the column – I with column – II.

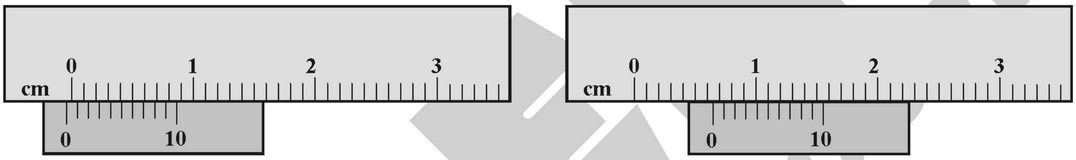
Column–I (Number)		**Column–II (Number of significant digits)**	
(A)	1001	(p)	5
(B)	0100.1	(q)	4
(C)	100.100	(r)	6
(D)	0.001001	(s)	3

21. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1s resolution. What is the accuracy in the determination of g ? If answer is n% fill 18n.

22. The pitch of a screw gauge is 1 mm and there are 50 divisions on its cap. When nothing is put in between the studs, 44th division of the circular scale coincides with the reference line and zero of main scale is not visible. When a plate is placed between the studs, the main scale reads 5 divisions and the circular scale reads 25 divisions. The true thickness of plate is $a \times 10^{-5}$ m, find the value of a.

23. In an optical bench experiment to determine the focal length of the concave mirror, the least count of the bench is 0.1 cm. The object needle reading is 10.7 cm and the image needle reading is 5.7 cm. The mirror is positioned at 15.7 cm. Find the maximum possible percent error in the focal length of the mirror with this set of readings. (Round off to nearest integer).

24. The main scale of a vernier callipers reads in millimeter and its vernier is divided into 10 divisions which coincides with 9 divisions of the main scale. The reading for shown situation is found to be $\frac{23x}{10}$ mm. Find the value of x.



25. The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given the length is 5.0 cm and diameter is 2.00 cm. Find the percentage error in the calculated value of volume.

26. An open organ pipe containing air resonates in fundamental mode due to a tuning fork. The measured values of length ℓ(in cm) of the pipe and radius r (in cm) of the pipe are $\ell = 94 \pm 0.1$, $r = 5 \pm 0.05$. The velocity of the sound in air is accurately known. The maximum percentage error in the measurement of the frequency of that tuning fork by this experiment is given by α^2%. Find the value of 10α.

27. The time period of oscillation of a simple pendulum is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

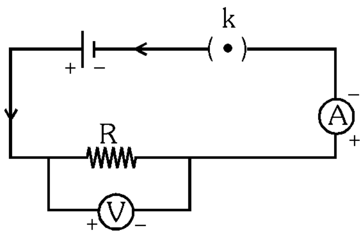
The length of the pendulum is measured as $l = 10 \pm 0.1$cm and the time period as $T = 0.5 \pm 0.02$ s. Determine percentage error in the value of g.

28. Volume of a gas undergoing certain process varies with temperature as shown $V = V_0\left(\frac{T_0}{T}\right)^{1/2} e^{\left[\frac{2}{3}\frac{(T-T_0)}{T_0}\right]}$

where T_0 is initial temperature, V_0 is initial volume. If apparatus used for measuring temperature can measure temperature with an accuracy of 0.2 K, find the percentage error in calculation of volume at temp $T = \frac{3T_0}{4}$ (V_0 and T_0 are accurately known)

29. Intensity observed in an interference pattern is $I = I_0 \sin^2\theta$. At $\theta = 30°$, intensity $I = 5 \pm 0.0020$ W/m^2. If $I_0 = 20$ W/m^2 and percentage error in angle θ is $\frac{n}{\pi}\sqrt{3}\times 10^{-2}\%$, then the value of n is.

30. Mr. Vivek Taparia performed an experiment to verify Ohm's law. He connected following circuit to measure voltage and current.



Here R is the unknown resistance, V the voltmeter, A the ammeter and K is the key. The value of R from following readings is given by $\alpha \times 10^{\beta}$ kΩ, then find the value of $\alpha + \beta$.

V(volt)	1	2	3	4	5
I(mA)	1.40	2.83	5.68	7.11	8.54

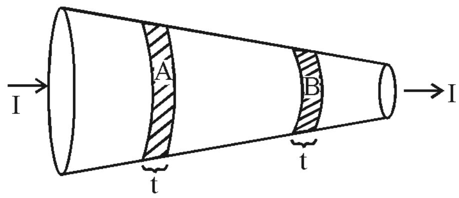
31. Time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{\ell}{g}}$ where ℓ is the length of pendulum and g is acceleration due to gravity. If percentage increase in the length and acceleration due to gravity are 69% and 21% respectively then find out percentage increase in time period.

* * * * *

ERROR ANALYSIS & EXPERIMENT			ANSWER KEY
1. Ans. (B)	**2. Ans. (D)**	**3. Ans. (A)**	**4. Ans. (C)**
5. Ans. (C)	**6. Ans. (A)**	**7. Ans. (A)**	**8. Ans. (D)**
9. Ans. (D)	**10. Ans. (B)**	**11. Ans. (B)**	**12. Ans. (B)**
13. Ans. (A)	**14. Ans. (C)**	**15. Ans. (A)**	**16. Ans. (A)**
17. Ans. (A)	**18. Ans. (B)**	**19. Ans. (D)**	
20. Ans. (A) – q, (B) – q, (C) – r, (D) – q,		**21. Ans. 049**	**22. Ans. 562**
23. Ans. 2	**24. Ans. 3**	**25. Ans. 3**	**26. Ans. 4**
27. Ans. 9%	**28. Ans. 0**	**29. Ans. 4**	**30. Ans. 6**
31. Ans. 18.18			

BASICS OF CURRENT ELECTRICITY

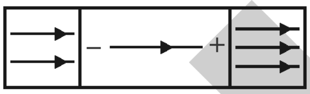
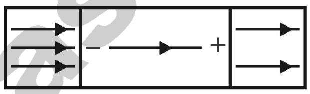
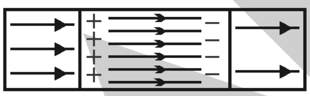
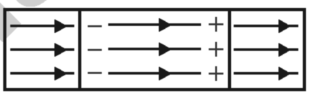
1. Figure shows a homogeneous conductor with decreasing cross-sectional area along the flow of current. Consider two elementary disks A and B of same thickness on conductor as shown. Choose the correct option(s) :-



(A) Drift velocity of electrons at B is greater than at A.
(B) No. of electrons per unit volume is same at A and B.
(C) Resistance of segment B is bigger than that of A.
(D) Electric field, current density and resistivity, all are bigger at B than at A.

2. Consider a wire in the shape of a circle carrying a current. Note that as the current progresses along the wire, the direction of current density vector changes in a particular manner, while the current remain unaffected. The agent that is essentially responsible for this is
(A) Source of emf.
(B) electric field produced by charges accumulated on the surface of wire
(C) the charges just behind a given segment of wire which push them just the right way by repulsion
(D) the charges ahead

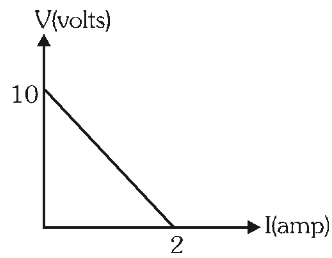
3. Which of the following electric field pattern is correct inside the conductor having three materials of resistivity ?

(A) 
(B) 
(C) 
(D) 

4. The total momentum of electrons in a straight wire of length 1000 m carrying a current of 70 A is closest to :-
(A) 40×10^{-8} N-sec (B) 30×10^{-8} N-sec (C) 50×10^{-8} N-sec (D) 70×10^{-8} N-sec

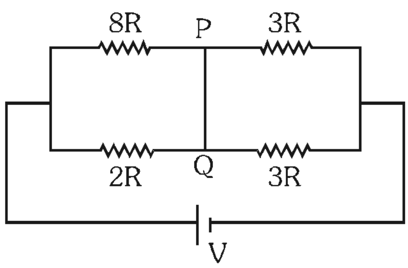
CIRCUITS

5. A battery of e.m.f. E and internal resistance r is connected to R. Resistance R can be adjusted to any value greater than or equal to zero. A graph is plotted between the current passing through the resistance (I) and potential difference (V) across it. Select the correct alternatives



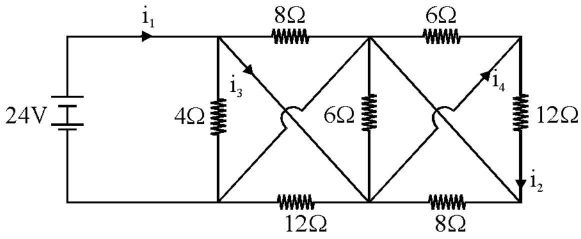
(A) Internal resistance of the battery may be 5 Ω.
(B) Emf of the battery is 10 V
(C) Maximum current which can be taken from the battery is 2 A
(D) V-I graph can never be a straight lines as shown in the figure.

6. Choose correct option(s) corresponding to the given circuit



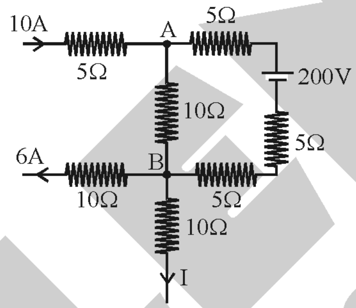
(A) current in PQ will be zero
(B) current in PQ will be P $\rightarrow$ Q
(C) current in PQ will be Q $\rightarrow$ P
(D) Equivalent resistance is $\frac{31R}{10}$

7. For the circuit shown in figure



(A) $i_1 = 24$ A (B) $i_2 = 2$A (C) $i_3 = 15$A (D) $i_4 = 6$A

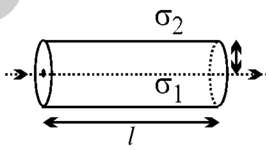
8. In the given diagram choose correct options :-



(A) The value of I is 4A (B) The current from the cell is 4A.

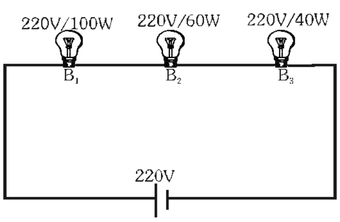
(C) Voltage drop across AB is 140 V. (D) The current from the cell is 10A.

9. A long conductor of circular cross-section has radius r and lenght *l* as shown in the figure. The conductivity of the material near the axis is σ_1. and increases linearly with the distance from axis and becomes σ_2 near the surface. Find the resistance of the conductor if the current enters from the one end and leaves from the other end.



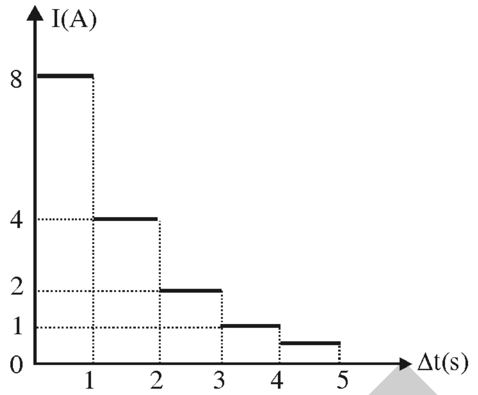
JOULE HEATING

10. Figure shows three bulbs B_1, B_2 & B_3. If R, P & I represents resistance, power, and current then choose the ***INCORRECT*** statement.



(A) $R_{B1} > R_{B2} > R_{B3}$ (B) $P_{B1} > P_{B2} > P_{B3}$ (C) $P_{B1} < P_{B2} < P_{B3}$ (D) $I_{B1} > I_{B2} > I_{B3}$

11. The current in a wire of resistance 10Ω varies as shown. Select correct alternative(s).



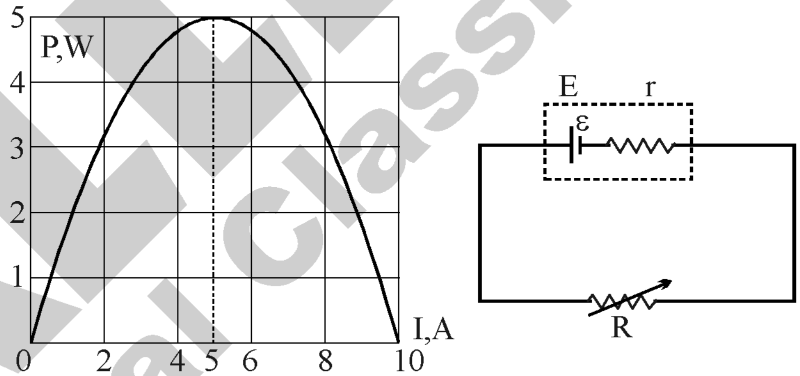
(A) The heat produced in the wire in 4 s is 852.5 J

(B) The heat produced in the wire in 4 s is 850 J

(C) The charge flows across any section of the wire in 4 s is 15 C

(D) The charge flows across any section of the wire in 4 s is 15.5 C

12. Figure shows the net power dissipated in R versus the current in a simple circuit shown.



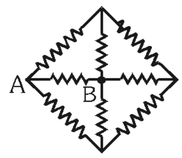
(A) The internal resistance of battery is 0.2 Ω.

(B) The emf of battery is 2V

(C) R at which power is 5W is 2.5Ω

(D) at i = 2A, power is 3.2 W

13. In the circuit diagram each resistor of resistance 5Ω. The points A and B are connected to the terminals of a cell of electromotive force 9 volt and internal resistance 2/3Ω.



(A) The heat produced in the cell is 6W.

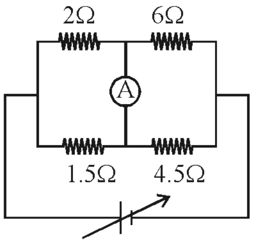
(B) The current in the resistor connected directly between A and B is 1.4A.

(C) The current in the resistor connected directly between A and B is 1.8 A.

(D) None of the above is correct.

14. In column-I, we have certain situations where a battery of variable voltage is connected in a circuit. Column-II gives comments on current in element A on variation of voltage :-

Column-I | **Column-II**

(A) 

(P) on increasing V, i may/will increase

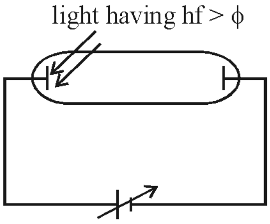
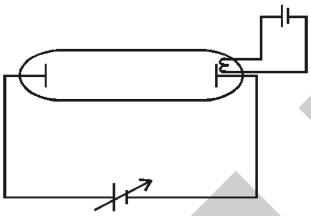
(B) 

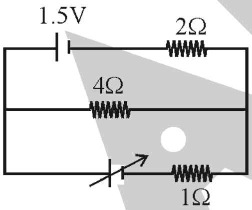
photo electric setup
A $\rightarrow$ photoelectric tube

(Q) On increasing V, i may/will decrease

(C) 

A $\rightarrow$ x ray tube

(R) On increasing V, i may/will not change at all

(D) 

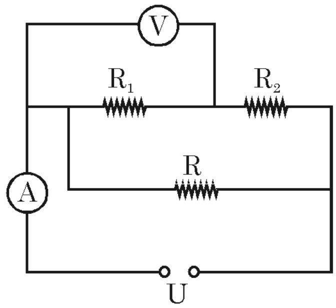
A $\rightarrow$ 4Ω resistor

(S) On reversing V, i may/will be zero

(T) On reversing V, i may/will increase

ELECTRICAL INSTRUMENTS

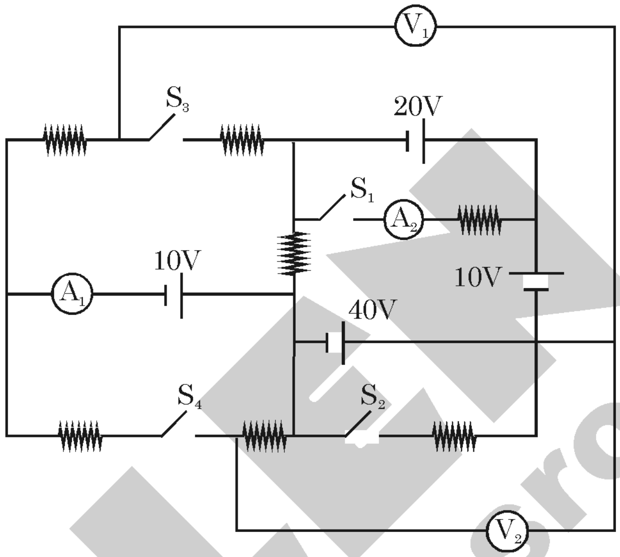
15. What are the resistances of the resistors R_1 and R_2, shown in the figure, if the voltage supply is 40 V, and the power dissipated in resistor R is 80 W, the readings on the ammeter and on the voltmeter are 3 A and 30 V, respectively. (All devices are ideal)



(A) $R_1 = 30\ \Omega$ (B) $R_2 = 30\ \Omega$ (C) $R_1 = 10\Omega$ (D) $R_2 = 10\Omega$

Answer Q.16, Q.17 and Q.18 by appropriately matching the information given in the three columns of the following table.

In given circuit, all batteries, voltmeters and ammeters are ideal. Voltmeters and ammeters have only +ive scale for reading. Resistance of each resistor is 5Ω. Reading of voltmeters are V_1 and V_2 and of ammeters are A_1 and A_2. Initially all switches are closed.



	Coloumn–I $\lvert A_1 - A_2\rvert$		Column-II V_1		Column-III V_2
(I)	3 A	(i)	20 V	(P)	45 V
(II)	0 A	(ii)	30 V	(Q)	35 V
(III)	5 A	(iii)	50 V	(R)	40 V
(IV)	1 A	(iv)	40 V	(S)	25 V

16. Only switch S_2 is open

(A) (I) (iii) (S) (B) (IV) (ii) (P) (C) (I) (iii) (P) (D) (IV) (ii) (S)

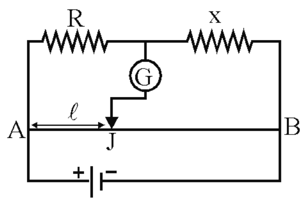
17. Only switch S_3 is open :

(A) (III) (iii) (R) (B) (IV) (ii) (S) (C) (I) (iii) (P) (D) (II) (iv) (Q)

18. Only switch S_1 is open :

(A) (III) (iii) (P) (B) (I) (iii) (R) (C) (IV) (ii) (P) (D) (III) (ii) (P)

19. In the meter bridge experiments initially balance point is J, where AJ=ℓ. One wants to make some changes in the shown setup. After any change balance length being AJ' = ℓ', then choose the correct statement(s). [Here R ≠x]



(A) If in shown set-up the galvanometer and battery are inter changed current through galvanometer is zero.

