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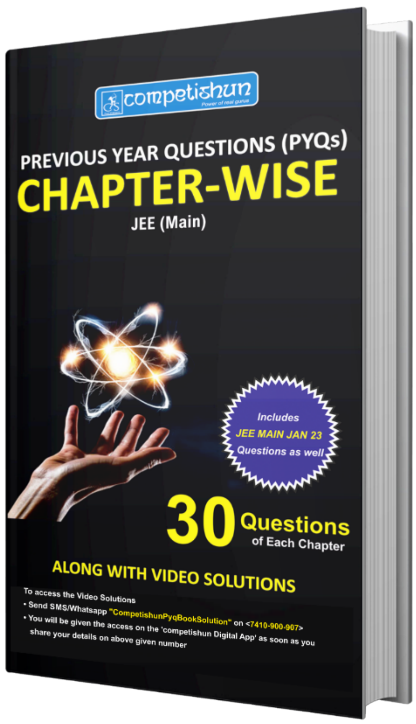
PHYSICS

Important Previous Year Questions
PYQ's

CONTENT



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PREVIOUS YEAR QUESTIONS (PYQs)
CHAPTER-WISE
JEE (Main)
Includes JEE MAIN JAN 23 Questions as well
30 Questions of Each Chapter
ALONG WITH VIDEO SOLUTIONS

CONTENT - SOLUTION

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- MATHEMATICAL TOOLS & RECTILINEAR MOTION

(Important Questions Only)

1 In a car race on straight road, car A takes a time t less than car B at the finish and passes finishing point with a speed 'v' more than that of car B. Both the cars start from rest and travel with constant acceleration a_1 and a_2 respectively. Then 'v' is equal to: **[JEE MAIN_{S1}_090119]**

(1) $\frac{a_1+a_2}{2}t$ (2) $\frac{2a_1a_2}{a_1+a_2}t$ (3) $\sqrt{2a_1a_2}\,t$ (4) $\sqrt{a_1a_2}\,t$

2. The position of a particle as a function of time t, is given by **[JEE-Main_{S2}_090419]**

$x(t) = at + bt^2 - ct^3$

where a, b and c are constants. When the particle attains zero acceleration, then its velocity will be :

(1) $a+\frac{b^2}{4c}$ (2) $a+\frac{b^2}{3c}$ (3) $a+\frac{b^2}{2c}$ (4) $a+\frac{b^2}{c}$

3. A particle is moving with speed $v = b\sqrt{x}$ along positive x-axis. Calculate the speed of the particle at time t = τ (assume that the particle is at origin at t = 0). **[JEE-Main_{S2}_120419]**

(1) $b^2\tau$ (2) $\frac{b^2\tau}{4}$ (3) $\frac{b^2\tau}{2}$ (4) $\frac{b^2\tau}{\sqrt{2}}$

4. A small ball of mass m is thrown upward with velocity u from the ground. The ball experiences a resistive force mkv^2, where v is its speed. The maximum height attained by the ball is

[JEE-Main_(S2)_040920]

(1) $\frac{1}{2k}\tan^{-1}\frac{ku^2}{g}$ (2) $\frac{1}{k}\ln\left(1+\frac{ku^2}{2g}\right)$ (3) $\frac{1}{2k}\ln\left(1+\frac{ku^2}{g}\right)$ (4) $\frac{1}{k}\tan^{-1}\frac{ku^2}{2g}$

5. A particle is projected with velocity v_0 along x-axis. A damping force is acting on the particle which is proportional to the square of the distance from the origin i.e., $ma = -ax^2$.. The distance at which the particle stops : **[JEE-Main_{S2}_240221]**

(1) $\left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{2}}$ (2) $\left(\frac{2v_0}{3\alpha}\right)^{\frac{1}{3}}$ (3) $\left(\frac{2v_0^2}{3\alpha}\right)^{\frac{1}{2}}$ (4) $\left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{3}}$

6. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time elapsed is t seconds, the total distance travelled is :

[JEE MAIN_{S1}_170321]

(1) $\frac{4\alpha\beta}{(\alpha+\beta)}t^2$ (2) $\frac{2\alpha\beta}{(\alpha+\beta)}t^2$ (3) $\frac{\alpha\beta}{2(\alpha+\beta)}t^2$ (4) $\frac{\alpha\beta}{4(\alpha+\beta)}t^2$

7. The instantaneous velocity of a particle moving in a straight line is given as $v = \alpha t + \beta t^2$, where α and β are constants. The distance travelled by the particle between 1s and 2s is : **[JEE MAIN_{S2}_250721]**

(1) $3\alpha + 7\beta$ (2) $\frac{3}{2}\alpha+\frac{7}{3}\beta$ (3) $\frac{\alpha}{2}+\frac{\beta}{3}$ (4) $\frac{3}{2}\alpha+\frac{7}{2}\beta$

8. A ball is thrown up with a certain velocity so that it reaches a height 'h'. Find the ratio of the two different times of the ball reaching $\frac{h}{3}$ in both the directions. **[JEE MAIN_{S1}_270721]**

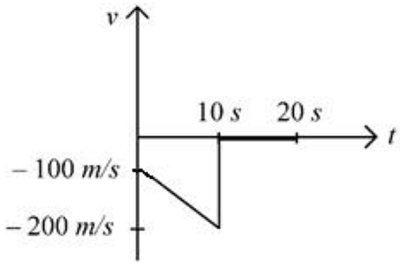
(1) $\frac{\sqrt{2}-1}{\sqrt{2}+1}$ (2) $\frac{1}{3}$ (3) $\frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}+\sqrt{2}}$ (4) $\frac{\sqrt{3}-1}{\sqrt{3}+1}$

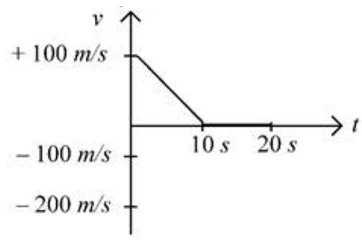
9. Two buses P and Q start from a point at the same time and move in a straight line and their positions are represented by $X_P(t) = \alpha t + \beta t^2$ and $X_Q(t) = ft - t^2$. At what time, both the buses have same velocity ? **[JEE MAIN_{S2}_250622]**

(1) $\frac{\alpha - f}{1+\beta}$ (2) $\frac{\alpha + f}{2(\beta - 1)}$ (3) $\frac{\alpha + f}{2(1+\beta)}$ (4) $\frac{f-\alpha}{2(1+\beta)}$

10. A bullet is shot vertically downwards with an initial velocity of 100 m/s from a certain height. Within 10 s, the bullet reaches the ground and instantaneously comes to rest due to the perfectly inelastic collision. The velocity time curve for total time t = 20 s will be : (Take g = 10 m/s^2)

[JEE Main_{S1}_270722]

(1)


(2)


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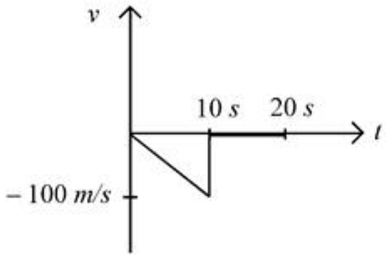
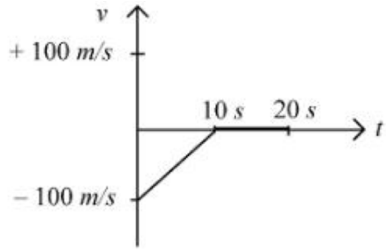
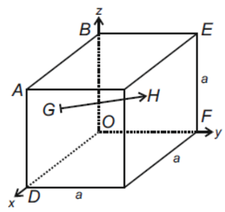


(4)


11. At time t = 0 a particle starts travelling from a height $7\hat{z}$ cm in a plane keeping z coordinate constant. At any instant of time it's position along the x and y directions are defined as 3t and 5t^3 respectively. At t = 1s acceleration of the particle will be **[JEE Main_{S2}_280722]**

(1) –30 y (2) 30 y (3) 3x + 15 y (4) $3x + 15y + 7\hat{z}$

12. In the cube of side 'a' shown in the figure, the vector from the central point of the face ABOD to the central point of the face BEFO will be **[JEE_MAIN_{S1}_100119]**



(1) $\frac{1}{2}a(\hat{j}-\hat{i})$ (2) $\frac{1}{2}a(\hat{i}-\hat{k})$ (3) $\frac{1}{2}a(\hat{j}-\hat{k})$ (4) $\frac{1}{2}a(\hat{k}-\hat{j})$

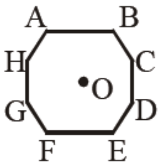
13. Two vectors $\vec{A}$ and $\vec{B}$ have equal magnitudes. The magnitude of $\left(\vec{A}+\vec{B}\right)$ is 'n' times the magnitude $\left(\vec{A}-\vec{B}\right)$. The angle between $\vec{A}$ and $\vec{B}$ is : **[JEE_MAIN_{S2}_100119]**

(1) $\cos^{-1}\left[\frac{n-1}{n+1}\right]$ (2) $\cos^{-1}\left[\frac{n^2-1}{n^2+1}\right]$ (3) $\sin^{-1}\left[\frac{n-1}{n+1}\right]$ (4) $\sin^{-1}\left[\frac{n^2-1}{n^2+1}\right]$

14. In an octagon ABCDEFGH of equal side, what is the sum of **[JEE MAIN_{S1}_250221]**

$\overrightarrow{AB}+\overrightarrow{AC}+\overrightarrow{AD}+\overrightarrow{AE}+\overrightarrow{AF}+\overrightarrow{AG}+\overrightarrow{AH}'$

if, $\overrightarrow{AO}=2\hat{i}+3\hat{j}-4\hat{k}$

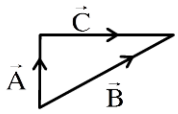
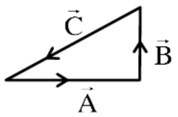
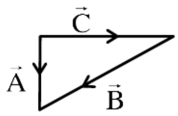
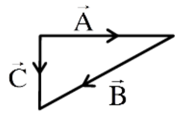


(1) $-16\hat{i}-24\hat{j}+32\hat{k}$ (2) $16\hat{i}+24\hat{j}-32\hat{k}$ (3) $16\hat{i}+24\hat{j}+32\hat{k}$ (4) $16\hat{i}-24\hat{j}+32\hat{k}$

15. Two vectors $\vec{P}$ and $\vec{Q}$ have equal magnitudes. If the magnitude of $\vec{P}+\vec{Q}$ is n times magnitude of $\vec{P}-\vec{Q}$, then angle between $\vec{P}$ and $\vec{Q}$ is : **[JEE Main_{S2}_200721]**

(1) $\sin^{-1}\left(\frac{n-1}{n+1}\right)$ (2) $\cos^{-1}\left(\frac{n-1}{n+1}\right)$ (3) $\sin^{-1}\left(\frac{n^2-1}{n^2+1}\right)$ (4) $\cos^{-1}\left(\frac{n^2-1}{n^2+1}\right)$

16. Match List I with List II. **[JEE Main_{S1}_250721]**

List I		List II	
(a)	$\vec{C}-\vec{A}-\vec{B}=0$	(i)	
(b)	$\vec{A}-\vec{C}-\vec{B}=0$	(ii)	
(c)	$\vec{B}-\vec{A}-\vec{C}=0$	(iii)	
(d)	$\vec{A}+\vec{B}=-\vec{C}$	(iv)	

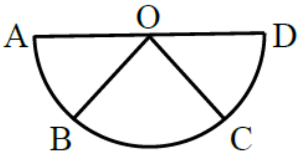
Choose the correct answer from the options given below :

(1) (a) → (iv), (b) → (i) , (c) → (iii), (d) → (ii) (2) (a) → (iv), (b) → (iii) , (c) → (i), (d) → (ii)

(3) (a) → (iii), (b) → (ii) , (c) → (iv), (d) → (i) (4) (a) → (i), (b) → (iv) , (c) → (ii), (d) → (iii)

17. **Assertion A :** If A, B, C, D are four points on a semi-circular arc with centre at 'O' such that $|\overrightarrow{AB}| = |\overrightarrow{BC}| = |\overrightarrow{CD}|$, then $\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} = 4\overrightarrow{AO} + \overrightarrow{OB} + \overrightarrow{OC}$ **[JEE Main_{S1}_27072021]**

Reason R : Polygon law of vector addition yields $\overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} + \overrightarrow{AD} = 2\overrightarrow{AO}$



In the light of the above statements, choose the most appropriate answer from the options given below :

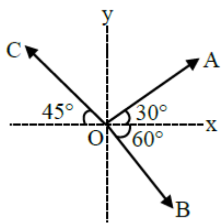
(1) A is correct but R is not correct.

(2) A is not correct but R is correct.

(3) Both A and R are correct and R is the correct explanation of A.

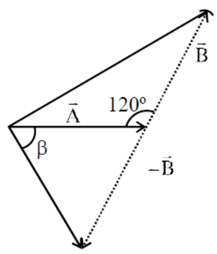
(4) Both A and R are correct but R is not the correct explanation of A.

18. The magnitude of vectors $\overrightarrow{OA}, \overrightarrow{OB}$ and $\overrightarrow{OC}$ in the given figure are equal. The direction of $\overrightarrow{OA} + \overrightarrow{OB} - \overrightarrow{OC}$ with x-axis will be :- **[JEE Main_{S1}_260821]**



(1) $\tan^{-1}\frac{(1-\sqrt{3}-\sqrt{2})}{(1+\sqrt{3}+\sqrt{2})}$ (2) $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1+\sqrt{3}-\sqrt{2})}$ (3) $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1-\sqrt{3}+\sqrt{2})}$ (4) $\tan^{-1}\frac{(1+\sqrt{3}-\sqrt{2})}{(1-\sqrt{3}-\sqrt{2})}$

19. The angle between vector $(\vec{A})$ and $(\vec{A}-\vec{B})$ is :- **[JEE Main_{S2}_260821]**



(1) $\tan^{-1}\left(\frac{-\frac{B}{2}}{A-B\frac{\sqrt{3}}{2}}\right)$ (2) $\tan^{-1}\left(\frac{A}{0.7B}\right)$ (3) $\tan^{-1}\left(\frac{\sqrt{3}B}{2A-B}\right)$ (4) $\tan^{-1}\left(\frac{B\cos\theta}{A-B\sin\theta}\right)$

20. The sum of two forces $\vec{P}$ and $\vec{Q}$ is $\vec{R}$ such that $|\vec{R}| = |\vec{P}|$. The angle θ (in degrees) that the resultant of $2\vec{P}$ and $2\vec{Q}$ will make with $\vec{Q}$ is, _____. **[JEE-Main_(S2)_070120]**

21. If $\vec{P} \times \vec{Q} = \vec{Q} \times \vec{P}$, the angle between $\vec{P}$ and $\vec{Q}$ is θ (0° < q < 360°). The value of 'q' will be _________°. **[JEE Main_{S2}_250221]**

22. Three particles P, Q and R are moving along the vectors $\vec{A}=\hat{i}+\hat{j}, \vec{B}=\hat{j}+\hat{k}$ and $\vec{C}=-\hat{i}+\hat{j}$ respectively. They strike on a point and start to move in different directions. Now particle P is moving normal to the plane which contains vector $\vec{A}$ and $\vec{B}$. Similarly particle Q is moving normal to the plane which contains vector $\vec{A}$ and $\vec{C}$. The angle between the direction of motion of P and Q is $\cos^{-1}\left(\frac{1}{\sqrt{x}}\right)$. Then the value of x is__________. **[JEE Main_{S2}_220721]**

23. If $\vec{P}=3\hat{i}+\sqrt{3}\hat{j}+2\hat{k}$ and $\vec{Q}=4\hat{i}+\sqrt{3}\hat{j}+2.5\hat{k}$ then, The unit vector in the direction of $\vec{P}\times\vec{Q}$ is $\frac{1}{x}(\sqrt{3}\,\hat{i}+\hat{j}-2\sqrt{3}\,\hat{k})$. The value of x is **[JEE Main_{S1}_250123]**

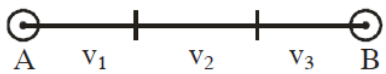
24. A particle is moving along the x-axis with its coordinate with time 't' given by x(t) = 10 + 8t – 3t^2. Another particle is moving along the y-axis with its coordinate as a function of time given by y(t) = 5 – 8t^3. At t = 1 s, the speed of the second particle as measured in the frame of the first particle is given as $\sqrt{v}$. Then v (in m/s) is ________. **[JEE-Main_{S1}_080120]**

25. A ball is dropped from the to of a 100 m high tower on a planet. In the last $\frac{1}{2}$ s before hitting the ground, it covers a distance of 19 m. Acceleration due to gravity (in ms^{-2}) near the surface on that planet is _______. **[JEE-Main_{S2} _080120]**

26. The distance x covered by a particle in one dimensional motion varies with time t as $x^2 = at^2 + 2bt + c$. If the acceleration of the particle depends on x as x^{-n}, where n is an integer, the value of n is _____. **[JEE-Main_{S1}_090120]**

27. Two spherical balls having equal masses with radius of 5 cm each are thrown upwards along the same vertical direction at an interval of 3s with the same initial velocity of 35 m/s, then these balls collide at a height of .... m. (Take g = 10 m/s^2) **[JEE MAIN_{S1}_260821]**

28. A car covers AB distance with first one–third at velocity v_1 ms^{-1}, second one–third at v_2 ms^{-1} and last one–third at v_3 ms^{-1}. If $v_3 = 3v_1$, $v_2 = 2v_1$ and $v_1 = 11$ ms^{-1} then the average velocity of the car is ________ ms^{-1}. **[JEE Main_{S2}_280622]**



29. A tennis ball is dropped on to the floor from a height of 9.8 m. It rebounds to a height 5.0 m. Ball comes in contact with the floor for 0.2s. The average acceleration during contact is ____ 2 ms^{-2}. [Given g = 10 ms^{-2}] **[JEE Main_S1_290123]**

30. A horse rider covers half the distance with 5 m/s speed. The remaining part of the distance was travelled with speed 10 m/s for half the time and with speed 15 m/s for other half of the time. The mean speed of the rider averaged over the whole time of motion is x/7 m/s. The value of x is **[JEE Main_{S1}_300123]**

ANSWER KEY

1	(4)	2.	(2)	3.	(3)	4.	(3)	5.	(4)	6.	(3)	7.	(2)
8.	(3)	9.	(4)	10.	(1)	11.	(2)	12.	(1)	13.	(2)	14.	(2)
15.	(4)	16.	(2)	17.	(4)	18.	(1)	19.	(3)	20.	(90)	21.	180
22.	(3)	23.	(4)	24.	(580)	25.	(08.00)	26.	(3)	27.	(50)	28.	(18)
29.	120	30.	(50)										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- PROJECTILE MOTION & RELATIVE MOTION

(Important Questions Only)

1. Two guns A and B can fire bullets at speeds 1 km/s and 2 km/s respectively. From a point on a horizontal ground, they are fired in all possible directions. The ratio of maximum areas covered by the bullets fired by the two guns, on the ground is **[JEE_MAIN_{S1}_100119]**

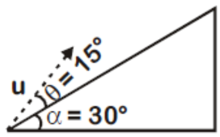
(1) 1 : 4 (2) 1 : 8 (3) 1 : 2 (4) 1 : 16

2. A body is projected at t = 0 with a velocity 10 ms^{-1} at an angle of 60° with the horizontal. The radius of curvature of its trajectory at t = 1 s is R. Neglecting air resistance and taking acceleration due to gravity g = 10 ms^{-2}, the value of R is **[JEE MAIN_{S1}_110119]**

(1) 5.1 m (2) 2.5 m (3) 2.8 m (4) 10.3 m

3. A plane is inclined at an angle α = 30° with respect to the horizontal. A particle is projected with a speed u = 2 ms–1, from the base of the plane, making an angle θ = 15° with respect to the plane as shown in the figure. The distance from the base, at which the particle hits the plane is close to:

(Take g = 10 ms^{-2}) **[JEE MAIN _{S2}_100419]**



(1) 18 cm (2) 20 cm (3) 14 cm (4) 26 cm

4. The trajectory of a projectile near the surface of the earth is given as y = 2x – $9x^2$. If it were launched at an angle θ_0 with speed v_0 then (g = 10 ms^{-2}): **[JEE-Main_{S1}_120419]**

(1) $\theta_0 = \sin^{-1}\left(\frac{1}{\sqrt{5}}\right)$ and $v_0 = \frac{5}{3}ms^{-1}$

(2) $\theta_0 = \cos^{-1}\left(\frac{2}{\sqrt{5}}\right)$ and $v_0 = \frac{3}{5}ms^{-1}$

(3) $\theta_0 = \cos^{-1}\left(\frac{1}{\sqrt{5}}\right)$ and $v_0 = \frac{5}{3}ms^{-1}$

(4) $\theta_0 = \sin^{-1}\left(\frac{2}{\sqrt{5}}\right)$ and $v_0 = \frac{3}{5}ms^{-1}$

5. Two particles are projected from the same point with the same speed u such that they have the same range R, but different maximum heights, h_1 and h_2. Which of the following is correct?

[JEE-Main_{S2}_120419]

(1) $R^2 = 4 h_1h_2$ (2) $R^2 = 16 h_1h_2$

(3) $R^2 = 2 h_1h_2$ (4) $R^2 = h_1h_2$

6. The trajectory of a projectile in a vertical plane is y = αx – βx^2, where α and β are constants and x & y are respectively the horizontal and vertical distances of the projectile from the point of projection. The angle of projection θ and the maximum height attained H are respectively given by :-

[JEE MAIN__{S2}_260221]

(1) $\tan^{-1}\alpha, \frac{\alpha^2}{4\beta}$ (2) $\tan^{-1}\beta, \frac{\alpha^2}{2\beta}$ (3) $\tan^{-1}\alpha, \frac{4\alpha^2}{\beta}$ (4) $\tan^{-1}\left(\frac{\beta}{\alpha}\right), \frac{\alpha^2}{\beta}$

7. A player kicks a football with an initial speed of 25 ms^{-1} at an angle of 45° from the ground. What are the maximum height and the time taken by the football to reach at the highest point during motion? (Take g = 10 ms^{-2}) **[JEE MAIN_{S2}_270821]**

(1) h_{max} = 10 m   T = 2.5 s   (2) h_{max} = 15.625 m   T = 3.54 s

(3) h_{max} = 15.625 m   T = 1.77 s   (4) h_{max} = 3.54 m   T = 0.125 s

8. A helicopter is flying horizontally with a speed 'v' at an altitude 'h' has to drop a food packet for a man on the ground. What is the distance of helicopter from the man when the food packet is dropped? **[JEE MAIN_{S2}_310821]**

(1) $\sqrt{\frac{2ghv^2+1}{h^2}}$ (2) $\sqrt{2ghv^2+h^2}$ (3) $\sqrt{\frac{2v^2h}{g}+h^2}$ (4) $\sqrt{\frac{2gh}{v^2}+h^2}$

9. A projectile is projected with velocity of 25 m/s at an angle θ with the horizontal. After t seconds its inclination with horizontal becomes zero. If R represents horizontal range of the projectile, the value of θ will be : [use g = 10 m/s²] **[JEE Main_{S1}_240622]**

(1) $\frac{1}{2}\sin^{-1}\left(\frac{5t^2}{4R}\right)$ (2) $\frac{1}{2}\sin^{-1}\left(\frac{4R}{5t^2}\right)$ (3) $\tan^{-1}\left(\frac{4t^2}{5R}\right)$ (4) $\cot^{-1}\left(\frac{R}{20t^2}\right)$

10. Given below are two statements. One is labelled as **[JEE Main_{S2}_250622]**
Assertion A and the other is labelled as **Reason R**.

Assertion A : Two identical balls A and B thrown with same velocity 'u' at two different angles with horizontal attained the same range R. If A and B reached the maximum height h_1 and h_2 respectively, then $R = 4\sqrt{h_1h_2}$

Reason R: Product of said heights.

$$h_1h_2 = \left(\frac{u^2\sin^2\theta}{2g}\right)\cdot\left(\frac{u^2\cos^2\theta}{2g}\right)$$

Choose the CORRECT answer :

(1) Both A and R are true and R is the correct explanation of A.

(2) Both A and R are true but R is NOT the correct explanation of A.

(3) A is true but R is false

(4) A is false but R is true

11. A projectile is launched at an angle 'α' with the horizontal with a velocity 20 ms^{-1}. After 10 s, its inclination with horizontal is 'β'. The value of tanβ will be : (g = 10 ms^{-2}) **[JEE Main_{S1}_270622]**

(1) tanα + 5secα (2) tanα – 5secα (3) 2tanα – 5secα (4) 2tanα + 5secα

12. Two balls A and B are placed at the top of 180 m tall tower. Ball A is released from the top at t = 0 s. Ball B is thrown vertically down with an initial velocity 'u' at t = 2 s. After a certain time, both balls meet 100 m above the ground. Find the value of 'u' in ms^{-1}. [use g = 10 ms^{-2}] : **[JEE Main_{S1}_290622]**

(1) 10   (2) 15   (3) 20   (4) 30

13. A body of mass 10 kg is projected at an angle of 45° with the horizontal. The trajectory of the body is observed to pass through a point (20, 10). If T is the time of flight, then its momentum vector, at time $t = \frac{R}{\sqrt{2}}$, is__________ [Take g = 10 m/s²] **[JEE Main_{S2}_270722]**

(1) $100\hat{i} + (100\sqrt{2} - 200)\hat{j}$
(2) $100\sqrt{2}\,\hat{i} + (100\sqrt{2} - 200\sqrt{2})\hat{j}$
(3) $100\,\hat{i} + (100 - 200\sqrt{2})\hat{j}$
(4) $100\sqrt{2}\,\hat{i} + (100\sqrt{2} - 200)\hat{j}$

14. A ball is projected with kinetic energy E, at an angle of 60º to the horizontal. The kinetic energy of this ball at the highest point of its flight will become : **[JEE Main_{S1}_290722]**

(1) Zero (2) $\frac{E}{2}$ (3) $\frac{E}{4}$ (4) E

15. The maximum vertical height to which a man can throw a ball is 136 m. The maximum horizontal distance upto which he can throw the same ball is **[JEE Main_{S1}_240123]**

(1) 192 m (2) 136 m (3) 272 m (4) 68 m

16. Two objects are projected with same velocity 'u' however at different angles α and β with the horizontal. If $\alpha + \beta = 90°$, the ratio of horizontal range of the first object to the 2nd object will be :
[JEE Main_{S2}_250123]

(1) 4 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 1

17. A child stands on the edge of the cliff 10 m above the ground and throws a stone horizontally with an initial speed of 5 ms^{-1}. Neglecting the air resistance, the speed with which the stone hits the ground will be ______ ms–1 (given, g = 10 ms^{-2}). **[JEE-Main_{S1}_010223]**

(1) 20 (2) 15 (3) 30 (4) 25

18. Ship A is sailing towards north-east with velocity $\vec{v} = 30\hat{i} + 50\hat{j}$ km/hr where $\hat{i}$ points east and $\hat{j}$, north. Ship B is at a distance of 80 km east and 150 km north of Ship A and is sailing towards west at 10 km/hr. A will be at minimum distance from B in: **[JEE-Main_{S1}_080419]**

(1) 2.2 hrs. (2) 4.2 hrs. (3) 3.2 hrs. (4) 2.6 hrs.

19. A bullet of mass 20 g has an initial speed of 1ms^{-1}, just before it starts penetrating a mud wall of thickness 20 cm. If the wall offers a mean resistance of 2.5 × 10^{-2} N, the speed of the bullet after emerging from the other side of the wall is close to : **[JEE MAIN_{S2}_100419]**

(1) 0.4 ms^{-1} (2) 0.7 ms^{-1} (3) 0.3 ms^{-1} (4) 0.1 ms^{-1}

20. Train A and train B are running on parallel tracks in the opposite directions with speeds of 36 km/hour and 72 km/hour, respectively. A person is walking in train A in the direction opposite to its motion with a speed of 1.8 km/ hour. Speed (in ms^{-1}) of this person as observed from train B will be close to : (take the distance between the tracks as negligible) **[JEE-Main_{S1}_ 020920]**

(1) 30.5 ms^{-1} (2) 29.5 ms^{-1} (3) 31.5 ms^{-1} (4) 28.5 ms^{-1}

21. A mosquito is moving with a velocity $\vec{v} - = 0.5t^2\hat{i} + 3t\hat{j} + 9\hat{k}$ m/s and accelerating in uniform conditions. What will be the direction of mosquito after 2s ? **[JEE MAIN_{S2}_160321]**

(1) $\tan^{-1}\left(\frac{2}{3}\right)$ from x - axis
(2) $\tan^{-1}\left(\frac{2}{3}\right)$ from y - axis

(3) $\tan^{-1}\left(\frac{5}{2}\right)$ from y - axis (4) $\cos^{-1}\frac{2}{11}$(from x – axis) $= \tan^{-1}\frac{\sqrt{117}}{2}$

22. A boy reaches the airport and finds that the escalator is not working. He walks up the stationary escalator in time t_1. If he remains stationary on a moving escalator then the escalator takes him up in time t_2. The time taken by him to walk up on the moving escalator will be : **[JEE Main_{S2}_200721]**

(1) $\frac{t_1 t_2}{t_2 - t_1}$ (2) $\frac{t_1 + t_2}{2}$ (3) $\frac{t_1 t_2}{t_2 + t_1}$ (4) $t_2 - t_1$

23. From the top of a tower, a ball is thrown vertically upward which reaches the ground in 6 s. A second ball thrown vertically downward from the same position with the same speed reaches the ground in 1.5 s. A third ball released, from the rest from the same location, will reach the ground in ________ s.