(B) radius of wire AB is double then $\ell' = 2\ell$

(C) if length of wire AB is doubled then $\ell'=2\ell$

(D) If the values of R and x both are double and then interchanged then $\ell'=\ell$

20. In the standard post office box setup

(A) the null point reading implies the position of jockey for which reading of galvanometer is zero.

(B) the null point reading means consecutive readings at which the galvanometer deflects in the opposite direction.

(C) the key connected to Galvanometer is switched on after switching on the key connected to battery.

(D) the key connected to Galvanometer is switched off after switching off the key connected to battery.

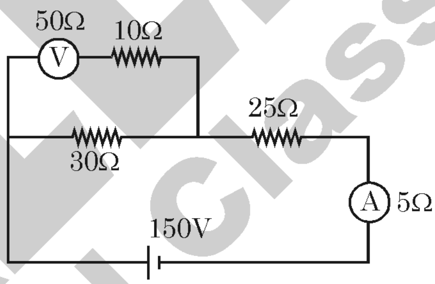
21. A 20 m long potentiometer wire has a resistance of 20 ohm. It is connected in series with a battery of emf 3V and a resistance of 10Ω. The internal resistance of cell is negligible. If the length can be read accurately up to 1 mm, the potentiometer can read voltage

(A) up to minimum of 0.2 mV
(B) with an accuracy of 0.2 mV
(C) with an accuracy of 0.1 mV
(D) upto maximum of 2V

22. A micrometer has a resistance of 10 Ω and a full scale range of 50 μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. The correct range and resistances combination (approximately) :-

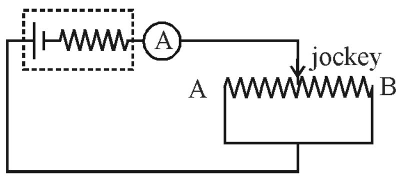
(A) 50 V range with 10 kΩ resistance in series
(B) 10 V range with 200 kΩ resistance in series
(C) 5 mA range with 1Ω resistance in parallel
(D) 10 mA range with 1 Ω resistance in parallel

23. For given circuit, choose the correct option(s) :



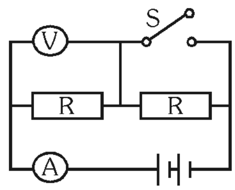
(A) Reading of voltmeter is 50 V
(B) Reading of voltmeter is 60 V
(C) Reading of ammeter is 3A
(D) Reading of ammeter is 4A

24. The circuit diagram shows a source of emf 10 V having an internal resistance of 2.5Ω connected to an ideal ammeter. The jockey can be slided to different points on the Rheostat whose total resistance is 10Ω. What can be the reading of the ammeter.



(A) 1A
(B) 2A
(C) 3A
(D) 4A

25. The diagram shows a circuit with two identical resistors. The battery has a negligible internal resistance. What will the effect on the ammeter and voltmeter be if the switch S is closed ?



	Column I		**Column II**
(A)	Ammeter reading	(P)	Increases
(B)	Voltmeter reading	(Q)	Decreases
(C)	Equivalent resistance of circuit	(R)	Does not change
(D)	Power dissipated across R in right branch	(S)	Becomes zero
		(T)	Cannot be determined

26. In a meter bridge experiment, the unknown resistance was connected in left branch and a resistance box in right branch. The resistance in resistance box is 50Ω (known acurately). There is no end correction. The least count of meter bridge is 1mm. The null point was obtained at 40.0cm from left end. Now the radius of wire was measured by a screw guage with pitch of 1mm and no. of divisions on circular scale as 100. The screw guage read 1 main scale division and 60 circular scale divisions. The length of resistor was measured using a vernier callipers with 1mm as 1 main scale division and 9 main scale division = 10 vernier scale divisions. The length is 2.2 cm as main scale reading and 5^{th} vernier scale division coinciding. The percentage error in measurement of resistivity is approximately.

* * * * *

CURRENT ELECTRICITY — ANSWER KEY

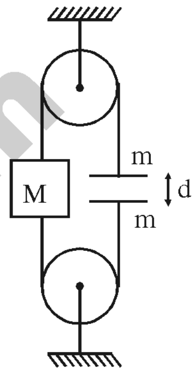
1. Ans. (A,B,C) **2. Ans. (B)** **3. Ans. (A)** **4. Ans. (A)**
5. Ans. (A,B,C) **6. Ans. (C,D)** **7. Ans. (A, B, C, D)** **8. Ans. (A, B, C)**
9. Ans. $\frac{1}{R} = \frac{\pi r^2}{3l}(2\sigma_2 + \sigma_1)$ **10. Ans. (A,B,D)** **11. Ans. (B,C)**
12. Ans. (A, B, D) **13. Ans. (A,B)** **14. Ans. (A)-R,S; (B)-Q,R,T; (C)-R,S; (D)- P,S**
15. Ans. (A,D) **16. Ans. (B)** **17. Ans. (C)** **18. Ans. (D)**
19.Ans. (AC) **20. Ans. (B,C)** **21. Ans. (C, D)** **22. Ans. (B)**
23. Ans. (A,C) **24. Ans. (B,C,D)**
25. Ans. (A) → (P) ; (B) → (P) ; (C) → (Q) ; (D) → (Q,S) **26. Ans. 2**

BASICS OF CAPACITORS

1. An electron enters the region between the plates of a parallel plate capacitor at a point equidistant from either plate. The capacitor plates are 2×10^{-2} m apart & 10^{-1} m long . A potential difference of 300 volt is kept across the plates. Assuming that the initial velocity of the electron is parallel to the capacitor plates, calculate the largest value of the velocity of the electron so that it does not fly out of the capacitor at the other end.

2. Two parallel plate condensers A & B having capacities 1 μF & 5 μF are charged separately to the same potential of 100 volt . Now the positive plate of A is connected to the negative plate of B & the negative plate of A to the positive plate of B. Find the final charges on each condenser & the total loss of electrical energy in the condensers.

3. Two plates of mass m each are connected to mass M by two light inextensible strings. The pulleys are ideal. To hold system in equilibrium, we need to charge the plates by a battery of at least 8 volts. If distance between plates is 1μm, capacitance formed is 1μF, ($g = 10$ m/s^2). What are possible values of M & m ?



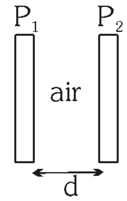
(A) M = 12.8 kg

(B) m = 3.2 kg

(C) M = 6.4 kg

(D) m = 1.6 kg

4. Two conducting large plates P_1 & P_2 are placed parallel to each other at very small separation 'd'. The plate area of either face of plate is A. A charge +2Q is given to plate P_1 & –Q to the plate P_2 (neglect ends effects). If plate P_1 & P_2 are now connected by conducting wire, then total amount of heat produced is

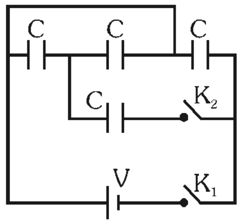


(A) $\frac{4Q^2d}{3\epsilon_0 A}$ (B) $\frac{9}{8}\frac{Q^2d}{\epsilon_0 A}$

(C) $\frac{3Q^2d}{4\epsilon_0 A}$ (D) None of these

CAPACITOR CIRCUITS

5. How does the total energy stored in the capacitors in the circuit shown in the figure change when first switch K_1 is closed (process–1) and then switch K_2 is also closed (process–2). Assume that all capacitor were initially uncharged ?



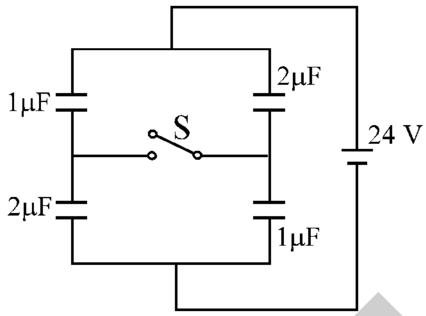
(A) Increases in process–1

(B) Increases in process–2

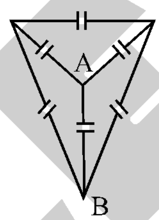
(C) Decreases in process–2

(D) Magnitude of change in process–2 is less than that in process–1

6. Four uncharged capacitors are charged by 24 V battery as shown in the figure. How much charge (in μC) flows through S when it is closed?



7. Find the effective capacitance between points A and B in the networks shown below. All capacitors are of 1 μF



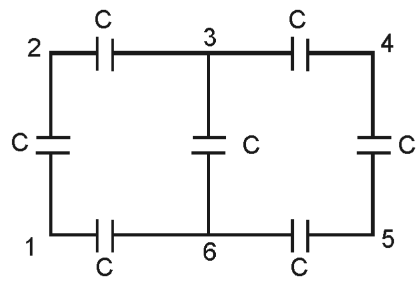
8. For the given circuit, select the correct alternative(s)

(A) The equivalent capacitance between points 1 & 2 is $\frac{15C}{11}$

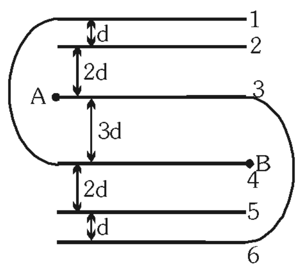
(B) The equivalent capacitance between points 3 & 6 is $\frac{5C}{3}$

(C) The equivalent capacitance between points 1 & 3 is $\frac{15C}{14}$

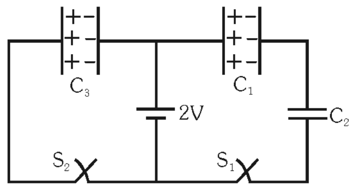
(D) The equivalent capacitance between points 3 & 5 is $\frac{14C}{15}$



9. There are six plates of equal area A and the plates are arranged as shown in figure. The equivalent capacitance between points A and B is $\frac{\alpha \in_0 A}{d}$. Find value of α.



10. Three capacitors $C_1 = 2\mu F$, $C_2 = 2\ \mu F$ and $C_3 = 3\mu F$ having initial charges $4\mu C$, zero and $1\mu C$ connected through a battery of emf 2V as shown, on closing the switches S_1 and S_2.



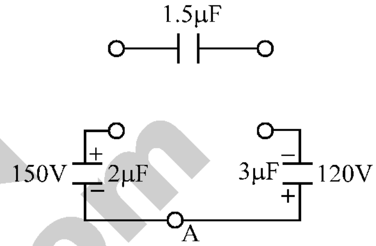
(A) charge on capacitor C_1 is $4\mu C$

(B) charge on capacitor C_2 is 0

(C) charge on capacitor C_3 is $6\mu C$

(D) charge flown through S_2 is $5\mu C$

11. Two capacitors of 2 μF and 3 μF are charged to 150 volt and 120 volt respectively. The plates of capacitor are connected as shown in the figure. A discharged capacitor of capacity 1.5 μF falls to the free ends of the wire. Then



(A) charge on the 1.5 μF capacitors is 180 μC

(B) charge on the 2μF capacitor is 120 μC

(C) positive charge flows through A from right to left.

(D) positive charge flows through A from left to right.

12. A parallel plate air capacitor is connected to a battery. If plates of the capacitor are slowly pulled apart, then which of the following statements is/are **INCORRECT** ?

(A) Strength of electric field inside the capacitor remains unchanged, if battery is disconnected before pulling the plates.

(B) During the process, negative work is done by an external force applied to pull the plates whether battery is disconnected or it remains connected.

(C) Potential energy in the capacitor decreases if the battery remains connected during pulling plates apart.

(D) Potential energy in the capacitor decreases if the battery is disconnected before pulling plates apart.

DIELECTRICS

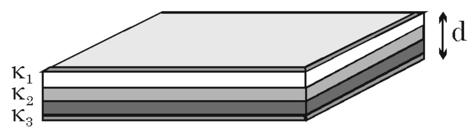
13. A potential difference of 300 V is applied between the plates of a plane capacitor spaced 1 cm apart. A plane parallel glass plate with a thickness of 0.5 cm and a plane parallel paraffin plate with a thickness of 0.5 cm are placed in the space between the capacitor plates find :

(i) Intensity of electric field in each layer.

(ii) The drop of potential in each layer.

(iii) The surface charge density of the charge on capacitor plates. Given that : $k_{glass} = 6$, $k_{paraffin} = 2$

14. A parallel plate capacitor is filled with 3 dielectric materials of same thickness, as shown in the sketch. The dielectric constants are such that $\kappa_3 > \kappa_2 > \kappa_1$. Let the magnitudes of the electric field in and potential drops across each dielectric be $E_3, E_2, E_1, \Delta V_3, \Delta V_2$, and ΔV_1, respectively. Which one of the following statements is true?



(A) $E_3 < E_2 < E_1$ and $\Delta V_3 < \Delta V_2 < \Delta V_1$

(B) $E_3 > E_2 > E_1$ and $\Delta V_3 > \Delta V_2 > \Delta V_1$

(C) $E_3 < E_2 < E_1$ and $\Delta V_3 > \Delta V_2 > \Delta V_1$

(D) $E_3 > E_2 > E_1$ and $\Delta V_3 < \Delta V_2 < \Delta V_1$

15. We have a parallel plate capacitor made of two conducting, circular sheets of radius 2R each. They are kept at a small separation d between them. Suppose, we insert a circular shape dielectric of radius R and thickness d, between the gap with its centre coinciding with the plate centres the dielectric constant is k. The correct statement is/are :

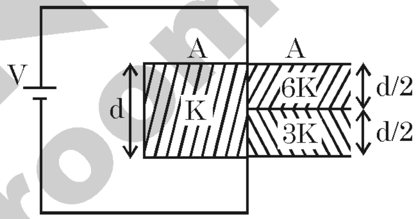
(A) Capacitance of the capacitor is $\dfrac{(k+3)\in_0 \pi R^2}{d}$

(B) Capacitance of the capacitor is $\dfrac{k\in_0 \pi\left(4R^2\right)}{d}$

(C) Ratio of electric field in the region with dielectric & without dielectric is 1

(D) Ratio of electric field in the region with dielectric & without dielectric is 1 : k

16. 3 dielectric slabs (each of area A) are filled between capacitor of plate area 2A. Capacitor is connected with battery of emf V. Electric field and electric field energy stored in dielectric k, 6k, 3k are E_1, E_2, E_3 and U_1, U_2, U_3 respectively :



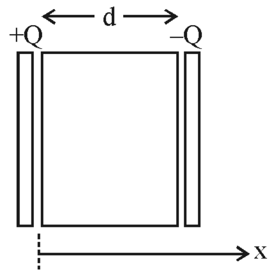
(A) Total energy stored in capacitors is $\dfrac{5Ak\in_0 V^2}{2d}$

(B) $E_1 : E_2 : E_3 :: 3 : 2 : 4$

(C) $U_1 : U_2 : U_3 :: 3 : 4 : 8$

(D) Capacitance of capacitor is $\dfrac{5Ak\in_0}{d}$.

17. A dielectric slab is filled in between the plates of parallel plate charged capacitor. Di-electric constant of the capacitor varies with x as $k = \dfrac{x}{d}k_0$. Capacitor is not connected with the battery. Then choose the correct statement(s) :-



(A) Net electric field inside the di-electric is uniform throughout the capacitor.

(B) Net electric field inside the dielectric decreases on moving along x-direction inside the capacitor.

(C) Bound charge density inside the di-electric is zero.

(D) Bound charge density inside the dielectric is non-uniform.

18. Following operation can be performed on a capacitor :

X – connect the capacitor to a battery of emf E.

Y – disconnect the battery.

Z – reconnect the battery with polarity reversed.

W – insert a dielectric slab in the capacitor.

(A) In XYZ (perform X, then Y, then Z) the stored electric energy remains unchanged and no thermal energy is developed.

(B) The charge appearing on the capacitor is greater after the action XWY than after the action XYW.

(C) The electric energy stored in the capacitor is greater after the action WXY than after the action XYW.

(D) The electric field in the capacitor after the action XW is the same as that after WX.

19. A parallel plate capacitor with plate area A and separation d has charge Q. A slab of dielectric constant k is inserted in space between the plates almost completely fills the space. If E_0 and C_0 be the electric field and capacitance before inserting the slab, then

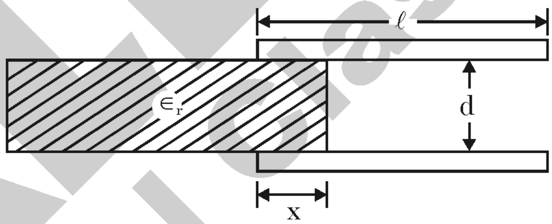
(A) the electric field after inserting the slab is $\frac{E_0}{k}$

(B) the capacitance after inserting the slab is $k\,C_0$

(C) the induced charge on the slab is $Q\left(1-\frac{1}{k}\right)$

(D) the energy stored in the capacitor becomes $\frac{U_0}{k}$, U_0 being the energy of the capacitor before inserting the slab

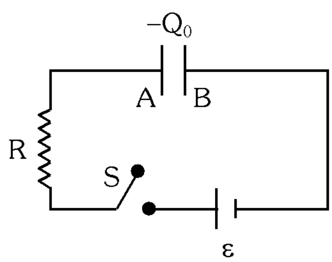
20. Two square plates with side length ℓ are arranged parallel to each other at distance d. They are charged to a potential difference V_0 and isolated from the source. A dielectric with a permittivity $\varepsilon_r = 2$ whose thickness is d and width is equal to that of the plates is drawn into the space between the plates. The length of the dielectric is greater than ℓ (figure). The resulting force F acting on the dielectric at distance $x = \ell/2$ is $\frac{\alpha C V_0^2}{\beta \ell}$ where $C = \frac{\varepsilon_0 \ell^2}{d}$. Take α and β as minimum integers.Find β-α.



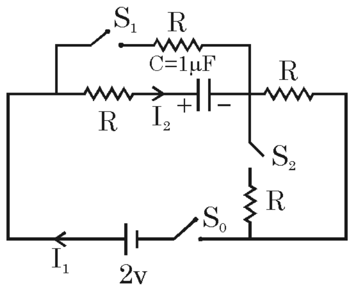
R-C CIRCUITS

21. The figure shows a RC circuit with a parallel plate capacitor. Before switching on the circuit, plate A of the capacitor has a charge $-Q_0$ while plate B has no net charge. Now, at t = 0, the circuit is switched on. How much time (in second) will elapse before the net charge on plate A becomes zero.