[JEE Main_{S1}_240622]

24. A ball is projected vertically upward with an initial velocity of 50 ms^{-1} at t = 0s. At t = 2s. another ball is projected vertically upward with same velocity. **[JEE Main_{S2}_260622]**

At t =________s, second ball will meet the first ball (g = 10 ms^{-2}).

25. If the initial velocity in horizontal direction of a projectile is unit vector $\hat{i}$ and the equation of trajectory is y = 5x (1 – x). The y component vector of the initial velocity is _____ $\hat{j}$ (Take g = 10 m / s^2)

[JEE Main_{S1}_260722]

26. An object is projected in the air with initial velocity u at an angle θ. The projectile motion is such that the horizontal range R, is maximum. Another object is projected in the air with a horizontal range half of the range of first object. The initial velocity remains same in both the case. The value of the angle of projection, at which the second object is projected, will be ________degree.

[JEE Main_{S1}_290722]

27. Two bodies are projected from ground with same speeds 40 ms^{-1} at two different angles with respect to horizontal. The bodies were found to have same range. If one of the body was projected at an angle of 60°, with horizontal then sum of the maximum heights, attained by the two projectiles, is _______m. (Given g=10 ms^{-2}) **[JEE MAIN__{S2}_310123]**

28. A swimmer can swim with velocity of 12 km/h in still water. Water flowing in a river has velocity 6 km/h. The direction with respect to the direction of flow of river water he should swim in order to reach the point on the other bank just opposite to his starting point is _________°. (Round off to the Nearest Integer) (find the angle in degree) **[JEE MAIN_{S2}_160321]**

29. A person is swimming with a speed of 10 m/ s at an angle of 120° with the flow and reaches to a point directly opposite on the other side of the river. The speed of the flow is 'x' m/s. The value of 'x' to the nearest integer is ______. **[JEE MAIN_{S1}_180321]**

30. The speed of a swimmer is 4 km h^{-1} in still water. If the swimmer makes his strokes normal to the flow of river of width 1 km, he reaches a point 750 m down the stream on the opposite bank. The speed of the river water is _______km h^{-1} . **[JEE Main_{S2}_310123]**

ANSWER KEY

1.	(4)	2.	(3)	3.	(2)	4.	(3)	5.	(2)	6.	(1)	7.	(3)
8.	(3)	9.	(4)	10.	(1)	11.	(2)	12.	(4)	13.	(4)	14.	(3)
15.	(3)	16.	(4)	17.	(2)	18.	(4)	19.	(2)	20.	(2)	21.	(4)
22.	(3)	23.	3	24.	6	25.	5	26.	15	27.	80	28.	12
29.	5	30.	3										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- NEWTON'S LAWS OF MOTION

(Important Questions Only)

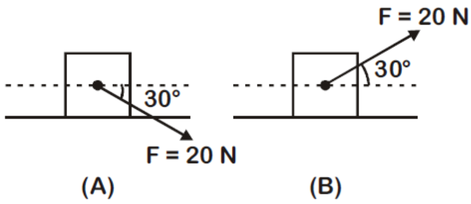
1. A mass of 10 kg is suspended vertically by a rope from the roof. When a horizontal force is applied on the roof at some point, the rope deviated at an angle of 45° at the roof point. If the suspended mass is at equilibrium, the magnitude of the force applied is ($g = 10\ ms^{-2}$) **[JEE_MAIN_{S1}_090119]**

(1) 100 N (2) 200 N (3) 70 N (4) 140 N

2. A particle of mass m is moving in a straight line with momentum p. Starting at time t = 0, a force F = kt acts in the same direction on the moving particle during time interval T so that its momentum changes from p to 3p. Here k is a constant. The value of T is **[JEE_MAIN_{S2}_110119]**

(1) $\sqrt{\frac{2k}{p}}$ (2) $2\sqrt{\frac{p}{k}}$ (3) $\sqrt{\frac{2p}{k}}$ (4) $2\sqrt{\frac{k}{p}}$

3. A block of mass 5 kg is (i) pushed in case (A) and (ii) pulled in case (B), by a force F = 20 N, making an angle of 30° with the horizontal, as shown in the figures. The coefficient of friction between the block and floor is $\mu = 0.2$. The difference between the accelerations of the block, in case (B) and case (A) will be : ($g = 10\ ms^{-2}$) **[JEE-Main_{S2}_120419]**

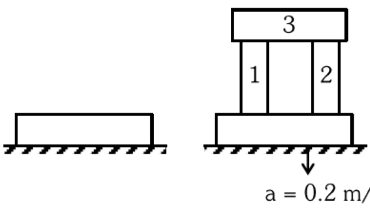


(1) $0.4\ ms^{-2}$ (2) $3.2\ ms^{-2}$ (3) $0\ ms^{-2}$ (4) $0.8\ ms^{-2}$

4. A 60 HP electric motor lifts an elevator having a maximum total load capacity of 2000 kg. If the frictional force on the elevator is 4000 N, the speed of the elevator at full load is close to : (1 HP = 746 W, $g = 10\ ms^{-2}$) **[JEE-Main_(S1) _070120]**

(1) $1.5\ ms^{-1}$ (2) $1.9\ ms^{-1}$ (3) $1.7\ ms^{-1}$ (4) $2.0\ ms^{-1}$

5. A steel block of 10 kg rests on a horizontal floor as shown. When three iron cylinders are placed on it as shown, the block and cylinders go down with an acceleration $0.2\ m/s^2$. The normal reaction R' by the floor if mass of the iron cylinders are equal and of 20 kg each, is ______ N. [Take $g = 10\ m/s^2$ and $\mu_2 = 0.2$] **[JEE Main_{S1}_200721]**



(1) 716 (2) 686 (3) 714 (4) 684

6. A force $\vec{F} = (40\hat{i} + 10\hat{j})N$ acts on a body of mass 5 kg. If the body starts from rest, its position vector $\vec{r}$ -at time t = 10 s, will be : **[JEE Main_{S2}_250721]**

(1) $(100\hat{i} + 400\hat{j})m$ (2) $(100\hat{i} + 100\hat{j})m$ (3) $(400\hat{i} + 100\hat{j})m$ (4) $(400\hat{i} + 400\hat{j})m$

7. A particle of mass M originally at rest is subjected to a force whose direction is constant but magnitude varies with time according to the relation **[JEE Main_{S2}_270721]**

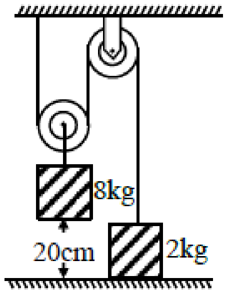
$$F = F_0\left[1 - \left(\frac{t-T}{T}\right)^2\right]$$

Where F_0 and T are constant. The force acts only for the time interval 2T. The velocity v of the particle after time 2T is :

(1) $2F_0T/M$ (2) $F_0T/2M$ (3) $4F_0T/3M$ (4) $F_0T/3M$

8. The boxes of masses 2 kg and 8 kg are connected by a massless string passing over smooth pulleys. Calculate the time taken by box of mass 8 kg to strike the ground starting from rest. (use g = 10 m/s²)

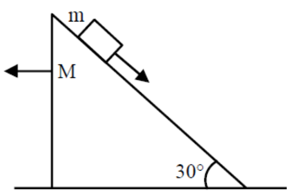
[JEE (MAIN)_{S2}_270821]



(1) 0.34 s (2) 0.2 s (3) 0.25 s (4) 0.4 s

9. A block of mass m slides on the wooden wedge, which in turn slides backward on the horizontal surface. The acceleration of the block with respect to the wedge is : Given m = 8 kg, M = 16 kg Assume all the surfaces shown in the figure to be frictionless.

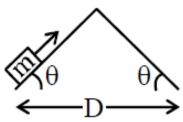
[JEE (MAIN)_{S2}_010921]



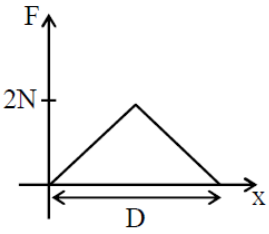
(1) $\frac{4}{3}g$ (2) $\frac{6}{5}g$ (3) $\frac{3}{5}g$ (4) $\frac{2}{3}g$

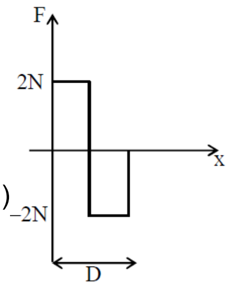
10. An object of mass 'm' is being moved with a constant velocity under the action of an applied force of 2N along a frictionless surface with following surface profile.

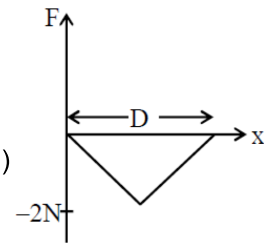
[JEE (MAIN)_{S2}_010921]

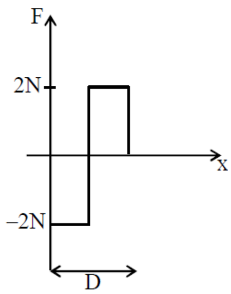


The correct applied force vs distance graph will be:

(1) 

(2) 

(3) 

(4) 

11. A person is standing in an elevator. In which situation, he experiences weight loss ?

[JEE Main_{S1}_260622]

(1) When the elevator moves upward with constant acceleration

(2) When the elevator moves downward with constant acceleration

(3) When the elevator moves upward with uniform velocity

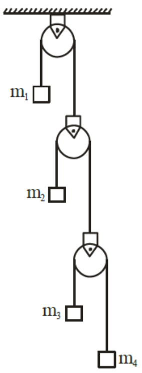
(4) When the elevator moves downward with uniform velocity

12. Time period of a simple pendulum in a stationary lift is 'T'. If the lift accelerates with $\frac{g}{6}$ vertically upwards then the time period will be : (where g = acceleration due to gravity)

[JEE Main_{S1}_260622]

(1) $\sqrt{\frac{6}{5}}T$ (2) $\sqrt{\frac{5}{6}}T$ (3) $\sqrt{\frac{6}{7}}T$ (4) $\sqrt{\frac{7}{6}}T$

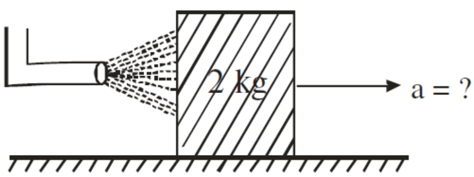
13. In the arrangement shown in figure a_1, a_2, a_3 and a_4 are the accelerations of masses m_1, m_2, m_3 and m_4 respectively. Which of the following relation is true for this arrangement? **[JEE Main_{S2}_260622]**



(1) $4a_1 + 2a_2 + a_3 + a_4 = 0$ (2) $a_1 + 4a_2 + 3a_3 + a_4 = 0$

(3) $a_1 + 4a_2 + 3a_3 + 2a_4 = 0$ (4) $2a_1 + 2a_2 + 3a_3 + a_4 = 0$

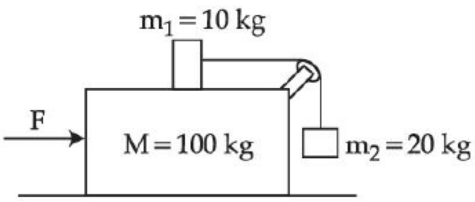
14. A block of metal weighing 2 kg is resting on a frictionless plane (as shown in figure). It is struck by a jet releasing water at a rate of 1 kgs^{-1} and at a speed of 10 ms^{-1}. Then, the initial acceleration of the block, in ms^{-2}, will be : **[JEE Main_{S1}_290622]**



Plane

(1) 3 (2) 6 (3) 5 (4) 4

15. Three masses M = 100 kg, m_1 = 10 kg and m_2 = 20 kg are arranged in a system as shown in figure. All the surfaces are frictionless and strings are inextensible and weightless. The pulleys are also weightless and frictionless. A force F is applied on the system so that the mass m_2 moves upward with an acceleration of 2 ms^{-2}. The value of F is : (Take g = 10 ms^{-2}) **[JEE Main_{S1}_260722]**



(1) 3360 N (2) 3380 N (3) 3120 N (4) 3240 N

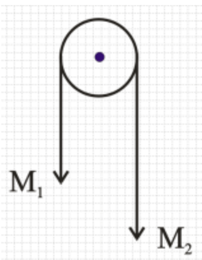
16. A monkey of mass 50kg climbs on a rope which can withstand the tension (T) of 350N. If monkey initially climbs down with an acceleration of 4m / s^2 and then climbs up with an acceleration of 5m / s^2. Choose the correct option (g = 10m/s^2) **[JEE Main_{S1}_260722]**

(1) T = 700N while climbing upward (2) T = 350 N while going downward

(3) Rope will break while climbing upward (4) Rope will break while going downward

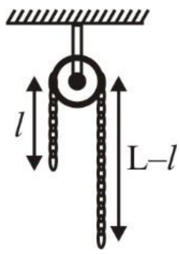
17. Two masses M_1 and M_2 are tied together at the two ends of a light inextensible string that passes over a frictionless pulley. When the mass M_2 is twice that of M_1. the acceleration of the system is a_1. When the mass M_2 is thrice that of M_1. The acceleration of The system is a_2. The ratio $\frac{a_1}{a_2}$ will be:

[JEE Main_{S2}_260722]



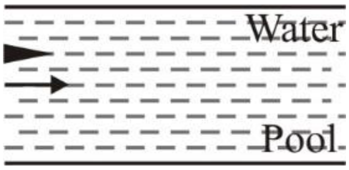
(1) $\frac{1}{3}$ (2) $\frac{2}{3}$ (3) $\frac{3}{2}$ (4) $\frac{1}{2}$

18. A uniform metal chain of mass m and length 'L' passes over a massless and frictionless pulley. It is released from rest with a part of its length 'l' is hanging on one side and rest of its length 'L – l' is hanging on the other side of the pulley. At a certain point of time, when $l = \frac{L}{x}$, the acceleration of the chain is $\frac{g}{2}$. The value of x is............ **[JEE Main_{S2}_280722]**



(1) 6 (2) 2 (3) 1.5 (4) 4

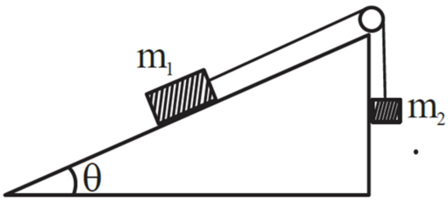
19. A bullet of mass 200 g having initial kinetic energy 90 J is shot inside a long swimming pool as shown in the figure. If it's kinetic energy reduces to 40 J within 1s, the minimum length of the pool, the bullet has a to travel so that it completely comes to rest is **[JEE Main_{S2}_280722]**



(1) 45 m (2) 90 m (3) 125 m (4) 25 m

20. Two bodies of masses m_1 = 5 kg and m_2 = 3 kg are connected by a light string going over a smooth light pulley on a smooth inclined plane as shown in the figure. The system is at rest. The force exerted by the inclined plane on the body of mass m_1 will be : [Take g = 10 ms^{-2}]

[JEE Main_{S2}_290722]



(1) 30 N (2) 40 N (3) 50 N (4) 60 N

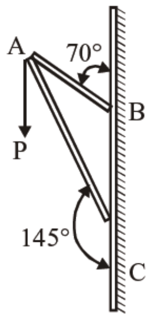
21. Force acts for 20 s on a body of mass 20 kg, starting from rest, after which the force ceases and then body describes 50 m in the next 10 s. The value of force will be : **[JEE Main_{S2}_290123**

(1) 40 N (2) 5 N (3) 20 N (4) 10 N

22. A person standing on a spring balance inside a stationary lift measures 60 kg. The weight of that person if the lift descends with uniform downward acceleration of 1.8 m/s^2 will be_ N. [g = 10 m/s^2]

[JEE MAIN_{S1}_260221]

23. Consider a frame that is made up of two thin massless rods AB and AC as shown in the figure. A vertical force $\vec{P}$ of magnitude 100 N is applied at point A of the frame. **[JEE MAIN_{S1}_160321]**

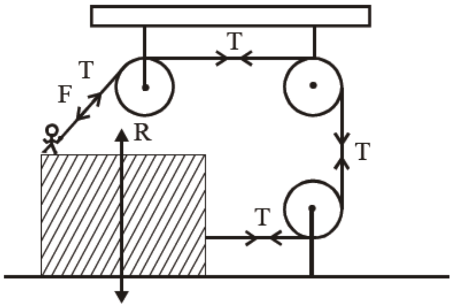


Suppose the force is $\vec{P}$ resolved parallel to the arms AB and AC of the frame. The magnitude of the resolved component along the arm AC is xN. The value of x, to the nearest integer, is ________.

[Given : sin (35°) = 0.573, cos (35°) = 0.819

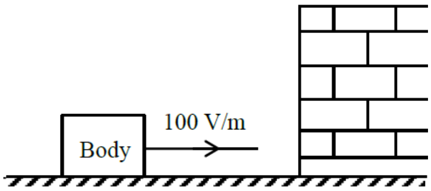
sin (110°) = 0.939, cos (110°) = –0.342]

24. A boy of mass 4 kg is standing on a piece of wood having mass 5kg. If the coefficient of friction between the wood and the floor is 0.5, the maximum force that the boy can exert on the rope so that the piece of wood does not move from its place is ________N.(Round off to the Nearest Integer) [Take g = 10 ms^{-2}] **[JEE MAIN_{S2}_170321]**



25. A bullet of mass 0.1 kg is fired on a wooden block to pierce through it, but it stops after moving a distance of 50 cm into it. If the velocity of bullet before hitting the wood is 10 m/s and it slows down with uniform deceleration, then the magnitude of effective retarding force on the bullet is 'x' N. The value of 'x' to the nearest integer is ______ . **[JEE MAIN_{S1}_180321]**

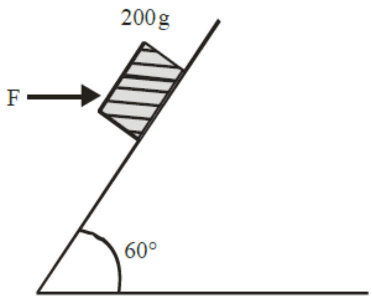
26. A body having specific charge 8 μC/g is resting on a frictionless plane at a distance 10 cm from the wall (as shown in the figure). It starts moving towards the wall when a uniform electric field of 100 V/m is applied horizontally towards the wall. If the collision of the body with the wall is perfectly elastic, then the time period of the motion will be ______ s. **[JEE Main_{S1}_200721]**



27. A car is moving on a plane inclined at 30° to the horizontal with an acceleration of 10 ms^{-2} parallel to the plane upward. A bob is suspended by a string from the roof of the car.
The angle in degrees which the string makes with the vertical is______. (Take g = 10 ms^{-2})
[JEE MAIN_{S2}_310821]

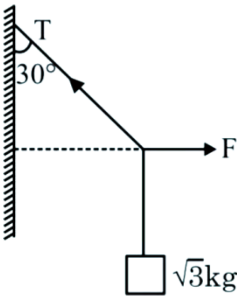
28. A block of mass 200 g is kept stationary on a smooth inclined plane by applying a minimum horizontal force $F = \sqrt{x}\,N$ as shown in figure. The value of x = ________.

[JEE Main_{S2}_250622]



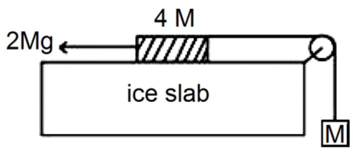
29. A block of $\sqrt{3}$ kg is attached to a string whose other end is attached to the wall. An unknown force F is applied so that the string makes an angle of 30° with the wall. The tension T is : (Given g = 10 ms^{-2})

[JEE MAIN_S2_300123]



30. A hanging mass M is connected to a four times bigger mass by using a string-pulley arrangement. as shown in the figure. The bigger mass is placed on a horizontal ice-slab and being pulled by 2 Mg force. In this situation. tension in the string is $\frac{x}{5}$Mg for x = _________. Neglect mass of the string and friction of the block (bigger mass) with ice slab. (Given g = acceleration due to gravity)

[JEE Main_{S1}_280622]



ANSWER KEY

1.	(1)	2.	(2)	3.	(4)	4.	(2)	5.	(2)	6.	(3)	7.	(3)
8.	(4)	9.	(4)	10.	(2)	11.	(2)	12.	(3)	13.	(1)	14.	(3)
15.	(1)	16.	(3)	17.	(2)	18.	(4)	19.	(1)	20.	(2)	21.	(2)
22.	492	23.	82	24.	30	25.	10	26.	1	27.	30	28.	12
29.	20	30.	6										

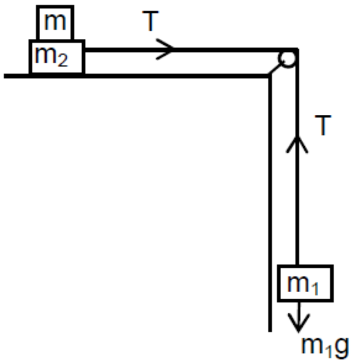
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- FRICTION & CIRCULAR MOTION

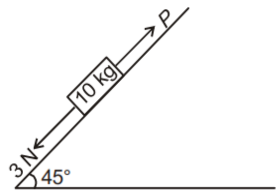
(Important Questions Only)

1. Two masses m_1 = 5kg and m_2 = 10 kg connected by an inextensible string over a frictionless pulley are moving as shown in the figure. The coefficient of friction of horizontal surface is 0.15. The minimum weight m that should be put on top of m_2 to stop the motion is : **[JEE MAIN_080418]**



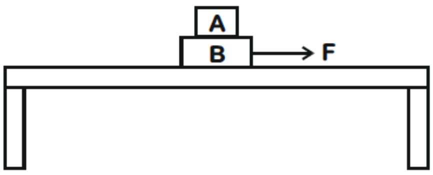
(1) 43.3 kg (2) 10.3 kg (3) 18.3 kg (4) 23.33 kg

2 A block of mass 10 kg is kept on a rough inclined plane as shown in the figure. A force of 3 N is applied on the block. The coefficient of static friction between the plane and the block is 0.6. What should be the minimum value of force P, such that the block doesnot move downward?
(take g= 10 ms^{-2}) **[JEE_MAIN_{S1}_090119]**



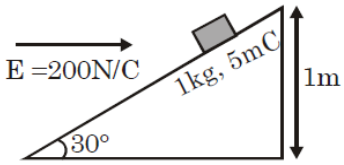
(1) 25 N (2) 32 N (3) 18 N (4) 23 N

3 Two blocks A and B of masses m_A = 1 kg and m_B = 3 kg are kept on the table as shown in figure. The coefficient of friction between A and B is 0.2 and between B and the surface of the table is also 0.2. The maximum force F that can be applied on B horizontally, so that the block A does not slide over the block B is: [Take g = 10 m/s^2] **[JEE MAIN_{S2}_100419]**



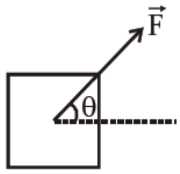
(1) 40 N (2) 12 N (3) 16 N (4) 8 N

4. An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field 200 $\frac{N}{C}$ as shown in the figure. A body of mass 1kg and charge 5 mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom. [g = 9.8 m/s^2, sin 30° = $\frac{1}{2}$; cos 30° = $\frac{\sqrt{3}}{2}$] **[JEE MAIN_{S2}_260221]**



(1) 0.92 s (2) 0.46 s (3) 2.3 s (4) 1.3 s

5. A block of mass m slides along a floor while a force of magnitude F is applied to it at an angle θ as shown in figure. The coefficient of kinetic friction is μ_K. Then, the block's acceleration 'a' is given by : (g is acceleration due to gravity) **[JEE MAIN_{S1}_160321]**

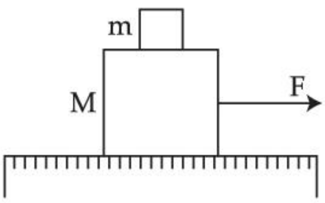


(1) $-\frac{F}{m}\cos\theta-\mu_K\left(g-\frac{F}{m}\sin\theta\right)$ (2) $\frac{F}{m}\cos\theta-\mu_K\left(g-\frac{F}{m}\sin\theta\right)$

(3) $\frac{F}{m}\cos\theta-\mu_K\left(g+\frac{F}{m}\sin\theta\right)$ (4) $\frac{F}{m}\cos\theta+\mu_K\left(g-\frac{F}{m}\sin\theta\right)$

6. A system of two blocks of masses m = 2 kg and M = 8 kg is placed on a smooth table as shown in figure. The coefficient of static friction between two blocks is 0.5. The maximum horizontal force F that can be applied to the block of mass M so that the blocks move together will be :

[JEE Main_{S1}_270622]



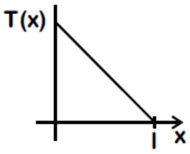
(1) 9.8 N (2) 39.2 N (3) 49 N (4) 78.4 N

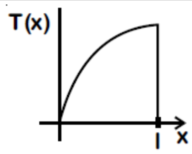
7. A body of mass 10 kg is moving with an initial speed of 20 m/s. The body stops after 5 s due to friction between body and the floor. The value of the coefficient of friction is: (Take acceleration due to gravity g = 10 ms^{-2}) **[JEE Main_{S2}_310123]**

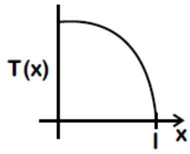
(1) 0.2 (2) 0.3 (3) 0.5 (4) 0.4

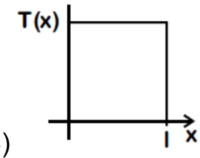
8. A uniform rod of length l is being rotated in a horizontal plane with a constant angular speed about an axis passing through one of its ends. If the tension generated in the rod due to rotation is T(x) at a distance x from the axis, then which of the following graphs depicts it most closely?