(Given $C = 1\mu F$, $Q_0 = 1mC$, $\varepsilon = 1000$ V and $R = \frac{2\times10^6}{\ln 3}\Omega$)



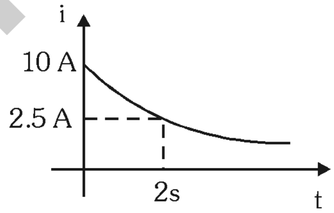
22. In the given figure initially all switches are open and the capacitor has charge q. At t = 0, switch S_0 is closed alongwith S_1 or S_2 or both. Column I has the entries for the actions on switches and column II has the values of currents I_1 & I_2 at t = 0. (R = 1Ω)



Column-I		Column-II	
(A)	S_0 and S_1 closed and q = 1 μC	(P)	$I_1 < 2I_2$
(B)	S_0 and S_1 closed and q = –1μC	(Q)	$I_2 = 0$
(C)	S_0, S_1 and S_2 closed and q = 1μC	(R)	$I_1 > 4I_2$
(D)	S_0, S_1 and S_2 closed and q = –1μC	(S)	$I_1 > 1A$
		(T)	$I_1 \leq 1A$

23. The figure, a graph of the current in a discharging circuit of a capacitor through a resistor of reistance 10Ω.

(A) The initial potential difference across the capactitor is 100 volt.

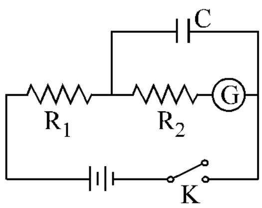


(B) The capacitance of the capacitor is $\frac{1}{10\ell n2}$F.

(C) The total heat produced in the circuit will be $\frac{500}{\ell n2}$ joules.

(D) The thermal power in the resistor will decrease with a time constant $\frac{1}{2\ell n2}$ second.

24. In the connection shown in the figure the switch K is open and the capacitor is uncharged. Then we close the switch and let the capacitor charge upto the maximum and open the switch again. The values indicated by the galvanometer.



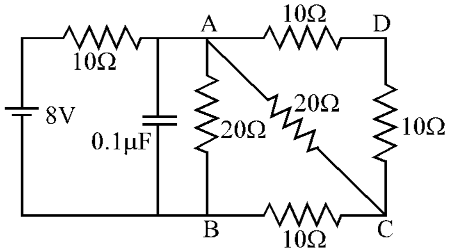
(A) increases after closing the switch and then decreases after opening the switch

(B) direction of current is same through the galvanometer before and after opening the switch again

(C) after opening the switch again energy dissipation in R_1 is zero

(D) after opening the switch again energy dissipation in R_2 is zero

25. A capacitor of capacitance 0.1 μF is connected to a battery of emf 8V as shown in the fig. Under steady state condition



(A) charge on the capacitor is 0.4 μC.

(B) charge on the capacitor is 0.2 μC

(C) current in the resistor between point A and B is 0.2 A

(D) current in the resistor between point A and B is 0.4 A

* * * * *

CAPACITORS ANSWER KEY

1. Ans. $\dfrac{\sqrt{4.8}}{2\sqrt{9.1}} \times 10^8$ **m/s** **2. Ans.** $\dfrac{200}{3}$ **μC,** $\dfrac{1000}{3}$ **μC, 0.0167 J** **3. Ans. (B,C,D)**

4. Ans. (B) **5. Ans. (A,B,D)** **6. Ans. 12** **7. Ans. 2μF** **8. Ans. (A,B,C)**

9. Ans. 1 **10. Ans. (A,B,C)** **11. Ans. (A,B,C)** **12. Ans. (B,D)**

13. Ans. (i) 1.5×10^4 V/m, 4.5×10^4 V/m, (ii) 75 V, 225 V, (iii) 8×10^{-7} C/m^2

14. Ans. (A) **15. Ans. (A,C)** **16. Ans. (A, B, C, D)** **17. Ans. (B,D)**

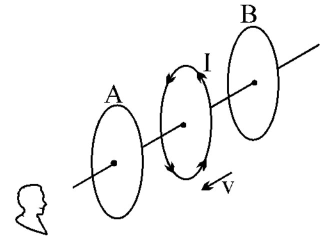
18. Ans. (B, C, D) **19. Ans. (A, B, C, D)** **20. Ans. 7**

21. Ans. 2 **22. Ans. (A) Q,R,T; (B) P,S; (C) R,S; (D) P,S** **23. Ans. (A, B, C, D)**

24. Ans. (A, B, C) **25. Ans. (A, C)**

MOTIONAL EMF

1. Three wire loops and an observer are positioned as shown in the figure. From the observer's point of view, a current I flows counterclockwise in the middle loop, which is moving towards the observer with a velocity *v*. Loops A and B are stationary. This same observer would notice that



(A) clockwise currents are induced in loops A and B

(B) counterclockwise currents are induced in loops A and B

(C) a clockwise current is induced in loop A, but a counterclockwise current is induced in loop B

(D) a counterclockwise current is induced in loop A, but a clockwise current is induced in loop B

2. A small loop of wire of area A = 0.01 m^2, N = 40 turns and resistance R = 20Ω is initially kept in a uniform magnetic field B in such a way that the field is normal to the plane of the loop. When it is pulled out of the magnetic field, a total charge of $Q = 2 \times 10^{-5}$C flows through the coil. The magnitude of the field B is :-

(A) 1×10^{-3} T

(B) 4×10^{-3} T

(C) zero

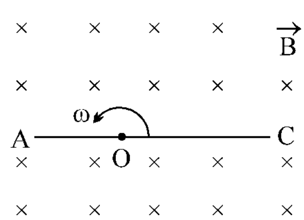
(D) unobtainable, as the data is insufficient

3. A metallic rod is being rotated in a uniform magnetic field with a constant angular velocity ω. The rotation axis of the rod is vertical and passing through its midpoint. If specific charge of free electrons in the rod is (e/m), then for what value of ω (vector) will the potential difference between the tip of the rod and its midpoint be zero? Take magnetic field to be vertically upwards.

(A) Be/m upwards (B) $Be/2m$ upwards

(C) Be/m downwards (D) $Be/2m$ downwards

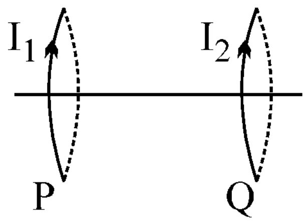
4. A conducting rod AC of length 4*l* is rotated about a point O in a uniform magnetic field $\vec{B}$ directed into the paper. AO = *l* and OC = 3*l*. Then



(A) $V_A - V_0 = \frac{B\omega l^2}{2}$ (B) $V_0 - V_C = \frac{9}{2} B \omega l^2$

(C) $V_A - V_C = 4B \omega l^2$ (D) $V_C - V_0 = \frac{9}{2} B \omega l^2$

5. Two circular coils P & Q are fixed coaxially & carry currents I_1 and I_2 respectively



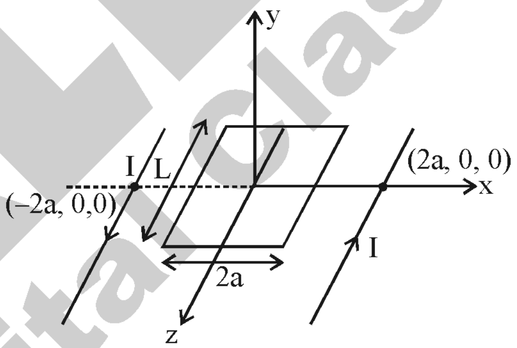
(A) if $I_2 = 0$ & P moves towards Q, a current in the same direction as I_1 is induced in Q

(B) if $I_1 = 0$ & Q moves towards P, a current in the opposite direction to that of I_2 is induced in P.

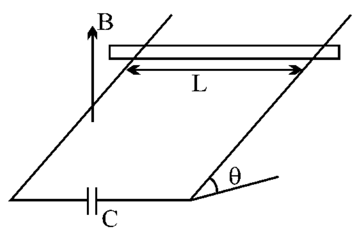
(C) when $I_1 \neq 0$ and $I_2 \neq 0$ are in the same direction then the two coils tend to move apart .

(D) when $I_1 \neq 0$ and $I_2 \neq 0$ are in opposite directions then the coils tends to move apart.

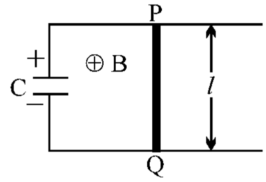
6. Two very long wires parallel to the Z-axis (in xz plane) and a distance '4a' (along x-axis) apart carry equal currents I in opposite directions as shown in the figure. A rectangular strip of width 2a and length L has its center on the origin midway between the wires, calculate the net upward magnetic flux through strip. If the answer is $\frac{n\mu_0 IL\ell n3}{2\pi}$ fill n in OMR sheet.



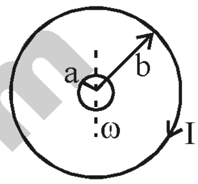
7. A horizontal conducting rod of length L mass m is released on rough conducting parallel rails separated by distance L which are inclined to horizontal at an angle θ. There is a uniform vertical magnetic field B. The two rails are connected through a capacitor of capacitance C. Find velocity of the rod and charge on the capacitor as function of time if coefficient of friction between rails and the rod is μ.



8. In figure shown, the capacitor is charged to potential V_0. A constant, uniform magnetic field B exists into the plane of paper. At time t = 0, a rod of length l, mass m and resistance R is placed between point P and Q. Assume that system is on horizontal plane and wires connecting capacitors are smooth and resistanceless. Find the current through the rod as a function of time.



9. A very small circular loop of radius a is initially coplanar and concentric with a much larger circular loop of radius b (>>a). A constant current I is passed in the large loop which is kept fixed in space and the small loop is rotated with angular velocity ω about a diameter. The resistance of the small loop is R & its self inductance is negligible. The current in the larger loop is clockwise. (Here θ is to be measured from axis of large ring)



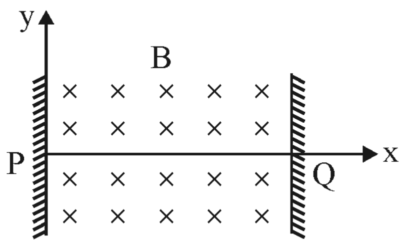
(A) The current in the small loop as a function of time is $\dfrac{\pi a^2\mu_0 I\omega \sin\omega t}{2bR}$

(B) The current in the small loop as a function of time is $\dfrac{\pi a^2\mu_0 I\omega \cos\omega t}{2bR}$

(C) Torque that must be exerted on the small loop to rotate it, is $\dfrac{\omega}{R}\left(\dfrac{\pi b^2\mu_0 I\sin\omega t}{2b}\right)^2$

(D) Torque that must be exerted on the small loop to rotate it, is $\dfrac{\omega}{R}\left(\dfrac{\pi a^2\mu_0 I\sin\omega t}{2b}\right)^2$

10. A standing wave y = 2 A sin kx cos ωt is setup in the conducting wire PQ fixed at both ends by two vertical walls (see the figure). The region between the walls contains a constant magnetic field B. The wire is found to vibrate in the 3rd harmonic (where PQ = L) :-



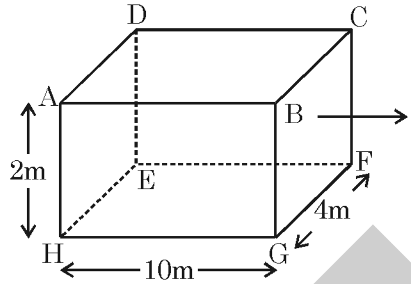
(A) The maximum emf induced is $\dfrac{4AB\omega}{k}$

(B) The time when the emf becomes zero for the first time is $\dfrac{\pi}{2\omega}$

(C) The total emf induced is always zero between x = 0 and x = 2L/3

(D) At t = 0, the emf in the entire wire is zero.

11. A train is going from Kanpur to Patna in east direction at 90 km/hr. The compartment can be assumed to be a metal box whose dimensions are as shown in the figure. The horizontal component of earth's magnetic field is 0.04 T with an angle of dip as 37°. The angle of declination is zero.



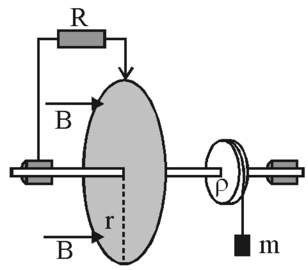
(A) The potential difference between A & B is 0.

(B) The potential difference between B & C is 3 V

(C) The potential difference between B & D is 0.6 V

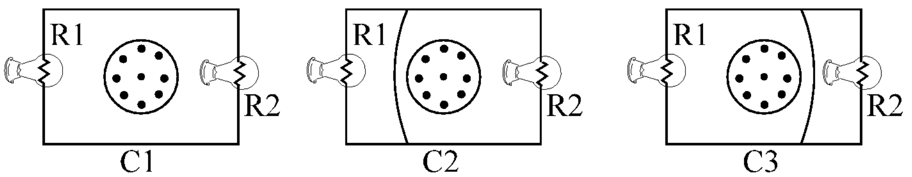
(D) The potential difference between B & G is 2 V

12. A disc of radius r is made of a material of negligible resistance and can rotate about a horizontal shaft. A smaller disc of radius ρ is fixed onto the same shaft and has a massless cord wrapped around it, which is attached to a small object of mass m as shown. Two ends of a resistor of resistance R are connected to the perimeter of the disc and to the shaft by wiping contacts. The system is then placed into a uniform horizontal magnetic field B and mass m is released. Find the constant angular velocity (in rad/s) with which the disc will rotate after a certain time. If your answer is ω give value of $\frac{\omega}{20}$. Data : r = 10 cm, ρ = 2 cm, R = 0.01 Ω, B = 0.2 T, m = 50 g.



INDUCED ELECTRIC FIELD

13. A solenoid is oriented end-on so that its opening is perpendicular to the circuit containing the two light bulbs as drawn in figure C1. For figure C2 and C3, a shorting wire of negligible resistance is added as shown. Assume that the magnetic field from the solenoid, shown coming out of the plane of the page, decreases uniformly with time at the same rate for each circuit. Rank the circuits for the brightness of the bulb labeled R1 from brightest to dimmest.

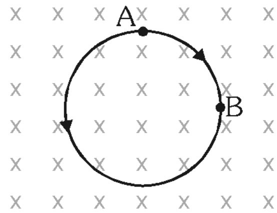


(A) C1> C3 >C2 (B) C1 > C2 = C3 (C) C2 > C3 > C1 (D) C3 > C1 > C2

14. **Statement–1:** In a region of time varying magnetic field, two charges of same magnitude moves from A to B in clockwise and anticlockwise manner. Work done in clockwise path is equal to work done in anticlockwise path.

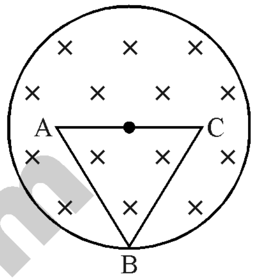
and

Statement–2: Work done in electrostatic field is independent of path.



(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1.
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1.
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

15. An equilateral triangle ABC of side a is placed in the magnetic field with side AC and its centre coinciding with the centre of the magnetic field. The magnetic field varies with time as B = kt. The emf induced across side AB is

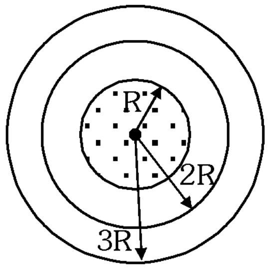


(A) $\frac{\sqrt{3}}{4}a^2k$ (B) Zero
(C) $\frac{\sqrt{3}}{8}a^2k$ (D) $\frac{(\sqrt{2}-1)}{2}a^2k$

16. A smooth insulating ring of radius R, with a bead having charge q is placed horizontally and in a uniform magnetic field of strength B_0 and perpendicular to the ring plane. Starting from t = 0, the magnetic field is changed to $B(t) = B_0 + \alpha t$, where α is a positive constant. The contact force between the ring and bead as a function of time is (Neglect gravity)

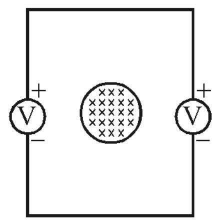
(A) $\frac{\alpha q^2 Rt}{m}(2B_0+\alpha t)$ (B) $\frac{\alpha q^2 Rt}{4m}(2B_0+\alpha t)$ (C) $\frac{\alpha q^2 Rt}{4m}(B_0+\alpha t)$ (D) $\frac{4\alpha q^2 Rt}{m}(2B_0+\alpha t)$

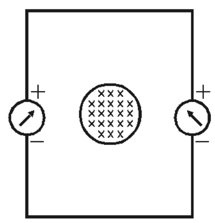
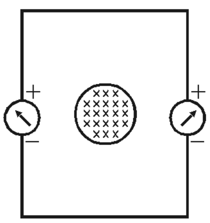
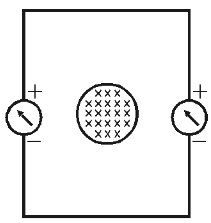
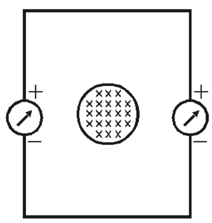
17. A uniform magnetic field $\vec{B}$ exists in circular region of radius R as shown which is decreasing with time at a constant rate. There is a concentric wooden ring which have uniformly distributed charge Q and radius 2R and another concentric uncharged copper ring of radius 3R, then select **incorrect** alternative. (Assume rings are placed on frictionless surface) :-



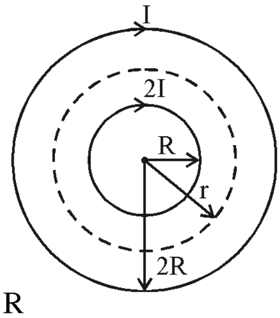
(A) There is no induced current in wooden ring
(B) Induced electric field in wooden ring is more in magnitude then copper ring
(C) Induced electric field in copper ring is more in magnitude then wooden ring
(D) Wooden ring will start rotating

18. Two similar voltmeters with large resistance are connected in a loop as shown. Inside the loop, there is a cylindrical region through which magnetic flux is distributed uniformly. The magnetic field increases uniformly with time. The voltmeters are bidirectional i.e. the needle deflects to right if current in it flows from + terminal to – terminal and needle deflects to left if current in it flows from – terminal to + terminal. Which of the following figures show the readings of voltmeters correctly :-



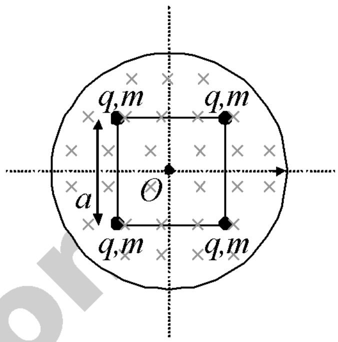
(A)  (B)  (C)  (D) 

19. A long solenoid contains another coaxial solenoid (whose radius R is half of its own). Their coils have same numbers of turns per unit length and initially both carry no current. At any moment the current flowing in the inner coil is twice as large as that in the outer one and their directions are the same. As a result of the increasing current a charged particle initially at rest between the solenoids, starts moving along a circular trajectory. The radius of the circular trajectory is :



(A) $\frac{5}{4}R$ (B) $\sqrt{2}\,R$ (C) $\frac{7}{6}R$ (D) $\sqrt{3}\,R$

20. Four identical charge particles each of mass 0.1kg and charge $2C$ connected to each other via massless non-conducting rods of equal length. The whole arrangement is placed in a cylindrical region carrying a uniform magnetic field as shown in the figure (B_0 = 4T, a = 1m). Suddenly the magnetic field is switched off. Then choose the correct statement(s) :-



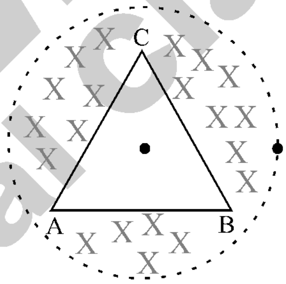
(A) the angular momentum of the system is 8 Nm/s

(B) the angular momentum of the system is $8\sqrt{2}$ Nm/s

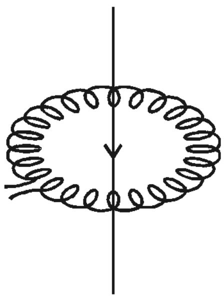
(C) Angular velocity of the system is 40 rad/s

(D) the magnetic field at point O after the magnetic field is switched off is non zero.