[JEE Main_{S1}_120419]

(1) 

(2) 

(3) 

(4) 

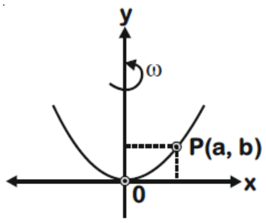
9. A particle of mass m is fixed to one end of a light spring having force constant k and unstretched length l. The other end is fixed. The system is given an angular speed ω about the fixed end of the spring such that it rotates in a circle in gravity free space. Then the stretch in the spring is

[JEE-Main_{S1}_080120]

(1) $\dfrac{ml\omega^2}{k-\omega m}$ (2) $\dfrac{ml\omega^2}{k+\omega m^2}$ (3) $\dfrac{ml\omega^2}{k+m\omega}$ (4) $\dfrac{ml\omega^2}{k-m\omega^2}$

10. A bead of mass m stays at point P(a, b) on a wire bent in the shape of a parabola $y = 4Cx^2$ and rotating with angular speed ω (see figure). The value of ω is (neglect friction)

[JEE Main_{S1} _020920]



(1) $2\sqrt{2gC}$ (2) $2\sqrt{gC}$ (3) $\sqrt{\dfrac{2g}{C}}$ (4) $\sqrt{\dfrac{2gC}{ab}}$

11. A modern grand-prix racing car of mass m is travelling on a flat track in a circular arc of radius R with a speed v. If the coefficient of static friction between the tyres and the track is μ_s, then the magnitude of negative lift F_L acting downwards on the car is : (Assume forces on the four tyres are identical and g = acceleration due to gravity) **[JEE MAIN_{S1}_170321]**

(1) $m\left(\dfrac{v^2}{\mu_s R}+g\right)$ (2) $m\left(\dfrac{v^2}{\mu_s R}-g\right)$ (3) $m\left(g-\dfrac{v^2}{\mu_s R}\right)$ (4) $-m\left(g+\dfrac{v^2}{\mu_s R}\right)$

12. The normal reaction 'N' for a vehicle of 800 kg mass, negotiation a turn on a 30° banked road at maximum possible speed without skidding is _______$\times 10^3$ kg m/s². **[JEE MAIN_{S1}_200721]**

(1) 10.2 (2) 7.2 (3) 12.4 (4) 6.96

13. A particle of mass m is suspended from a ceiling through a string of length L. The particle moves in a horizontal circle of radius r such that $r = \dfrac{L}{\sqrt{2}}$. The speed of particle will be :

[JEE MAIN_{S2}_260821]

(1) $\sqrt{rg}$ (2) $\sqrt{2rg}$ (3) $2\sqrt{rg}$ (4) $\sqrt{\dfrac{rg}{2}}$

14. A stone of mass m, tied to a string is being whirled in a vertical circle with a uniform speed. The tension in the string is : **[JEE Main_{S2}_240622]**

(1) the same throughout the motion

(2) minimum at the highest position of the circular path

(3) minimum at the lowest position of the circular path

(4) minimum when the rope is in the horizontal position

15. A disc with a flat small bottom beaker placed on it at a distance R from its center is revolving about an axis passing through the center and perpendicular to its plane with an angular velocity ω. The coefficient of static friction between the bottom of the beaker and the surface of the disc is μ. The beaker will revolve with the disc if : **[JEE Main_{S2}_250622]**

(1) $R \le \frac{\mu g}{2\omega^2}$ (2) $R \le \frac{\mu g}{\omega^2}$ (3) $R \ge \frac{\mu g}{2\omega^2}$ (4) $R \ge \frac{\mu g}{\omega^2}$

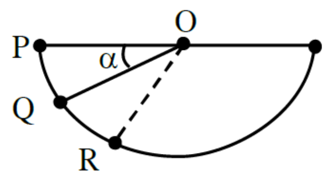
16. For a particle in uniform circular motion, the acceleration $\vec{a}$ at any point P(R,θ) on the circular path of radius R is (when θ is measured from the positive x –axis and v is uniform speed) :

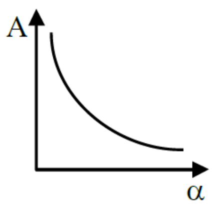
[JEE Main_{S2}_250622]

(1) $-\frac{v^2}{R}\sin\theta\hat{i} + \frac{v^2}{R}\cos\theta\hat{j}$ (2) $-\frac{v^2}{R}\cos\theta\hat{i} + \frac{v^2}{R}\sin\theta\hat{j}$

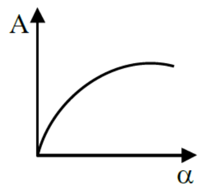
(3) $-\frac{v^2}{R}\cos\theta\hat{i} - \frac{v^2}{R}\sin\theta\hat{j}$ (4) $-\frac{v^2}{R}\hat{i} + \frac{v^2}{R}\hat{j}$

17. A ball is released from rest from point P of a smooth semi-spherical vessel as shown in figure. The ratio of the centripetal force and normal reaction on the ball at point Q is A while angular position of point Q is a with respect to point P. Which of the following graphs represent the correct relation between A and a when ball goes from Q to R ? **[JEE Main_{S1}_260622]**





(1)



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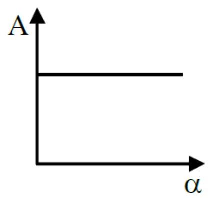

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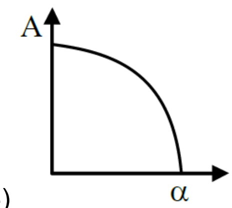


(4)

18. One end of a massless spring of spring constant k and natural length l_0 is fixed while the other end is connected to a small object of mass m lying on a frictionless table. The spring remains horizontal on the table. If the object is made to rotate at an angular velocity ω about an axis passing through fixed end, then the elongation of the spring will be: **[JEE Main_{S2}_270622]**

(1) $\frac{k - m\omega^2 l_0}{m\omega^2}$ (2) $\frac{m\omega^2 l_0}{k + m\omega^2}$ (3) $\frac{m\omega^2 l_0}{k - m\omega^2}$ (4) $\frac{k + m\omega^2 l_0}{m\omega^2}$

19. A stone tide to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of change in its velocity, as it reaches a position where the string is horizontal, is $\sqrt{x(u^2 - gL)}$. The value of x is **[JEE Main_{S2}_270622]**

(1) 3 (2) 2 (3) 1 (4) 5

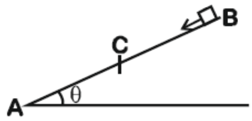
20. A ball is spun with angular acceleration $\alpha = 6t^2 - 2t$ where t is in second and α is in rads^{-2}. At t = 0, the ball has angular velocity of 10 rads^{-1} and angular position of 4 rad. The most appropriate expression for the angular position of the ball is: **[JEE Main_{S2}_280622]**

(1) $\frac{3}{2}t^4 - t^2 + 10t$ (2) $\frac{t^4}{2} - \frac{t^3}{3} + 10t + 4$ (3) $\frac{2t^4}{3} - \frac{t^3}{6} + 10t + 12$ (4) $2t^4 - \frac{t^3}{2} + 5t + 4$

21. A body of mass 200g is tied to a spring of spring constant 12.5 N/m, while the other end of spring is fixed at point O. If the body moves about O in a circular path on a smooth horizontal surface with constant angular speed 5 rad/s, then the ratio of extension in the spring to its natural length will be : **[JEE Main_{S2}_240123]**

(1) 1 : 2 (2) 1 : 1 (3) 2 : 3 (4) 2 : 5

22. A small block starts slipping down from a point B on an inclined plane AB, which is making an

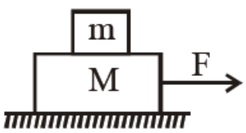


angle θ with the horizontal section BC is smooth and the remaining section CA is rough with a coefficient of friction μ. It is found that the block comes to rest as it reaches the bottom (point A) of the inclined plane. If BC = 2AC, the coefficient of friction is given by $\mu = k\tan\theta$. The value of k is ________.

[JEE-Main_{S1} _020920]

23. An inclined plane is bent in such a way that the vertical cross-section is given by $y = \frac{x^2}{4}$ where y is in vertical and x in horizontal direction. If the upper surface of this curved plane is rough with coefficient of friction μ = 0.5, the maximum height in cm at which a stationary block will not slip downward is ________ cm. **[JEE-Main_{S1}_240221]**

24. Two blocks (m = 0.5 kg and M = 4.5 kg) are arranged on a horizontal frictionless table as shown in figure. The coefficient of static friction between the two blocks is $\frac{3}{7}$. Then the maximum horizontal force that can be applied on the larger block so that the blocks move together is _____ N. (Round off to the Nearest Integer) [Take g as 9.8 ms^{-2}] **[JEE MAIN_{S1}_170321]**



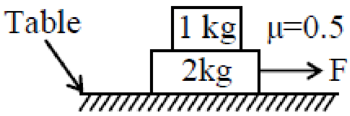
25. A body of mass 1 kg rests on a horizontal floor with which it has a coefficient of static friction $\frac{1}{\sqrt{3}}$. It is desired to make the body move by applying the minimum possible force F N. The value of F will be __________. (Round off to the Nearest Integer)

[Take g = 10 ms^{-2}] **[JEE MAIN_{S2}_170321]**

26. A body of mass '*m*' is launched up on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of friction between the body and plane is $\frac{\sqrt{x}}{5}$ if the time of ascent is half of the time of descent. The value of x is _____. **[JEE MAIN_{S2}_200721]**

27. The coefficient of static friction between two blocks is 0.5 and the table is smooth. The maximum horizontal force that can be applied to move the blocks together is ....N. (take g = 10 ms^{-2})

[JEE MAIN_{S2}_260821]



28. A uniform chain of 6 m length is placed on a table such that a part of its length is hanging over the edge of the table. The system is at rest. The co-efficient of static friction between the chain and the surface of the table is 0.5, the maximum length of the chain hanging from the table is __________m.

[JEE Main_{S1}_250622]

29. A small bob tied at one end of a thin string of length 1m is describing a vertical circle so that the maximum and minimum tension in the string are in the ratio 5 : 1. The velocity of the bob at the height position is _____ m/s. (Take g = 10 m/s^2) **[JEE MAIN_{S1}_020221]**

30. A curved in a level road has a radius 75m. The maximum speed of a car turning this curved road can be 30 m/s without skidding. If radius of curved road is changed to 48 m and the coefficient of friction between the tyres and the road remains same, then maximum allowed speed would be__m/s.

[JEE Main_{S2}_250622]

ANSWER KEY

1.	(4)	2	(2)	3	(3)	4.	(4)	5.	(2)	6.	(3)	7.	(4)
8.	(3)	9.	(4)	10.	(1)	11.	(2)	12.	(1)	13.	(1)	14.	(2)
15.	(2)	16.	(3)	17.	(3)	18.	(3)	19.	(2)	20.	(2)	21.	(3)
22.	3	23.	25	24.	21	25.	5	26.	3	27.	15	28.	2
29.	5	30.	24										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

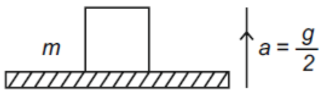
Chapter Name :- WORK, POWER & ENERGY

(Important Questions Only)

1. A particle is moving in a circular path of radius a under the action of an attractive potential $U = -\frac{k}{2r^2}$. Its total energy is : **[JEE MAIN_080418]**

(1) zero (2) $-\frac{3}{2}\frac{k}{a^2}$ (3) $-\frac{k}{4a^2}$ (4) $\frac{k}{2a^2}$

2 A block of mass m is kept on a platform which starts from rest with constant acceleration $\frac{g}{2}$ upward, as shown in fig. Work done by normal reaction on block in time t is **[JEE MAIN_{S1}_100119]**

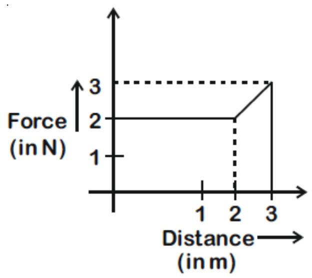


(1) $\frac{3m\,g^2t^2}{8}$ (2) $\frac{m\,g^2t^2}{8}$ (3) 0 (4) $\frac{m\,g^2t^2}{8}$

3 A body of mass 1 kg falls freely from a height of 100 m, on a platform of mass 3 kg which is mounted on a spring having spring constant k = 1.25 × 10^6 N/m. The body sticks to the platform and the spring's maximum compression is found to be x. Given that g = 10 ms^{-2}, the value of x will be close to **[JEE MAIN _{S1}_110119]**

(1) 80 cm (2) 8 cm (3) 2 cm (4) 40 cm

4 A particle moves in one dimension from rest under the influence of a force that varies with the distance travelled by the particle as shown in the figure. The kinetic energy of the particle after it has travelled 3 m is **[JEE MAIN_{S1}_080419]**



(1) 4 J (2) 2.5 J (3) 5 J (4) 6.5 J

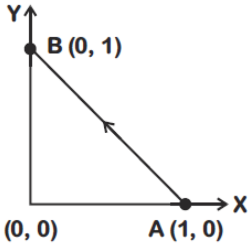
5. A uniform cable of mass 'M' and length 'L' is placed on a horizontal surface such that its $\left(\frac{1}{n}\right)^{th}$ part is hanging below the edge of the surface. To lift the hanging part of the cable upto the surface, the work done should be: **[JEE MAIN_{S1}_09042019]**

(1) $\frac{MgL}{n^2}$ (2) nMgL (3) $\frac{MgL}{2n^2}$ (4) $\frac{2MgL}{n^2}$

6. A spring whose unstretched length is l has a force constant k. The spring is cut into two pieces of unstretched lengths l_1 and l_2 where, $l_1 = nl_2$ and n is an integer. The ratio k_1/k_2 of the corresponding force constants, k_1 and k_2 will be **[JEE MAIN_{S2}_120419]**

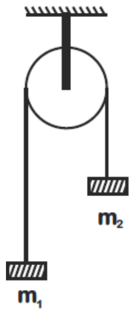
(1) n^2 (2) $\frac{1}{n^2}$ (3) n (4) $\frac{1}{n}$

7. Consider a force $\vec{F} = -x\hat{i} + y\hat{j}$. The work done by this force in moving a particle from point A(1, 0) to B (0, 1) along the line segment is : (all quantities are in SI units) **[JEE-Main_(S1)_090120]**



(1) 2 (2) 1 (3) $\frac{1}{2}$ (4) $\frac{3}{2}$

8. A uniformly thick wheel with moment of inertia I and radius R is free to rotate about its centre of mass (see fig.), A massless string is warapped over its rim and two blocks of masses m_1 and m_2 ($m_1 > m_2$) are attached to the ends of the string. The system is released from rest. The angular speed of the wheel when m_1 descents by a distance h is **[JEE-Main_(S2)_090120]**



(1) $\left[\frac{(m_1 - m_2)}{(m_1 + m_2)R^2 + I}\right]^{\frac{1}{2}} gh$ (2) $\left[\frac{2(m_1 - m_2)gh}{(m_1 + m_2)R^2 + I}\right]^{\frac{1}{2}}$

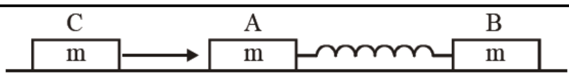
(3) $\left[\frac{m_1 - m_2}{(m_1 + m_2)R^2 + I}\right]^{\frac{1}{2}} gh$ (4) $\left[\frac{2(m_1 - m_2)gh}{(m_1 + m_2)R^2 + I}\right]^{\frac{1}{2}}$

9. If the potential energy between two molecules is given by $U = \frac{A}{r^6} + \frac{B}{r^{12}}$, then at equilibrium, separation between molecules, and the potential energy are **[JEE-Main_(S1) _060920]**

(1) $\left(\frac{2B}{A}\right)^{\frac{1}{6}}, -\frac{A^2}{2B}$ (2) $\left(\frac{B}{2A}\right)^{\frac{1}{6}}, -\frac{A^2}{2B}$ (3) $\left(\frac{2B}{A}\right)^{\frac{1}{6}}, -\frac{A^2}{4B}$ (4) $\left(\frac{B}{A}\right)^{\frac{1}{6}}, 0$

10. Two identical blocks A and B each of mass m resting on the smooth horizontal floor are connected by a light spring of natural length L and spring constant K. A third block C of mass m moving with a speed v along the line joining A and B collides with A. The maximum compression in the spring is

[JEE MAIN_{S2}_170321]



(1) $v\sqrt{\frac{M}{2K}}$ (2) $\sqrt{\frac{mv}{2K}}$ (3) $\sqrt{\frac{mv}{K}}$ (4) $\sqrt{\frac{m}{2K}}$

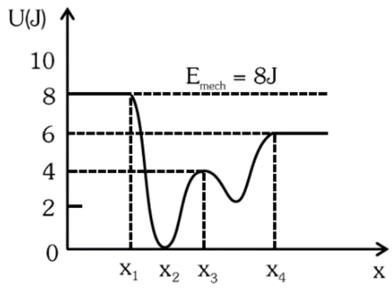
11. If the Kinetic energy of a moving body becomes four times its initial Kinetic energy, then the percentage change in its momentum will be: **[JEE Main_{S2}_200721]**

(1) 100% (2) 200% (3) 300% (4) 400%

12. A person pushes a box on a rough horizontal platform surface. He applies a force of 200 N over a distance of 15 m. Thereafter, he gets progressively tired and his applied force reduces linearly with distance to 100 N. The total distance through which the box has been moved is 30 m. What is the work done by the person during the total movement of the box? **[JEE-Main_{S2}_040920]**

(1) 5690 J (2) 3280 J (3) 5250 J (4) 2780 J

13. Given below is the plot of a potential energy function U (x) for a system, in which a particle is in one dimensional motion, while a conservative force F(x) acts on it. Suppose that E_{mech} = 8 J, the incorrect statement for this system is : **[JEE MAIN_{S2}_270721]**



[where K.E. = kinetic energy]

(1) at $x > x_4$, K.E. is constant throughout the region.

(2) at $x < x_1$, K.E. is smallest and the particle is moving at the slowest speed.

(3) at $x = x_2$, K.E. is greatest and the particle is moving at the fastest speed.

(4) at $x = x_3$ K.E. = 4 J

14. An automobile of mass 'm' accelerates starting from origin and initially at rest, while the engine supplies constant power P. The position is given as a function of time by :

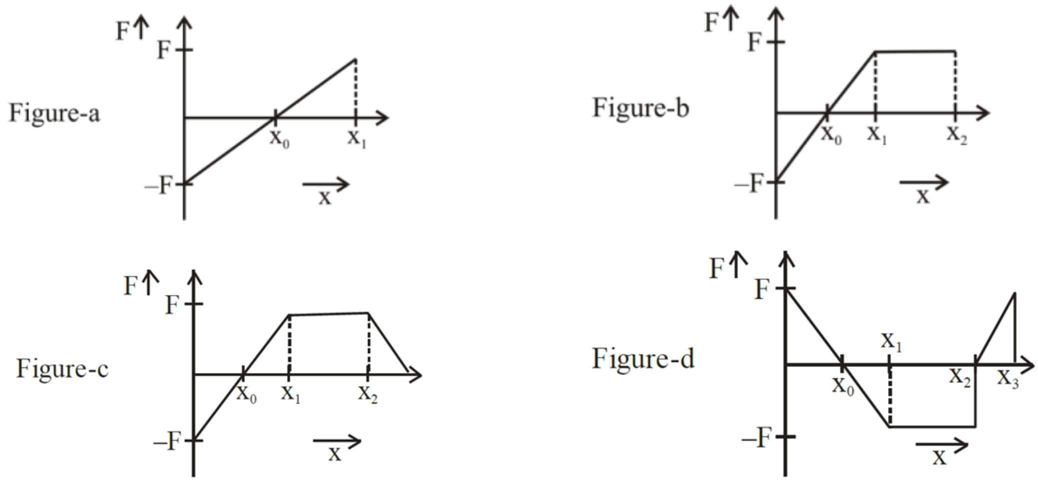
[JEE MAIN _{S2}_270721]

(1) $\left(\frac{9P}{8m}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ (2) $\left(\frac{8P}{9m}\right)^{\frac{1}{2}} t^{\frac{2}{3}}$ (3) $\left(\frac{9m}{8P}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ (4) $\left(\frac{8P}{9m}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$

15. A particle experiences a variable force $\vec{F} = (4x\hat{i} + 3y^2\hat{j})$ in a horizontal x-y plane. Assume distance in meters and force is newton. If the particle moves from point (1, 2) to point (2, 3) in the x-y plane, the Kinetic Energy changes by **[JEE Main_{S1}_240622]**

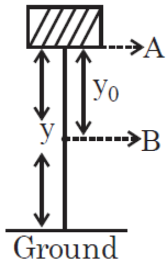
(1) 50.0 J (2) 12.5 J (3) 25.0 J (4) 0 J

16. Arrange the four graphs in descending order of total work done; where W_1, W_2, W_3 and W_4 are the work done corresponding to figure a, b, c and d respectively. **[JEE Main_{S2}_260622]**



(1) $W_3 > W_2 > W_1 > W_4$
(2) $W_3 > W_2 > W_4 > W_1$
(3) $W_2 > W_3 > W_4 > W_1$
(4) $W_2 > W_3 > W_1 > W_4$

17. In the given figure, the block of mass m is dropped from the point 'A'. The expression for kinetic energy of block when it reaches point 'B' is : **[JEE Main_{S2}_290622]**



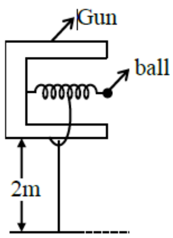
(1) $\frac{1}{2}mgy_0^2$
(2) $\frac{1}{2}mgy^2$
(3) $mg(y - y_0)$
(4) mgy_0

18. If momentum of a body is increased by 20%, then its kinetic energy increases by :

[JEE Main_{S2}_290722]

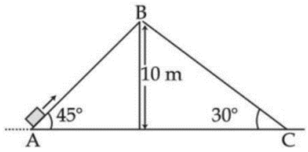
(1) 36%
(2) 40%
(3) 44%
(4) 48%

19. In a spring gun having spring constant 100 N/m a small ball 'B' of mass 100 g is put in its barrel (as shown in figure) by compressing the spring through 0.05 m. There should be a box placed at a distance 'd' on the ground so that the ball falls in it. If the ball leaves the gun horizontally at a height of 2 m above the ground. The value of d is _____ m. ($g = 10\ m/s^2$) **[JEE Main_{S1}_200721]**

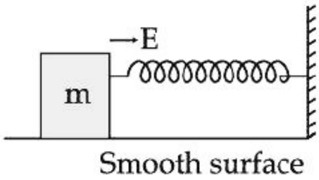


20. Two inclined planes are placed as shown in figure. A block is projected from the Point A of inclined plane AB along its surface with a velocity just sufficient to carry it to the top Point B at a height 10 m. After reaching the Point B the block solids down on inclined plane BC. Time it takes to reach to the point C from point A is $t(\sqrt{2}+1)s$. The value of t is..........(use $g = 10\ m/s^2$)

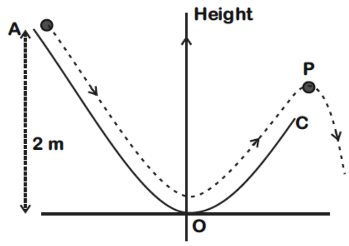
[JEE Main_{S2}_270722]



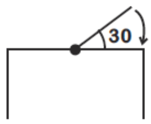
21. A block of mass 'm' (as shown in figure) moving with kinetic energy E compresses a spring through a distance 25 cm when, its speed is halved. The value of spring constant of used spring will be nE Nm^{-1} for n = ________________. **[JEE Main_{S1}_280722]**



22. A particle (m = 1 kg) slides down a frictionless track (AOC) starting from rest at a point A (height 2 m). After reaching C, the particle continues to move freely in air as a projectile. When it reaching its highest point P (height 1 m), the kinetic energy of the particle (in J) is : (figure drawn is schematic and not to scale; take g = 10 ms^{-2}) **[JEE-Main_(S1)_070120]**



23. One end of a straight uniform 1 m long bar is pivoted on horizontal table. It is released from rest when it makes an angle 30° from the horizontal (see figure). Its angular speed when it hits the table is given as $\sqrt{n}\,s^{-1}$, where n is an integer. The value of n is ______ **[JEE-Main_(S1)_090120]**



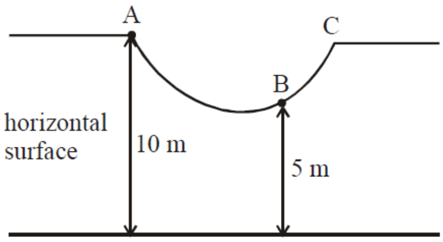
24. A block starts moving up an inclined plane of inclination 30° with an initial velocity of v_0. It comes back to its initial position with velocity $\frac{v_0}{2}$. The value of the coefficient of kinetic friction between the block and the inclined plane is close to $\frac{I}{1000}$. The nearest integer to I is _______.

[JEE-Main_(S2) _030920]

25. A body of mass 2 kg is driven by an engine delivering a constant power of 1 J/s. The body starts from rest and moves in a straight line. After 9 seconds, the body has moved a distance (in m) _______.

[JEE-Main_(S2) _050920]

26. As shown in the figure, a particle of mass 10 kg is placed at a point A. When the particle is slightly displaced to its right, it starts moving and reaches the point B. The speed of the particle at B is x m/s. (Take g = 10 m/s^2) The value of 'x' to the nearest integer is_____. **[JEE MAIN _{S1}_180321]**



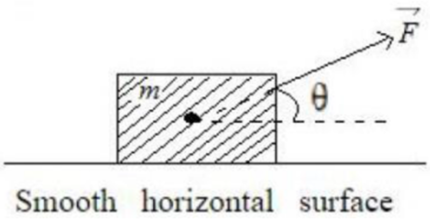
27. A pendulum bob has a speed of 3 m/s at its lowest position. The pendulum is 50 cm long. The speed of bob, when the length makes an angle of 60º to the vertical will be ($g = 10\ m/s^2$) _____m/s.

[JEE Main {S1}_250721]

28. A uniform chain of length 3 meter and mass 3 kg overhangs a smooth table with 2 meter laying on the table. If k is the kinetic energy of the chain in joule as it completely slips off the table, then the value of k is .... (Take $g = 10\ m/s^2$) **[JEE MAIN_{S1}_260821]**

29. A ball of mass 100 g is dropped from a height h = 10 cm on a platform fixed at the top of vertical spring (as shown in figure). The ball stays on the platform and the platform is depressed by a distance $\frac{h}{2}$. The spring constant is ________ Nm^{-1}. (Use $g = 10\ ms^{-2}$) **[JEE Main_{S1}_240622]**

30. An object of mass 'm' initially at rest on a smooth horizontal plane starts moving under the action of force F = 2N. In the process of its linear motion, the angle θ (as shown in figure) between the direction of force and horizontal varies as $\theta = kx$, where k is a constant and x is the distance covered by the object from its initial position. The expression of kinetic energy of the object will be $E = \frac{n}{k}\sin\theta$. The value of n is___. **[JEE Main_{S1}_250123]**



ANSWER KEY

1.	(1)	2	(1)	3.	(3)	4.	(4)	5.	(3)	6.	(4)	7.	(2)
8.	(2)	9.	(3)	10.	(1)	11.	(1)	12.	(3)	13.	(2)	14.	(4)
15.	(3)	16.	(1)	17.	(4)	18.	(3)	19.	1	20.	2	21.	24
22.	10.00	23.	15	24.	346	25.	18.00	26.	10	27.	2	28.	40
29.	120	30.	2										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- CENTRE OF MASS

(Important Questions Only)

1. It is found that if a neutron surffers an elastic collinear collision with deuterium at rest, fractional loss of its energy is p_d, while for its similar collision with carbon nucleus at rest, fractional loss of energy is p_c. The values of p_d and p_c are respectively: **[JEE MAIN_08042018]**

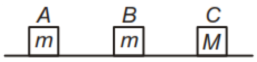
(1) (0, 0) (2) (0, 1) (3) (.89, .28) (4) (.28, .89)

2. The mass of a hydrogen molecule is 3.32×10^{-27} kg. If 10^{23} hydrogen molecules strike, per second a fixed wall of area 2 cm^2 at an angle of 45° to the normal, and rebound elastically with a speed of 10^3 m/s then the pressure on the wall is nearly : **[JEE MAIN_08042018]**

(1) 2.35×10^2 N/m^2 (2) 4.70×10^2 N/m^2 (3) 2.35×10^3 N/m^2 (4) 4.70×10^3 N/m^2

3. Three blocks A, B and C are lying on a smooth horizontal surface, as shown in the figure. A and B have equal masses, *m* while C has mass M. Block A is given an initial speed v towards B due to which it collides with B perfectly inelastically. The combined mass collides with C, also perfectly inelastically $\frac{5}{6}$ th of the initial kinetic energy is lost in whole process. What is value of M/m?

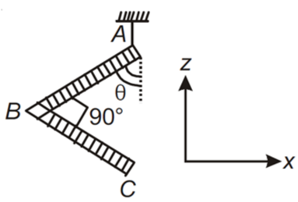
[JEE MAIN_{S1}_090119]



(1) 3 (2) 4 (3) 2 (4) 5

4. An L- shaped object, made of thin rods of uniform mass density, is suspended with a string as shown in figure. If AB = BC, and the angle made by AB with downward vertical is θ, then

[JEE MAIN_{S1}_090119]

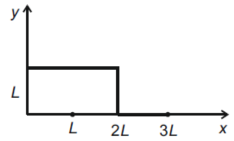


(1) $\tan\theta = \frac{1}{2}$ (2) $\tan\theta = \frac{2}{\sqrt{3}}$ (3) $\tan\theta = \frac{1}{3}$ (4) $\tan\theta = \frac{1}{2\sqrt{3}}$

5. A piece of wood of mass 0.03 kg is dropped from the top of a 100 m height building. At the same time, a bullet of mass 0.02 kg is fired vertically upwards, with a velocity 100 ms^{-1}, from the ground. The bullet gets embedded in the wood. Then the maximum height to which the combined system reaches above the top of the building before falling below is (g = 10 ms^{-2}) **[JEE MAIN_{S1}_100119]**

(1) 30 m (2) 40 m (3) 20 m (4) 10 m

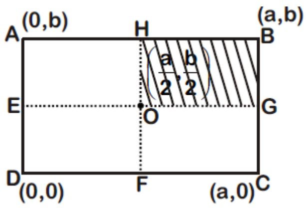
6. The position vector of the centre of mass $\vec{r}_{cm}$ of an asymmetric uniform bar of negligible area of cross-section as shown in figure is **[JEE MAIN_{S1}_120119]**



(1) $\vec{r}_{cm} = \frac{5}{8}L\hat{x} + \frac{13}{8}L\hat{y}$ (2) $\vec{r}_{cm} = \frac{3}{8}L\hat{x} + \frac{11}{8}L\hat{y}$

(3) $\vec{r}_{cm} = \frac{13}{8}L\hat{x} + \frac{5}{8}L\hat{y}$ (4) $\vec{r}_{cm} = \frac{11}{8}L\hat{x} + \frac{3}{8}L\hat{y}$

7. A uniform rectangular thin sheet ABCD of mass M has length a and breath b, as shown in the figure. If the shaded portion HBGO is cut-off, the coordinates of the centre of mass of the remaining portion will be: **[JEE-Main_{S2}_080419**



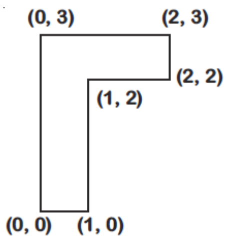
(1) $\left(\frac{2a}{3}, \frac{2b}{3}\right)$ (2) $\left(\frac{5a}{12}, \frac{5b}{12}\right)$ (3) $\left(\frac{3a}{4}, \frac{3b}{4}\right)$ (4) $\left(\frac{5a}{3}, \frac{5b}{3}\right)$

8. A particle of mass 'm' is moving with speed '2v' and collides with a mass '2m' moving with speed 'v' in the same direction. After collision, the first mass is stopped completely while the second one splits into two particles each of mass 'm', which move at angle 45° with respect to the original direction.

The speed of each of the moving particle will be **[JEE-Main_{S2}_090419]**

(1) $v/(2\sqrt{2})$ (2) $v/\sqrt{2}$ (3) $\sqrt{2}v$ (4) $2\sqrt{2}v$

9. The coordinates of centre of mass of a uniform flag shaped lamina (thin flat plate) of mass 4 kg. (The coordinates of the same are shown in figure) are **(JEE-Main_(S1)_080120]**

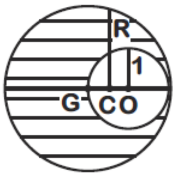


(1) (0.75 m, 1.75 m) (2) (1.25 m, 1.50 m) (3) (1 m, 1.75 m) (4) (0.75 m, 0.75 m)

10. A particle of mass m is dropped from a height h above the ground. At the same time another particle of the same mass is thrown vertically upwards from the ground with a speed of $\sqrt{2gh}$. If they collide head-on completely inelastically, the time taken for the combined mass to reach the ground, in units of $\sqrt{\frac{h}{g}}$ is **[JEE-Main_(S2) _080120]**

(1) $\sqrt{\frac{1}{2}}$ (2) $\sqrt{\frac{3}{4}}$ (3) $\frac{1}{2}$ (4) $\sqrt{\frac{3}{2}}$

11. As shown in fig. when a spherical cavity (centred at O) of radius 1 is cut out of a uniform sphere of radius R (centred at C), the centre of mass of remaining (shaded) part of sphere is at G, i.e. on the surface of the cavity. R can be determined by the equation **[JEE-Main_(S2)_080120]**



(1) $(R^2 + R + 1)(2 - R) = 1$ (2) $(R^2 - R + 1)(2 - R) = 1$

(3) $(R^2 - R - 1)(2 - R) = 1$ (4) $(R^2 + R - 1)(2 - R) = 1$

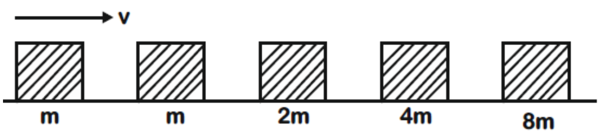
12. A rod of length L has non-uniform linear mass density given by $\rho(x) = a + b\left(\frac{x}{L}\right)^2$, where a and b are constants and $0 \le x \le L$. The value of x for the centre of mass of the rod is at **[JEE-Main_(S2) _090120]**

(1) $\frac{3}{2}\left(\frac{a+b}{2a+b}\right)L$ (2) $\frac{4}{3}\left(\frac{a+b}{2a+3b}\right)L$ (3) $\frac{3}{2}\left(\frac{2a+b}{3a+b}\right)L$ (4) $\frac{3}{4}\left(\frac{2a+b}{3a+b}\right)L$

13. A particle of mass m is projected with a speed u from the ground at an angle $\theta = \pi/3$ w.r.t. horizontal (x-axis). When it has reached its maximum height, it collides completely inelastically with another particle of the same mass and velocity $u\hat{i}$. The horizontal distance covered by the combined mass before reaching the ground is **[JEE-Main_(S2) _090120]**

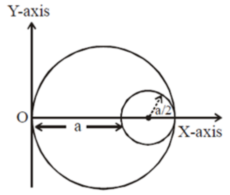
(1) $\frac{5}{8}\frac{u^2}{g}$ (2) $\frac{3\sqrt{2}}{4}\frac{u^2}{g}$ (3) $\frac{3\sqrt{3}}{8}\frac{u^2}{g}$ (4) $2\sqrt{2}\frac{u^2}{g}$

14. Blocks of masses m, 2m, 4m and 8m are arranged in a line on a frictionless floor. Another block of mass m, moving with speed v along the same line (see figure) collides with mass m in perfectly inelastic manner. All the subsequent collisions are also perfectly inelastic. By the time the last block of mass 8 m starts moving the total energy loss is p% of the original energy. Value of 'p' is close to **[JEE-Main_(S1) _040920]**



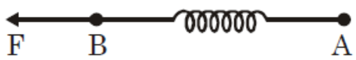
(1) 37 (2) 77 (3) 87 (4) 94

15. A circular hole of radius $\left(\frac{a}{2}\right)$ is cut out of a circular disc of radius 'a' as shown in figure. The centroid of the remaining circular portion with respect to point 'O' will be : **[JEE-Main_{S2}_240221]**



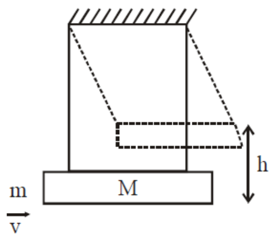
(1) $\frac{1}{6}a$ (2) $\frac{10}{11}a$ (3) $\frac{5}{6}a$ (4) $\frac{2}{3}a$

16. Two masses A and B, each of mass M are fixed together by a massless spring. A force acts on the mass B as shown in figure. If the mass A starts moving away from mass B with acceleration 'a', then the acceleration of mass B wil be :- **[JEE MAIN_{S2}_260221]**



(1) $\frac{Ma-F}{M}$ (2) $\frac{MF}{F+Ma}$ (3) $\frac{F+Ma}{M}$ (4) $\frac{F-Ma}{M}$

17. A large block of wood of mass M = 5.99 kg is hanging from two long massless cords. A bullet of mass m = 10g is fired into the block and gets embedded in it. The (block + bullet) then swing upwards, their centre of mass rising a vertical distance h = 9.8 cm before the (block + bullet) pendulum comes momentarily to rest at the end of its arc. The speed of the bullet just before collision is : (Take g = 9.8 ms^{-2}) **[JEE MAIN _{S2}160321]**



(1) 841.4 m/s (2) 811.4 m/s (3) 831.4 m/s (4) 821.4 m/s

18. A rubber ball is released from a height of 5 m above the floor. It bounces back repeatedly, always rising to 81/100 of the height through which it falls. Find the average speed of the ball. (Take g = 10 ms^{-2}) **[JEE MAIN _{S2}_170321]**

(1) 3.0 ms^{-1} (2) 3.50 ms^{-1} (3) 2.0 ms^{-1} (4) 2.50 ms^{-1}

19. A bullet of '4g' mass is fired from a gun of mass 4 kg. If the bullet moves with the muzzle speed of 50 ms^{-1}, the impulse imparted to the gun and velocity of recoil of gun are : **[JEE MAIN_{S2}_220721]**

(1) 0.4 kg ms^{-1}, 0.1 ms^{-1} (2) 0.2 kg ms^{-1}, 0.05 ms^{-1}
(3) 0.2 kg ms^{-1}, 0.1 ms^{-1} (4) 0.4 kg ms^{-1}, 0.05 ms^{-1}

20. The initial mass of a rocket is 1000 kg. Calculate at what rate the fuel should be burnt so that the rocket is given an acceleration of 20 ms^{-2}. The gases come out at a relative speed of 500 ms^{-1} with respect to the rocket :[Use g = 10 m/s^2] **[JEE MAIN_{S1}_260821]**

(1) 6.0×10^2 kg s^{-1} (2) 500 kg s^{-1} (3) 10 kg s^{-1} (4) 60 kg s^{-1}

21. Two blocks of masses 10 kg and 30 kg are placed on the same straight line with coordinates (0, 0) cm and (x, 0) cm respectively. The block of 10 kg is moved on the same line through a distance of 6 cm towards the other block. The distance through which the block of 30 kg must be moved to keep the position of centre of mass of the system unchanged is : **[JEE Main_{S1}_270622]**

(1) 4 cm towards the 10 kg block (2) 2 cm away from the 10 kg block

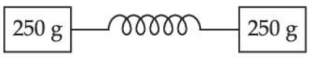
(3) 2 cm towards the 10 kg block (4) 4 cm away from the 10 kg block

22. What percentage of kinetic energy of a moving particle is transferred to a stationary particle when it strikes the stationary particle of 5 times its mass? **[JEE Main_{S1}_270622]**

(Assume the collision to be head-on elastic collision)

(1) 50.0% (2) 66.6% (3) 55.5% (4) 33.3%

23. As per the given figure, two blocks each of mass 250g are connected to a spring of spring constant 2Nm^{-1}. If both are given velocity v in opposite directions, then maximum elongation of the spring is : **[JEE Main_{S1}_260722]**



(1) $\frac{v}{2\sqrt{2}}$ (2) $\frac{v}{2}$ (3) $\frac{v}{4}$ (4) $\frac{v}{\sqrt{2}}$

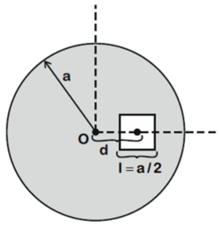
24. A machine gun of mass 10 kg fires 20 g bullets at the rate of 180 bullets per minute with a speed of 100 m s^{-1} each. The recoil velocity of the gun is : **[JEE Main_{S2}_300123]**

(1) 0.02 m/s (2) 2.5 m/s (3) 1.5 m/s (4) 0.6 m/s

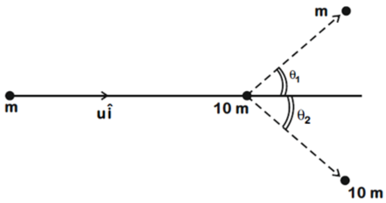
25. A body A, of mass m = 0.1 kg has an initial velocity of $3\hat{i}$ ms^{-1}. It collides elastically with another body, B of the same mass which has an initial velocity of $5\hat{j}$ ms^{-1}. After collision, A moves with a velocity $\vec{v} = 4(\hat{i} + \hat{j})$. The energy of B after collision is written as $\frac{x}{10}$J. The value of x is ________.

[JEE-Main_(S1) _080120]

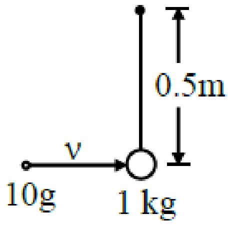
26. A square shaped hole of side $l = \frac{a}{2}$ is carved out at a distance $d = \frac{a}{2}$ from the centre 'O' of a uniform circular disk of radius a. If the distance of the centre of mass of the remaining portion from O is $-\frac{a}{X}$, value of X (to the nearest integer) is_______. **[JEE-Main_{S2}_020920]**



27. A particle of mass m is moving along the x-axis with initial velocity $u\hat{i}$. It collides elastically with a particle of mass 10 m at rest and then moves with half its initial kinetic energy (see figure). If $\sin\theta_1 = \sqrt{n}\sin\theta_2$ then value of n is __________. **[JEE-Main_{S2}_020920]**



28. A bullet of 10 g, moving with velocity v, collides head-on with the stationary bob of a pendulum and recoils with velocity 100 m/s. The length of the pendulum is 0.5 m and mass of the bob is 1 kg. The minimum value of ν = ______ m/s so that the pendulum describes a circle. (Assume the string to be inextensible and g = 10 m/s^2) **[JEE MAIN_{S2}_270821]**



29. Three identical spheres each of mass M are placed at the corners of a right angled triangle with mutually perpendicular sides equal to 3 m each. Taking point of intersection of mutually perpendicular sides as origin, the magnitude of position vector of centre of mass of the system will be x m. The value of x is **[JEE Main_{S2}_250722]**

30. A body of mass 1 kg collides head on elastically with a stationary body of mass 3 kg. After collision, the smaller body reverses its direction of motion and moves with a speed of 2m/s. The initial speed of the smaller body before collision is ________ ms^{-1}. **[JEE Main_{S2}_250123]**

ANSWER KEY

1.	(3)	2.	(3)	3.	(2)	4.	(3)	5.	(2)	6.	(3)	7.	(2)
8.	(4)	9.	(1)	10.	(4)	11.	(1)	12.	(4)	13.	(3)	14.	(4)
15.	(3)	16.	(4)	17.	(3)	18.	(4)	19.	(2)	20.	4	21.	(3)
22.	(3)	23.	(2)	24.	(4)	25.	01	26.	23	27.	10	28.	400
29.	2	30.	4										

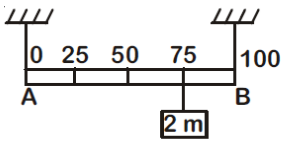
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- RIGID BODY DYNAMIC (ROTATIONAL DYNAMICS)

(Important Questions Only)

1.



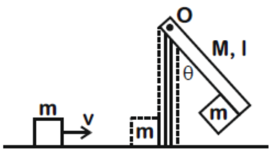
[JEE-Main_(S1) _020920]

Shown in the figure is rigid and uniform one meter long rod AB held in horizontal position by two strings tied to its ends and attached to the ceiling. The rod is of mass 'm' and has another weight of mass 2 m hung at a distance of 75 cm from A. The tension in the string at A is

(1) 0.5 mg (2) 2 mg (3) 0.75 mg (4) 1 mg

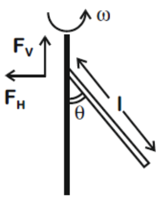
2. A block of mass m = 1 kg slides with velocity v = 6 m/s on a frictionless horizontal surface and collides with a uniform vertical rod and sticks to it as shown. The rod is pivoted about O and swings as a result of the collision making angle θ before momentarily coming to rest. If the rod has mass M = 2 kg and length l = 1 m, the value of θ is approximately (take g = 10 m/s^2)

[JEE-Main_(S1) _030920]



(1) 49° (2) 55° (3) 63° (4) 69°

3.

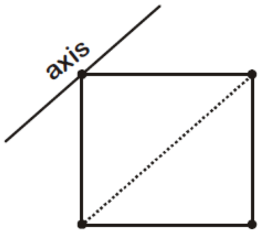


A uniform rod of length 'l' is pivoted at one of its ends on a vertical shaft of negligible radius. When the shaft rotates at angular speed ω the rod makes an angle θ with it (see figure). To find θ equate the rate of change of angular momentum (direction going into the paper) $\frac{ml^2}{12}\omega^2\sin\theta\cos\theta$ about the centre of mass (CM) to the torque provided by the horizontal and vertical forces F_H and F_V about the CM. The value of θ is then such that **[JEE-Main_(S2) _030920]**

(1) $\cos\theta = \frac{g}{l\omega^2}$ (2) $\cos\theta = \frac{2g}{3l\omega^2}$ (3) $\cos\theta = \frac{g}{2l\omega^2}$ (4) $\cos\theta = \frac{3g}{2l\omega^2}$

4. Four point masses, each of mass m, are fixed at the corners of a square of side ℓ. The square is rotating with angular frequency ω, about an axis passing through one of the corners of the square and parallel to its diagonal, as shown in the figure. The angular momentum of the square about this axis is

[JEE-Main_(S1) _060920]



(1) $3\,m\,\ell^2\omega$ (2) $4\,m\,\ell^2\omega$ (3) $m\,\ell^2\omega$ (4) $2\,m\,\ell^2\omega$

5. The linear mass density of a thin rod AB of length L varies from A to B as $\lambda(x)=\lambda_0\left(1+\frac{x}{L}\right)$, where x is the distance from A. If M is the mass of the rod then its moment of inertia about an axis passing through A and perpendicular to the rod is **[JEE-Main_(S2) 060920]**

(1) $\frac{2}{5}ML^2$ (2) $\frac{5}{12}ML^2$ (3) $\frac{3}{7}ML^2$ (4) $\frac{7}{18}ML^2$

6. Moment of inertia (M.I.) of four bodies, having same mass and radius, are reported as ;

I_1 = M.I. of thin circular ring about its diameter. **[JEE-Main_{S1}_240221]**

I_2 = M.I. of circular disc about an axis

perpendicular to the disc and going through the centre,

I_3 = M.I. of solid cylinder about its axis and

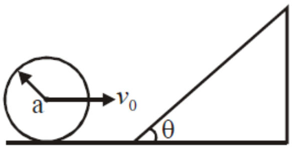
I_4 = M.I. of solid sphere about its diameter.

Then :

(1) $I_1 + I_3 < I_2 + I_4$ (2) $I_1 + I_2 = I_3 + \frac{5}{2}I_4$

(3) $I_1 = I_2 = I_3 > I_4$ (4) $I_1 = I_2 = I_3 < I_4$

7. A sphere of radius 'a' and mass 'm' rolls along a horizontal plane with constant speed v_0. It encounters an inclined plane at angle θ and climbs upward. Assuming that it rolls without slipping, how far up the sphere will travel ? **[JEE-(Main)_{S2}_250221]**



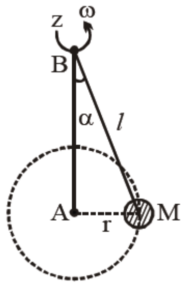
(1) $\frac{10v_0^2}{7g\sin\theta}$ (2) $\frac{v_0^2}{5g\sin\theta}$ (3) $\frac{7}{10}\frac{v^2}{g}$ (4) $\frac{v_0^2}{2g\sin\theta}$

8. A cord is wound round the circumference of wheel of radius r. The axis of the wheel is horizontal and the moment of inertia about it is I. A weight mg is attached to the cord at the end. The weight falls from rest. After falling through a distance 'h', the square of angular velocity of wheel will be :-

[JEE MAIN_{S2}_260221]

(1) $\frac{2mgh}{I+2mr^2}$ (2) $\frac{2mgh}{I+mr^2}$ (3) 2 gh (4) $\frac{2gh}{I+mr^2}$

9 A mass M hangs on a massless rod of length *l* which rotates at a constant angular frequency. The mass M moves with steady speed in a circular path of constant radius. Assume that the system is in steady circular motion with constant angular velocity ω. The angular momentum of M about point A is L_A which lies in the positive z direction and the angular momentum of M about B is L_B. The correct statement for this system is : **[JEE MAIN_{S1}_170321]**



(1) L_A and L_B are both constant in magnitude and direction
(2) L_B is constant in direction with varying magnitude
(3) L_B is constant, both in magnitude and direction
(4) L_A is constant, both in magnitude and direction

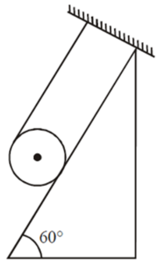
10. Consider a uniform wire of mass M and length L. It is bent into a semicircle. Its moment of inertia about a line perpendicular to the plane of the wire passing through the centre is :

[JEE MAIN_{S1}_180321]

(1) $\frac{1}{4}\frac{ML^2}{\pi^2}$ (2) $\frac{2}{5}\frac{ML^2}{\pi^2}$ (3) $\frac{ML^2}{\pi^2}$ (4) $\frac{1}{2}\frac{ML^2}{\pi^2}$

11. A solid cylinder of mass m is wrapped with an inextensible light string and, is placed on a rough inclined plane as shown in the figure. The frictional force acting between the cylinder and the inclined plane is :

[JEE MAIN _{S1}_180321]



[The coefficient of static friction, μ_s, is 0.4]

(1) $\frac{7}{2}mg$ (2) 5 mg (3) $\frac{mg}{5}$ (4) 0

12. Two discs have moments of intertia I_1 and I_2 about their respective axes perpendicular to the plane and passing through the centre. They are rotating with angular speeds, ω_1 and ω_2 respectively and are brought into contact face to face with their axes of rotation coaxial. The loss in kinetic energy of the system in the process is given by : **[JEE MAIN_{S2}_270821]**

(1) $\frac{I_1I_2}{(I_1+I_2)}(\omega_1-\omega_2)^2$ (2) $\frac{(I_1-I_2)^2\omega_1\omega_2}{2(I_1+I_2)}$ (3) $\frac{I_1I_2}{2(I_1+I_2)}(\omega_1-\omega_2)^2$ (4) $\frac{(\omega_1-\omega_2)^2}{2(I_1+I_2)}$

13. Solid spherical ball is rolling on a frictionless horizontal plane surface about its axis of symmetry. The ratio of rotational kinetic energy of the ball to its total kinetic energy is :- **[JEE Main_{S2}_260622]**

(1) $\frac{2}{5}$ (2) $\frac{2}{7}$ (3) $\frac{1}{5}$ (4) $\frac{7}{10}$

14. Match List-I with List-II **[JEE Main_{S1}_280622]**

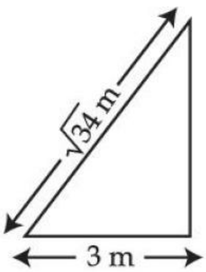
	List-I		List-II
A	Moment of inertia of solid sphere of radius R about any tangent	I	$\frac{5}{3}MR^2$
B	Moment of inertia of hollow sphere of radius (R) about any tangent	II	$\frac{7}{5}MR^2$
C	Moment of inertia of circular ring of radius (R) about its diameter.	III	$\frac{1}{4}MR^2$
D	Moment of inertia of circular disc of radius (R) about any diameter.	IV	$\frac{1}{2}MR^2$

Question: Choose the correct answer from the options given below

(1) A-II, B-I, C-IV, D-III (2) A-I, B-II, C-IV, D-III

(3) A-II, B-I, C-III, D-IV (4) A-I, B-II, C-III, D-IV

15. A $\sqrt{34}$ m long ladder weighing 10 kg leans on a frictionless wall. Its feet rest on the floor 3 m away from the wall as shown in the figure. If F_f and F_w are the reaction forces of the floor and the wall, then ratio of F_w/F_f will be: (Use g = 10 m/s²) **[JEE Main_{S2}_280622]**



(1) $\frac{6}{\sqrt{110}}$ (2) $\frac{3}{\sqrt{113}}$ (3) $\frac{3}{\sqrt{109}}$ (4) $\frac{2}{\sqrt{109}}$

16. A solid cylinder and a solid sphere, having same mass M and radius R, roll down the same inclined plane from top without slipping. They start from rest. The ratio of velocity of the solid cylinder to that of the solid sphere, with which they reach the ground, will be : **[JEE Main_{S1}_250722]**

(1) $\sqrt{\frac{5}{3}}$ (2) $\sqrt{\frac{4}{5}}$ (3) $\sqrt{\frac{3}{5}}$ (4) $\sqrt{\frac{14}{15}}$

17. A uniform thin bar of mass 6 kg and length 2.4 meter is bent to make an equilateral hexagon. The moment of inertia about an axis passing through the centre of mass and perpendicular to the plane of hexagon is ____ $\times 10^{-1}$ kg m^2. **[JEE-Main_{S2}_240221]**

18. A circular disc reaches from top to bottom of an inclined plane of length 'L'. When it slips down the plane, it takes time 't_1'. When it rolls down the plane, it takes time t_2. The value of $\frac{t_2}{t_1}$ is $\sqrt{\frac{3}{x}}$. The value of x will be _______. **[JEE Main_{S1}_200721]**

19. A rod of mass M and length L is lying on a horizontal frictionless surface. A particle of mass 'm' travelling along the surface hits at one end of the rod with a velocity 'u' in a direction perpendicular to the rod. The collision is completely elastic. After collision, particle comes to rest. The ratio of masses $\left(\frac{m}{M}\right)$ is $\frac{1}{x}$. The value of 'x' will be _______. **[JEE Main_{S1}_200721]**

20. Two bodies, a ring and a solid cylinder of same material are rolling down without slipping an inclined plane. The radii of the bodies are same. The ratio of velocity of the centre of mass at the bottom of the inclined plane of the ring to that of the cylinder is $\frac{\sqrt{x}}{2}$. Then, the value of x is ______. **[JEE Main_{S1}_200721]**

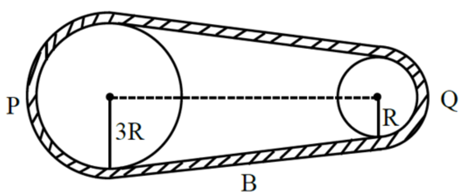
21. A particle of mass 'm' is moving in time 't' on a trajectory given by **[JEE Main_{S1}_250721]**

$\vec{r} = 10\alpha t^2\hat{i} + 5\beta(t-5)\hat{j}$

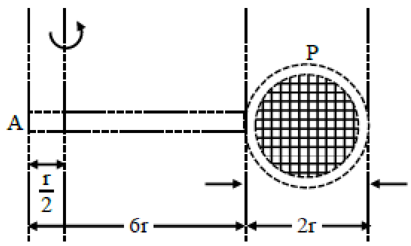
Where α and β are dimensional constants.

The angular momentum of the particle becomes the same as it was for t = 0 at time t = ________ seconds.

22. In the given figure, two wheels P and Q are connected by a belt B. The radius of P is three times as that of Q. In case of same rotational kinetic energy, the ratio of rotational inertias $\left(\frac{I_1}{I_2}\right)$ will be x : 1. The value of x will be ____. **[JEE MAIN _{S2}_270721]**



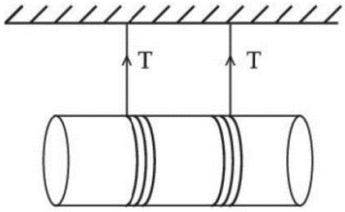
23. Consider a badminton racket with length scales as shown in the figure. **[JEE MAIN_{S1}_260821]**



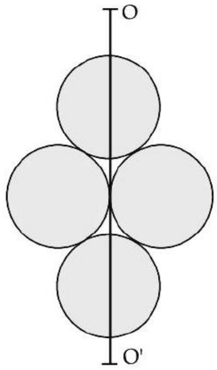
If the mass of the linear and circular portions of the badminton racket are same (M) and the mass of the threads are negligible, the moment of inertia of the racket about an axis perpendicular to the handle and in the plane of the ring at, $\frac{r}{2}$ distance from the end A of the handle will be .... Mr^2.

24. A pulley of radius 1.5 m is rotated about its axis by a force $F = (12\,t - 3t^2)$ N applied tangentially (while t is measured in seconds). If moment of inertia of the pulley about its axis of rotation is 4.5 kg m^2, the number of rotations made by the pulley before its direction of motion is reversed, will be $\frac{K}{\pi}$. The value of K is______. **[JEE Main_{S1}_270722]**

25. A solid cylinder length is suspended symmetrically through two massless strings, as shown in the figure. The distance from the initial rest position, the cylinder should by unbinding the strings to achieve a speed of 4 ms^{-1}, is ……….cm. (take g = 10 ms^{-2}) **[JEE Main_{S2}_270722]**



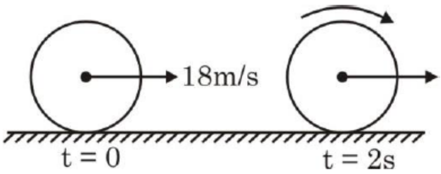
26. Four identical discs each of mass 'M' and diameter 'a' are arranged in a small plane as shown in figure. If the moment of inertia of the system about OO' is $\frac{x}{4}Ma^2$. Then, the value of x will be___________. **[JEE Main_{S1}_280722]**



27. A solid sphere of mass 1 kg rolls without slipping on a plane surface. Its kinetic energy is 7×10^{-3} J. The speed of the centre of mass of the sphere is______ cm s^{-1}. **[JEE MAIN_23_S1_310123]**

28. When two resistance R_1 and R_2 connected in series and introduced into the left gap of a meter bridge and a resistance of 10 Ω is introduced into the right gap, a null point is found at 60 cm from left side. When R_1 and R_2 are connected in parallel and introduced into the left gap, a resistance of 3 Ω is introduced into the right-gap to get null point at 40 cm from left end. The product of R_1 R_2 is _____ Ω^2 **[JEE Main_{S2}_290123]**

29. A uniform disc of mass 0.5 kg and radius r is projected with velocity 18 m/s at t = 0 s on a rough horizontal surface. It starts off with a purely sliding motion at t = 0 s. After 2s it acquires a purely rolling motion (see figure). The total kinetic energy of the disc after 2s will be _________ J (given, coefficient of friction is 0.3 and g = 10 m/s^2). **[JEE Main_{S2}_300123]**



30. A thin uniform rod of length 2m. cross sectional area 'A' and density 'd' is rotated about an axis passing through the centre and perpendicular to its length with angular velocity ω . If value of ω in terms of its rotational kinetic energy E is $\sqrt{\frac{\alpha E}{Ad}}$ then the value of α is _____.

[JEE Main_{S1}_300123]

ANSWER KEY

1.	(4)	2.	(3)	3.	(4)	4.	(1)	5.	(4)	6.	(3)	7.	(3)
8.	(2)	9	(4)	10.	(3)	11.	(3)	12.	(3)	13.	(2)	14.	(1)
15.	(3)	16.	(4)	17.	8	18.	2	19.	4	20.	3	21.	10
22.	9	23.	52	24.	18	25.	120	26.	3	27.	10	28.	30
29.	54	30.	3										

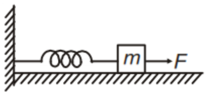
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- SIMPLE HARMONIC MOTION

(Important Questions Only)

1. A block of mass m, lying on a smooth horizontal surface, is attached to a spring (of negligible mass) of spring constant k. The other end of the spring is fixed, as shown in the figure. The block is initially at rest in its equilibrium position. If now the block is pulled with a constant force F, the maximum speed of the block is [JEE_MAIN_{S1}_090119]



(1) $\frac{F}{\pi\sqrt{mk}}$ (2) $\frac{\pi F}{\sqrt{mk}}$ (3) $\frac{2F}{\sqrt{mk}}$ (4) $\frac{F}{\sqrt{mk}}$

2. A rod of mass 'M' and length '2L' is suspended at its middle by a wire. It exhibits torsional oscillations; if two masses each of 'm' are attached at distance 'L/2' from its centre on both sides, it reduces the oscillation frequency by 20%. The value of ratio m/M is close to: [JEE_MAIN _{S1}_090119]

(1) 0.77 (2) 0.17 (3) 0.37 (4) 0.57

3. A particle executes simple harmonic motion with an amplitude of 5 cm. When the particle is at 4 cm from the mean position, the magnitude of its velocity in SI units is equal to that of its acceleration. Then, its periodic time in seconds is [JEE_MAIN_{S2}_100119]

(1) $\frac{4\pi}{3}$ (2) $\frac{3}{8}\pi$ (3) $\frac{8\pi}{3}$ (4) $\frac{7}{3}\pi$

4. A particle undergoing simple harmonic motion has time dependent displacement given by $x(t) = A\sin\frac{\pi t}{90}$

The ratio of kinetic to potential energy of this particle at t = 210 s will be [JEE_MAIN_{S1}_110119]

(1) 1 (2) 3 (3) 2 (4) $\frac{1}{3}$

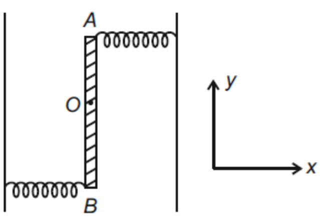
5. A simple pendulum of length 1 m is oscillating with an angular frequency 10 rad/s. The support of the pendulum starts oscillating up and down with a small angular frequency of 1 rad/s and an amplitude of 10^{-2} m. The relative change in the angular frequency of the pendulum is best given by

[JEE_MAIN_{S2}_110119]

(1) 10^{-3} rad/s (2) 10^{-1} rad/s (3) 10^{-5} rad/s (4) 1 rad/s

6. Two light identical springs of spring constant k are attached horizontally at the two ends of a uniform horizontal rod AB of length l and mass m. The rod is pivoted at its centre 'O' and can rotate freely in horizontal plane. The other ends of the two springs are fixed to rigid supports as shown in figure. The rod is gently pushed through a small angle and released. The frequency of resulting oscillation is

[JEE MAIN_{S1}_120119]



(1) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (2) $\frac{1}{2\pi}\sqrt{\frac{2k}{m}}$ (3) $\frac{1}{2\pi}\sqrt{\frac{3k}{m}}$ (4) $\frac{1}{2\pi}\sqrt{\frac{6k}{m}}$

7. A simple pendulum, made of a string of length l and a bob of mass m, is released from a small angle θ_0. It strikes a block of mass M, kept on a horizontal surface at its lowest point of oscillations, elastically. It bounces back and goes up to an angle θ_1. Then M is given by **[JEE MAIN_{S1}_120119]**

(1) $m\left(\frac{\theta_0+\theta_1}{\theta_0-\theta_1}\right)$ (2) $\frac{m}{2}\left(\frac{\theta_0-\theta_1}{\theta_0-\theta_1}\right)$ (3) $\frac{m}{2}\left(\frac{\theta_0+\theta_1}{\theta_0-\theta_1}\right)$ (4) $m\left(\frac{\theta_0-\theta_1}{\theta_0+\theta_1}\right)$

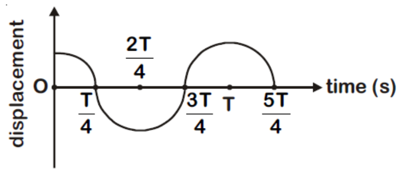
8. A damped harmonic oscillator has a frequency of 5 oscillations per second. The amplitude drops to half its value for every 10 oscillations. The time it will take to drop to $\frac{1}{1000}$ of the original amplitude is close to: **[JEE MAIN_{S2}_080419]**

(1) 100 s (2) 10 s (3) 50 s (4) 20 s

9. A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stopwatch with 1 s resolution measures the time taken for 40 oscillation to be 50 s. The accuracy in g is **[JEE MAIN_{S2}_080120]**

(1) 3.40% (2) 2.40% (3) 5.40% (4) 4.40%

10. The displacement time graph of a particle executing S.H.M is given in figure (sketch is schematic and not to scale) **[JEE MAIN_{S2}_020920]**



Which of the following statements is/are true for this motion?