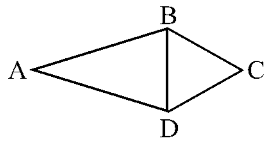
21. A triangular wire frame (each side = 2m) is placed in a region of time variant magnetic field having dB/dt = $\sqrt{3}$ T/s. The magnetic field is perpendicular to the plane of the triangle. The base of the triangle AB has a resistance 1 Ω while the other two sides have resistance 2Ω each. The magnitude of potential difference between the points A and B will be



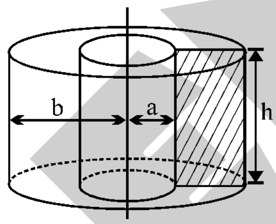
22. An infinite wire carrying current $i = i_0 \sin \omega t$ is kept along the axis of a toroid of mean radius a. The cross section area of the toroid is A (<< a^2). If the resistance of toroid is R, find the mean power dissipated P in the toroid. Number of turns in toroid = N. i_0 = 10A, ω = 100 rad/s, N = 1000, A = 1 cm^2, a = 10 cm, R = 1μΩ. Fill 100 P in OMR sheet.



23. A wire loop ABCD is divided into two parts. AB = AD = 2m, BC = CD = BD =1m. The wire loop is lying on X–Y plane. The resistance per unit length of the wire is 2Ω/m. There exists a time dependent magnetic field $\vec{B} = (2.5t)\hat{k}$ T. Find the current flowing through each parts.



24. A ring of a rectangular cross section (see figure) is made of a material whose resistivity is ρ. The ring is placed in a homogeneous magnetic field. The intensity of the magnetic field is directed along the axis of the ring and increases directly with times, B = kt. Find the current induced in the ring.



* * * * *

EMI & AC-01 **ANSWER KEY**

1. Ans. (C) **2. Ans. (A)** **3. Ans. (A)** **4. Ans. (B, C)**
5. Ans. (B, D) **6. Ans. 2**

7. Ans. $v = \dfrac{g(\sin\theta - \mu\cos\theta)t}{1 + \dfrac{B^2 l^2 \cos\theta}{m}(\cos\theta + \mu\sin\theta)}$, $q = C\,B\,l\cos\theta \times v$

8. Ans. $i = \dfrac{V_0}{R} e^{-t\left(\frac{m + CB^2 l^2}{mCR}\right)}$

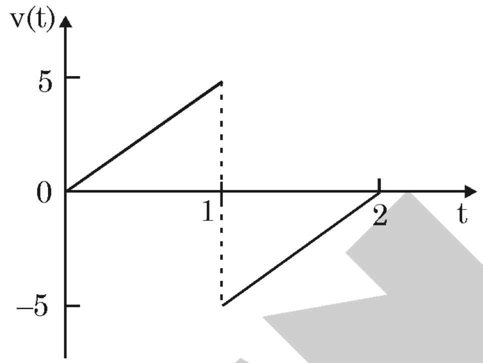
9. Ans. (A,D) **10. Ans. (A,C,D)** **11. Ans. (A, B, D)** **12. Ans. 5**
13. Ans. (D) **14. Ans. (D)** **15. Ans. (C)** **16. Ans. (B)**
17. Ans. (C) **18. Ans. (A)** **19. Ans. (B)** **20. Ans. (A, C, D)**
21. Ans. 0.4 V **22. Ans. 2**

23. Ans. $I_{BA} = I_{AD} = 0.3$ A, $I_{DB} = 0.018$ A, $I_{DC} = I_{CB} = 0.28$ A

24. Ans. $\dfrac{kh}{4\rho}(b^2 - a^2)$

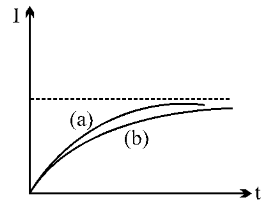
SELF INDUCTANCE

1. If the voltage waveform in figure is applied to a 10-mH inductor, find the inductor current Assume $i(0) = 0$.



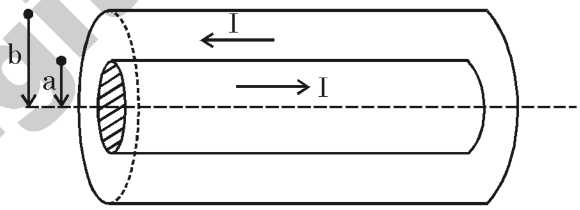
(A) The current through the inductor at t = 1 seconds is 5×10^{-2} A
(B) The current through the inductor at t = 2 seconds is 0 A
(C) The current through the inductor at t = 1 seconds is 250 A
(D) The current through the inductor at t = 2 seconds is 5×10^{-3} A

2. A circuit consisting of a constant e.m.f. 'E', a self induction 'L' and a resistance 'R' is closed at t = 0. The relation between the current I in the circuit and time t is as shown by curve 'a' in the fig. When one or more of parameters E, R & L are changed , the curve 'b' is obtained .The steady state current is same in both the cases. Then it is possible that :



(A) E & R are kept constant & L is increased
(B) E & R are kept constant & L is decreased
(C) E & R are both halved and L is kept constant
(D) E & L are kept constant and R is decreased

3. A long co-axial cable carries current I as shown in figure. (Current flows down the surface of inner cylinder of radius a and back along the outer cylinder of radius b.) Choose the correct statement(s) :



(A) The magnetic energy stored in a section of length ℓ is $\frac{\mu_0 I^2 \ell}{4\pi} \ell n\left(\frac{b}{a}\right)$

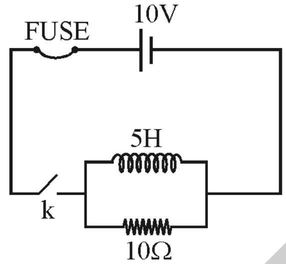
(B) The magnetic field between the cylinders have magnitude of $\frac{\mu_0 I}{2\pi(b-a)}$

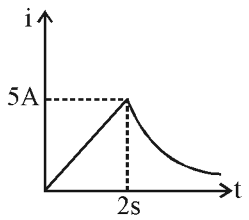
(C) Self inductance of the cable of length ℓ is $\frac{\mu_0 \ell}{4\pi} \ell n\left(\frac{b}{a}\right)$

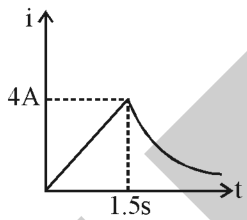
(D) Magnetic field outside the cylinder is zero.

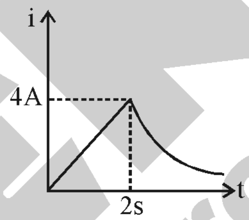
4. A solenoid has an inductance of 10 Henry & a resistance of 2 Ω. It is connected to a 10 volt battery. How long will it take for the magnetic energy to reach 1/4 of its maximum value ?

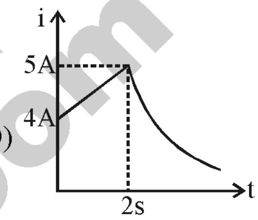
5. In the circuit shown, fuse blows when current through fuse reaches 5A. The graph showing current variation of current through inductor with time is :



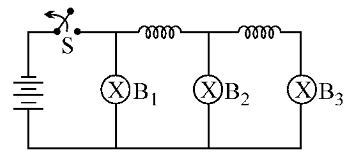
(A)


(B)


(C)


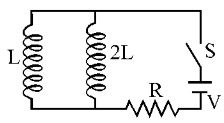
(D)


6. The circuit shown in figure consisting of three identical lamps and two coils is connected to a direct current source. The ohmic resistance of the coils is negligible. After some time switch S is opened. Which of the following statement(s) is/are **correct** for the instant immediately after opening the switch?



(A) All the lamps are turned off
(B) Brightness of B_2 & B_3 remains unchanged
(C) Brightness of B_1 suddenly increases
(D) Insufficient data to draw any conclusion.

7. In the circuit shown, the switch is closed at t = 0. The current through the inductor of inductance L varies with time as :



(A) (2V/3R) [1 – exp (–3Rt/2L)]
(B) (2V/3R) exp (–3Rt/2L)
(C) (V/R) [1 – exp (–3Rt/2L)]
(D) (V/R) [1– exp (–Rt/2L)]

8. In the circuit of the previous question, the switch is opened at t = 0, after being closed for a long time. The current through the inductor of inductance L at any time t > 0 is :
(A) (V/3R) exp (–3Rt/2L)
(B) zero
(C) (V/R) exp (–3Rt/2L)
(D) ∞

9. A current I is circulating in a super conducting coil of inductance L. The temperature of the coil is now raised above the critical temperature so that the coil acquires a resistance R. Then, the total heat energy dissipated in a time $\Delta t = L/R$ after the critical temperature is crossed is
(A) $LI^2/4$
(B) $LI^2[e-1]/e$
(C) $LI^2\,[1-(1/e^2)]/2$
(D) None

MUTUAL INDUCTANCE

10. If the difference between the equivalent inductance in the following figures is nL then find the value of n. Given coupling coefficient is $C=\sqrt{2}$ (Where coupling coefficient is defined as $C = \frac{\sqrt{L_1L_2}}{M}$)

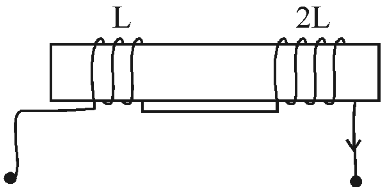


Figure (A)

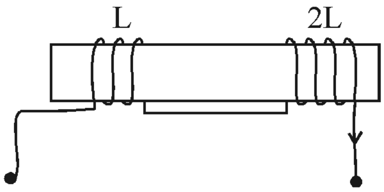
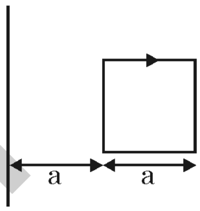


Figure (B)

(A) 2 (B) 3 (C) 4 (D) 5

11. A very long straight conductor and a square conducting frame lie in a plane and are separated from each other as shown in the figure a = 10 cm. If current in the square frame is increasing a rate of 2 A/s in clockwise direction :-



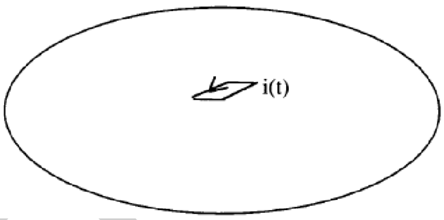
(A) Mutual inductance of the two loops is $2\ell n2 \times 10^{-8}$H

(B) The current induced in the wire is upwards.

(C) The current induced in the wire is downwards.

(D) The current induced in the wire is zero.

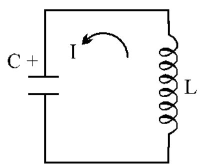
12. Consider the two loops with common center and on the same plane shown in the Figure. The large circular loop has radius R = 10 cm, and the small square loop has side a = 1 cm. There is a current circulating in the small loop given by $i(t) = i_0 t/\tau$, with $i_0 = \frac{2}{\pi} \times 100$ A, $\tau = 2\times10^{-2}$ sec. Emf **(in microvolts)** induced in the large loop is



LC-CIRCUIT

13. A perfect conductor of mass M is free to slide without friction on two horizontal conducting parallel rails, which have a separation = d between them. An ideal inductor of inductance L is connected between one side ends of the two rails. A uniform and constant magnetic field B, directed vertically upwards, exists in the region. The conductor is given an initial velocity v_0 away from the inductor side end at t = 0. Its displacement coordinate, measured +ve in the direction v_0 is x. Find its v(t) and x(t) for t > 0.

14. At time t = 0, the LC circuit shown in the figure has equal amount of energy stored in the capacitor C = 20 μF and in the inductor, each equal to 200 μJ. The current amplitude in the circuit is $1/\sqrt{10}$ A. Find

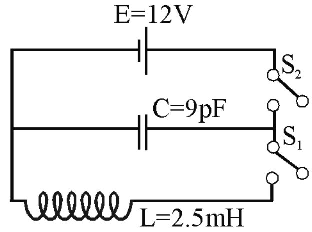


(i) the natural frequency of oscillation

(ii) the value of the inductance L.

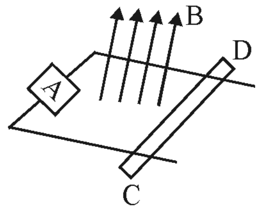
(iii) the equation for charge and current in terms of t.

15. In the circuit shown, the capacitor is initially charged with a 12 V battery, when switch S_1 is open and switch S_2 is closed. S_1 is then closed and, at the same time, S_2 is opened. The maximum value of current in the circuit is



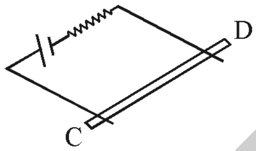
(A) 0.38 mA (B) 0.84 mA
(C) 0.72 mA (D) 0.1 mA

16. A homogeneous magnetic field B is perpendicular to a sufficiently long fixed track of width ℓ which is horizontal. A frictionless rod of mass m straddles the two rail of the track as shown in the figure. Entire arrangement lies in horizontal plane. For the situation suggested in column-II match the appropriate entries in column-I. The rails are also resistanceless.

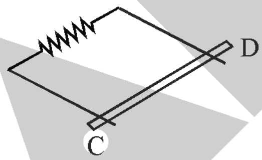


Column-I

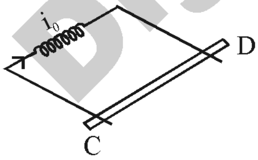
(A) A is a battery of emf V and internal resistance R. The conducting rod is initially at rest.



(B) A is a resistance. The non-conducting rod is projected to the right with a velocity V_0



(C) A is an inductor having with initial current i_0. It is having no resistance and CD is a conducting rod. (consider no loss of energy)



(D) A is a resistance. The conducting rod is projected to the right with a velocity V_0.

Column-II

(P) Energy is dissipated during the motion.

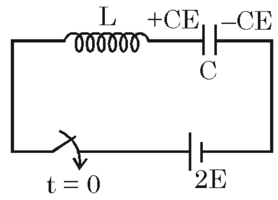
(Q) The rod moves with a constant velocity after a long time.

(R) After a certain time interval rod will change its direction of motion.

(S) If a constant force is applied on the rod to the right, it can move with a constant velocity from starting itself

(T) The rod stops after some time permanently in absence of an external force.

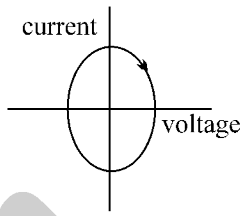
17. Maximum charge on capacitor after switch is closed :-



(A) 2CE (B) 4CE (C) 3CE (D) None of these

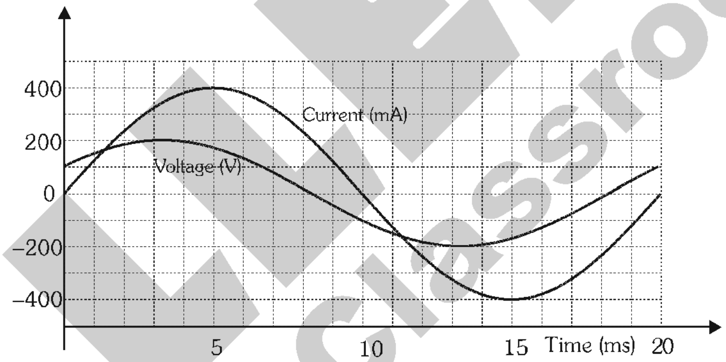
AC-CIRCUIT

18. The graph shows the current versus the voltage in a driven RLC circuit at a fixed frequency. The arrow indicates the direction that this curve is drawn as time progresses. In this plot, the



(A) Current lags the voltage by about 90 degrees
(B) Current leads the voltage by about 90 degrees
(C) Current and voltage are in phase
(D) Current and voltage are 180 degrees out of phase

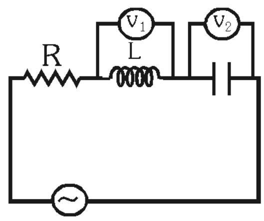
19. The given graph shows variation with time in the source voltage and steady state current drawn by a series RLC circuit. Which of the following statements is/are correct?



(A) Current lags the voltage.
(B) Resistance in the circuit is $250\sqrt{3}\ \Omega$.
(C) Reactance in the circuit is 250Ω.
(D) Average power dissipation in the circuit is $20\sqrt{3}$ W.

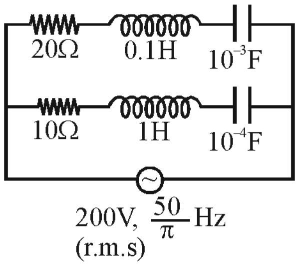
20. If a resistance of 30 Ω, a capacitor of capacitive reactance 20 Ω and an inductor of inductive reactance 60 Ω are connected in series to a 100 V, 50 Hz power source, then
(A) a current of 2.0 A flows
(B) a current of 3.33 A flows
(C) power factor of the circuit is zero.
(D) power factor of the circuit is 3/5

21. In the circuit shown, resistance R = 100 Ω, inductance $L = \frac{2}{\pi}$H and capacitance $C = \frac{8}{\pi}\mu F$ are connected in series with an ac source of 200 volt and frequency 'f'. If the readings of the hot wire voltmeters V_1 and V_2 are same then :



(A) f = 125 Hz (B) f = 250 π Hz
(C) Current through R is 2A (D) $V_1 = V_2 = 1000$ volt

22. Choose the correct option(s) :-



(A) r.m.s. current drawn from the source is 30A

(B) r.m.s. current drawn from the source is $10\sqrt{5}$A

(C) average power loss in the circuit is 6kW

(D) average power loss in the circuit is zero.

23. An inductor 4H and a resistance 5Ω are connected in series with an A.C source. At a particular instant, voltage across inductor is 3 volt and across resistor is 4 volt. For that particular instant, choose correct options.

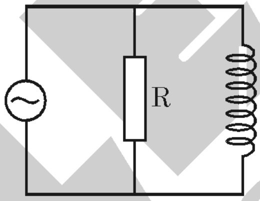
(A) Voltage across source is 5 volt

(B) Voltage across source may be 7 volt

(C) voltage across source may be 1 volt

(D) Current in circuit is 0.8 Amp

24. In a circuit, alternating voltage with amplitude U_o = 100 V. is applied. The phase difference between current and voltage through the source is equal $\varphi = \pi/4$. R = 100 Ohm and the inductance is resistance free. Take ω = 100 rad/s



(A) The amplitude of current is $\sqrt{2}$ amp.

(B) The average power dissipated is 50 W

(C) The inductance is 1H

(D) The amplitude of current through the inductance is 0.5 A

25. The primary winding of step-down transformer with a turn ratio 10 has a source voltage of 120 V connected to it. The resistance of the secondary and primary winding is negligible, the current in secondary is I = 5 A.

(A) The current in primary is 0.5 A

(B) The power delivered to the load is 60 W

(C) The load resistance is 24 ohms

(D) The voltage across the load is 1200 V.

* * * * *

EMI & AC-02 **ANSWER KEY**

1. Ans. (B, C) **2. Ans. (A,C)** **3. Ans. (A,D)** **4. Ans.** $\mathbf{t = \frac{L}{R}\,\ell n\, 2 = 3.47}$ **sec**

5. Ans. (C) **6. Ans. (B,C)** **7. Ans. (A)** **8. Ans. (B)**

9. Ans. (C) **10. Ans. (C)** **11. Ans. (A, C)** **12. Ans. 2**

13. Ans. $\mathbf{x = v_0/\omega \sin \omega t}$**, where** $\mathbf{\omega = \mathit{l}B/\sqrt{mL}}$**,** $\mathbf{v_0 \cos \omega t}$

14. Ans. (i) 398 Hz, (ii) 8 mH, (iii) $\mathbf{I = \frac{1}{\sqrt{10}}\cos\left(2500t + \frac{\pi}{4}\right)A,\ q = \frac{400}{\sqrt{10}}\sin\left(2500t + \frac{\pi}{4}\right)\mu C}$

15. Ans. (C) **16. Ans. (A) P,Q; (B) Q; (C) R; (D) P,S,T** **17. Ans. (C)**

18. Ans. (B) **19. Ans. (A,B,C,D)** **20. Ans. (A,D)** **21. Ans. (A,C,D)**

22. Ans. (A, C) **23. Ans. (B,C,D)** **24. Ans. (A,B,C)** **25. Ans. (A,B)**

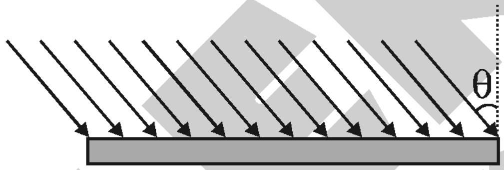
PHOTOELECTRIC EFFECT

1. A beam of light has two wavelengths 3100 Å and 4133 Å with a total intensity of 12.8 W/m^2 equally distributed between the two wavelengths. The beam falls normally on an area of a clean metallic surface of work function 3.1 eV. Assume that there is no loss of energy by reflection and that each energetically capable photon ejects one electron. How many electrons will emit per second from the face area ?

(A) 2×10^{19} (B) 10^{19}

(C) 10^{18} (D) 2×10^{18}

2. The radiation of intensity I is falling obliquely on a surface. Area of surface exposed to radiation is A. Select correct alternative



(A) If surface is perfectly reflecting surface then force experienced due to radiation is $\frac{IA\cos^2\theta}{c}$

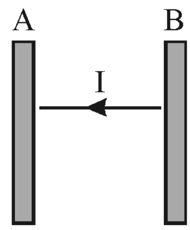
(B) If surface is perfectly absorbing surface then force experienced due to radiation is $\frac{IA\cos^2\theta}{c}$

(C) If surface is perfectly absorbing surface then force experienced due to radiation is $\frac{IA\cos\theta}{c}$

(D) If surface is partially reflecting surface then force experienced due to radiation is $\frac{\beta IA\cos^2\theta}{c}$

where β is a constant and depends upon nature of surface.

3. A parallel beam of light of intensity I is incident normally on a plane surface A which absorbs 50% of the incident light. The reflected light falls on B which is perfect reflector, the light reflected by B is again partly reflected and partly absorbed and this process continues. For all absorption by A, asborption coefficient is 0.5. The pressure experienced by A due to light is :-



(A) $\frac{1.5\,I}{c}$ (B) $\frac{I}{c}$

(C) $\frac{3I}{4c}$ (D) $\frac{3I}{c}$

4. When photons of energy 4.25 eV strike the surface of a metal "A", the ejected photoelectrons have maximum kinetic energy, T_A expressed in eV and de Broglie wavelength λ. The maximum kinetic energy of photoelectrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50 \text{ eV})$. If the de Broglie wavelength of these photoelectrons is $\lambda_B = 2\lambda_A$, then :

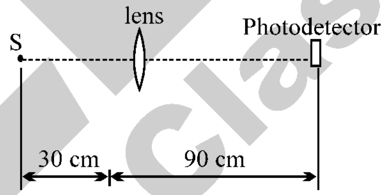
(A) the work function of A is 2.25 eV
(B) the work function of B is 4.20 eV
(C) $T_A = 2.00$ eV
(D) $T_B = 2.75$ eV

5. Photons of wavelength 248 nm fall on a metal surface whose work function is 2.2 eV. Assume that each photoelectron inside the metal lattice may come out of the surface or collide with the lattice before coming out. In each collision with the lattice, it loses 20% of its existing energy. Which of the following can be a kinetic energy of an ejected photoelectron?

(A) 2.8 eV (B) 2.24 eV (C) 1.8 eV (D) 1 eV

6. An isolated copper ball of radius 9 mm having work function 4.47 eV is illuminated by electromagnetic radiation of wavelength 1243 Å. Find the maximum charge on the ball.

7. A disc shaped photoelectric detector of area 0.5 cm^2 generates current when light of frequency > that of yellow light falls on it. The photoelectron generation efficiency is 20%. In the arrangement shown, S is an isotropic 100 watt point monochromatic light source with $\lambda = 4000$ Å. The focal of the lens is 20 cm and its circular area is 4 cm^2. Find the photocurrent in the detector assuming all rays to be paraxial w.r.t. lens.



BOHR'S THEORY

8. Lyman alpha, the n=1 to n=2 transition in atomic hydrogen occurs at 1215 Å.

(A) Radiation of wavelength longer than 911 Å can photo–ionize hydrogen atom in ground state.

(B) Radiation of wavelength longer than 3645 Å can photo–ionize hydrogen atom in first excited state.

(C) Radiation of wavelength longer than 228 Å can photo–ionize He^+ ion in ground state.

(D) Radiation of wavelength longer than 1215 Å can photo–ionize He^+ ion atom in first excited state.

9. The total energy of a hydrogen atom in its ground state is -13.6eV. If the potential energy in the first excited state is taken as zero then the total energy in the ground state will be :

(A) –3.4eV (B) 3.4 eV (C) – 6.8eV (D) 6.8eV

10. A positronium atom is a system that consist of a positron and an electron that orbit each other. Choose the wrong statement.

(A) The Rydberg constant for positronium is half as large as it is for ordinary hydrogen atom.

(B) Wavelength in the positronium spectral lines are all twice of those corresponding in the hydrogen spectrum

(C) In positronium electron and positron rotate about common centre of mass

(D) Wavelengths in the positronium spectral lines are all half of those corresponding in the hydrogen spectrum.

11. Applying Bohr's model choose the correct statement(s) :-

(A) K_β photon of aluminium will be more energetic than K_α photon of Lithium

(B) K_α photon of Beryllium will be more energetic than K_α photon of Lithium

(C) K_α photon of sodium will be more energetic than K_α photon of magnesium

(D) K_α photon of aluminium will be less energetic than K_β photon of aluminium

12. A particle of mass m moves along a circular orbit in a central potential field given by $U(r) \propto r^2$. Assuming Bohr's quantization conditions to be valid. Choose correct statement(s) regarding this.

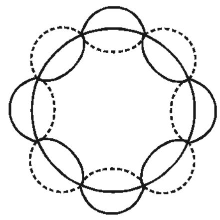
(A) Ratio of radii of fourth Bohr orbit (n = 4) and ground state orbit is 4

(B) Ratio of radii of fourth Bohr orbit (n = 4) and ground state orbit is 2

(C) Energy levels are equally spaced

(D) Separation between successive energy levels increase as n increases.

13. Figure shows stationary orbit of an hydrogen atom upon the transition of electron from given excited state to ground state.



(A) Average change in angular momentum is $\frac{3h}{2\pi}$.

(B) The ratio of de-Broglie wavelengths in final state to initial state is 4.

(C) Energy of emitted photon is nearly 12.75 eV.

(D) Ratio of orbital time period in final state to initial state is 4^3.

14. A moving neutron collides with stationary H-atom in ground state. As a result it excites and then de excites. The corresponding radiation fall on a surface, having work function σ. The minimum value of required kinetic energy for neutron is E_0 and possible minimum value of de broglie wavelength of emitted photoelectrons is λ_0. If neutron hits stationary He^+ ion instead of stationary H atom, then minimum value of kinetic energy for neutron is E_1. Then

(A) The value of energy transferred from neutron to H-atom is $\frac{3E_0}{4}$.

(B) The value of λ_0 is $\frac{h}{\sqrt{m_e(E_0 - 2\sigma)}}$.

(C) The value of E_1 is $4E_0$

(D) The value of E_1 is $\frac{5E_0}{2}$

15. A hydrogen like atom (atomic number Z) is in higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energy 22.95eV and 5.15eV respectively. Alternatively, the atom from the same excited state can make transition to the second excited state by successively emitting two photons of energies 2.4eV and 8.7eV respectively. Find the values of n and Z.

X-RAYS

16. X-ray from a tube with a target A of atomic number Z shows strong K lines for target A and weak K lines for impurities. The wavelength of K_α lines is λ_z for target A and λ_1 and λ_2 for two impurities. If

$$\frac{\lambda_z}{\lambda_1} = 4 \text{ and } \frac{\lambda_z}{\lambda_2} = \frac{1}{4}$$

Screening constant of K_α lines to be unity. Select the correct statement(s)

(A) The atomic number of first impurity is 2Z – 1

(B) The atomic number of first impurity is 2Z+ 1

(C) The atomic number of second impurity is $\frac{(Z+1)}{2}$

(D) The atomic number of second impurity is $\frac{Z}{2} + 1$

17. An X-ray tube is operating at 50 kV and 10 mA. The target material of the tube has mass of 1 kg and specific heat 495 J kg^{-1} °C^{-1}. One percent of applied electric power is converted into X-rays and the remaining energy goes into heating the target. Then :

(A) a suitable target material must have high melting temperature

(B) a suitable target material must have low thermal conductivity

(C) the average rate of rise of temperature of the target would be 1°C/sec

(D) the minimum wavelength of X-rays emitted is about 0.25×10^{-10} m

* * * * *

MODERN PHYSICS-1 — **ANSWER KEY**

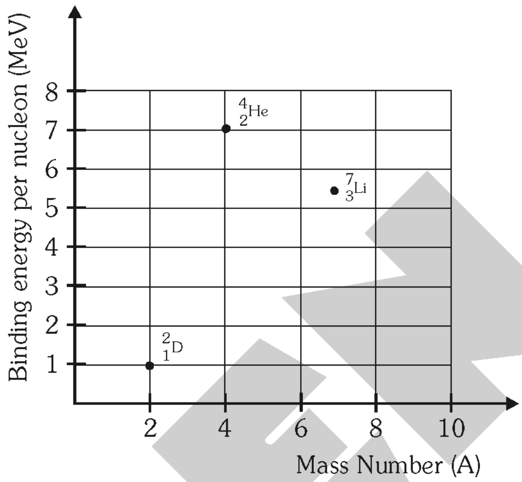
ANSWER KEY

1. Ans. (B)	**2. Ans. (C)**	**3. Ans. (D)**	**4. Ans. (A, B, C)**	**5. Ans. (A, C, D)**
6. Ans. 5.5×10^{-12} C		**7. Ans. $\frac{1}{279\pi}$ A**	**8. Ans. (A)**	**9. Ans. (C)**
10. Ans. (D)	**11. Ans. (A,B,D)**	**12. Ans. (B,C)**	**13. Ans. (A,C,D)**	**14. Ans. (A,B,D)**
15. Ans. z = 3, n = 7		**16. Ans. (A,C)**	**17. Ans. (A,C,D)**	

NUCLEAR PHYSICS

1. The positions of ${}_1^2D, {}_2^4He$ and ${}_3^7Li$ are shown on the binding energy curve as shown in figure.

The energy released in the fusion reaction. ${}_1^2D + {}_3^7Li \rightarrow 2\,{}_2^4He + {}_0^1n$



(A) 20 MeV (B) 16 MeV (C) 8 MeV (D) 1.6 MeV

2. The radionuclide ${}_6^{11}C$ decays by β^+ emission.

Given that $m({}_6^{11}C) = 11.011434$ u

$m({}_5^{11}B) = 11.009305$ u

$m_e = 0.000548$ u, $1u = 931.5$ MeV/c^2

The Q-value of this decay process is :-

(A) 0.962 MeV (B) 0.962×10^3 MeV (C) 0.962 eV (D) 0

3. The mass of certain nuclei is given as follows:

${}_{84}^{210}Po$: 209.982857 amu; ${}_{82}^{206}Pb$: 205.974449 amu;

${}_{83}^{209}Bi$: 208.980383 amu; ${}_{83}^{210}Bi$: 209.984105 amu;

${}_{84}^{209}Po$: 208.982416 amu; ${}_{85}^{210}At$: 209.987131 amu;

$m_n = 1.007276$ amu; $m_p = 1.008665$ amu;

$m_e = 0.000549$ amu; $m_\alpha = 4.002603$ amu

Which nuclear reaction can ${}_{84}^{210}Po$ undergo ?

(1) α decay (2) β^- decay (3) β^+ decay (4) k capture

(A) all 4 (B) 1 only (C) 1, 2 & 4 only (D) 1 & 3 only

4. The following deuterium reactions and corresponding reaction energies are found to occur :

${}^{14}N(d, p){}^{15}N$, Q = 8.53 MeV

${}^{15}N(d, \alpha){}^{13}C$, Q = 7.58 MeV

${}^{13}C(d, \alpha){}^{11}B$, Q = 5.16 MeV

The notation $^{14}N(d, p)^{15}N$ represents the reaction

$^{14}N + d \rightarrow\ ^{15}N + p$

$_2^4He = 4.0026$ amu, $_1^2H = 2.014$ amu, $_1^1H = 1.0078$ amu, n = 1.0087 amu (1 amu = 931 Mev)

The Q values of the reaction $^{11}B(\alpha, n)^{14}N$ is :-

(A) 0.5 eV (B) 0.5 MeV (C) 0.05 MeV (D) 0.05 eV

RADIOACTIVITY

5. A nucleus has a radius of 7.2×10^{-15} m. When an α-decay takes place from this nucleus, ratio of number of neutrons and number of protons in the daughter nucleus becomes $\frac{65}{41}$:-

(A) Parent nucleus is $_{84}Po$.
(B) Daughter nucleus is $_{82}Pb$.
(C) Mass number of daughter nucleus is 216.
(D) Mass number of parent nucleus is 216.

6. A radioactive sample has a half life of 40 seconds. When its activity is measured 80 seconds after the begining, it is found to be 6.932×10^{18} dps. During this time total energy released is 6×10^{8} joule ($\ell n2 = 0.6932$) :-

(A) The initial number of atoms in the sample is 1.6×10^{20}
(B) The initial number of atoms in the sample is 1.6×10^{21}
(C) Energy released per fission is 5×10^{-13} J
(D) Energy released per fission is $\frac{5}{3} \times 10^{-13}$ J

7. Choose the **CORRECT** option(s) :

(A) Strong nuclear force is a spin dependent force.
(B) Strong nuclear force between an electron and proton is same as between a proton and neutron.
(C) Strong nuclear force is a short range force.
(D) Strong nuclear force is always attractive in nature.

8. A source contains two phosphorous radionuclides $^{32}_{15}P$ $(T_{1/2} = T_1)$ and $^{33}_{15}P(T_{1/2} = T_2)$. Initially 10% of the decays come from $^{33}_{15}P$. How long one must wait until 90% do so ?

(A) $t=\frac{4\ell n3}{\ell n2\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$ (B) $t=\frac{4\ell n3}{\ell n2\left(\frac{1}{T_1}+\frac{1}{T_2}\right)}$ (C) $t=\frac{2\ell n3}{\ell n2\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$ (D) None of these

9. The probability of disintegration per second of a nucleus in a given radio active sample

(A) increases proportional to the life time lived by the nucleus
(B) decreases with the life time lived
(C) is independent of the life time lived
(D) depends upon the total number of identical nuclei present in the sample

10. For a substance the average life for α-emission is 1620 years and for β emission is 405 years. After how much time the 1/4 of the material remains by simultaneous emission :-
(A) 648 years (B) 324 years (C) 449 years (D) 810 years

11. A radioactive sample decays by three modes simultaneously. Half lives corresponding to these modes are in G.P. and half life of sample is 10 years. When the sample decays by the mode having largest half life it takes 70 years for the sample to become half. If sample decays exclusively by other modes possible values of half life is :
(A) 28 years (B) 35 years (C) 14 years (D) 17.5 years

MATTER WAVES

12. A particle of mass 6.6×10^{-30} kg starts (t = 0) moving on a straight line with velocity 10 m/s. Its velocity decreases with time, however rate of change of de-Broglie wavlength associated with particle remains constant at 10^{-4} m/s. (Take h = 6.6×10^{-34} J–s) :-
(A) Velocity of particle at t = 0.9s is 1 m/s
(B) Velocity of particle at t = 0.9s is 6 m/s
(C) Magnitude of retaration of particle at t = 0.9 s is 4 m/s^2
(D) Magnitude of retaration of particle at t = 0.9 s is 1 m/s^2

13. Neutrons in thermal equilibrium with matter at 27°C can be thought to behave like ideal gas. Assuming them to have a speed of v_{rms}, what is their De broglie wavelength λ (in nm). Fill 156λ in the OMR sheet.
[Take $m_n = 1.69 \times 10^{-27}$ kg. $k = 1.44 \times 10^{-23}$ J/K, $h = 6.60 \times 10^{-34}$ Jsec]

14. An electron is confined to a tube of length L. Its potential energy in first half of the tube is zero, while the potential energy in other half is 12 eV. If the total energy of electron is 16 eV, find the ratio of the longest to the shortest de Broglie wavelength of an electron in the tube.