(A) The force is zero at $t=\frac{3T}{4}$

(B) The acceleration is maximum at t = T

(C) The speed is maximum at $t=\frac{T}{4}$

(D) The P.E. is equal to K.E. of the oscillation at $t=\frac{T}{2}$

(1) (B), (C) and (D) (2) (A) and (D)

(3) (A), (B) and (C) (4) (A), (B) and (D)

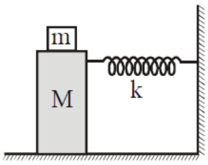
11. A ring is hung on a nail. It can oscillate, without slipping or sliding (i) in its plane with a time period T_1 and, (ii) back and forth in a direction perpendicular to its plane, with a period T_2. The ratio $\frac{T_1}{T_2}$ will be **[JEE-Main_{S2}_050920]**

(1) $\frac{1}{3}$ (2) $\frac{\sqrt{2}}{3}$ (3) $\frac{2}{3}$ (4) $\frac{3}{\sqrt{2}}$

12. When a particle of mass m is attached to a vertical spring of spring constant k and released, its motion is described by $y(t) = y_0 \sin^2 \omega t$, where 'y' is measured from the lower end of unstretched spring. Then ω is **[JEE-Main_{S2}_060920]**

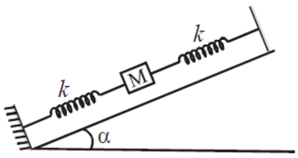
(1) $\sqrt{\frac{2g}{y_0}}$ (2) $\frac{1}{2}\sqrt{\frac{g}{y_0}}$ (3) $\sqrt{\frac{g}{2y_0}}$ (4) $\sqrt{\frac{g}{y_0}}$

13. In the given figure, a mass M is attached to a horizontal spring which is fixed on one side to a rigid support. The spring constant of the spring is k. The mass oscillates on a frictionless surface with time period T and amplitude A. When the mass is in equilibrium position, as shown in the figure, another mass m is gently fixed upon it. The new amplitude of oscillation will be : **[JEE-Main_{S1}}_240221]**



(1) $A\sqrt{\frac{M-m}{M}}$ (2) $A\sqrt{\frac{M}{M+m}}$ (3) $A\sqrt{\frac{M+m}{M}}$ (4) $A\sqrt{\frac{M}{M-m}}$

14. In the given figure, a body of mass M is held between two massless springs, on a smooth inclined plane. The free ends of the springs are attached to firm supports. If each spring has spring constant k, the frequency of oscillation of given body is : **[JEE-Main_{S2}_240221]**



(1) $\frac{1}{2\pi}\sqrt{\frac{k}{2M}}$ (2) $\frac{1}{2\pi}\sqrt{\frac{2k}{Mg \sin \alpha}}$ (3) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (4) $\frac{1}{2\pi}\sqrt{\frac{k}{Mg \sin \alpha}}$

15. $Y = A \sin(\omega t + \phi_0)$ is the time-displacement equation of a SHM. At t = 0 the displacement of the particle is $Y = \frac{A}{2}$ and it is moving along negative x-direction. Then the initial phase angle ϕ_0 will be :

[JEE MAIN_{S2}_250221]

(1) $\frac{\pi}{6}$ (2) $\frac{\pi}{3}$ (3) $\frac{5\pi}{6}$ (4) $\frac{2\pi}{3}$

16. A particle executes S.H.M., the graph of velocity as a function of displacement is :-

[JEE MAIN_{S2}_260221]

(1) A circle (2) A parabola (3) An ellipse (4) A helix

17. For what value of displacement the kinetic energy and potential energy of a simple harmonic oscillation become equal ? **[JEE MAIN _{S1}_170321]**

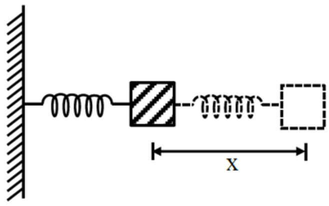
(1) x = 0 (2) $x = \pm A$ (3) $x = \pm\frac{A}{\sqrt{2}}$ (4) $x = \frac{A}{2}$

18. The time period of a pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$. The measured value of the length of pendulum is 10 cm known to a 1mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 second using a clock is 1s resolution. The percentage accuracy in the determination of 'g' using this pendulum is 'x'. The value of 'x' to the nearest integer is:– **[JEE MAIN_{S1}_180321]**

(1) 2% (2) 3% (3) 5% (4) 4%

19. The motion of a mass on a spring, with spring constant K is as shown in figure.

[JEE MAIN_{S2}_220721]



The equation of motion is given by x(t) = A sin ωt + B cos ωt with $\omega = \sqrt{\frac{K}{m}}$

Suppose that at time t = 0, the position of mass is x(0) and velocity v (0), then its displacement can also be represented as x (t) = C cos (ωt – ϕ), where C and ϕ are :

(1) $C = \sqrt{\frac{2v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

(2) $C = \sqrt{\frac{2v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{x(0)\omega}{2v(0)}\right)$

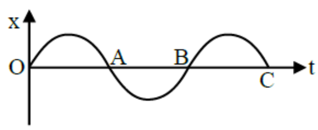
(3) $C = \sqrt{\frac{v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{x(0)\omega}{v(0)}\right)$

(4) $C = \sqrt{\frac{v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

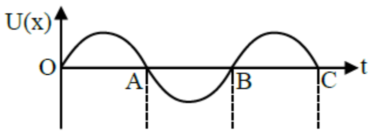
20. An object of mass 0.5 kg is executing simple harmonic motion. It amplitude is 5 cm and time period (T) is 0.2 s. What will be the potential energy of the object at an instant $t = \frac{T}{4}$s starting from mean position. Assume that the initial phase of the oscillation is zero. **[JEE MAIN_{S2}_270721]**

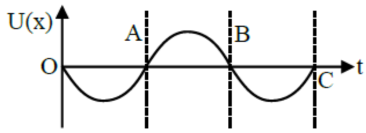
(1) 0.62 J (2) 6.2×10^{-3} J (3) 1.2×10^3 J (4) 6.2×10^3 J

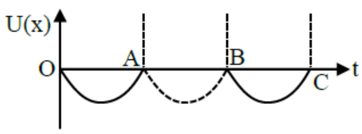
21. The variation of displacement with time of a particle executing free simple harmonic motion is shown in the figure. **[JEE MAIN_{S1}_270821]**

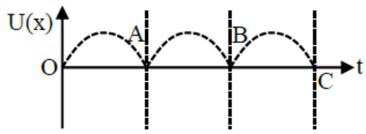


The potential energy U(x) versus time (t) plot of the particle is correctly shown in figure :

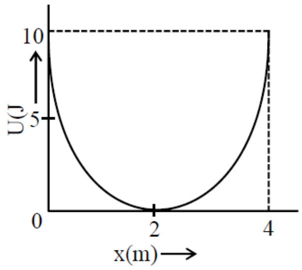
(1) 

(2) 

(3) 

(4) 

22. A mass of 5 kg is connected to a spring. The potential energy curve of the simple harmonic motion executed by the system is shown in the figure. A simple pendulum of length 4 m has the same period of oscillation as the spring system. What is the value of acceleration due to gravity on the planet where these experiments are performed? **[JEE MAIN_{S2}_010921]**



(1) 10 m/s² (2) 5 m/s² (3) 4 m/s² (4) 9.8 m/s²

23. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**. **[JEE MAIN_{S2}_240123]**

Assertion A: A pendulum clock when taken to Mount Everest becomes fast.

Reason R: The value of g (acceleration due to gravity) is less at Mount Everest than its value on the surface of earth.

In the light of the above statements, choose the most appropriate answer from the options given below

(1) Both A and R are correct but R is NOT the correct explanation of A

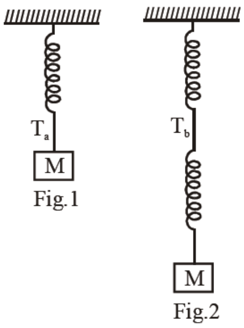
(2) Both A and R are correct and R is the correct explanation of A

(3) A is not correct but R is correct

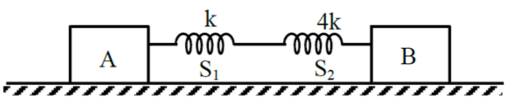
(4) A is correct but R is not correct

24. Consider two identical springs each of spring constant k and negligible mass compared to the mass M as shown. Fig.1 shows one of them and Fig.2 shows their series combination. The ratios of time period of oscillation of the two SHM is $\frac{T_b}{T_a} = \sqrt{x}$, where value of x is ______. **[JEE MAIN _{S1}_170321]**

(Round off to the Nearest Integer)



25. In the reported figure, two bodies A and B of masses 200 g and 800 g are attached with the system of springs. Springs are kept in a stretched position with some extension when the system is released. The horizontal surface is assumed to be frictionless. The angular frequency will be ________ rad/s when k = 20 N/m. **[JEE MAIN_{S1}_250721]**

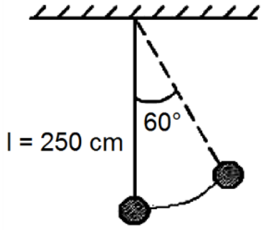


26. The acceleration due to gravity is found upto an accuracy of 4% on a planet. The energy supplied to a simple pendulum to known mass 'm' to undertake oscillations of time period T is being estimated. If time period is measured to an accuracy of 3%, the accuracy to which E is known as ....%

[JEE MAIN_{S2}_260821]

27. A pendulum is suspended by a string of length 250 cm. The mass of the bob of the pendulum is 200 g. The bob is pulled aside until the string is at 60° with vertical as shown in the figure. After releasing the bob. the maximum velocity attained by the bob will be ______________ ms^{-1}. (if $g = 10\ m/s^2$)

[JEE MAIN _{S1}_280622]



28. As per given figure, two springs of spring constants K and 2K are connected to mass m. If the period of oscillation in figure (a) is 3s, then the period of oscillation in figure (b) will be $\sqrt{x}$ s. The value of x is________.

[JEE MAIN_{S2}_260722]

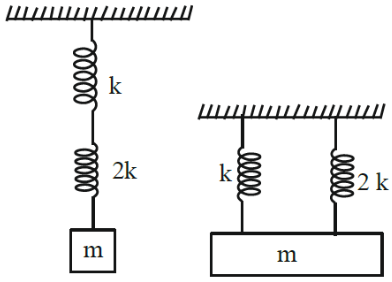


figure (a) figure (b)

29. A mass 0.9 kg, attached to a horizontal spring, executes SHM with an amplitude A_1. When this mass passes through its mean position, then a smaller mass of 124 g is placed over it and both masses move together with amplitude A_2. If the ratio $\frac{A_1}{A_2}$ is $\frac{\alpha}{\alpha - 1}$, then the value of α will be________.

[JEE MAIN_{S1}_270722]

30. A mass m attached to free end of a spring executes SHM with a period of 1s. If the mass is increased by 3 kg the period of oscillation increases by one second, the value of mass m is _________ kg.

[JEE MAIN_{S2}_240123

ANSWER KEY

1.	**(4)**	**2.**	**(3)**	**3.**	**(3)**	**4.**	**(4)**	**5.**	**(1)**	**6.**	**(4)**	**7.**	**(1)**
8.	**(4)**	**9.**	**(4)**	**10.**	**(3)**	**11.**	**(2)**	**12.**	**(3)**	**13.**	**(2)**	**14.**	**(3)**
15.	**(3)**	**16.**	**(3)**	**17.**	**(3)**	**18.**	**(2)**	**19.**	**(4)**	**20.**	**(1)**	**21.**	**(4)**
22.	**(3)**	**23.**	**(3)**	**24.**	**2**	**25.**	**10**	**26.**	**14**	**27.**	**5**	**28.**	**2**
29.	**16**	**30.**	**1**										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- WAVE ON A STRING

(Important Questions Only)

1. The equation of a wave on a string of linear mass density 0.04 kg m^{-1} is given by y = 0.02 (m) sin $\left[2\pi\left(\frac{t}{0.04(s)}-\frac{x}{0.50(m)}\right)\right]$. The tension in the string is : **[JEE MAIN_250410]**

(1) 4.0 N (2) 12.5 N (3) 0.5 N (4) 6.25 N

2. The transverse displacement y(x,t) of a wave on a string is given by

$$y(x,t) = e^{-\left(ax^2+bt^2+2\sqrt{ab}\ xt\right)}$$

This represents a : **[JEE MAIN_010511]**

(1) wave moving in +x–direction with speed $\sqrt{\frac{a}{b}}$

(2) wave moving in –x-direction with speed $\sqrt{\frac{b}{a}}$

(3) standing wave of frequency $\sqrt{b}$

(4) standing wave of frequency $\frac{1}{\sqrt{b}}$

3. A travelling wave represented by y = A sin ((ωt – kx) is superimposed on another wave represented by y = A sin (ωt + kx). The resultant is : **[JEE_MAIN_010511]**

(1) A wave travelling along + x direction

(2) A wave travelling along – x direction

(3) A standing wave having nodes at x = $\frac{n\lambda}{2}$, n = 0, 1, 2 ....

(4) A standing wave having nodes at x = $\left(n+\frac{1}{2}\right)\frac{\lambda}{2}$; n = 0, 1, 2 .....

4. **Statement - 1 :** **[JEE_MAIN_010511]**

Two longitudinal waves given by equations : y_1 (x, t) = 2a sin (ωt – kx) and y_2 (x, t) = a sin (2ωt – 2kx) will have equal intensity.

Statement - 2:

Intensity of waves of given frequency in same medium is proportional to square of amplitude only.

(1) Statement-1 is true, statement-2 is false.

(2) Statement-1 is true, statement-2 is true, statement-2 is the correct explanation of statment-1

(3) Statement-1 is true, statement-2 is true, statement-2 is not the correct explanation of statement-1

(4) Statement-1 is false, statement-2 is true.

5. A heavy ball of mass M is suspended from the ceiling of a car by a light string of mass m(m << M). When the car is at rest, the speed of transverse waves in the string is 60 ms^{-1}. When the car has acceleration a, the wave-speed increases to 60.5 ms^{-1}. The value of a, in terms of gravitational acceleration g, is closest to **[JEE MAIN {S1}_090119]**

(1) $\frac{g}{30}$ (2) $\frac{g}{5}$ (3) $\frac{g}{20}$ (4) $\frac{g}{10}$

6. A string of length 1 m and mass 5 g is fixed at both ends. The tension in the string is 8.0 N. The string is set into vibration using an external vibrator of frequency 100 Hz. The separation between successive nodes on the string is close to **[JEE MAIN {S1}_100119]**

(1) 33.3 cm (2) 10.0 cm (3) 16.6 cm (4) 20.0 cm

7. Equation of travelling wave on a stretched string of linear density 5 g/m is y = 0.03 sin(450t – 9x) where distance and time are measured in SI units. The tension in the string is **[JEE MAIN {S1}_110119]**

(1) 10 N (2) 7.5 N (3) 5 N (4) 12.5 N

8. A travelling harmonic wave is represented by the equation y(x, t) = 10^{-3} sin (50t + 2x), where x and y are in meter and t is in seconds. Which of the following is a correct statement about the wave?

[JEE MAIN_{S1}_120119]

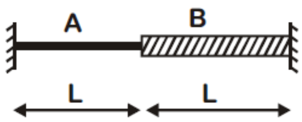
(1) The wave is propagating along the negative x-axis with speed 25 ms^{-1}.

(2) The wave is propagating along the positive x-axis with speed 100 ms^{-1}.

(3) The wave is propagating along the negative x-axis with speed 100 ms^{-1}.

(4) The wave is propagating along the positive x-axis with speed 25 ms^{-1}.

9.



A wire of length 2L, is made by joining two wires A and B of same length but different radii r and 2r and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of antinodes in wire A is p and that in B is q then the ratio p : q is **[JEE-Main_{S1}_080419]**

(1) 4 : 9 (2) 1 : 2 (3) 3 : 5 (4) 1 : 4

10. A string is clamped at both the ends and it is vibrating in its 4th harmonic. The equation of the stationary wave is Y = 0.3 sin (0.157x) cos (200πt). The length of the string is : (All quantities are in SI units)

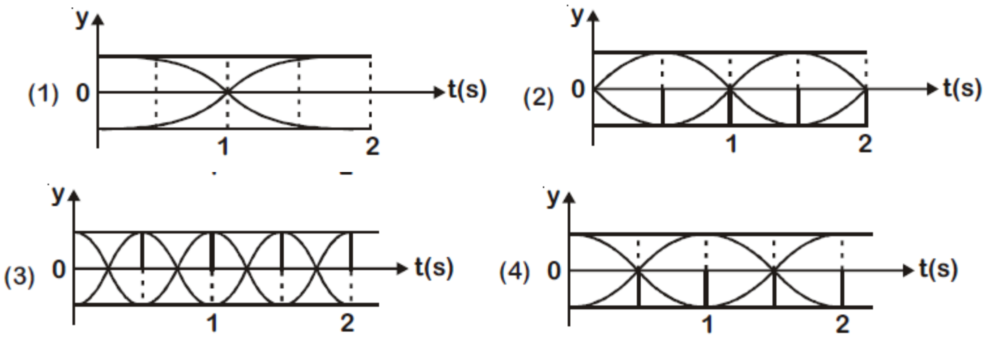
[JEE MAIN_{S1}_09042019]

(1) 60 m (2) 20 m (3) 40 m (4) 80 m

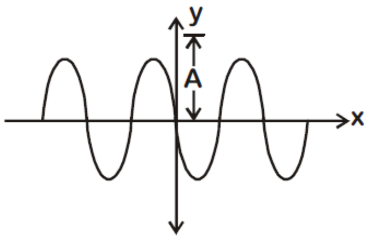
11. A string 2.0 m long and fixed at its ends is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is **[JEE MAIN_{S2}_090419]**

(1) 320 m/s, 120 Hz (2) 320 m/s, 80 Hz (3) 180 m/s, 80 Hz (4) 180 m/s, 120 Hz

12. The correct figure that shows, schematically, the wave pattern produced by superposition of two waves of frequencies 9 Hz and 11 Hz, is : **[JEE MAIN_{S2}_10042019]**



13. A progressive wave travelling along the positive x-direction is represented by $y(x,t) = A\sin(kx-\omega t+\phi)$. Its snapshot at t = 0 is given in the figure. **[JEE-MAIN_{S1}_120419]**



For this wave, the phase ϕ is :

(1) π (2) $-\frac{\pi}{2}$ (3) $\frac{\pi}{2}$ (4) 0

14. Speed of transverse wave on a straight wire (mass 6.0 g, length 60 cm and area of crosssection 1.0 mm^2) is 90 ms^{-1}. If the Young's modulus of wire is 16×10^{11} Nm^{-2}, the extension of wire over its natural length is: **[JEE MAIN_(S1)_070120]**

(1) 0.01 mm (2) 0.02 mm (3) 0.04 mm (4) 0.03 mm

15. A transverse wave travels on a taut steel wire with a velocity of v when tension in it is 2.06×10^4 N. When the tension is changed to T, the velocity changed to v/2. The value of T is close to

[JEE-Main_(S2)_080120]

(1) 30.5×10^4 N (2) 2.50×10^4 N (3) 5.15×10^3 N (4) 10.2×10^2 N

16. A uniform thin rope of length 12 m and mass 6 kg hangs vertically from a rigid support and a block of mass 2 kg is attached to its free end. A transverse short wavetrain of wavelength 6 cm is produced at the lower end of the rope. What is the wavelength of the wavetrain (in cm) when it reaches the top of the rope? **[JEE-Main_(S1)_030920]**

(1) 6 (2) 3 (3) 12 (4) 9

17. Which of the following equations represents a travelling wave ? **[JEE-MAIN_{S2}_240221]**

(1) $y = A\sin(15x - 2t)$ (2) $y = Ae^{-x^2}(vt + \theta)$ (3) $y = Ae^x\cos(\omega t - \theta)$ (4) $y = A\sin x \cos\omega t$

18. The equations of two waves are given by : **[JEE MAIN_{S1}_240622]**

$y_1 = 5\sin 2\pi (x - vt)$cm

$y_2 = 3\sin 2\pi (x - vt + 1.5)$cm

These waves are simultaneously passing through a string. The amplitude of the resulting wave is

(1) 2 cm (2) 4 cm (3) 5.8 cm (4) 8 cm

19. A transverse wave is represented by $y = 2\sin (\omega t - kx)$ cm. The value of wavelength (in cm) for which the wave velocity becomes equal to the maximum particle velocity, will be ; **[JEE Main_{S2}_260722]**

(1) 4π (2) 2π (3) π (4) 2

20. In the wave equation $y = 0.5\sin\frac{2\pi}{\lambda}(400t - x)m$ the velocity of the wave will be :

[JEE Main_{S1}_280722]

(1) 200 m/s (2) $200\sqrt{2}\,m/s$ (3) 400 m/s (4) $400\sqrt{2}\,m/s$

21. A longitudinal wave is represented by $x = 10\sin 2\pi\left(nt - \frac{x}{\lambda}\right)$cm . The maximum particle velocity will be four times the wave velocity if the determined value of wavelength is equal to :

[JEE MAIN_{S1}_290622]

(1) 2π (2) 5π (3) π (4) $\frac{5\pi}{2}$

22. A travelling wave is described by the equation y(x, t) = [0.05 sin (8x – 4t] m. The velocity of the wave is : [all the quantities are in SI unit] **[JEE MAIN_{S1}_240123]**

(1) 4 ms^{-1} (2) 2 ms^{-1} (3) 0.5 ms^{-1} (4) 8 ms^{-1}

23. A steel wire with mass per unit length 7.0×10^{-3} kg m^{-1} is under tension of 70 N. The speed of transverse waves in the wire will be: **[JEE MAIN_{S1}_010223]**

(1) 200 π m/s (2) 100 m/s (3) 10 m/s (4) 50 m/s

24. The percentage increase in the speed of transverse waves produced in a stretched string if the tension is increased by 4%, will be ________%. **[JEE MAIN_{S2}_250221]**

25. The mass per unit length of a uniform wire is 0.135 g/cm. A transverse wave of the form y = –0.21 sin (x + 30t) is produced in it, where x is in meter and t is in second. Then, the expected value of tension in the wire is $x \times 10^{-2}$ N. Value of x is . (Round-off to the nearest integer) **[JEE MAIN_{S1}_260221]**

26. The amplitude of wave disturbance propagating in the positive x-direction is given by $y = \frac{1}{(1+x)^2}$ at time t = 0 and $y = \frac{1}{1+(x-2)^2}$ at t = 1s, where x and y are in meres. The shape of wave does not change during the propagation. The velocity of the wave will be _____ m/s.

[JEE MAIN_{S1}_200721]

27. A wire having a linear mass density 9.0×10^{-4} kg/m is stretched between two rigid supports with a tension of 900 N. The wire resonates at a frequency of 500 Hz. The next higher frequency at which the same wire resonates is 550 Hz. The length of the wire is ____m. **[JEE MAIN_{S2}_310821]**

28. Two travelling waves of equal amplitudes and equal frequencies move in opposite directions along a string. They interfere to produce a stationary wave whose equation is given by

[JEE MAIN_{S2}_240622]

$$y = 10\cos(\pi x)\sin\left(\frac{2\pi t}{T}\right)\text{cm}$$

The amplitude of the particle at $x = \frac{4}{3}$ cm will be _______ cm.

29. The speed of a transverse wave passing through a string of length 50 cm and mass 10 g is 60 ms^{-1}. The area of cross-section of the wire is 2.0 mm^2 and its Young's modulus is 1.2×10^{11} Nm^{-2}. The extension of the wire over its natural length due to its tension will be $x \times 10^{-5}$ m. The value of x is_______. **[JEE MAIN_{S2}_290722]**

30. The displacement equations of two interfering waves are given by **[JEE MAIN_{S2}_310123]**

$y_1 = 10\sin\left(\omega t + \frac{\pi}{3}\right)$cm and $y_2 = 5\left[\sin(\omega t) + \sqrt{3}\cos\omega t\right]$cm respectively. The amplitude of the resultant wave is _____cm.

ANSWER KEY

1.	(4)	2.	(2)	3.	(4)	4.	(1)	5.	(2)	6.	(4)	7.	(4)
8.	(1)	9.	(2)	10.	(4)	11.	(2)	12.	(3)	13.	(1)	14.	(4)
15.	(3)	16.	(3)	17.	(1)	18.	(1)	19.	(1)	20.	(3)	21.	(2)
22.	(3)	23.	(2)	24.	2	25.	1215	26.	2	27.	10	28.	5
29.	15	30.	20										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- SOUND WAVE

(Important Questions Only)

1. A granite rod of 60 cm length is clamped at its middle point and is set into longitudinal vibrations. The density of granite is 2.7×10^3 kg/m^3 and its Young's modulus is 9.27×10^{10} Pa. What will be the fundamental frequency of the longitudinal vibrations ? **[JEE MAIN_08042018]**

(1) 10kHz (2)7.5kHz (3) 5kHz (4) 2.5kHz

2. A musician using an open flute of length 50 cm produces second harmonic sound waves. A person runs towards the musician from another end of a hall at a speed of 10 km/h. If the wave speed is 330 m/s, the frequency heard by the running person shall be close to **[JEE MAIN_{S2}_090119]**

(1) 500 Hz (2) 753 Hz (3) 333 Hz (4) 666 Hz

3. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the speed of the train is reduced to 17 m/s, the frequency registered is f_2. If speed of sound is 340 m/s, then the ratio $\frac{f_1}{f_2}$ is **[JEE MAIN_{S1}_100119]**

(1) $\frac{21}{20}$ (2) $\frac{20}{19}$ (3) $\frac{18}{17}$ (4) $\frac{19}{18}$

4. A closed organ pipe has a fundamental frequency of 1.5 kHz. The number of overtones that can be distinctly heard by a person with this organ pipe will be : (Assume that the highest frequency a person can hear is 20,000 Hz) **[JEE MAIN {S2}_100119]**

(1) 7 (2) 4 (3) 6 (2) 5

5. A person standing on an open ground hears the sound of a jet aeroplane, coming from north at an angle 60° with ground level. But he finds the aeroplane right vertically above his position. If v is the speed of sound, speed of the plane is **[JEE MAIN {S1}_120119]**

(1) $\frac{2v}{\sqrt{3}}$ (2) $\frac{\sqrt{3}}{2}v$ (3) $\frac{v}{2}$ (4) v

6. The pressure wave, $P = 0.01\sin[1000\ t - 3x]Nm^{-2}$, corresponds to the sound produced by a vibrating blade on a day when atmospheric temperature is 0°C. On some other day when temperature is T, the speed of sound produced by the same blade and at the same frequency is found to be 336 ms^{-1}. Approximate value of T is : **[JEE MAIN_{S1}_09042019]**

(1) 4°C (2) 12°C (3) 15°C (4) 11°C

7. A stationary source emits sound waves of frequency 500 Hz. Two observers moving along a line passing through the source detect sound to be of frequencies 480 Hz and 530 Hz. Their respective speeds are, in ms^{-1}, (Given speed of sound = 300 m/s) **[JEE-MAIN_{S2}_100419]**

(1) 12, 16 (2) 16, 14 (3) 8, 18 (4) 12, 18

8. A source of sound S is moving with a velocity of 50 m/s towards a stationary observer. The observer measures the frequency of the source as 1000 Hz. What will be the apparent frequency of the source when it is moving away from the observer after crosssing him? **[JEE MAIN_{S2}_10042019]**
(Take velocity of sound in air is 350 m/s)

(1) 857 Hz (2) 1143 Hz (3) 807 Hz (4) 750 Hz

9. A small speaker delivers 2 W of audio output. At what distance from the speaker will one detect 120 dB intensity sound? [Given reference intensity of sound as 10^{-12} W/m^2] **[JEE MAIN_{S2}_120419]**

(1) 30 cm (2) 40 cm (3) 10 cm (4) 20 cm

10. A tuning fork of frequency 480 Hz is used in an experiment for measuring speed of sound (v) in air by resonance tube method. Resonance is observed to occur at two successive lengths of the air column, l_1 = 30 cm and l_2 = 70 cm. Then, v is equal to **[JEE MAIN_{S2}_120419]**

(1) 332 ms^{-1} (2) 384 ms^{-1} (3) 379 ms^{-1} (4) 338 ms^{-1}

11. Three harmonic waves having equal frequency ν and same intensity I_0, have phase angles $0, \frac{\pi}{4}$ and $-\frac{\pi}{4}$ respectively. When they are superimposed the intensity of the resultant wave is close to

[JEE MAIN_{S1}_090120]

(1) $3I_0$ (2) $5.8I_0$ (3) $0.2I_0$ (4) I_0

12. For a transverse wave travelling along a straight line, the distance between two peaks (crests) is 5 m, while the distance between one crest and one trough is 1.5 m. The possible wavelengths (in m) of the waves are **[JEE MAIN_{S1}_040920]**

(1) 1, 2, 3, ... (2) 1, 3, 5, ... (3) $\frac{1}{1}, \frac{1}{3}, \frac{1}{5}, ...$ (4) $\frac{1}{2}, \frac{1}{4}, \frac{1}{6}, ...$

13. Assume that the displacement (s) of air is proportional to the pressure difference (Δp) created by a sound wave. Displacement (s) further depends on the speed of sound (v), density of air (ρ) and the frequency (f). If Δp^{-10} Pa, v^{-300} m/s, ρ^{-1} kg/m^3 and f^{-1000} Hz, then s will be of the order of (take the multiplicative constant to be 1) **[JEE MAIN_(S1)_050920]**

(1) $\frac{3}{100}$mm (2) 10 mm (3) 1 mm (4) $\frac{1}{10}$mm

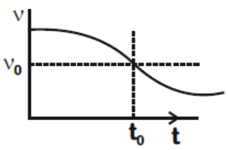
14. In a resonance tube experiment when the tube is filled with water up to a height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the tuning fork frequency is **[JEE MAIN_(S1)_050920]**

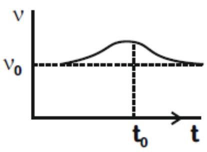
(1) 2200 Hz (2) 3300 Hz (3) 1100 Hz (4) 550 Hz

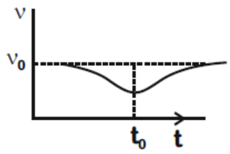
15. An object of mass m is suspended at the end of a massless wire of length L and area of cross-section, A. Young modulus of the material of the wire is Y. If the mass is pulled down slightly its frequency of oscillation along the vertical direction is **[JEE MAIN_{S1}_060920]**

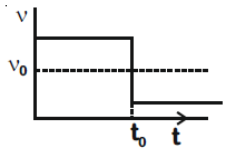
(1) $f = \frac{1}{2\pi}\sqrt{\frac{mL}{YA}}$ (2) $f = \frac{1}{2\pi}\sqrt{\frac{YA}{mL}}$ (3) $f = \frac{1}{2\pi}\sqrt{\frac{YL}{mA}}$ (4) $f = \frac{1}{2\pi}\sqrt{\frac{mA}{YL}}$

16. A sound source S is moving along a straight track with speed v, and is emitting sound of frequency ν_0 (see figure). An observer is standing at a finite distance, at the point O, from the track. The time variation of frequency heard by the observer is best represented by (t_0 represents the instant when the distance between the source and observer is minimum) **[JEE MAIN_{S1}_060920]**

(1) 

(2) 

(3) 

(4) 

17. A tuning fork A of unknown frequency produces 5 beats/s with a fork of known frequency 340 Hz. When fork A is filed, the beat frequency decreases to 2 beats/s. What is the frequency of fork A ?

[JEE MAIN_{S2}_260221]

(1) 342 Hz (2) 345 Hz (3) 335 Hz (4) 338 Hz

18. The velocity of sound in a gas. in which two wavelengths 4.08 m and 4.16 m produce 40 beats in 12s, will be : **[JEE Main_{S1}_280622]**

(1) 2.82.8 ms^{-1} (2) 175.5 ms^{-1} (3) 353.6 ms^{-1} (4) 707.2 ms^{-1}

19. A one metre long (both ends open) organ pipe is kept in a gas that has double the density of air at STP. Assuming the speed of sound in air at STP in 300 m/s, the frequency difference between the fundamental and second harmonic of this pipe is ________ Hz. **[JEE MAIN_{S1}_080120]**

20. A signal of 0.1 kW is transmitted in a cable. The attenuation of cable is –5 dB per km and cable length is 20 km. The power received at receiver is 10^{-x} W. The value of x is ______.

[Gain in dB = $10 \log_{10}\left(\frac{P_0}{P_i}\right)$] **[JEE MAIN_{S2}_240221]**

21. Two cars are approaching each other at an equal speed of 7.2 km/hr. When they see each other, both blow horns having frequency of 676 Hz. The beat frequency heard by each driver will be _____ Hz. [Velocity of sound in air is 340 m/s.] **[JEE-MAIN_{S2}_240221]**

22. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open pipe is $\frac{x}{3}L\sqrt{\frac{\rho_1}{\rho_2}}$ where x is ________. (Round off to the Nearest Integer) **[JEE MAIN_{S2}_160321]**

23. Two cars X and Y are approaching each other with velocities 36 km/h and 72 km/h respectively. The frequency of a whistle sound as emitted by a passenger in car X, heard by the passenger in car Y is 1320 Hz. If the velocity of sound in air is 340 m/s, the actual frequency of the whistle sound produced is .... Hz. **[JEE MAIN_{S1}_270821]**

24. A tuning fork is vibrating at 250 Hz. The length of the shortest closed organ pipe that will resonate with the tuning fork will be _____ cm. (Take speed of sound in air as 340 ms^{-1}) **[JEE MAIN_{S2}_270821]**

25. A set of 20 tuning forks is arranged in a series of increasing frequencies. If each fork gives 4 beats with respect to the preceding fork and the frequency of the last fork is twice the frequency of the first, then the frequency of last fork is _______Hz. **[JEE MAIN_{S2}_260622]**

26. A tuning fork of frequency 340 Hz resonates in an air column of length 125 cm in a cylindrical tube closed at one end. When water is slowly poured in it, the minimum height of water required for observing resonance once again is ______cm. (Velocity of sound in air is 340 ms^{-1})
[JEE MAIN_{S2}_280622]

27. In an experiment to determine the velocity of sound in air at room temperature using a resonance is observed when the air column has a length of 20.0 cm for a tuning fork of frequency 400 Hz is used. The velocity of the sound at room temperature is 336 ms^{-1}. The third resonance is observed when the air column has a length of ____cm. **[JEE MAIN_{S2}_290622]**

28. An observer is riding on a bicycle and moving towards a hill at 18 kmh^{-1}. He hears a sound from a source at some distance behind him directly as well as after its reflection from the hill. If the original frequency of the sound as emitted by source is 640 Hz and velocity of the sound in air is 320 m/s, the beat frequency between the two sounds heard by observer will be _____ Hz.
[JEE MAIN_{S1}_250722]

29. The frequency of echo will be _______ Hz if the train blowing a whistle of frequency 320 Hz is moving with a velocity of 36 km/h towards a hill from which an echo is heard by the train driver. Velocity of sound in air is 330 m/s. **[JEE MAIN_{S1}_280722]**

30. A train blowing a whistle of frequency 320 Hz approaches an observer standing on the platform at a speed of 66 m/s. The frequency observed by the observer will be (given speed of sound = 330 ms^{-1}) _______ Hz. **[JEE MAIN_{S2}_250123]**

ANSWER KEY

1.	**(3)**	**2.**	**(4)**	**3.**	**(4)**	**4.**	**(3)**	**5.**	**(3)**	**6.**	**(1)**	**7.**	**(4)**
8.	**(4)**	**9.**	**(2)**	**10.**	**(2)**	**11.**	**(2)**	**12.**	**(3)**	**13.**	**(1)**	**14.**	**(1)**
15.	**(2)**	**16.**	**(1)**	**17.**	**(3)**	**18.**	**(4)**	**19.**	**106**	**20.**	**8**	**21.**	**8**
22.	**4**	**23.**	**1210**	**24.**	**34**	**25.**	**152**	**26.**	**50**	**27.**	**104**	**28.**	**20**
29.	**340**	**30.**	**400**										

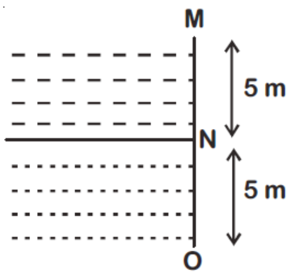
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- FLUID MECHANICS

(Important Questions Only)

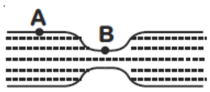
1.



Two liquids of densities ρ_1 and ρ_2 ($\rho_2 = 2\rho_1$) are filled up behind a square wall of side 10 m as shown in figure. Each liquid has a height of 5 m. The ratio of the forces due to these liquids exerted on upper part MN to that at the lower part NO is (Assume that the liquids are not mixing) **[JEE-Main_(S2) _080120]**

(1) 1/4 (2) 1/2 (3) 2/3 (4) 1/3

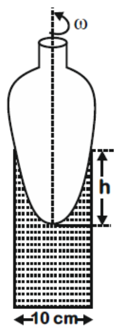
2. Water flows in a horizontal tube (see figure). The pressure of water changes by 700 Nm^{-2} between A and B where the area of cross section are 40 cm^2 and 20 cm^2, respectively. Find the rate of flow of water through the tube. (density of water = 1000 kgm^{-3}) **[JEE-Main_(S1)_090120]**



(Fig.)

(1) 3020 cm^3/s (2) 1810 cm^3/s (3) 2720 cm^3/s (4) 2420 cm^3/s

3. A cylindrical vessel containing a liquid is rotated about its axis so that the liquid rises at its sides as shown in the figure. The radius of vessel is 5 cm and the angular speed of rotation is ω rad s^{-1}. The difference in the height, h (in cm) of liquid at the centre of vessel and at the side will be **[JEE-Main_(S1) _020920]**



(1) $\frac{2\omega^2}{25g}$ (2) $\frac{5\omega^2}{2g}$ (3) $\frac{2\omega^2}{5g}$ (4) $\frac{25\omega^2}{2g}$

4. A air bubble of radius 1 cm in water has an upward acceleration 9.8 cm s^{-2}. The density of water is 1 gm cm^{-3} and water offers negligible drag force on the bubble. The mass of the bubble is (g = 980 cm/s^2)

[JEE-Main_(S1) _040920]

(1) 1.52 gm (2) 4.51 gm (3) 3.15 gm (4) 4.15 gm

5. Two identical cylindrical vessels are kept on the ground and each contain the same liquid of density d. The area of the base of both vessels is S but the height of liquid in one vessel is x_1 and in the other, x_2. When both cylinders are connected through a pipe of negligible volume very close to the bottom, the liquid flows from one vessel to the other until it comes to equilibrium at a new height. The change in energy of the system in the process is **[JEE-Main_(S2)_040920]**

(1) $gdS(x_2 + x_1)^2$ (2) $\frac{1}{4}gdS(x_2 - x_1)^2$ (3) $\frac{3}{4}gdS(x_2 - x_1)^2$ (4) $gdS\left(x_2^2 + x_1^2\right)$

6. A hollow spherical shell at outer radius R floats just submerged under the water surface. The inner radius of the shell is r. If the specific gravity of the shell material is $\frac{27}{8}$ w.r.t water, the value of r is

[JEE-Main_(S1) _050920]

(1) $\frac{2}{3}R$ (2) $\frac{4}{9}R$ (3) $\frac{1}{3}R$ (4) $\frac{8}{9}R$

7. A fluid is flowing through a horizontal pipe of varying cross-section, with speed v ms^{-1} at a point where the pressure is P pascal. At another point where pressure is $\frac{P}{2}$ pascal its speed is V ms^{-1}. If the density of the fluid is ρ kg m^{-3} and the flow is streamline, then V is equal to :

[JEE Main_(S2) _060920]

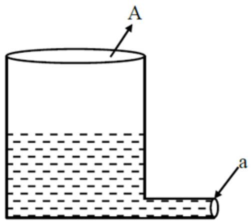
(1) $\sqrt{\frac{P}{\rho}+v^2}$ (2) $\sqrt{\frac{2P}{\rho}+v^2}$ (3) $\sqrt{\frac{P}{\rho}+v}$ (4) $\sqrt{\frac{P}{2\rho}+v^2}$

8. The pressure acting on a submarine is 3×10^5 Pa at a certain depth. If the depth is doubled, the percentage increase in the pressure acting on the submarine would be :
(Assume that atmospheric pressure is 1×10^5 Pa density of water is 10^3 kg m^{-3}, g = 10 ms^{-2})

[JEE MAIN_{S1}_160321]

(1) $\frac{200}{3}\%$ (2) $\frac{200}{5}\%$ (3) $\frac{5}{200}\%$ (4) $\frac{3}{200}\%$

9. A light cylindrical vessel is kept on a horizontal surface. Area of base is A. A hole of crosssectional area 'a' is made just at its bottom side. The minimum coefficient of friction necessary to prevent sliding the vessel due to the impact force of the emerging liquid is (a < < A) : **[JEE MAIN_{S1}_270721]**



(1) $\frac{A}{2a}$ (2) $\frac{a}{A}$ (3) $\frac{2a}{A}$ (4) None of these

10. A raindrop with radius R = 0.2 mm falls from a cloud at a height h = 2000 m above the ground Assume that the drop is spherical throughout its fall and the force of buoyance may be neglected, then the terminal speed attained by the raindrop is : **[JEE MAIN_{S2}_270721]**

[Density of water f_w = 1000 kg m^{-3} and Density of air f_a = 1.2 kg m^{-3}, g = 10 m/s^2 Coefficient of viscosity of air = 1.8 × 10^{-5} Nsm^{-2}]

(1) 250.6 ms^{-1} (2) 43.56 ms^{-1} (3) 4.94 ms^{-1} (4) 14.4 ms^{-1}

11. Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube.

[Take surface tension of water T = 7.3 × 10^{-2} Nm^{-1}, angle of contact = 0°, g = 10 ms^{-2} and density of water = 1.0 × 10^3 kg m^{-2}] **[JEE MAIN_{S1}_260821]**

(1) 3.62 mm (2) 2.19 mm (3) 5.34 mm (4) 4.97 mm

12. The terminal velocity (v_t) of the spherical rain drop depends on the radius (r) of the spherical rain drop as:- **[JEE Main_{S1}_250622]**

(1) $r^{1/2}$ (2) r (3) r^2 (4) r^3

13. If ρ is the density and η is coefficient of viscosity of fluid which flows with a speed v in the pipe of diameter d, the correct formula for Reynolds number R_e is : **[JEE Main_{S2}_260622]**

(1) $R_e = \frac{\eta d}{\rho v}$ (2) $R_e = \frac{\eta v}{\rho d}$ (3) $R_e = \frac{\rho v d}{\eta}$ (4) $R_e = \frac{\eta}{\rho v d}$

14. Sixty four conducting drops each of radius 0.02 m and each carrying a charge of 5 μC are combined to form a bigger drop. The ratio of surface density of bigger drop to the smaller drop will be :

[JEE Main_{S2}_260622]

(1) 1 : 4 (2) 4 : 1 (3) 1 : 8 (4) 8 : 1

15. The velocity of a small ball of mass 'm' and density d_1, when dropped in a container filled with glycerine, becomes constant after some time. If the density of glycerine is d_2, then the viscous force acting on the ball, will be : **[JEE Main_{S1}_270622]**

(1) $mg\left(1-\frac{d_1}{d_2}\right)$ (2) $mg\left(1-\frac{d_2}{d_1}\right)$ (3) $mg\left(\frac{d_1}{d_2}-1\right)$ (4) $mg\left(\frac{d_2}{d_1}-1\right)$

16. A drop of liquid of density ρ is floating half immersed in a liquid of density σ and surface tension 7.5×10^{-4} Ncm^{-1}. The radius of drop in cm will be : (Take : $g = 10$ m/s^2) **[JEE Main_{S2}_250722]**

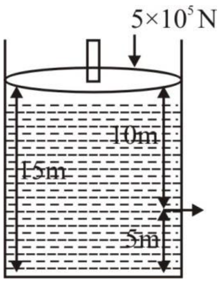
(1) $\frac{15}{\sqrt{2\rho-\sigma}}$ (2) $\frac{15}{\sqrt{\rho-\sigma}}$ (3) $\frac{3}{2\sqrt{\rho-\sigma}}$ (4) $\frac{3}{20\sqrt{2\rho-\sigma}}$

17. A pressure-pump has a horizontal tube of cross-sectional area 10 cm^2 for the outflow of water at a speed of 20 m/s. The force exerted on the vertical wall just in front of the tube which stops water horizontally flowing out of the tube, is: [given : density of water = 1000 kg/m^3] **[JEE Main_{S2}_280722]**

(1) 300 N (2) 500 N (3) 250 N (4) 400 N

18. Consider a cylindrical tank of radius 1 m is filled with water. The top surface of water is at 15 m from the bottom of the cylinder. There is a hole on the wall of cylinder at a height of 5m from the bottom. A force of 5×10^5 N is applied at the top surface of water using a piston. The speed of efflux from the hole will be :

(given atmospheric pressure $P_A = 1.01 \times 10^5$ Pa, density of water $\rho_w = 1000$ kg/m^3 and gravitational acceleration $g = 10$ m/s^2) **[JEE Main_{S2}_280722]**



(1) 11.6 m/s (2) 10.8 m/s (3) 17.8 m/s (4) 14.4 m/s

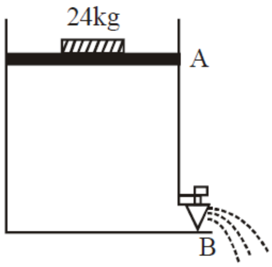
19. A fully loaded boeing aircraft has a mass of 5.4×10^5 kg. Its total wing area is 500 m^2. It is in level flight with a speed of 1080 km/h. If the density of air ρ is 1.2 kg/m^3, the fractional increase in the speed of the air on the upper surface of the wing relative to the lower surface in percentage will be ($g = 10$ m/s^2)

[JEE MAIN_{S2}_290123]

(1) 16 (2) 6 (3) 8 (4) 10

20. A hydraulic press can lift 100 kg when a mass 'm' is placed on the smaller piston. It can lift _______kg when the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times keeping the same mass 'm' on the smaller piston. **[JEE-Main_{S1}_240221]**

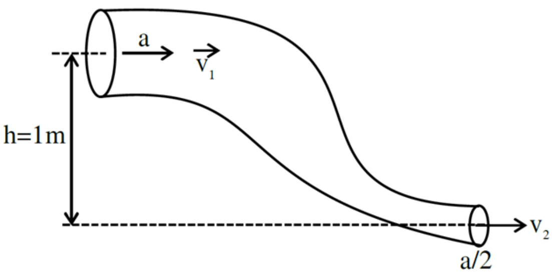
21. Consider a water tank as shown in the figure. It's cross-sectional area is 0.4 m^2. The tank has an opening B near the bottom whose cross-section area is 1 cm^2. A load of 24 kg is applied on the water at the top when the height of the water level is 40 cm above the bottom, the velocity of water coming out the opening B is v ms^{-1}. The value of v, to the nearest integer, is___.
[Take value of g to be 10 ms^{-2}] **[JEE MAIN_{S1}_180321]**



22. The water is filled upto height of 12 m in a tank having vertical sidewalls. A hole is made in one of the walls at a depth 'h' below the water level. The value of 'h' for which the emerging stream of water strikes the ground at the maximum range is _______m. **[JEE MAIN_{S2}_270721]**

23. An ideal fluid of density 800 kgm^{-3}, flows smoothly through a bent pipe (as shown in figure) that tapers in cross-sectional area from a to $\frac{a}{2}$. The pressure difference between the wide and narrow sections of pipe is 4100 Pa. At wider section, the velocity of fluid is $\frac{\sqrt{x}}{6} ms^{-1}$ for x = ... (Given g = 10 m^{-2})

[JEE Main_{S1}_260622]



24. The area of cross-section of a large tank is 0.5 m^2 It has a narrow opening near the bottom having area of cross-section 1 cm^2. A load of 25 kg is applied on the water at the top in the tank. Neglecting the speed of water in the tank, the velocity of the water, coming out of the opening at the time when the height of water level in the tank is 40 cm above the bottom, will be _______ cms^{-1}. [Take g = 10 ms^{-2}]
[JEE Main_{S1}_270622]

25. A small spherical ball of radius 0.1 mm and density 10^4 kg m^{-3} falls freely under gravity through a distance h before entering a tank of water. If after entering the water the velocity of ball does not change and it continue to fall with same constant velocity inside water, then the value of h will be_____m.(Given g = 10 ms^{-2}, viscosity of water = 1.0×10^{-5} N-sm^{-2}). **[JEE Main_{S2}_290622]**

26. The diameter of an air bubble which was initially 2 mm, rises steadily through a solution of density 1750 kg m^{-3} at the rate of 0.35 cms^{-1}. The coefficient of viscosity of the solution is __________poise (in nearest integer). (the density of air is negligible). **[JEE Main_{S1}_280722]**

27. A tube of length 50 cm is filled completely with an incompressible liquid of mass 250 g and closed at both ends. The tube is then rotated in horizontal plane about one of its ends with a uniform angular velocity $X \times \sqrt{F}$ $rads^{-1}$. If F be the force exerted by the liquid at the other end then the value of x will be________. **[JEE Main_{S2}_290722]**

28. The velocity of a small ball of mass 0.3 g and density 8 g/cc when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is 1.3 g/cc, then the value of viscous force acting on the ball will be x × 10^{-4} N, the value of x is _______. [use g = 10 m/s^2] **[JEE Main_{S2}_290722]**

29. The metallic bob of simple pendulum has the relative density 5. The time period of this pendulum is 10 s. If the metallic bob is immersed in water, then the new time period becomes $5\sqrt{x}$ s. The value of x will be_______. **[JEE Main_{S2}_290722]**

30. The surface of water in a water tank of cross section area 750 cm^2 on the top of a house is h(m). above the tap level. The speed of water coming out through the tap of cross section area 500 mm^2 is 30 cm/s. At that instant, $\frac{dh}{dt}$ is x × 10^{-3} m/s. The value of x will be_____. **[JEE MAIN_{S2}_010223]**

ANSWER KEY

1.	(1)	2.	(3)	3.	(4)	4.	(4)	5.	(2)	6.	(4)	7.	(1)
8.	(1)	9.	(3)	10.	(3)	11.	(2)	12.	(3)	13.	(3)	14.	(2)
15.	(2)	16.	(1)	17.	(4)	18.	(3)	19.	(4)	20.	25600	21.	3
22.	6	23.	363	24.	300	25.	20	26.	11	27.	4	28.	25
29.	5	30.	2										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- ELASTICITY AND VISCOSITY (PROPERTIES OF SOLID) & SURFACE TENSION

(Important Questions Only)

1. A solid sphere of radius r made of a soft material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area a floats on the surface of the liquid, covering entire cross section of cylindrical container. When a mass m is placed on the surface of the piston to compress the liquid the fractional decrement in the radius of the sphere, $\left(\frac{dr}{r}\right)$ is :

[JEE MAIN_080418]

(1) $\frac{mg}{3Ka}$ (2) $\frac{mg}{Ka}$ (3) $\frac{Ka}{mg}$ (4) $\frac{Ka}{3mg}$

2. The density of a material is SI units is 128 kg m^{-3}. In certain units in which the unit of length is 25 cm and the unit of mass is 50 g, the numerical value of density of the material is **[JEE MAIN_{S1}_100119]**

(1) 640 (2) 410 (3) 40 (4) 16

3. A load of mass M kg is suspended from a steel wire of length 2 m and radius 1.0 mm in Searle's apparatus experiment. The increase in length produced in the wire is 4.0 mm. Now th load is fully immersed in a liquid of relative density 2. The relative density of the material of load is 8.

The new value of increase in length of the steel wire is: **[JEE MAIN_{S2}_120119]**

(1) 4.0 mm (2) zero (3) 5.0 mm (4) 3.0 mm

4. A boy's catapult is made of rubber cord which is 42 cm long, with 6 mm diameter of crosssection and of negligible mass. The boy keeps a stone weighing 0.02 kg on it and stretches the cord by 20 cm by applying a constant force. When released, the stone flies off with a velocity of 20 ms^{-1}. Neglect the change in the area of cross-section of the cord while stretched. The Young's modulus of rubber is closest to: **[JEE Main_{S1}_080419]**

(1) 10^4 Nm^{-2} (2) 10^3 Nm^{-2} (3) 10^8 Nm^{-2} (4) 10^6 Nm^{-2}

5. Young's moduli of two wires A and B are in the ratio 7 : 4. Wire A is 2 m long and has radius R. Wire B is 1.5 m long and has radius 2 mm. If the two wires stretch by the same length for a given load, then the value of R is close to **[JEE-Main_{S2}_080419]**

(1) 1.3 mm (2) 1.9 mm (3) 1.5 mm (4) 1.7 mm

6. The ratio of surface tensions of mercury and water is given to be 7.5 while the ratio of their densities is 13.6. Their contact angles, with glass, are close to 135° and 0°, respectively. It is observed that mercury gets depressed by an amount h in a capillary tube of radius r_1, while water rises by the same amount h in a capillary tube of radius r_2. The ratio, (r_1/r_2), is then close to : **[JEE Main_M_{S2}_100419]**

(1) 4/5 (2) 2/3 (3) 3/5 (4) 2/5

7. The elastic limit of brass is 379 MPa. What should be the minimum diameter of a brass rod if it is to support a 400 N load without exceeding its elastic limit? **[JEE MAIN_{S2}_100419]**

(1) 0.90 mm (2) 1.16 mm (3) 1.00 mm (4) 1.36 mm

8. If Y, K and η are the values of Young's modulus, bulk modulus and modulus of rigidity of any material respectively. Choose the correct relation for these parameters. **[JEE Main_{S1}_240221]**

(1) $Y = \frac{9K\eta}{3K - \eta} N/m^2$ (2) $\eta = \frac{3YK}{9K + Y} N/m^2$

(3) $Y = \frac{9K\eta}{2\eta + 3K} N/m^2$ (4) $K = \frac{Y\eta}{9\eta - 3Y} N/m^2$

9. In Millikan's oil drop experiment, what is viscous force acting on an uncharged drop of radius 2.0×10^{-5} m and density 1.2×10^3 kgm^{-3} ? Take viscosity of liquid = 1.8×10^{-5} Nsm^{-2}. (Neglect buoyancy due to air). **[JEE MAIN_{S1}_270821]**

(1) 3.8×10^{-11} N (2) 3.9×10^{-10} N (3) 1.8×10^{-10} N (4) 5.8×10^{-10} N

10. A uniform heavy rod of weight 10 kg ms^{-2}, cross-sectional area 100 cm^2 and length 20 cm is hanging from a fixed support. Young modulus of the material of the rod is 2×10^{11} Nm^{-2}. Neglecting the lateral contraction, find the elongation of rod due to its own weight. **[JEE MAIN_{S2}_310821]**

(1) 2×10^{-9} m (2) 5×10^{-8} m (3) 4×10^{-8} m (4) 5×10^{-10}m

11. Space between two concentric conducting spheres of radii a and b (b > a) is filled with a medium of resistivity ρ. The resistance between the two spheres will be: **[JEE MAIN_{S2}_100419]**

(1) $\frac{\rho}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$ (2) $\frac{\rho}{2\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$ (3) $\frac{\rho}{2\pi}\left(\frac{1}{a} + \frac{1}{b}\right)$ (4) $\frac{\rho}{4\pi}\left(\frac{1}{a} + \frac{1}{b}\right)$

12. A small spherical droplet of density d is floating exactly half immersed in a liquid of density ρ and surface tension T. The radius of the droplet is (take note that the surface tension applies an upward force on the droplet) **[JEE-Main_{S2}_090120]**

(1) $r = \sqrt{\frac{3T}{(2d - \rho)g}}$ (2) $r = \sqrt{\frac{T}{(d + \rho)g}}$ (3) $r = \sqrt{\frac{T}{(d - \rho)g}}$ (4) $r = \sqrt{\frac{2T}{3(d + \rho)g}}$

13. A capillary tube made of glass of radius 0.15 mm is dipped vertically in a beaker filled with methylene iodide (surface tension = 0.05 Nm–1, density = 667 kg m^{-3}) which rises to height h in the tube. It is observed that the two tangents drawn from liquid-glass interfaces (from opp. sides of the capillary) make an angle of 60° with one another. Then h is close to (g = 10 ms^{-2}) **[JEE-Main_{S2}_020920]**

(1) 0.049 m (2) 0.087 m (3) 0.137 m (4) 0.172 m

14. Two small drops of mercury each of radius R coalesce to form a single large drop. The ratio of total surface energy before and after the change is : **[JEE MAIN_{S2}_200721]**