* * * * *

MODERN PHYSICS-2					ANSWER KEY
		ANSWER KEY			
1. Ans. (B)	2. Ans. (A)	3. Ans. (B)	4. Ans. (C)	5. Ans. (A, B, D)	
6. Ans. (B, C)	7. Ans. (A,C)	8. Ans. (A)	9. Ans. (C)	10. Ans. (C)	11. Ans. (B,D)
12. Ans. (A, D)	13. Ans. 22	14. Ans. 2			

MIRROR

1. Two mirror's are inclined at an angle of 30° one of the ray is incident parallel to the one of the mirror. Then select the correct statement(s)-

(A) Ray will undergo five reflections from the system

(B) Total deviation from the system will 120°

(C) Ray will retrace it path finally

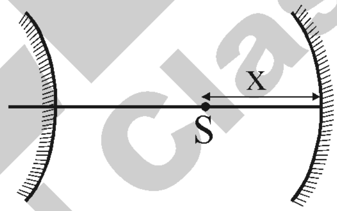
(D) Total deviation suffered by the ray will be 90°

2. A ray of light travelling in the direction $\frac{1}{5}(3\hat{i}+4\hat{j})$ is incident on a plane mirror. After reflection, it travel along the direction $\frac{1}{5}(3\hat{i}-4\hat{j})$. Then choose the correct statement(s).

(A) Mirror is kept in x-y plane (B) Normal of the mirror is along $-\hat{j}$

(C) Angle of incidence is 37° (D) Mirror is kept in x-z plane

3. A convex mirror and a concave mirror are placed on the same optic axis, separated by distance L = 20cm. The radius of curvature of each mirror has a magnitude of 12 cm. A light source is located at a distance x from the concave mirror as shown in figure.



(A) The rays from the source return to the source after reflecting first from the convex mirror and then from the concave mirror for x = 8 cm.

(B) The rays from the source return to the source after reflecting first from the convex mirror and then from the concave mirror for x = 16 cm.

(C) If the rays from the source return to the source after first reflecting from the concave mirror and then from the convex mirror for x = 8 cm.

(D) If the rays from the source return to the source after first reflecting from the concave mirror and then from the convex mirror for x = 16 cm.

4. A point object is placed on the axis of a concave mirror of focal length 24 cm such that the image is formed at a distance of 48 cm from the pole. Distance of the object from pole may be

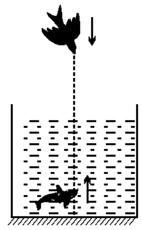
(A) 48 cm (B) 16 cm (C) 32 cm (D) 20 cm

REFRACTION AT PLANE SURFACE

5. The apparent depth of water in cylindrical water tank of diameter 2R cm is reducing at the rate of x cm/minute when water is being drained out at a constant rate. The amount of water drained in c.c. per minute is (n_1 = refractive index of air, n_2 = refractive index of water) :-

(A) $x \pi R^2 n_1/n_2$ (B) $x \pi R^2 n_2/n_1$ (C) $2 \pi R n_1/n_2$ (D) $\pi R^2 x$

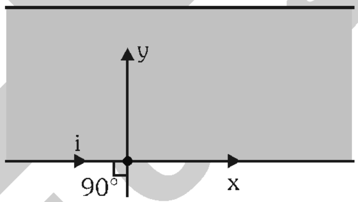
6. A bird in air is diving vertically over a tank with speed 6 cm/s. Base of the tank is silvered. A fish in the tank is rising upward along the same line with speed 4 cm/s. [Take: $\mu_{water} = 4/3$]



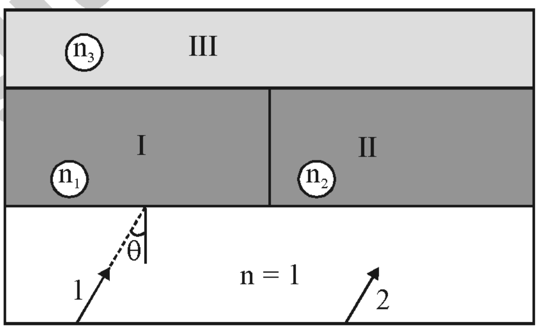
	Column I	**Column II (in cm/s)**
(A)	Speed of the image of fish as seen by the bird directly	(P) 12
(B)	Speed of the image of fish formed after reflection from the mirror as seen by the bird	(Q) 4
(C)	Speed of image of bird relative to the fish looking upwards	(R) 9
(D)	Speed of image of bird relative to the fish looking downwards in the mirror	(S) 3

7. A ray of light is falling on a glass sphere of $\mu = \sqrt{3}$ such that the incident ray and the emergent ray, when produced, intersect at a point on the surface of the sphere. The angle of incidence in degrees is found to be $\frac{2\pi}{k}$. Find the value of k.

8. In direction of y, medium become denser as $\mu = 1 + y^2$ above x–axis. A light ray enters at an angle almost at 90° at origin. At what value of y, the slope of path of light is $\sqrt{3}$.



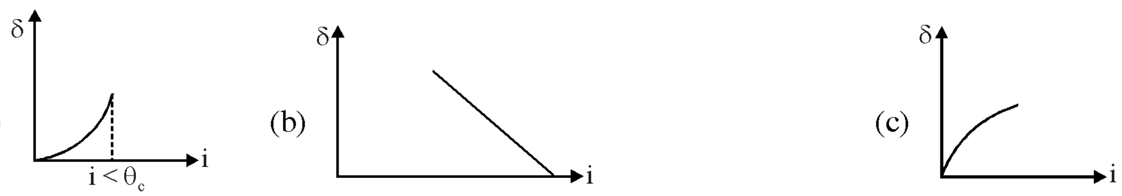
9. Three medium with refractive index n_1, n_2 and n_3 ($n_1 > n_2 > n_3 > 1$) are as shown in Figure. The two beams are parallel to each other, with a beam-1 passes only through the medium I and III, and beam-2- through the medium II and III. Determine the angle between the beams in the medium III.



(A) $\sin^{-1}\left(\frac{\sin\theta}{n_1}\right) - \sin^{-1}\left(\frac{\sin\theta}{n_2}\right)$ (B) $\sin^{-1}\left(\frac{n_3\sin\theta}{n_1}\right) - \sin^{-1}\left(\frac{n_3\sin\theta}{n_2}\right)$

(C) $\sin^{-1}\left(\frac{n_1\sin\theta}{n_3}\right) - \sin^{-1}\left(\frac{n_2\sin\theta}{n_3}\right)$ (D) None of these

10. Following are graphs of angle of deivation versus angle of incidence.



Based on the above graphs mark the correct options.

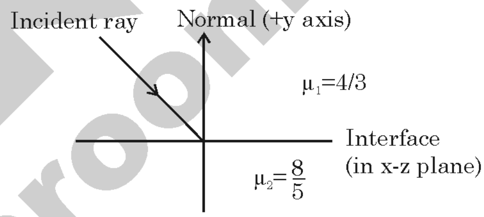
(A) Graph-a may be a part of the graph for ray of light that travels from denser to rarer medium.

(B) Graph-b may be for ray of light that is totally internally reflected from a denser to rarer medium boundary.

(C) Graph-c may be a part of the graph for ray of light that travels from rarer to denser medium.

(D) Graph-b may be a part of the graph for ray of light that is reflected from a plane mirror.

11. A light ray incident in a medium of refractive index $\frac{4}{3}$ is shown in diagram. Interface seperating the two mediums lies in xz plane. Vector along incident ray is $3\hat{i} - 4\hat{j}$.



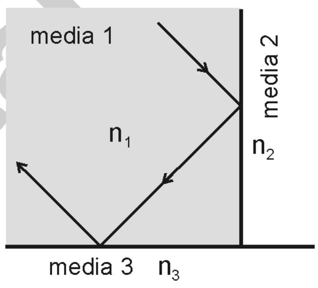
(A) Angle of incidence is 37°.

(B) The angle of refraction is 60º.

(C) The angle of refraction is 30°

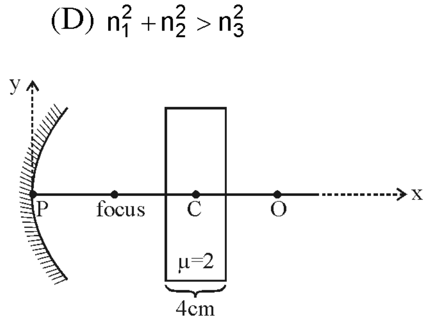
(D) If angle of incidence of the incident ray is greater than the critical angle then total internal reflection takes place.

12. In the diagram shown, light is incident on the interface between media 1 (refractive index n_1) and 2 (refractive index n_2) at angle slightly greater than the critical angle, and is totally reflected. The light is then also totally reflected at the interface between media 1 and 3 (refractive index n_3), after which it travels in a direction opposite to its initial direction. The media must have a refractive indices such that



(A) $n_1 < n_2 < n_3$ (B) $n_1^2 - n_3^2 > n_2^2$ (C) $n_1^2 - n_2^2 < n_3^2$ (D) $n_1^2 + n_2^2 > n_3^2$

13. A concave mirror of focal length 50 cm is placed at origin as shown in diagram. A point sized object is placed at O (x = 152 cm). A glass slab of thickness 4 cm, μ = 2, is placed symmetrically around C. Light can not reach from object to mirror without passing through slab. Choose the correct option(s) :



(A) Image made by concave mirror will be at x = 75 cm

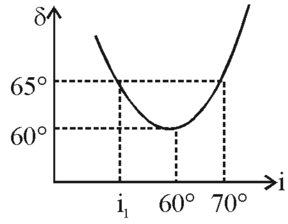
(B) Final image made by entire optical system will be at x = 77 cm.

(C) Final image of the system will be real.

(D) Final image of the system will be virtual.

PRISM

14. The angle of deviation (δ) vs angle of incidence (i) is plotted for a prism. Choose the **CORRECT** statement(s).



(A) The angle of prism is 60°

(B) The refractive index of the prism is $n = \sqrt{3}$

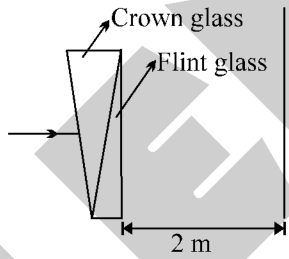
(C) For deviation to be 65° the angle of incidence $i_1 = 55°$

(D) for minimum deviation, the angle of emergence e = 60°.

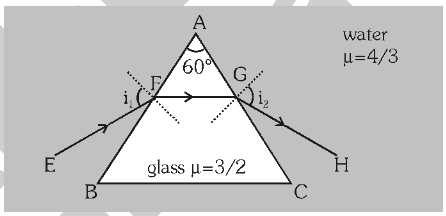
15. The refractive indices of the crown glass for violet and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. A prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other thin flint glass prism is combined with the crown glass prism such that the net mean deviation is 1.5° anticlockwise.

(i) Determine the angle of the flint glass prism.

(ii) A screen is placed normal to the emerging beam at a distance of 2m from the prism combination. Find the distance between red and violet spot on the screen. Which is the topmost colour on screen.

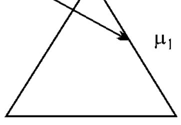


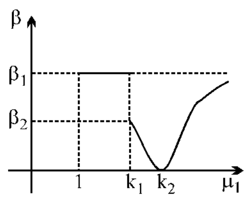
16. Consider an equilateral prism ABC of glass $\left(\mu = \frac{3}{2}\right)$ placed in water $\left(\mu = \frac{4}{3}\right)$



	Column–I		Column–II
(A)	FG is parallel to BC	(P)	maximum deviation
(B)	$i_1 = 90°$	(Q)	minimum deviation
(C)	$i_1 = i_2 = \sin^{-1}\left(\frac{9}{16}\right)$	(R)	TIR will take place at surface AC
(D)	EF is perpendicular to AB	(S)	No TIR will take place at surface BC
		(T)	Can't say anything

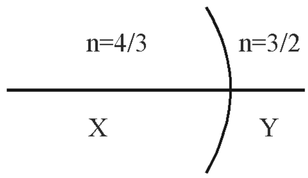
17. The diagram shows an equilateral prism. The medium on one side of the prism is μ_1. The refractive index of the prism is $\mu = 4/\sqrt{3}$. The diagram shows the variation of the magnitude of angle of deviation with respect to μ_1? Consider the light ray to be normally incident on the first face. Find the value of β_1, β_2, k_1 & k_2.





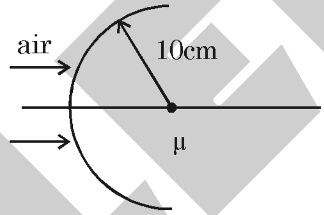
REFRACTION AT CURVED SURFACE

18. A concave spherical surface of radius of curvature 10 cm separates two mediums X and Y of refractive indices 4/3 and 3/2 respectively. Centre of curvature of the surface lies in the medium X. An object is placed in medium X. Choose **INCORRECT** option(s) :-



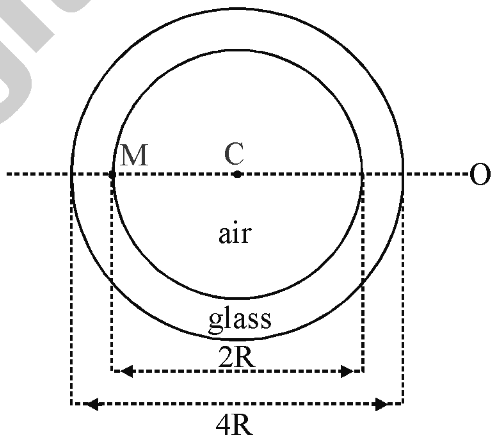
(A) Image is always real
(B) Image is real if the object distance is greater than 90 cm.
(C) Image is always virtual
(D) Image is virtual only if the object distance is less than 90 cm.

19. A spherical surface separates air & medium for which $\mu = 1.615$ for violet and $\mu = 1.600$ for red color. A paraxial beam parallel of optic axis is incident on the surface as shown. The distance between point of convergence for violet and red color is Δf.



(A) $\Delta f = 0.40$ cm
(B) Point of convergence for red is closer to optical centre than that for violet.
(C) Point of convergence for violet is closer to optical centre than that for red.
(D) $\Delta f = 0.84$ cm.

20. A hollow sphere of glass of R.I. n has a small mark M on its interior surface which is observed by an observer O from a point outside the sphere. C is the centre of the sphere. The inner cavity (air) is concentric with the external surface and thickness of the glass is every where equal to the radius of the inner surface. Find the distance by which the mark will appear nearer than it really is in terms of n and R assuming paraxial rays.



21. The principal axis of an optical device is along $y = -1$. If the image of a small body placed at $(-30,3)$ is formed at a point $(60, -3)$, then the optical device may be :-
(A) A convex lens of focal length 20 cm
(B) A concave mirror of focal length 60 cm
(C) A concave lens of focal length 20 cm
(D) A convex mirror of focal length 60 cm

22. In displacement method, the distance between object and the screen is 96 cm. The ratio of length of two images formed by a converging lens placed between them is 4. Then

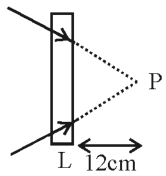
(A) ratio of the length of object to the length of shorter image is 2.

(B) distance between the two positions of the lens is 32 cm.

(C) focal length of the lens is 64/3 cm.

(D) when the shorter image is formed on screen, distance of the lens from the screen is 32 cm.

23. A beam of light converges to a point P. A device L is placed in the path of the convergent beam 12 cm from P as shown. Choose the correct option(s) :-



(A) If L is a convex lens of focal length 20 cm, the beam converges at a point at 4.5 cm distance from P

(B) If L is a convex lens of focal length 20 cm, the beam converges at a point at 10 cm distance from lens

(C) If L is a concave lens of focal length 16 cm, the beam converges at a point at 48 cm distance from lens

(D) If L is a plane mirror the beam converges at a point at 24 cm distance from P.

24. Variation of magnification (m) produced by a thin converging lens versus distance (v) of image from pole of the lens is plotted. Which of the following statements is/are correct?

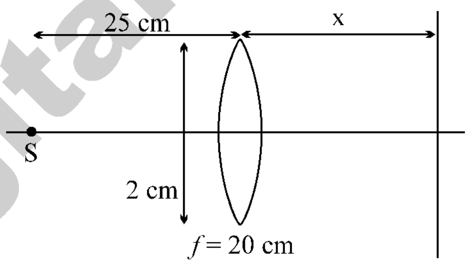
(A) Focal length of the lens is equal to intercept on v-axis.

(B) Focal length of the lens is equal to inverse of the magnitude slope of the line.

(C) Magnitude of intercept on m-axis is equal to unity.

(D) Magnitude of intercept on v-axis is equal to unity.

25. A point source of light S is placed on the axis of a lens of focal length 20 cm as shown. A screen is placed normal to the axis of lens at a distance x from it. Treat all rays as paraxial.



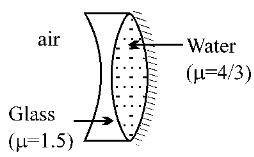
(A) As x is increased from zero intensity continuously decreases

(B) As x is increased from zero intensity first increases then decreases

(C) Intensity at centre of screen for x = 90 cm and x = 110 cm is same

(D) Radius of bright circle obtained on screen is equal to 1 cm for x = 200 cm

26. The radius of curvature of the left and right surface of the concave lens are 10cm and 15cm respectively. The radius of curvature of the mirror is 15cm.



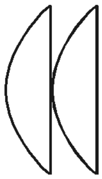
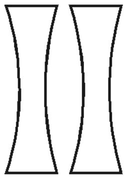
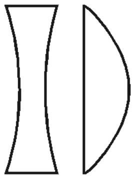
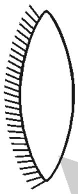
(A) equivalent focal length of the combination is –18cm.

(B) equivalent focal length of the combination is +36cm.

(C) the system behaves like a concave mirror.

(D) the system behaves like a convex mirror.