(1) $2^{1/3} : 1$ (2) $1 : 2^{1/3}$ (3) 2 : 1 (4) 1 : 2

15. Two wires of same length and radius are joined end to end and loaded. The Young's moduli of the material of the two wires are Y_1 and Y_2. The combination behaves as a single wire then its Young's modulus is : **[JEE Main_{S1}_250721]**

(1) $\dfrac{2Y_1Y_2}{3(Y_1+Y_2)}$ (2) $Y = \dfrac{2Y_1Y_2}{Y_1+Y_2}$ (3) $Y = \dfrac{Y_1Y_2}{2(Y_1+Y_2)}$ (4) $Y = \dfrac{Y_1Y_2}{Y_1+Y_2}$

16. A water drop of diameter 2 cm is broken into 64 equal droplets. The surface tension of water is 0.075 N/m. In this process the gain in surface energy will be : **[JEE Main_{S1}_280622]**

(1) 2.8×10^{-4} J (2) 1.5×10^{-3} J (3) 1.9×10^{-4} J (4) 9.4×10^{-5} J

17. A water drop of radius 1cm is broken into 729 equal droplets. If surface tension of water is 75 dyne/cm, then the gain in surface energy upto first decimal place will be : [Given π = 3.14]

[JEE Main_{S1}_260722]

(1) 8.5×10 J^{-4} J (2) 8.2×10 J^{-4} J (3) 7.5×10 J^{-4} J (4) 5.3×10 J^{-4} J

18. Surface tension of a soap bubble is 2.0×10^{-2} Nm^{-1}. Work done to increase the radius of soap bubble from 3.5 cm to 7 cm will be : [Take $\pi = \dfrac{22}{7}$] **[JEE Main_{S1}_290123]**

(1) 0.72×10^{-4} J (2) 5.76×10^{-4} J (3) 18.48×10^{-4} J (4) 9.24×10^{-4} J

19. A force is applied to a steel wire 'A', rigidly clamped at one end. As a result elongation in the wire is 0.2 mm. If same force is applied to another steel wire 'B' of double the length and a diameter 2.4 times that of the wire 'A', the elongation in the wire 'B' will be (wires having uniform circular cross sections)

[JEE Main_{S2}_300123]

(1) 6.06×10^{-2} mm (2) 2.77×10^{-2} mm (3) 3.0×10^{-2} mm (4) 6.9×10^{-2} mm

20. A uniform heating wire of resistance 36 Ω is connected across a potential difference of 240 V. The wire is then cut into half and potential difference of 240 V is applied across each half separately. The ratio of power dissipation in first case to the total power dissipation in the second case would be 1 : x, where x is........... **[JEE MAIN_{S2}_010921]**

21. In an experiment of determine the Young's modulus of wire of a length exactly 1m, the extension in the length of the wire is measured as 0.4mm with an uncertainty of ± 0.02 mm when a load of 1kg is applied. The diameter of the wire is measured as 0.4mm with an uncertainty of $\pm$ 0.01 mm. The error in the measurement of Young's modulus (ΔY) is found to be x × 10^{10} Nm^{-2}. The value of x is _____. [Take g = 10m/ s^2] **[JEE Main_{S1}_260722]**

22. A square aluminium (shear modulus is 25 × 10^9 Nm^{-2}) slab of side 60 cm and thickness 15 cm is subjected to a shearing force (on its narrow face) of 18.0 × 10^4 N. The lower edge is riveted to the floor. The displacement of the upper edge is______ μ m. **[JEE Main_{S1}_270722]**

23. A metal wire of length 0.5 m and cross-sectional area $10^{-4}m^2$ has breaking stress 5 × 10^8 Nm^{-2}. A block of 10 kg is attached at one end of the string and is rotating in a horizontal circle. the maximum linear velocity of block will be ______ms^{-1}. **[JEE Main_{S2}_290722]**

24. When a long glass capillary tube of radius 0.015 cm is dipped in a liquid, the liquid rises to a height of 15 cm within it. If the contact angle between the liquid and glass to close to 0°, the surface tension of the liquid, in milli Newton m^{-1}, is [$\rho_{(liquid)}$ = 900 kgm^{-3}, g = 10 ms^{-2}] (Give answer in closest integer) _____. **[JEE-Main_{S1}_030920]**

25. Suppose you have taken a dilute solution of oleic acid in such a way that its concentration becomes 0.01 cm^3 of oleic acid per cm^3 of the solution. Then you make a thin film of this solution (monomolecular thickness) of area 4 cm^2 by considering 100 spherical drops of radius $\left(\frac{3}{40\pi}\right)^{\frac{1}{3}} \times 10^{-3}$ cm. Then the thickness of oleic acid layer will be x × 10^{-14} m.
Where x is _______. **[JEE MAIN_{S2}_170321]**

26. Two separate wires A and B are stretched by 2 mm and 4 mm respectively, when they are subjected to a force of 2 N. Assume that both the wires are made up of same material and the radius of wire B is 4 times that of the radius of wire A. The length of the wires A and B are in the ratio of a : b. Then a/b can be expressed as 1/x where x is _______ . **[JEE MAIN_{S1}_180321]**

27. A stone of mass 20 g is projected from a rubber catapult of length 0.1 m and area of cross section 10^{-6} m^2 stretched by an amount 0.04 m. The velocity of the projected stone is __________ m/s. (Young's modulus of rubber = 0.5×10^9 N/m^2) **[JEE MAIN_{S1}_270721]**

28. A soap bubble of radius 3 cm is formed inside the another soap bubble of radius 6 cm. The radius of an equivalent soap bubble which has the same excess pressure as inside the smaller bubble with respect to the atmospheric pressure is .... cm. **[JEE MAIN_{S1}_260821]**

29. The velocity of upper layer of water in a river is 36 kmh^{-1}. Shearing stress between horizontal layers of water is 10^{-3} Nm^{-2}. Depth of the river is __________m. (Co-efficiency of viscosity of water is 10^{-2} Pa.s) **[JEE Main_{S1}_250622]**

30. A spherical soap bubble of radius 3 cm is formed inside another spherical soap bubble of radius 6 cm. If the internal pressure of the smaller bubble of radius 3 cm in the above system is equal to the internal pressure of the another single soap bubble of radius r cm. The value of r is……… **[JEE Main_{S2}_270722]**

ANSWER KEY

1.	**(1)**	**2.**	**(3)**	**3.**	**(4)**	**4.**	**(4)**	**5.**	**(4)**	**6.**	**(4)**	**7.**	**(2)**
8.	**(4)**	**9.**	**(2)**	**10.**	**(4)**	**11.**	**(1)**	**12.**	**(1)**	**13.**	**(2)**	**14.**	**(1)**
15.	**(2)**	**16.**	**(1)**	**17.**	**(3)**	**18.**	**(3)**	**19.**	**(4)**	**20.**	**4**	**21.**	**2**
22.	**48**	**23.**	**50**	**24.**	**101**	**25.**	**25**	**26.**	**32**	**27.**	**20**	**28.**	**2**
29.	**100**	**30.**	**2**										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- CALORIMETRY AND THERMAL EXPANSION

(Important Questions Only)

1. A rod, length L at room temperature and uniform area of cross section A, is made of a metal having coefficient of linear expansion α/°C. It is observed that an external compressive force F, is applied on each of its ends, prevents any change in the length of the rod, when its temperature rises by ΔTk. Young's modulus, Y, for this metal is **[JEE MAIN_{S1}_090119]**

(1) $\frac{F}{A\alpha(\Delta T - 273)}$ (2) $\frac{F}{A\alpha\Delta T}$ (3) $\frac{2F}{A\alpha\Delta T}$ (4) $\frac{F}{2A\alpha\Delta T}$

2. An unknown metal of mass 192 g heated to a temperature of 100°C was immersed into a brass calorimeter of mass 128 g containing 240 g of water at a temperature of 8.4°C. Calculate the specific heat of the unknown metal if water temperature stabilizes at 21.5°C. (Specific heat of brass is 394 J $kg^{-1}K^{-1}$) **[JEE MAIN_{S2}_100119]**

(1) 916 J $kg^{-1}K^{-1}$ (2) 1232 J $kg^{-1}K^{-1}$ (3) 654 J $kg^{-1}K^{-1}$ (4) 458 J $kg^{-1}K^{-1}$

3. A thermometer graduated according to a linear scale reads a value x_0 when in contact with boiling water, and $x_0/3$ when in contact with ice. What is the temperature of an object in °C, if this thermometer in the contact with the object reads $x_0/2$? **[JEE MAIN_{S2}_110119]**

(1) 40 (2) 60 (3) 35 (4) 25

4. A massless spring (k = 800 N/m), attached with a mass (500 g) is completely immersed in 1 kg of water. The spring is stretched by 2 cm and released so that it starts vibrating. What would be the order of magnitude of the change in the temperature of water when the vibrations stop completely? (Assume that the water container and spring receive negligible heat and specific heat of mass = 400 J/kg K, specific heat of water = 4184 J/kg K) **[JEE-Main_{S2}_090419]**

(1) 10^{-5} K (2) 10^{-1} K (3) 10^{-3} K (4) 10^{-4} K

5. When M_1 gram of ice at –10°C (specific heat = 0.5 cal $g^{-1}°C^{-1}$) is added to M_2 gram of water at 50°C, finally no ice is left and the water is at 0°C. The value of latent heat of ice, in cal g^{-1} is : **[JEE-Main_{S1}_120419]**

(1) $\frac{50M_2}{M_1} - 5$ (2) $\frac{5M_1}{M_2} - 50$ (3) $\frac{50M_2}{M_2}$ (4) $\frac{5M_2}{M_1} - 5$

6. One kg of water, at 20°C, is heated in an electric kettle whose heating element has a mean (temperature averaged) resistance of 20 Ω. The rms voltage in the mains is 200 V. Ignoring heat loss from the kettle, time taken for water to evaporate fully, is close to

[Specific heat of water = 4200 J/(kg °C),
Latent heat of water = 2260 kJ/kg] **[JEE-Main_{S2}_120419]**

(1) 16 minutes (2) 3 minutes (3) 22 minutes (4) 10 minutes

7. A calorimeter of water equivalent 20 g contains 180 g of water at 25°C. 'm' grams of steam at 100°C is mixed in it till the temperature of the mixture is 31°C. The value of 'm' is close to (Latent heat of water = 540 cal g^{-1}, specific heat of water = 1 cal g–1 $°C^{-1}$) **[JEE-Main_(S2) _030920]**

(1) 2 (2) 3.2 (3) 2.6 (4) 4

8. Two different wires having lengths L_1 and L_2, and respective temperature coefficient of linear expansion α_1 and α_2, are joined end-to-end. Then the effective temperature coefficient of linear expansion is

[JEE-Main_(S2) _050920]

(1) $\sqrt[2]{\alpha_1\alpha_2}$ (2) $4\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2L_1}{(L_2+L_1)^2}$ (3) $\frac{\alpha_1+\alpha_2}{2}$ (4) $\frac{\alpha_1L_1+\alpha_2L_2}{L_1+L_2}$

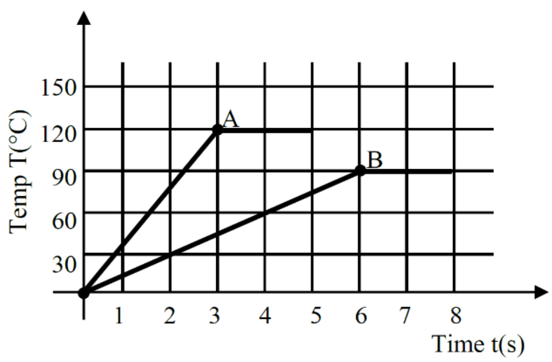
9. Two identical metal wires of thermal conductivities K_1 and K_2 respectively are connected in series. The effective thermal conductivity of the combination is : **[JEE MAIN_{S1}_170321]**

(1) $\frac{2K_1K_2}{K_1+K_2}$ (2) $\frac{K_1+K_2}{2K_1K_2}$ (3) $\frac{K_1+K_2}{K_1K_2}$ (4) $\frac{K_1K_2}{K_1+K_2}$

10. The value of tension in a long thin metal wire has been changed from T_1 to T_2. The lengths of the metal wire at two different values of tension T_1 and T_2 are ℓ_1 and ℓ_2 respectively. The actual length of the metal wire is : **[JEE Main_{S1}_200721]**

(1) $\frac{T_1\ell_2-T_2\ell_1}{T_1-T_2}$ (2) $\frac{T_1\ell_1-T_2\ell_2}{T_1-T_2}$ (3) $\frac{\ell_1-\ell_2}{2}$ (4) $\sqrt{T_1T_2\ell_1\ell_2}$

11. Two different metal bodies A and B of equal mass are heated at a uniform rate under similar conditions. The variation of temperature of the bodies is graphically represented as shown in the figure. The ratio of specific heat capacities is: **[JEE Main {S1}_250721]**



(1) $\frac{8}{3}$ (2) $\frac{3}{8}$ (3) $\frac{3}{4}$ (4) $\frac{4}{3}$

12. The temperature of equal masses of three different liquids x,y and z are 10ºC, 20ºC and 30ºC respectively. The temperature of mixture when x is mixed with y is 16ºC and that when y is mixed with z is 26ºC. The temperature of mixture when x and z are mixed will be :

[JEE MAIN_{S2}_260821]

(1) 28.32º C (2) 25.62º C (3) 23.84ºC (4) 20.28ºC

13. A huge circular arc of length 4.4 ly subtends an angle '4s' at the centre of the circle. How long it would take for a body to complete 4 revolution if its speed is 8 AU per second ?

Given : 1 ly = 9.46×10^{15} m **[JEE MAIN_{S1}_270821]**

1 AU = 1.5×10^{11} m

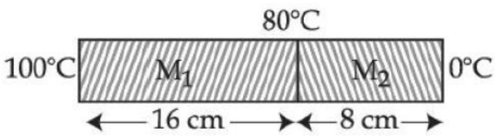
(1) 4.1×10^{8} s (2) 4.5×10^{10} s (3) 3.5×10^{6} s (4) 7.2×10^{8} s

14. The height of victoria falls is 63 m. What is the difference in temperature of water at the top and at the bottom of fall? [Given 1 cal = 4.2 J and specific heat of water = 1 cal g^{-1} $^{0}C^{-1}$]

[JEE MAIN_{S2}_270821]

(1) 0.147º C (2) 14.76º C (3) 1.476º C (4) 0.014º C

15. Two metallic blocks M_1 and M_2 of same area of cross-section are connected to each other (as shown in figure). If the thermal conductivity of M_2 is K then the thermal conductivity of M_1 will be : [Assume steady state heat conduction] **[JEE Main_{S1}_240622]**



(1) 10 K (2) 8 K (3) 12.5 K (4) 2 K

16. A 100 g of iron nail is hit by a 1.5 kg hammer striking at a velocity of 60 ms^{-1}. What will be the rise in the temperature of the nail if one fourth of energy of the hammer goes into heating the nail? [Specific heat capacity of iron = 0.42 Jg^{-1} °C^{-1}] **[JEE Main_{S2}_240622]**

(1) 675°C (2) 1600°C (3) 16.07°C (4) 6.75°C

17. A solid metallic cube having total surface area 24 m^2 is uniformly heated. If its temperature is increased by 10°C, calculate the increase in volume of the cube (Given : $\alpha = 5.0 \times 10^{-4}$ °C^{-1})

[JEE Main_{S2}_250622]

(1) 2.4×10^{6} cm^3 (2) 1.2×10^{5} cm^3 (3) 6.0×10^{4} cm^3 (4) 4.8×10^{5} cm^3

18. A copper block of mass 5.0 kg is heated to a temperature of 500°C and is placed on a large ice block. What is the maximum amount of ice that can melt? [Specific heat of copper: 0.39J g^{-1} °C^{-1} and latent heat of fusion of water : 335 J g^{-1}] **[JEE Main_{S2}_250622]**

(1) 1.5 kg (2) 5.8 kg (3) 2.9 kg (4) 3.8 kg

19. Resistance of the wire is measured as 2Ω and 3Ω at 10°C and 30°C respectively. Temperature co–coefficient of resistance of the material of the wire is : **[JEE Main_{S2}_280622]**

(1) 0.033°C^{-1} (2) –0.033°C^{-1} (3) 0.011°C^{-1} (4) 0.055°C^{-1}

20. At what temperature a gold ring of diameter 6.230 cm be heated so that it can be fitted on a wooden bangle of diameter 6.241 cm? Both the diameters have been measured at room temperature (27ºC). (Given: coefficient of linear thermal expansion of gold $\alpha_L = 1.4 \times 10^{-5}\ K^{-1}$)

[JEE Main_{S2}_290622]

(1) 125.7ºC (2) 91.7ºC (3) 425.7º (4) 152.7ºC

21. Heat energy of 184 kJ is given to ice of mass 600 g at –12°C, Specific heat of ice is 2222.3 J kg^{-1}° C^{-1} and latent heat of ice in 336 kJ/kg^{-1} **[JEE MAIN_{S2}_290123]**

(A) Final temperature of system will be 0°C.

(B) Final temperature of the system will be greater than 0°C.

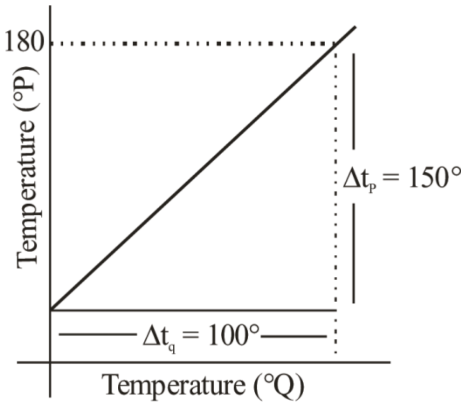
(C) The final system will have a mixture of ice and water in the ratio of 5 : 1.

(D) The final system will have a mixture of ice and water in the ratio of 1 : 5.

(E) The final system will have water only. Choose the correct answer from the options given below:

(1) A and D only (2) B and D only (2) A and E only (4) A and C only

22. The graph between two temperature scales P and Q is shown in the figure. Between upper fixed point and lower fixed point there are 150 equal divisions of scale P and 100 divisions on scale Q. The relationship for conversion between the two scales is given by : **[JEE MAIN_{S2}_250123]**



(1) $\frac{t_Q}{150} = \frac{t_P - 180}{100}$ (2) $\frac{t_Q}{100} = \frac{t_P - 30}{150}$ (3) $\frac{t_P}{180} = \frac{t_Q - 40}{100}$ (4) $\frac{t_P}{100} = \frac{t_Q - 180}{150}$

23. Three containers C_1, C_2 and C_3 have water at different temperatures. The table below shows the final temperature T when different amounts of water (given in liters) are taken from each container and mixed (assume no loss of heat during the process)

C_1	C_2	C_3	T
1ℓ	2ℓ	–	60°C
–	1ℓ	2ℓ	30°C
2ℓ	–	1ℓ	60°C
1ℓ	1ℓ	1ℓ	θ

The value of θ (in °C to the nearest integer) is _____. **[JEE MAIN_{S2} _080120]**

24. A bakelite beaker has volume capacity of 500 cc at 30°C. When it is partially filled with V_m volume (at 30°C) of mercury, it is found that the unfilled volume of the beaker remains constant as temperature is varied. If $\gamma_{(beaker)} = 6 \times 10^{-6}{}^\circ C^{-1}$ and $\gamma_{(mercury)} = 1.5 \times 10^{-4}\ {}^\circ C^{-1}$, where γ is the coefficient of volume expansion, then V_m (in cc) is close to ________. **[JEE MAIN_{S1}_030920]**

25. A steel rod with $y = 2.0 \times 10^{11}\ Nm^{-2}$ and $\alpha = 10^{-5}\ {}^\circ C^{-1}$ of length 4 m and area of cross-section 10 cm^2 is heated from 0° C to 400°C without being allowed to extend. The tension produced in the rod is $x \times 10^5$ N where the value of x is .... **[JEE MAIN_{S2}_010921]**

26. A steam engine intakes 50g of steam at 100°C per minute and cools it down to 20°C. If latent heat of vaporization of steam is 540 cal g^{-1}, then the heat rejected by the steam engine per minute is _____ × 10^3 cal. **[JEE MAIN_{S1}_250622]**

27. A geyser heats water flowing at a rate of 2.0 kg per minute from 30ºC to 70ºC. If geyser operates on a gas burner, the rate of combustion of fuel will be __________g min^{-1}
[Heat of combustion = 8×10^3 Jg^{-1} Specific heat of water = 4.2 Jg^{-1} ºC^{-1}]
[JEE MAIN_{S2}_260622]

28. A unit scale is to be prepared whose length does not change with temperature and remains 20 cm, using a bimetallic strip made of brass and iron each of different length. The length of both components would change in such a way that difference between their lengths remains constant. If length of brass is 40 cm and length of iron will be ______cm. **[JEE MAIN_{S1}_250722]**
($\alpha_{iron} = 1.2 \times 10^{-5}\ K^{-1}$ and $\alpha_{brass} = 1.8 \times 10^{-5}\ K^{-1}$).

29. A block of ice of mass 120 g at temperature 0°C is put in 300 gm of water at 25°C. The xg of ice melts as the temperature of the water reaches 0°C. The value of x is **[JEE Main_{S2}_250722]**
[Use: Specific heat capacity of water = 4200 Jkg^{-1}K^{-1}, Latent heat of ice = 3.5×10^5 Jkg^{-1}]

30. A faulty thermometer reads 5°C in melting ice and 95°C in steam. The correct temperature on absolute scale will be .... K when the faulty thermometer reads 41°C. **[JEE MAIN_{S2}_300123]**

ANSWER KEY

1.	(2)	2.	(1)	3.	(4)	4.	(1)	5.	(1)	6.	(3)	7.	(1)
8.	(4)	9.	(1)	10.	(1)	11.	(2)	12.	(3)	13.	(2)	14.	(1)
15.	(2)	16.	(3)	17.	(2)	18.	(3)	19.	(1)	20.	(4)	21.	(1)
22.	(2)	23.	50.00	24.	20.00	25.	8	26.	31	27.	42	28.	60
29.	90	30.	313										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- KTG & THERMODYNAMICS

(Important Questions Only)

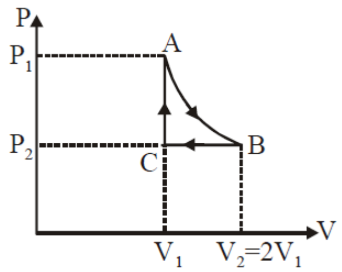
1. n mole a perfect gas undergoes a cyclic process ABCA (see figure) consisting of the following processes. **[JEE MAIN_{S1}_240221]**

$A \rightarrow B$: Isothermal expansion at temperature T so that the volume is doubled from V_1 to $V_2 = 2V_1$ and pressure changes from P_1 to P_2.

$B \rightarrow C$: Isobaric compression at pressure P_2 to initial volume V_1.

$C \rightarrow A$: Isochoric change leading to change of pressure from P_2 to P_1.

Total workdone in the complete cycle ABCA is :



(1) 0 (2) $nRT\left(\ln 2+\frac{1}{2}\right)$ (3) nRTln2 (4) $nRT\left(\ln 2-\frac{1}{2}\right)$

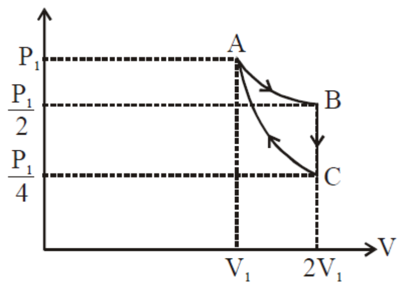
2. Match List-I with List-II : **[JEE-Main_{S1}_240221]**

List-I	**List-II**
(a) Isothermal	(i) Pressure constant
(b) Isochoric	(ii) Temperature constant
(c) Adiabatic	(iii) Volume constant
(d) Isobaric	(iv) Heat content is constant

Choose the correct answer from the options given below :

(1) (a) $\rightarrow$ (i), (b) $\rightarrow$ (iii), (c) $\rightarrow$ (ii), (d) $\rightarrow$ (iv)
(2) (a) $\rightarrow$ (ii), (b) $\rightarrow$ (iii), (c) $\rightarrow$ (iv), (d) $\rightarrow$ (i)
(3) (a) $\rightarrow$ (ii), (b) $\rightarrow$ (iv), (c) $\rightarrow$ (iii), (d) $\rightarrow$ (i)
(4) (a) $\rightarrow$ (iii), (b) $\rightarrow$ (ii), (c) $\rightarrow$ (i), (d) $\rightarrow$ (iv)

3. If one mole of an ideal gas at (P_1, V_1) is allowed to expand reversibly and isothermally (A to B) its pressure is reduced to one-half of the original pressure (see figure). This is followed by a constant volume cooling till its pressure is reduced to one-fourth of the initial value ($B \rightarrow C$). Then it is restored to its initial state by a reversible adiabatic compression (C to A). The net workdone by the gas is equal to : **[JEE-MAIN_{S2}_240221]**

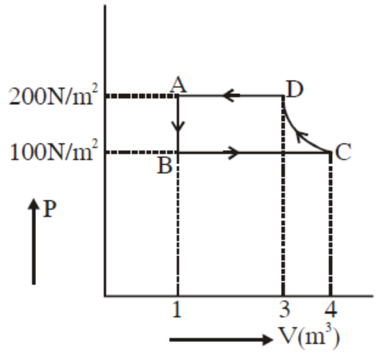


(1) $RT\left(\ln 2-\frac{1}{2(\gamma-1)}\right)$ (2) $-\frac{RT}{2(\gamma-1)}$ (3) 0 (4) RT ln 2

4. Two ideal polyatomic gases at temperatures T_1 and T_2 are mixed so that there is no loss of energy. If F_1 and F_2, m_1 and m_2, n_1 and n_2 be the degrees of freedom, masses, number of molecules of the first and second gas respectively, the temperature of mixture of these two gases is : **[JEE MAIN_{S1}_170321]**

(1) $\frac{n_1T_1+n_2T_2}{n_1+n_2}$ (2) $\frac{n_1F_1T_1+n_2F_2T_2}{n_1F_1+n_2F_2}$ (3) $\frac{n_1F_1T_1+n_2F_2T_2}{F_1+F_2}$ (4) $\frac{n_1F_1T_1+n_2F_2T_2}{n_1+n_2}$

5. The P-V diagram of a diatomic ideal gas system going under cyclic process as shown in figure. The work done during an adiabatic process CD is (use γ = 1.4) **[JEE MAIN_{S1}_180321]**



(1) –500 J (2) –400 J (3) 400 J (4) 200 J

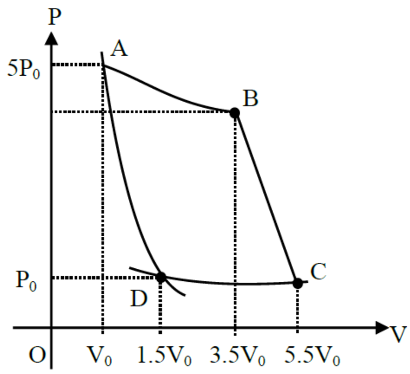
6. For an adiabatic expansion of an ideal gas, the fractional change in its pressure is equal to (where γ is the ratio of specific heats): **[JEE MAIN_{S1}_180321]**

(1) $-\gamma\times\frac{dV}{V}$ (2) $-\gamma\times\frac{V}{dV}$ (3) $-\frac{1}{\gamma}\times\frac{dV}{V}$ (4) $\frac{dV}{V}$

7. Two spherical soap bubbles of radii r_1 and r_2 in vacuum combine under isothermal conditions. The resulting bubble has a radius equal to : **[JEE MAIN_{S2}_250721]**

(1) $\frac{r_1r_2}{r_1+r_2}$ (2) $\sqrt{r_1\,r_2}$ (3) $\sqrt{r_1^2+r_2^2}$ (4) $\frac{r_1+r_2}{2}$

8. In the reported figure, there is a cyclic process ABCDA on a sample of 1 mol of a diatomic gas. The temperature of the gas during the process A → B and C → D are T_1 and T_2 ($T_1 > T_2$) respectively.
[JEE MAIN_{S1}_270721]



Choose the correct option out of the following for work done if processes BC and DA are adiabatic.