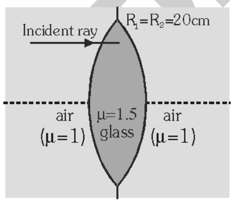
27. Four combination of two thin lenses/lens and mirror are given in list-I. The radius of curvature of all curved surfaces is same and the refractive index of all the lenses is 1.5. Focal length of a biconvex lens kept in air with same radius is f. Match lens combination in list-I with their equivalent focal length in air in list-II and select the correct answer using the code given below the lists:

List-I		List-II	
(P)		(1)	$\frac{f}{4}$
(Q)		(2)	$\frac{f}{2}$
(R)		(3)	f
(S)		(4)	2f

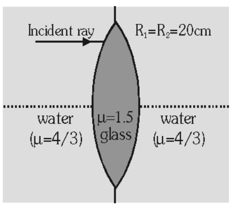
Code :

	P	Q	R	S
(A)	3	2	4	1
(B)	3	3	4	1
(C)	4	2	3	4
(D)	2	4	1	3

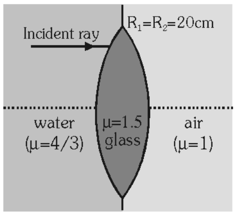
28. **Column I (optical system)** **Column II (focal length)**

(A) 

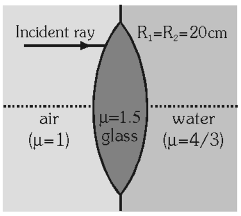
(P) 80 cm

(B) 

(Q) 40 cm

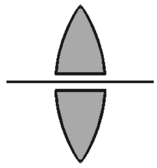
(C) 

(R) 30 cm

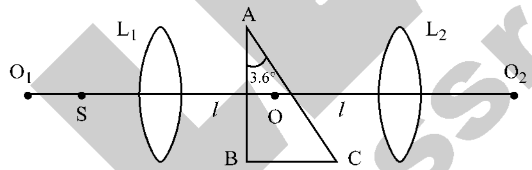
(D) 

(S) 20 cm

29. A point object is placed at a distance of 0.3m from a convex lens (focal length 0.2 m) cut into two halves each of which is displaced by 0.0005 m as shown in the figure. Find the position of the image. If more than one image is formed, find their number and the distance between them.



30. A thin right angled glass prism of cross-section ABC with a very small refracting angle $\alpha = 3.6°$ is placed between the convex lenses along a common axis O_1O_2 (as shown in figure)



The lenses are placed at equal distances l = 30 cm from the prism. The refractive index of the prism glass is $\mu = 1.5$. The surface AB does not reflect any light energy while the surface AC is partially reflecting and partially refracting. A point source of light S is placed at a distance of 20 cm to the left of the lens L_1 as shown. Considering the rays that are closed to the axis O_1O_2, find the possible position of the images(s) formed by this system. Show the image on a proper ray diagram. The focal lengths of the lenses L_1 and L_2 are 20 cm each. The face AB of the prism is normal to the axis O_1O_2.

* * * * *

GEOMETRICAL OPTICS **ANSWER KEY**

1. Ans. (A,C) **2. Ans. (B,C,D)** **3. Ans. (A,C)** **4. Ans. (A,B)**

5. Ans. (B) **6. Ans. (A) R; (B) S; (C) P; (D) Q** **7. Ans. 6**

8. Ans. 1 **9. Ans. (D)** **10. Ans. (A,B,D)** **11. Ans. (A,C)**

12. Ans. (B,D) **13. Ans. (A,B,D)** **14. Ans. (A,B,C,D)**

15. Ans. (i) 2°, (ii) $\frac{4\pi}{9}$ **mm, violet** **16. Ans. (A) Q,S; (B) P,S; (C) Q,S; (D) S**

17. Ans. 60°, 30°, 2, $\frac{4}{\sqrt{3}}$ **18. Ans. (A,B,D)** **19. Ans. (A,C)** **20. Ans. (n - 1)R/(3n - 1)**

21. Ans. (A,B) **22. Ans. (A, B, C, D)** **23. Ans. (C, D)** **24. Ans. (A,B,C)**

25. Ans. (B,C,D) **26. Ans. (A,C)** **27. Ans. (A)** **28. Ans. (A) S (B) P (C) R (D) Q**

29. Ans. [Number of images = 2, distance between them = 0.003 m]

30. Ans. $y_1 = f\,\delta_1 = 20 \times \frac{\pi}{100}$ cm $= \pi/5$ cm ; $y_2 = f\,\delta_2 = 20 \times \frac{3\pi}{50}$ cm $= 1.2\pi$ cm

YDSE

1. Consider an YDSE that has different slits width, as a result, amplitude of waves from two slits are A and 2A, respectively. If I_0 be the maximum intensity of the interference pattern, then intensity of the pattern at a point where phase difference between waves is ϕ, is .

(A) $I_0\cos^2\phi$ (B) $\frac{I_0}{3}\sin^2\frac{\phi}{2}$

(C) $\frac{I_0}{9}[5+4\cos\phi]$ (D) $\frac{I_0}{9}[5+8\cos\phi]$

2. If one of the slits of a standard YDSE apparatus is covered by a thin parallel sided glass slab so that it transmit only one half of the light intensity of the other, then :

(A) the fringe pattern will get shifted towards the covered slit.

(B) the fringe pattern will get shifted away from the covered slit.

(C) the bright fringes will be less bright and the dark ones will be more bright.

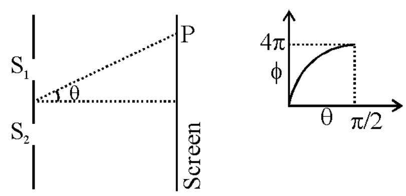
(D) the fringe width will remain unchanged.

3. In a Young's double-slit experiment, let A and B be the two slits. A thin film of thickness t and refractive index μ is placed in front of A. Let $\beta =$ fringe width. The central maximum will shift :

(A) towards A (B) towards B

(C) by $t(\mu-1)\frac{\beta}{\lambda}$ (D) by $\mu t\frac{\beta}{\lambda}$

4. In a YDSE setup, we plot the phase difference (ϕ) between both waves at point P on the screen against the angular position (θ) of point P on the screen. The graph is as shown below.



(A) The distance $S_1S_2 = 2\lambda$

(B) There are a total of 4 minima on the screen

(C) The first maxima above the centre is at $\theta = \frac{\pi}{4}$

(D) At $\theta = \frac{\pi}{6}$, intensity is maximum

5. In Young's Double slit experiment, the interference pattern is found to have an intensity ratio between the bright and dark fringe is 9. This implies that

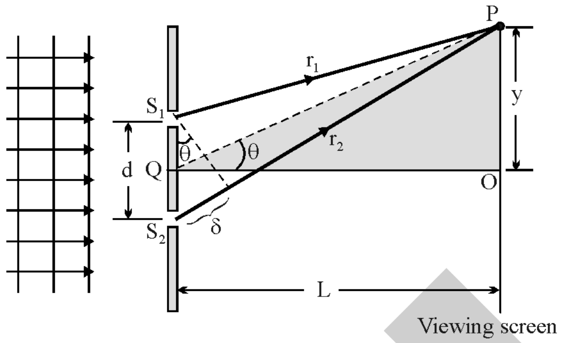
(A) the intensities at the screen due to the two slits are 5 and 4 units respectively.

(B) the intensities at the screen due to the two slits are 4 and 1 units respectively.

(C) the amplitude ratio is 3

(D) the amplitude ratio is 2

6. If you were to blow smoke into the space between the barrier of standard YDSE and the viewing screen of figure, the smoke would show :



(A) No evidence of interference between the barrier and the screen

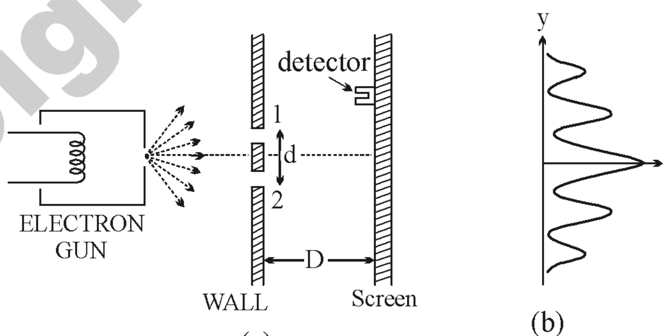
(B) Evidence of interference everywhere between the barrier and the screen.

(C) Maxima are localised and located on hyperboloids.

(D) Maxima are non-localised and located on hyperbolic planes.

Paragraph for question nos. 7 and 8

Let us do the Young's double slit experiment with electron rather than light waves. We make an electron gun which consists of a tungsten wire heated by an electric current and surrounded by a metal box with a hole in it. If the wire is at negative potential w.r.t. the box, electron emitted by the wire (thermionic emission) will be accelerated towards the walls and same will pass through the hole. All the electrons coming out of this gun will have the same energy, qV. In front of gun there is a wall with two slits in it as shown. Beyond the wall there is another plate which acts as a screen. The no. of electrons arriving at the screen/area/time can be measured. When the graph of this is plotted with y coordinate on the screen, we obtain the graph as seen in YDSE experiment. This can be explained using de broglie's hypothesis which states that electrons also behave like waves.



(a) (b)

7. Which of following would increase fringe width, assuming that $\lambda << d$?

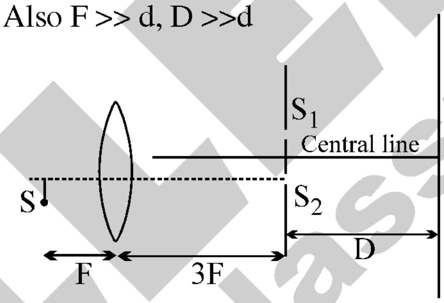
(A) Increase temperature of wire
(B) Decrease D
(C) Increase d
(D) Decrease voltage V

8. Suppose we go on increasing the voltage from a very low value. Beyond a certain voltage, we obtain 3 maxima on the screen. What is the voltage?

(A) $\frac{h^2}{2mqd^2}$ (B) $\frac{5h^2}{2mqd^2}$ (C) $\frac{9h^2}{2mqd^2}$ (D) $\frac{7h^2}{2mqd^2}$

9 In a Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4 while the lower slit is covered by another glass plate having the same thickness as the first one but having refractive index 1.7 . Interference pattern is observed using light of wavelength 5400 Å . It is found that the point P on the screen where the central maximum (n = 0) fell before the glass plates were inserted now has 3/4 the original intensity . It is further observed that what used to be the 5th maximum earlier, lies below the point P while the 6th minimum lies above P. Calculate the thickness of the glass plate.
(Absorption of light by glass plate may be neglected).

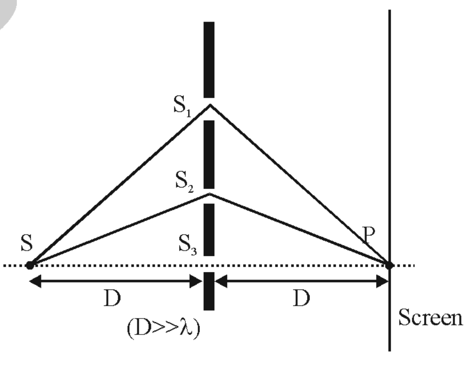
10. Observe the set up shown in the figure. What will be the position of the central maxima on the screen? Source S is d/2 distance below the optical axis and the optical axis is equal distance below the central line. (The separation between the slits is d and separation between the plane of slit and the screen is D and focal length of lens is F.) Also F >> d, D >>d



(A) $\frac{Dd}{2F}$ (B) $\frac{Dd}{F}$ (C) $\frac{Dd}{3F}$ (D) None

MODIFICATIONS OF YDSE

11. A monochromatic light source of wavelength λ is placed at S. Three slits S_1, S_2 and S_3, source S and point P is shown in the figure. If $S_1P - S_2P = \lambda/6$ and $S_1P - S_3P = 2\lambda/3$ and I be the intensity at P when only one slit is open, the intensity at P when all the three slits are open is :-



(A) 3I (B) 5I (C) 8I (D) 0

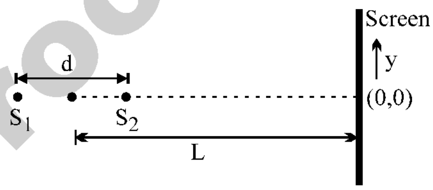
12. Two consequent plane waves of light of equal amplitude and each of wavelength $20\pi \times 10^{-8}$m propagating at an angle of $\frac{\pi}{1080}$ rad with respect to each other, fall almost normally on screen. The fringe width (in mm) on the screen is $\frac{108}{100n}$. Find the value of n.

13 Two monochromatic (wavelength = a/5) and coherent sources of electromagnetic waves are placed on the x-axis at the points (2a, 0) and (–a, 0). A detector moves in a circle of radius R(>>2a) whose centre is at the origin. The number of maximas detected during one circular revolution by the detector are :

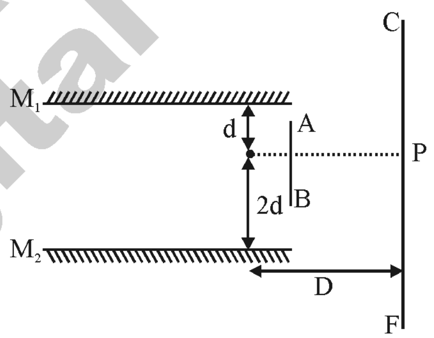
(A) 60 (B) 15 (C) 64 (D) None

14. The figure shows two points source which emit light of wavelength λ in phase with each other and are at a distance d = 5.5 λ apart along a line which is perpendicular to a large screen at a distance L from the centre of the source. Assume that d is much less than L. Which of the following statement is (are) correct?

(A) Five bright fringes appear on the screen
(B) Six bright fringes appear on the screen
(C) Point y = 0 corresponds to bright fringe
(D) Point y = 0 corresponds to dark fringe.



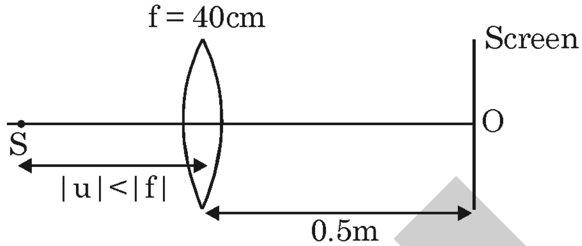
15. M_1 and M_2 are two plane mirror & S is monochromatic source. AB is a 'stop' which stops direct light to reach CF and allows reflected light from M_1 and M_2 to reach CF. P is a point on CF such that SP is parallel to M_1 & M_2 & perpendicular to CF :- (D >> d)



(A) Circular fringes will be formed on CF (B) P will be central maxima

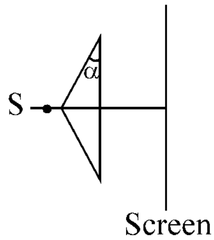
(C) P will be a point of maxima if $\lambda = \frac{6d^2}{D}$ (D) P will be a point of maxima if $\lambda = \frac{d^2}{D}$

16. A lens of focal length f = 40 cm is cut along the diameter into two equal halves. In this process, a layer of thickness t = 1mm is lost, then halves are put together to form a composite lens. In between focal plane and the composite lens a narrow slit is placed very close to the focal plane |u| < |f|. The slit is emitting monochromatic light of wavelength 0.6 μm. Behind the lens a screen is located at a distance L = 0.5 m from it as shown :-



(A) Fringe width is 0.12 mm
(B) Fringe width is 0.24 mm.
(C) Length of interference pattern is 1/8 cm
(D) Length of interference pattern is 1/16 cm

17. For the biprism experiment shown in the figure, the fringe width increases when

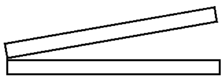


(A) biprism is moved towards the slit
(B) entire apparatus is submerged in a liquid having R.I. less than that of prism
(C) a biprism having smaller angle α is used
(D) the slit width is reduced

18. It is necessary to coat a glass lens with a non-reflecting layer. If the wavelength of the light in the coating is λ, the best choice is a layer of material having an index of refraction between those of glass and air and a minimum thickness of :

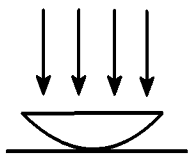
(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{2}$ (C) $\frac{3\lambda}{8}$ (D) λ

19 When monochromatic light is incident normally on a wedge-shaped thin air film, refer figure, an interference pattern may be seen by reflection. Which of the following is/are correct?



(A) Parallel fringes are observed
(B) If water is introduced into the region between the plates, the fringe separation decreases
(C) If the angle of the wedge is increased, the fringe separation decreases
(D) When white light is used there will not be a completely dark fringe

20 A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate as shown. The observed interference fringes from this combination shall be :



(A) straight
(B) circular
(C) equally spaced
(D) having fringe spacing which increases as we go outwards.

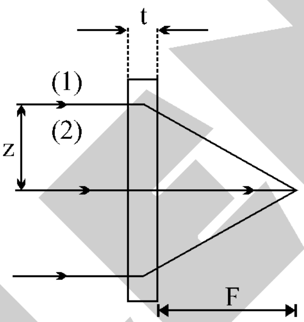
HUYGENS' PRINCIPLE

21. A parallel beam of light is incident on an equi-convex lens having radius of curvature R = 20 cm. Find the radius of curvature of emergent wavefront, just after emerging from lens: (reflective index of lens = 1.5)

(A) 10 cm (B) 5 cm (C) 1 cm (D) 20 cm

22 Plane wavefronts are incident on a glass slab which has refractive index as a function of distance Z, according to the relation $\mu = \mu_0^{-}(1 - Z^2/Z_0^2)$, where μ_0 is the refractive index along the axis and Z_0 is a constant. This glass slab can act as lens of focal length F. By using the concept of optical path length calculate the focal length of the slab. Consider t to be very small as compared to F.

[**Hint :** Equate the OPL of ray (1) and ray (2)]



(A) $Z_0^2/(2\mu_0 t)$ (B) $Z_0^2/(\mu_0 t)$ (C) $\mu_0 Z_0^2/(2t)$ (D) None

* * * * *

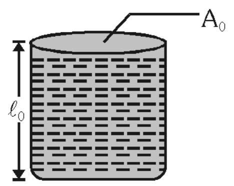
WAVE OPTICS			ANSWER KEY
1. Ans. (C)	2. Ans. (A,C,D)	3. Ans. (A,C)	4 Ans. (A,B,D)
5. Ans. (B,D)	6. Ans. (B,D)	7. Ans. (D)	8. Ans. (A)
9. Ans. 9.3 mm	10. Ans. (A)	11. Ans. (A)	12. Ans. 5
13. Ans. (A)	14. Ans. (A,D)	15. Ans. (C, D)	16. Ans. (B, C)
17.Ans. (A,B,C)	18. Ans. (A)	19. Ans. (A,B,C)	20. Ans. (A)
21. Ans. (D)	22. Ans. (A)		

THERMAL EXPANSION

1. When a building is constructed at 10°C, steel beam (cross sectional area 100 cm^2) is put in place with its ends cemented in pillars. If the sealed ends cannot move, what will be the compressional force in the beam when the temperature is 110^0C? For steel $Y = 2 \times 10^{11}$ Nm^{-2}, $\alpha = 1.2 \times 10^{-5}$ $^0C^{-1}$

(A) $1.2 \times 10^6 N$ (B) 2.4×10^5 N (C) 2.4×10^6 N (D) $3.6 \times 10^5 N$

2. The figure shows a glass tube (linear co-efficient of expansion is α) completely filled with a liquid of volume expansion co-efficient γ. On heating length of the liquid column does not change. Choose the correct relation between γ and α.

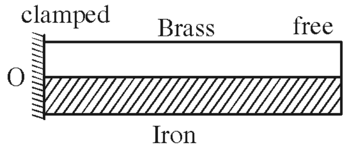


(A) $\gamma = \alpha$ (B) $\gamma = 2\alpha$ (C) $\gamma = 3\alpha$ (D) $\gamma = \frac{\alpha}{3}$

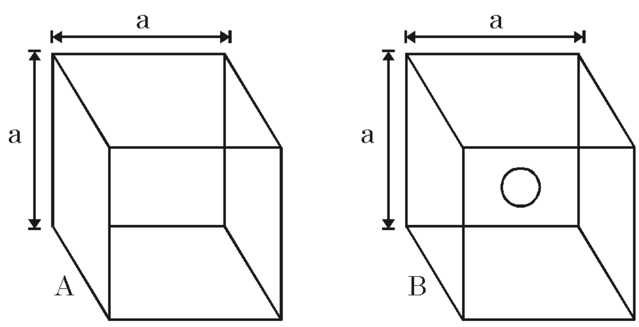
3. A thin copper rod rotates about an axis passing through its end and perpendicular to its length with a speed ω_0. The temperature of the copper rod is increased by 100° C. If the coefficient of linear expansion of copper is 2×10^{-5} / ° C, the percentage change in the angular speed of the rod is

(A) – 2% (B) – 4% (C) – 0.2% (D*) – 0.4%

4. A bimetallic strip consisting of a brass strip and a steel strip, each of length 1 m and each of thickness 0.5 cm is clamped at one end as shown in figure. Calculate the depression to the nearest integer (in cm) of the free end when it is heated by 100ºC. [Take : $\alpha_{iron} = 11 \times 10^{-6}$ $K^{-1;}$ $\alpha_{brass} = 19 \times 10^{-6}$ K^{-1}]



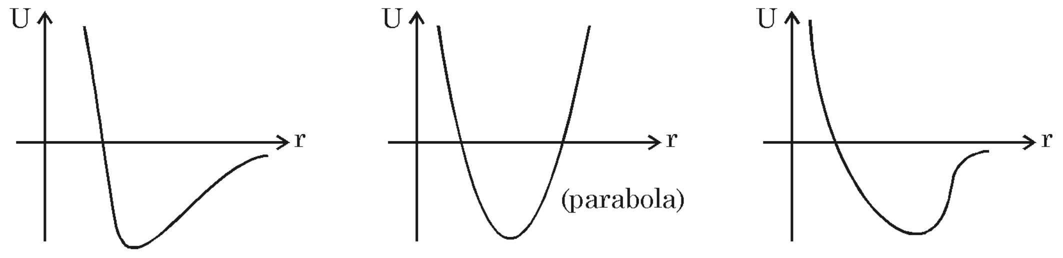
5. A and B are made up of an isotropic medium. Both A and B are of equal volume. Body B has cavity as shown in figure. Which of the following statement(s) is/are true when both the bodies are heated so that the temperature change in them is the same ?



(a) (b)

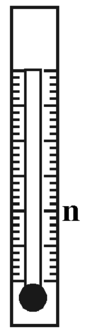
(A) The hole in B shrinks in size (B) A absorbs more heat
(C) Both absorbs same heat (D) The hole in B expands

6. Diagram shows the variation of potential energy with separation between the two atoms for three different substances. All the objects are nearly at absolute zero temperature. Choose the **CORRECT** statement(s):



(A) Substance 'A' expands on heating
(B) Substance 'B' contracts on heating.
(C) Substance 'C' contracts on heating.
(D) Substance 'B' neither expands nor contracts on heating.

7. A thermometer has a spherical bulb of volume 1 cm^3 having 1 cm^3 of mercury. A long cylindrical capillary tube is connected to spherical bulb. Volumetric coefficient of expansion of mercury is $1.8 \times 10^{-4}\ K^{-1}$; cross-section area of capillary is $1.8 \times 10^{-4}\ cm^2$. Ignoring expansion of glass, how far apart (in cm) on the stem are marks indicating 1K temperature change.

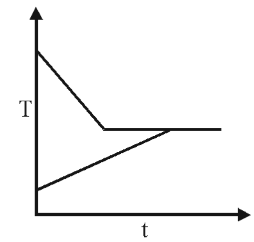


8. A metallic slab weighs 50 g in air. If it is immersed in a liquid at a temperature 25ºC. It weighs 45 g. When the temperature of the liquid is raised to 100ºC it weighs 45.1 g. Calculate the coefficient of cubical expansion of liquid assuming the linear coefficient of the metal to be $12 \times 10^{-6}\ C^{-1}$.

9. A clock with a metallic pendulum is 5 seconds fast each day at a temperature of 15°C and 10 seconds slow each day at a temperature of 30°C. Find coefficient of linear expansion for the metal.

CALORIMETRY

10. A sample A of liquid water and a sample B of ice of identical mass are kept in two neighbouring chambers in an otherwise insulated container. The chambers can exchange heat with each other. The graph of temperatures of the two chambers is plotted with time. $S_{ice} = \frac{S_{water}}{2}$:-



(A) Finally the contents in sample A is water.
(B) Equilibrium temperature is freezing point of water
(C) Ice melts partly
(D) Finally the contents in sample B is ice only.

11. 50 gm ice at –10°C is mixed with 10gm steam at 100°C. When the mixture finally reaches its steady state inside a calorimeter of water equivalent 1.5 gm then : [Assume calorimeter was initially at 0°C, Take latent heat of vaporization of water = 540 cal/gm, Latent heat of fusion of water = 80 cal/gm and specific heat capacity of water = 1 cal/gm-°C, specific heat of ice = 0.5 cal/gm°C]

(A) Mass of water remaining is 60 gm
(B) Mass of ice remaining is 3 gm
(C) Mass of steam remaining is 1.20 gm
(D) Final temperature is between 0°C and 100°C

12. A calorimeter of water equivalent 1 kg contains 10 kg of ice & 10 kg of water in thermal equilibrium. The atmospheric temperature is 15° below freezing point due to which the calorimeter loses heat. -As a result ice is formed inside the calorimeter at a rate of 10.8 gm per second. To try to compensate for this heat loss, steam at 100°C is supplied to the calorimeter at a rate of r. (L_V = 540 cal/gm, L_f = 80 cal/gm, sp heat of water 1 cal/gm °C.) Column-I gives the value of r and column-II gives the situation just after the introduction of steam.

	Column-I		**Column-II**
(A)	r = 1.6 gm/sec	(P)	Amount of ice in calorimeter increases.
(B)	r = 1.35 gm/sec	(Q)	Amount of water in calorimeter increases.
(C)	r = 1.2 gm/sec	(R)	Amount of ice remains constant at 10 kg
(D)	r = 1 gm/sec	(S)	Amount of water remains constant at 10 kg
		(T)	Amount of ice in calorimeter decreases.

THERMAL CONDUCTION

13. There is formation of layer of ice x cm thick on water, when the temperature of air is –θ°C (less than freezing point). The thickness of layer increases from x to y in the time t, then the value of t is given by-

(A) $\frac{(x+y)(x-y)\rho L}{2K\theta}$ (B) $\frac{(x-y)\rho L}{2K\theta}$ (C) $\frac{(x+y)(x-y)\rho L}{K\theta}$ (D) $\frac{(x-y)\rho LK}{2\theta}$

14. A rod of length ℓ and cross section area A has a variable thermal conductivity given by k = αT, where α is a positive constant and T is temperature in kelvin. Two ends of the rod are maintained at temperatures T_1 and T_2 ($T_1 > T_2$). Heat current flowing through the rod under steady state will be

(A) $\frac{A\alpha(T_1^2-T_2^2)}{\ell}$ (B) $\frac{A\alpha(T_1^2+T_2^2)}{\ell}$ (C) $\frac{A\alpha(T_1^2+T_2^2)}{3\ell}$ (D) $\frac{A\alpha(T_1^2-T_2^2)}{2\ell}$

15. The temperature at the bottom of a pond of depth L is 4ºC. The temperature of the air, just above the layer of ice frozen at the pond's surface is –2ºC for the past many days. The thermal conductivity of ice is three times that of water. The thickness of the frozen layer of ice must be

(A) 2L/3 (B) 2L/5 (C) L/3 (D) 3L/5

16. Two thin walled spheres of different materials, one with double the radius and one-fourth wall thickness of the other, are filled with ice. If the time taken for complete melting of ice in the sphere of larger radius is 25 minutes and that for smaller one is 16 minutes, the ratio of thermal conductivities of the materials of larger sphere to the smaller sphere is

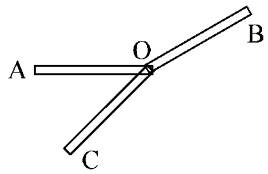
(A) 4 : 5 (B) 25 : 1 (C) 1 : 25 (D) 8 : 25

17. Two identical plates of metal are welded end to end as shown in figure (A), 20 cal of heat flows through it in 4 minutes when the ends were maintained at different tempeatures. If the plates are welded as shown in figure (B) and the ends were maintain at same temperature as in first case, the same amount of heat will flow through the plates in how many minutes ?


A B

18. An electric heater is used in a room of total wall area $50 m^2$ to maintain a constant temperature of 15°C inside when the outside temperature is –10°C. The walls have two different layers. The inner layer is of cement of thickness 2 cm, while the outer layer is of brick of thickness 10 cm. Assume that there is no loss of heat from the floor and the ceiling. Take the thermal conductivities of cement and brick to be 0.2 W/m°C and 0.5 W/m°C, respectively. If another identical heater is now switched on, along with the old heater, find the steady state temperature (in °C) inside the room, after a long time, if the outside temperature has now dropped to –15°C.

19. Three rods AO, BO and CO having equal lengths and equal area of cross section are connected as shown in the figure. The temperature of ends A, B and C are 30°C, 60°C and 90° respectively. The thermal conductivities of rods AO, BO and CO are in the ratio of 1 : 2 : 3. What is the temperature of junction O?

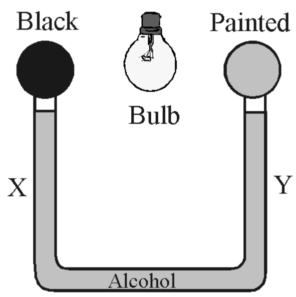


20. A 2m long wire of resistance 10 Ω and radius 0.5 mm is coated with plastic of thickness 0.5 mm. If a current of 2 A flows through the wire, find the temperature difference across the plastic insulation in steady state. Thermal conductivity of plastic is 0.005 J / (s – m –°C).

RADIATION

21. Assuming Newton's law of cooling to be valid. The temperature of body changes from 60°C to 40°C in 7 minutes. Temperature of surroundings being 10°C, its temperature after next 7 minutes, is :-
(A) 7°C (B) 14°C (C) 21°C (D) 28°C

22. The following figure shows two air-filled bulbs connected by a U-tube partly filled with alcohol. What happened to the levels of alcohol in the limbs X and Y when an electric bulb placed midway between the bulbs is lighted?



(A) The level of alcohol in limb X falls while that in limb Y rises
(B) The level of alcohol in limb X rises while that in limb Y falls
(C) The level of alcohol falls in both limbs
(D) The level of alcohol rises in both limbs

23. The shell of a space station is a blackened sphere in which a temperature T = 500 K is maintained due to the operation of the appliances of the station which supply heat at constant rate always. If the station is enveloped by a thin spherical black screen of nearly the same radius as the radius of the shell of the station then the new steady state temperature (approx.) of the shell of the station will be :-
(A)500 K (B) 700 K (C) 600 K (D) 450 K

24. You are a consultant for a cookware manufacturer who wishes to make a pan that will have two features: (1) absorb thermal energy from a flame as quickly as possible, and (2) have an inner surface that remains as hot as possible when cooking. Consider only radiation. You should recommend a pan with the
(A) outer and inner surfaces black.
(B) outer and inner surfaces shiny.
(C) outer surface shiny and inner surface black.
(D) outer surface black and inner surface shiny.

25. Two spherical black-bodies A and B, having radii r_A and r_B, where $r_B = 2r_A$ emit radiations with peak intensities at wavelengths 400 nm and 800 nm respectively. If their temperature are T_A and T_B respectively in Kelvin scale, their emissive powers are E_A and E_B and energies emitted per second are P_A and P_B then:
(A) $T_A / T_B = 2$
(B) $P_A / P_B = 4$
(C) $E_A / E_B = 8$
(D) $E_A / E_B = 4$

26. A metal block is placed in a room which is at 10°C for long time. Now it is heated by an electric heater of power 500 W till its temperature becomes 50°C. Its initial rate of rise of temperature is 2.5°C/sec. The heater is switched off and now a heater of 100W is required to maintain the temperature of the block at 50°C.(Assume Newtons Law of cooling to be valid)
(A) The heat capacity of the block is 200 J/°C
(B) The heat capacity of the block is 100 J/°C
(C) The rate of cooling of block at 50°C if the 100W heater is also switched off is 0.5°C/s
(D) The heat radiated per second when the block was 30°C is 50 W

27. The temperature of earth is maintained by a dynamic equilibrium between Sun and Earth. Sun & Earth can be assumed to be black bodies :
(A) If the power output of sun would double with changing the temperature, equilibrium temperature of earth also doubles.
(B) If the radius of sun doubles without changing its' power, its surface temperature would decrease by factor of $\sqrt{2}$.
(C) If the radius of earth doubles without any change in sun, it's equilibrium temperature would increase by factor of $\sqrt{2}$.
(D) If the distance between earth and sun would decrease by a factor of 2, the equilibrium temperature of earth would increase by factor of $\sqrt{2}$.

ANSWER KEY — **HEAT &TRANSFER**

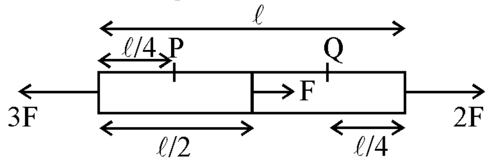
1. (C)	**2. (B)**	**3. (D)**	**4. (8)**	**5. (B,D)**	**6. (A,C,D)**	**7. (1)**
8. 3×10^{-4} /°C		**9.** $\alpha = 2.31 \times 10^{-5}$ °C^{-1}		**10. (B, D)**	**11. (A,D)**	
12. (A) Q, T ; (B) Q, R ; (C) P, S ; (D) P					**13. (A)**	**14. (D)**
15. (D)	**16. (D)**	**17. (1)**	**18. (035)**	**19. (70°C)**	**20.** $\frac{2000 \ln 2}{\pi}$	**21. (D)**
22. (A)	**23. (C)**	**24. (D)**	**25. (A,B)**	**26. (A,C,D)**	**27. (B,D)**	

PROPERTIES OF MATTER (ELASTICITY)

1. In a Searle's experiment for determination of Young's Modulus, when a load of 50 kg is added to a 3 meter long wire micrometer screw having pitch 1 mm needs to be given a quarter turn in order to restore the horizontal position of spirit level. Young's modulus of the wire if its cross sectional area is 10^{-5} m^2 is

(A) 6×10^{11}N/m^2 (B) 1.5×10^{11} N/m^2 (C) 3×10^{11} N/m^2 (D) None

2. In the figure shown a rod is kept on floor and applied some forces. The area of cross-section is A and Young's modulus is Y (Assume all forces are applied uniformly distributed throughout cross section of rod)



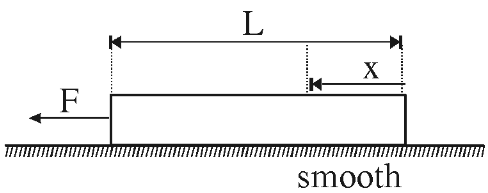
(A) Stress at P & Q are equal

(B) Stress at P is $\frac{3}{2}$ times stress at Q

(C) Elongation of rod under the forces is $\frac{5}{2}\frac{F\ell}{AY}$

(D) Strain at Q is $\frac{2F}{AY}$

3. A rod of mass m, uniform cross sectional area A and length L is accelerated by applying force F as shown in figure on a smooth surface. If Young's modulus of elasticity of the material of rod is Y. (Consider x as measured from the right end)



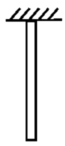
(A) Tension in rod as a function of distance x is $\frac{Fx}{2L}$

(B) Strain in rod is $\frac{F}{2AY}$

(C) Elastic potential energy stored in the rod is $\frac{F^2L}{8AY}$

(D) There is no stress in rod.

4. A uniform steel wire hangs from the ceiling and elongates due to its own weight. The ratio of elongation of the upper half of the wire to the elongation of the lower half of wire is

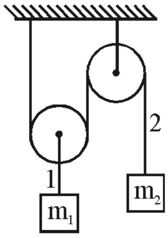


(A) 4 : 1 (B) 3 : 1 (C) 3 : 2 (D) None

5. A dress made of cloth will hang nicely, conforming to the shape of the body beneath, because cloth has both

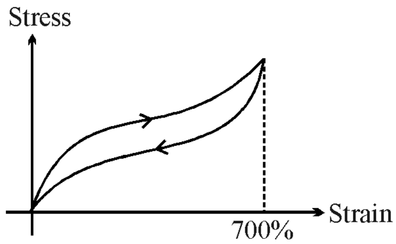
(A) a large Young's modulus and a low bulk modulus
(B) a low shear modulus and a low Young's modulus
(C) a large Young's modulus and a low shear modulus
(D) a low bulk modulus and a high shear modulus

6. In the figure shown the system is in equilibrium. In this system we have used two wires 1 and 2. The Young's modulus and radius of the wire 1 are two times and $2^{1/4}$ times respectively that of wire 2, then.



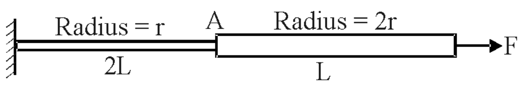
(A) Elastic energy density in wire 1 is equal to that of in wire 2
(B) Elastic energy density in wire 1 is greater than that of in wire 2
(C) Elastic energy density in wire 1 is less than that of in wire 2
(D) Stress in wire 1 is greater than stress in wire 2.

7. For a vulcanized rubber stress-strain curve is shown. The rubber is used as vibration absorbers. Choose the correct statement(s).



(A) After one complete cycle, compression in rubber is zero.
(B) The associated forces are non-conservative
(C) Work done by external agent in one full cycle is transformed into internal energy.
(D) The temperature of rubber rises.

8. Two steel wires of radii r and 2r are connected together end to end and tied to a wall as shown. The force stretches the combination by $\frac{27}{4}$ mm. How far does the junction point A move. (in mm)



9. A liquid of volumetric thermal expansion coefficient 200×10^{-6} /°C and bulk modulus = 1.2×10^9 Pa is filled in a spherical tank of negligible heat expansion coefficient. Its radius is 25 cm and wall thickness is 2 mm. When the temperature of the liquid is raised by 20 °C, find the tensile stress developed (in MPa) in the wall of the tank?

ANSWER KEY				PROPERTIES OF MATTER (ELASTICITY)
1. (A)	2. (B, C, D)	3. (B)	4. (B)	
5. (C)	6. (A,D)	7. (A, B, C, D)	8. (6)	9. (300)