(1) $W_{AB} = W_{DC}$ (2) $W_{AD} = W_{BC}$ (3) $W_{BC} + W_{DA} > 0$ (4) $W_{AB} < W_{CD}$

9. Two Carnot engines A and B operate in series such that engine A absorbs heat at T_1 and rejects heat to a sink at temperature T. engine B absorbs half of the heat rejected by Engine A and rejects heat to the sink at T_3. When workdone in both the cases is equal to value of T is : **[JEE MAIN_{S2}_270721]**

(1) $\frac{2}{3}T_1 + \frac{3}{2}T_3$ (2) $\frac{1}{3}T_1 + \frac{2}{3}T_3$ (3) $\frac{3}{2}T_1 + \frac{1}{3}T_3$ (4) $\frac{2}{3}T_1 + \frac{1}{3}T_3$

10. The rms speeds of the molecules of Hydrogen, Oxygen and Carbondioxide at the same temperature are V_H, V_O and V_C respectively then : **[JEE MAIN_{S1}_260821]**

(1) $V_H > V_O > V_C$ (2) $V_C > V_O > V_H$ (3) $V_H = V_O > V_C$ (4) $V_H = V_O = V_C$

11. A balloon carries a total load of 185 kg at normal pressure and temperature of 27°C. What load will the balloon carry on rising to a height at which the barometric pressure is 45 cm of Hg and the temperature is –7°C. Assuming the volume constant ? **[JEE MAIN_{S1}_270821]**

(1) 181.46 kg (2) 214.15 kg. (3) 219.07 kg (4) 123.54 kg

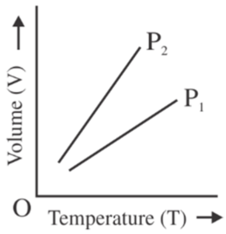
12. For an ideal gas the instantaneous change in pressure 'p' with volume 'v' is given by the equation $\frac{dp}{dv} = -ap$. If $p = P_0$ at $v = 0$ is the given boundary condition, then the maximum temperature one mole of gas can attain is : (Here R is the gas constant) **[JEE MAIN_{S2}_310821]**

(1) $\frac{p_0}{aeR}$ (2) $\frac{ap_0}{eR}$ (3) Infinity (4) 0ºC

13. A mixture of hydrogen and oxygen has volume 500 cm^3, temperature 300 K, pressure 400 kPa and mass 0.76 g. The ratio of masses of oxygen to hydrogen will be :- **[JEE MAIN_{S1}_310821]**

(1) 3 : 8 (2) 3 : 16 (3) 16 : 3 (4) 8 : 3

14. For a perfect gas, two pressures P_1 and P_2 are shown in figure. The graph shows: **[JEE MAIN_{S2}_270622]**



(1) $P_1 > P_2$ (2) $P_1 < P_2$

(3) $P_1 = P_2$ (4) Insufficient data to draw any conclusion

15. Given below are two statement : **[JEE MAIN_{S1}_280622]**

Statement – I : What μ amount of an ideal gas undergoes adiabatic change from state (P_1, V_1, T_1) to state (P_2, V_2, T_2), the work done is $W = \frac{NR(T_2 - T_1)}{1-\gamma}$, where $\gamma = \frac{C_P}{C_V}$ and R = universal gas constant,

Statement — II: In the above case. when work is done on the gas. the temperature of the gas would rise.

Choose the correct answer from the options given below:

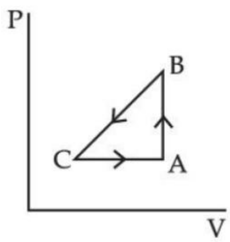
(1) Both statement—I and statement-II are true.

(2) Both statement—I and statement-II are false.

(3) Statement-I is true but statement-II is false.

(4) Statement-I is false but statement-II is true.

16. A sample of an ideal gas is taken through the cyclic process ABCA as shown in figure. It absorbs, 40 J of heat during the part AB, no heat during BC and rejects 60J of heat during CA. A work 50J is done on the gas during the part BC. The internal energy of the gas at A is 1560J. The work done by the gas during the part CA is: **[JEE MAIN_{S2}_280622]**



(1) 20 J (2) 30 J (3) –30J (4) –60 J

17. Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1 if the process is purely isothermal. W_2. if the process is purely adiabatic and W_3 if the process is purely isobaric. Then, choose the correct option.

[JEE Main_{S2}_290622]

(1) $W_1 < W_2 < W_3$ (2) $W_2 < W_3 < W_1$ (3) $W_3 < W_1 < W_2$ (4) $W_2 < W_1 < W_3$

18. A vessel contains 16g of hydrogen and 128 g of oxygen at standard temperature and pressure. The volume of the vessel in cm^3 is : **[JEE Main_{S2}_290622]**

(1) 72×10^5 (2) 32×10^5 (3) 27×10^4 (4) 54×10^4

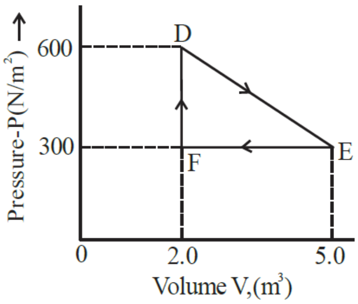
19. A monoatomic gas at pressure P and volume V is suddenly compressed to one eighth of its original volume. The final pressure at constant entropy will be: **[JEE MAIN_{S1}_260722]**

(1) P (2) 8P (3) 32P (4) 64 P

20. A Carnot engine has efficiency of 50%. If the temperature of sink is reduced by 40ºC, its efficiency increases by 30%. The temperature of the source ill be: **[JEE Main_{S1}_280722]**

(1) 166.7 K (2) 255.1 K (3) 266.7 K (4) 367.7 K

21. A thermodynamic system is taken from an original state D to an intermediate state E by the linear process shown in the figure. Its volume is then reduced to the original volume from E to F by an isobaric process. The total work done by the gas from D to E to F will be **[JEE Main_{S2}_290722]**



(1) –450 J (2) 450 J (3) 900 J (4) 1350 J

22. At 300 K, the rms speed of oxygen molecules is $\sqrt{\frac{\alpha+5}{\alpha}}$ times to that of its average speed in the gas.

Then, the value of α will be (used $\pi = \frac{22}{7}$) **[JEE MAIN_{S2}_290123]**

(1) 32 (2) 28 (3) 24 (4) 27

23. A bicycle tyre is filled with air having pressure of 270 kPa at 27ºC. The approximate pressure of the air in the tyre when the temperature increases to 36ºC is **[JEE MAIN_{S1}_290123]**

(1) 270 kPa (2) 262 KPa (3) 278 kPa (4) 360 kPa

24. In a certain thermodynamical process, the pressure of a gas depends on its volume as kV^3. The work done when the temperature changes from 100°C to 300°C will be ___ nR, where n denotes number of moles of a gas. **[JEE MAIN_{S1}_250221]**

25. The potential energy (U) of a diatomic molecule is a function dependent on r (interatomic distance) as $U = \frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3$ where, α and β are positive constants. The equilibrium distance between two atoms will be $\left(\frac{2\alpha}{\beta}\right)^{\frac{a}{b}}$, where a = _____. **[JEE MAIN_{S1}_250221]**

26. The volume V of a given mass of monoatomic gas changes with temperature T according to the relation $V = KT^{2/3}$. The workdone when temperature changes by 90 K will be xR. The value of x is [R = universal gas constant] **[JEE MAIN_{S2}_260221]**

27. A monoatomic gas performs a work of $\frac{Q}{4}$ where Q is the heat supplied to it. The molar heat capacity of the gas will be ________R during this transformation. Where R is the gas constant. **[JEE Main_{S2}_240622]**

28. At a certain temperature, the degrees of freedom per molecule for gas is 8. The gas performs 150 J of work when it expands under constant pressure. The amount of heat absorbed by the gas will be ……………..J. **[JEE Main_{S2}_280722]**

29. The pressure P_1 and density d_1 of diatomic gas $\left(\gamma = \frac{7}{5}\right)$ changes suddenly to P_2 (> P_1) and d_2 respectively during an adiabatic process. The temperature of the gas increases and becomes __________times of its initial temperature. (Given $\frac{d_2}{d_1} = 32$) **[JEE Main_{S1}_290722]**

30. One mole of a monoatomic gas is mixed with three moles of a diatomic gas. The molecular specific heat of mixture at constant volume is $\frac{\alpha^2}{4}R$ J/mol K; then the value of α will be ________. (Assume that the given diatomic gas has no vibrational mode.) **[JEE Main_{S1}_290722]**

ANSWER KEY

1.	(4)	2.	(2)	3.	(1)	4.	(2)	5.	(1)	6.	(1)	7.	(3)
8.	(2)	9.	(4)	10.	(1)	11.	(4)	12.	(1)	13.	(3)	14.	(1)
15.	(1)	16.	(2)	17.	(4)	18.	(3)	19.	(3)	20.	(3)	21.	(2)
22.	(2)	23.	(3)	24.	50	25.	1	26.	60	27.	2	28.	750
29.	4	30.	3										

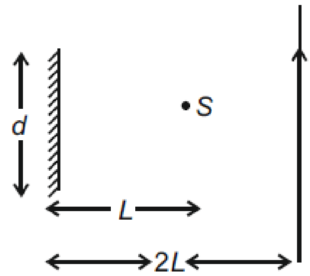
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- GEOMETRICAL OPTICS

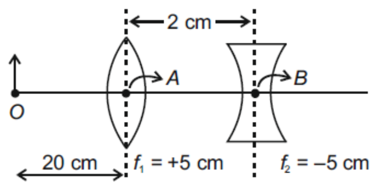
(Important Questions Only)

1. A point source of light, S is placed at a distance L in front of the centre of plane mirror of width d which is hanging vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror, at a distance 2L as shown below. The distance over which the man can see the image of the light source in the mirror is **[JEE MAIN_{S1}_120119]**



(1) $\frac{d}{2}$ (2) 3d (3) 2d (4) d

2. What is the position and nature of image formed by lens combination shown in figure? (f_1, f_2 are focal lengths) **[JEE_MAIN_{S1}_120119]**



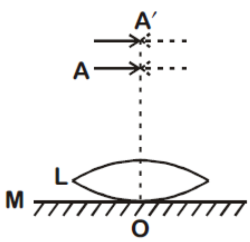
(1) $\frac{20}{3}$ cm from point B at right; real

(2) 70 cm from point B at right; real

(3) 40 cm from point B at right; real

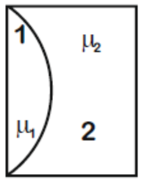
(4) 70 cm from point B at left; virtual

3. A thin convex lens L (refractive index = 1.5) is placed on a plane mirror M. When a pin is placed at A, such that OA = 18 cm, its real inverted image is formed at A itself, as shown in figure. When a liquid of refractive index μ_1 is put between the lens and the mirror, the pin has to be moved to A′, such that OA′ = 27 cm, to get its inverted real image at A′ itself. The value of μ_1 will be **[JEE MAIN_{S2}_090419]**



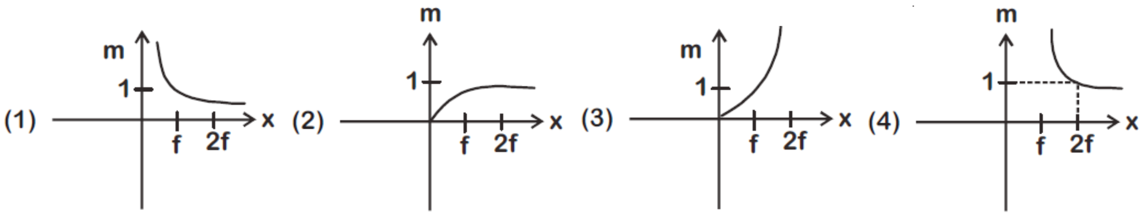
(1) $\sqrt{2}$ (2) $\frac{4}{3}$ (3) $\sqrt{3}$ (4) $\frac{3}{2}$

4. One plano-convex and one plano-concave lens of same radius of curvature 'R' but of different materials are joined side by side as shown in the figure. If the refractive index of the material of 1 is μ_1 and that of 2 is μ_2, then the focal length of the combination is : **[JEE MAIN_{S2}_100419]**



(1) $\dfrac{R}{2(\mu_1-\mu_2)}$ (2) $\dfrac{R}{2-(\mu_1-\mu_2)}$ (3) $\dfrac{R}{\mu_1-\mu_2}$ (4) $\dfrac{2R}{\mu_1-\mu_2}$

5. An object is gradually moving away from the focal point of a concave mirror along the axis of the mirror. The graphical representation of the magnitude of linear magnification (m) versus distance of the object from the mirror (x) is correctly given by
(Graphs are drawn schematically and are not to scale) **[JEE MAIN_(S2)_080120**



6. A prism of refractive index μ and angle of prism A is placed in the position of minimum angle of deviation. If minimum angle of deviation is also A, then in terms of refractive index

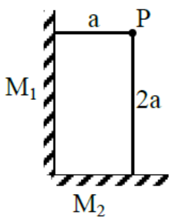
[JEE MAIN_{S2}_250721]

(1) $2\cos^{-1}\left(\dfrac{\mu}{2}\right)$ (2) $\sin^{-1}\left(\dfrac{\mu}{2}\right)$ (3) $\sin^{-1}\left(\sqrt{\dfrac{\mu-1}{2}}\right)$ (4) $\cos^{-1}\left(\dfrac{\mu}{2}\right)$

7. Car B overtakes another car A at a relative speed of 40 ms^{-1}. How fast will the image of car B appear to move in the mirror of focal length 10 cm fitted in car A, when the car B is 1.9 m away from the car A? **[JEE MAIN _{S1}_260821]**

(1) 4 ms^{-1} (2) 0.2 ms^{-1} (3) 40 ms^{-1} (4) 0.1 ms^{-1}

8. Two plane mirrors M_1 and M_2 are at right angle to each other shown. A point source 'P' is placed at 'a' and '2a' meter away from M_1 and M_2 respectively. The shortest distance between the images thus formed is : (Take $\sqrt{5}$ = 2.3) **[JEE (MAIN)_{S2}_310821]**



(1) 3a (2) 4.6 a (3) 2.3 a (4) $2\sqrt{10}\,a$

9. A glass tumbler having inner depth of 17.5 cm is kept on a table. A student starts pouring water (μ = 4/3) into it while looking at the surface of water from the above. When he feels that the tumbler is half filled, he stops pouring water. Up to what height, the tumbler is actually filled ?

[JEE (MAIN)_{S2}_010921]

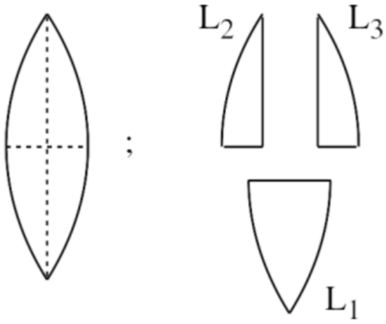
(1) 11.7 cm (2) 10 cm (3) 7.5 cm (4) 8.75 cm

10. Electric field of plane electromagnetic wave propagating through a non–magnetic medium is given by $E = 20\cos(2 \times 10^{10} t - 200x)$ V/m. The dielectric constant of the medium is equal to : (Take $\mu_r = 1$)

[JEE MAIN_{S2}_010921]

(1) 9 (2) 2 (3) $\frac{1}{3}$ (4) 3

11. A convex lens has power P. It is cut into two halves along its principal axis. Further one piece (out of the two halves) is cut into two halves perpendicular to the principal axis (as shown in figure). Choose the incorrect option for the reported pieces. **[JEE MAIN_{S2}_270622]**



(1) Power of $L_1 = \frac{P}{2}$ (2) Power of $L_2 = \frac{P}{2}$ (3) Power of $L_3 = \frac{P}{2}$ (4) Power of L_1 = P

12. Which of the following statement is correct ? **[JEE MAIN_{S1}_250722]**

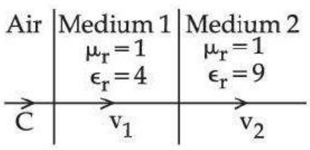
(1) In primary rainbow, observer sees red colour on the top and violet on the bottom

(2) In primary rainbow, observer sees violet colour on the top and red on the bottom

(3) In primary rainbow, light wave suffers total internal reflection twice before coming out of water drops

(4) Primary rainbow is less bright than secondary rainbow.

13. As shown in the figure, after passing through the medium 1. The speed of light v_2 in medium 2 will be : (Given $c = 3 \times 10^8$ ms^{-1}) **[JEE MAIN_{S1}_280722]**



(1) 1.0×10^8 ms^{-1} (2) 0.5×10^8 ms^{-1} (3) 1.5×10^8 ms^{-1} (4) 3.0×10^8 ms^{-1}

14. In normal adjustment, for a refracting telescope, the distance between objective and eye piece is 30 cm. The focal length of the objective, when the angular magnification of the telescope is 2, will be :

[JEE MAIN_{S1}_280722]

(1) 20 cm (2) 30 cm (3) 10 cm (4) 15 cm

15. The power of a lens (biconvex) is 1.25 m^{-1} in particular medium. Refractive index of the lens is 1.5 and radii of curvature are 20 cm and 40 cm respectively. The refractive index of surrounding medium :

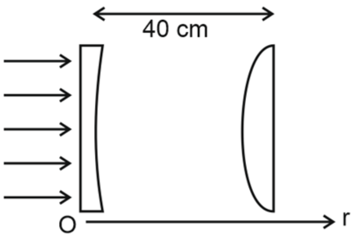
[JEE MAIN_{S2}_280722]

(1) 1.0 (2) $\frac{9}{7}$ (3) $\frac{3}{2}$ (4) $\frac{4}{3}$

16. In an experiment with a convex lens. The plot of the image distance (v') against the object distance (μ') measured from the focus gives a curve v' μ' = 225. If all the distances are measured in cm. The magnitude of the focal length of the lens is …………cm. **[JEE MAIN_{S2}_280722]**

17. The X-Y plane be taken as the boundary between two transparent media M_1 and M_2. M_1 in $Z \geq 0$ has a refractive index of $\sqrt{2}$ and M_2 with $Z < 0$ has a refractive index of $\sqrt{3}$. A ray of light travelling in M_1 along the direction given by the vector $\vec{A} = 4\sqrt{3}\hat{i} - 3\sqrt{3}\hat{j} - 5\hat{k}$, is incident on the plane of separation. The value of difference between the angle of incident in M_1 and the angle of refraction in M_2 will be ________degree. **[JEE MAIN_{S1}_290722]**

18. As shown in the figure, a combination of a thin plano concave lens and a thin plano convex lens is used to image an object placed at infinity. The radius of curvature of both the lenses is 30 cm and refraction index of the material for both the lenses is 1.75. Both the lenses are placed at distance of 40 cm from each other. Due to the combination, the image of the object is formed at distance x = ____ cm, from concave lens. **[JEE MAIN_{S1}_240123]**



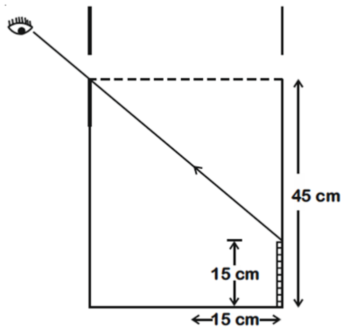
19. In an experiment of measuring the refractive index of a glass slab using travelling microscope in physics lab, a student measures real thickness of the glass slab as 5.25 mm and apparent thickness of the glass slab at 5.00 mm. Travelling microscope has 20 divisions in one cm on main scale and 50 divisions on Vernier scale is equal to 49 divisions on main scale. The estimated uncertainty in the measurement of refractive index of the slab is $\frac{x}{10} \times 10^{-3}$, where x is .... **[JEE MAIN_{S2}_290123]**

20. In an experiment for estimating the value of focal length of converging mirror, image of an object placed at 40 cm from the pole of the mirror is formed at distance 120 cm from the pole of the mirror. These distances are measured with a modified scale in which there are 20 small divisions in 1 cm. The value of error in measurement of focal length of the mirror is 1/K cm. The value of K is _______ .

[JEE MAIN_{S1}_300123]

21. An observer can see through a small hole on the side of a jar (radius 15 cm) at a point at height of 15 cm from the bottom (see figure). The hole is at a height of 45 cm. When the jar is filled with a liquid up to a height of 30 cm the same observer can see the edge at the bottom of the jar. If the refractive index of the liquid is N/100, where N is an integer, the value of N is _________.

[JEE MAIN_{S1}_030920]



22. The distance between an object and a screen is 100 cm. A lens can produce real image of the object on the screen for two different positions between the screen and the object. The distance between these two positions is 40 cm. If the power of the lens is close to $\left(\frac{N}{100}\right)$D where N is an integer, the value of N is __________.

[JEE MAIN_{S2}_040920]

23. The same size images are formed by a convex lens when the object is placed at 20cm or at 10cm from the lens. The focal length of convex lens is _____ cm. **[JEE MAIN_{S1}_020221]**

24. The image of an object placed in air formed by a convex refracting surface is at a distance of 10 m behind the surface. The image is real and is at $\frac{2^{nd}}{3}$ of the distance of the object from the surface .The wavelength of light inside the surface is $\frac{2}{3}$ times the wavelength in air. The radius of the curved surface is $\frac{x}{13}$ m. the value of 'x' is___________.

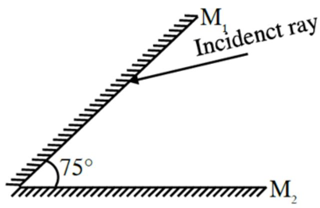
[JEE MAIN_{S2}_170321]

25. An object viewed from a near point distance of 25 cm, using a microscopic lens with magnification '6', gives an unresolved image. A resolved image is observed at infinite distance with a total magnification double the earlier using an eyepiece along with the given lens and a tube of length 0.6 m, if the focal length of the eyepiece is equal to _______ cm. **[JEE MAIN_{S1}_200721]**

26. Two identical thin biconvex lenses of focal length 15 cm and refractive index 1.5 are in contact with each other. The space between the lenses is filled with a liquid of refractive index 1.25. The focal length of the combination is ______ cm. **[JEE MAIN_{S1}_240622]**

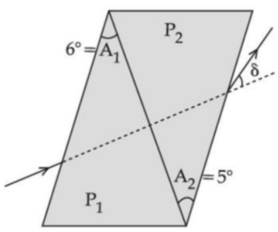
27. A ray of light is incident at an angle of incidence 60° on the glass slab of refractive index $\sqrt{3}$. After refraction, the light ray emerges out from other parallel faces and lateral shift between incident ray and emergent ray is $4\sqrt{3}$ cm. The thickness of the glass slab is _______ cm. **[JEE MAIN_{S2}_240622]**

28. A light ray is incident, at an incident angle θ_1, on the system of two plane mirrors M_1 and M_2 having an inclination angle 75° between them (as shown in figure). After reflecting from mirror M_1 it gets reflected back by the mirror M_2 with an angle of reflection 30°. The total deviation of the ray will be .... degree. **[JEE MAIN_{S1}_260622]**



29. A convex lens of focal length 20 cm is placed in front of convex mirror with principal axis coinciding each other. The distance between the lens and mirror is 10 cm. A point object is placed on principal axis at a distance of 60 cm from the convex lens. The image formed by combination coincides the object itself. The focal length of the convex mirror is _____ cm. **[JEE MAIN_{S2}_250722]**

30. A thin prism of angle 6º and refractive index for yellow light (n_Y) 1.5 is combined with another prism of angle 5º and n_Y = 1.55. The combination produces no dispersion. The net average deviation (δ) produced by the combination is $\left(\frac{1}{x}\right)^{\circ}$. The value of x is .... **[JEE MAIN_{S2}_270722]**



ANSWER KEY

1.	(2)	2.	(2)	3.	(2)	4.	(3)	5.	(4)	6.	(1)	7.	(4)
8.	(2)	9.	(2)	10.	(1)	11.	(1)	12.	(1)	13.	(1)	14.	(1)
15.	(4)	16.	15	17.	15	18.	120	19.	41	20.	32	21.	158
22.	476	23.	15	24.	30	25.	25	26.	10	27.	12	28.	210
29.	10	30.	4										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- ELECTROSTATICS

(Important Questions Only)

1. Three concentric metal shells A, B and C of respective radii a,b and c (a < b < c) have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is : **[JEE MAIN_080418]**

(1) $\dfrac{\sigma}{\varepsilon_0}\left[\dfrac{b^2-c^2}{b}+a\right]$ (2) $\dfrac{\sigma}{\varepsilon_0}\left[\dfrac{b^2-c^2}{c}+a\right]$

(3) $\dfrac{\sigma}{\varepsilon_0}\left[\dfrac{a^2-b^2}{a}+c\right]$ (4) $\dfrac{\sigma}{\varepsilon_0}\left[\dfrac{a^2-b^2}{b}+c\right]$

2. For a uniformly charged ring of radius R, the electric field on its axis has the largest magnitude at a distance h from its centre. Then value of h is : **[JEE MAIN_{S1}_090119]**

(1) $\dfrac{R}{\sqrt{2}}$ (2) $\dfrac{R}{\sqrt{5}}$ (3) R (4) $R\sqrt{2}$

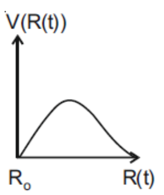
3. Charge is distributed within a sphere of radius R with volume charge density $\rho(r)=\dfrac{A}{r^2}e^{\frac{-2r}{a}}$, where A and a are constants. If Q is the total charge of this charge distribution, the radius R is:

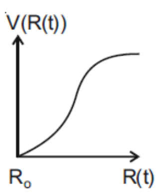
[JEE MAIN_{S1}_090119]

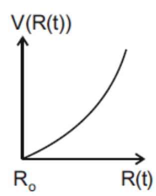
(1) $\dfrac{a}{2}\log\left(\dfrac{1}{1-\dfrac{Q}{2\pi aA}}\right)$ (2) $\dfrac{a}{2}\log\left(\dfrac{1}{2\pi aA}\right)$ (3) $a\log\left(1-\dfrac{Q}{2\pi aA}\right)$ (4) $a\log\left(\dfrac{1}{1-\dfrac{Q}{2\pi aA}}\right)$

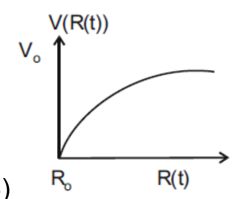
4. There is a uniform spherically symmetric surface charge density at a distance R_0 from the origin. The charge distribution is initially at rest and starts expanding because of mutual repulsion. The figure that represents best the speed $V_{(R(t))}$ of the distribution as a function of its instantaneous radius $R_{(t)}$ is

[JEE MAIN_{S1}_120119]

(1) 

(2) 

(3) 

(4) 

5. The bob of a simple pendulum has mass 2 g and a charge of 5.0 μC. It is at rest in a uniform horizontal electric field of intensity 2000 V/m. At equilibrium, the angle that the pendulum makes with the vertical is

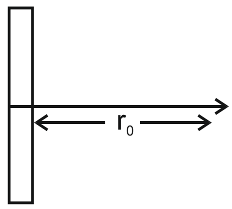
(take g = 10 m/s^2) **[JEE-MAIN_{S1}_080419]**

(1) $\tan^{-1}(0.2)$ (2) $\tan^{-1}(5.0)$ (3) $\tan^{-1}(2.0)$ (4) $\tan^{-1}(0.5)$

6. The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in metres. The values of constants are A = 20 SI unit and B = 10 SI unit. If the potential at x = 1 is V_1 and that at x = –5 is V_2, then $V_1 - V_2$ is : **[JEE MAIN_{S2}_080419]**

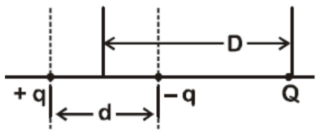
(1) 180 V (2) –520 V (3) 320 V (4) –48 V

7. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (ν) of the point charge, as a function of instantaneous distance r from line charge, is proportional to : **[JEE MAIN_{S2}_080419]**



(1) $\nu \propto \sqrt{\ln\left(\frac{r}{r_0}\right)}$ (2) $\nu \propto e^{+r/r_0}$ (3) $\nu \propto \ln\left(\frac{r}{r_0}\right)$ (4) $\nu \propto \left(\frac{r}{r_0}\right)$

8. A system of three charges are placed as shown in the figure : **[JEE MAIN_{S1}_090419]**



If D >> d, the potential energy of the system is best given by :

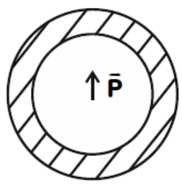
(1) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$ (2) $\frac{1}{4\pi\varepsilon_0}\left[+\frac{q^2}{d}+\frac{qQd}{D^2}\right]$

(3) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$ (4) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$

9. For point charges –q, +q, +q and –q are placed on y-axis at y = –2d, y = –d, y = +d and y =+2d, respectively. The magnitude of the electric field E at a point on the x-axis at x = D, with D >> d, will behave as: **[JEE MAIN_{S2}_090419]**

(1) $E \propto \frac{1}{D^3}$ (2) $E \propto \frac{1}{D}$ (3) $E \propto \frac{1}{D^4}$ (4) $E \propto \frac{1}{D^2}$

10. Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{P}$ as shown. In this case: **[JEE MAIN_{S1}_120419]**



(1) Surface charge density on the outer surface depends on $|\vec{P}|$

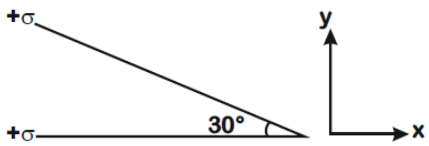
(2) Surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$

(3) Electric field outside the shell is the same as that of point charge at the centre of the shell

(4) Surface charge density on the inner surface of the shell is zero everywhere

11. Two infinite planes each with uniform surface charge density $+\sigma$ are kept in such a way that the angle between them is 30°. The electric field in the region shown between them is given by

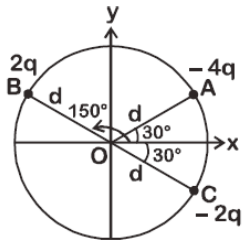
[JEE-MAIN_(S1) _070120]



(1) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}+\frac{\hat{x}}{2}\right]$ (2) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

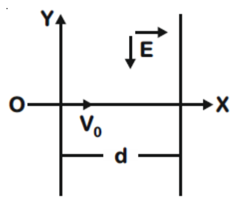
(3) $\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$ (4) $\frac{\sigma}{\varepsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{\hat{x}}{2}\right]$

12. Three charged particles A, B and C with charges –4q, 2q and –2q are present on the circumference of a circle of radius d. The charged particles A, C and centre O of the circle formed an equilateral triangle as shown in figure. Electric field at O along x-direction is **[JEE-MAIN_{S1} _080120]**



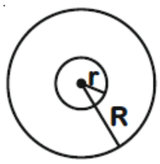
(1) $\frac{\sqrt{3}q}{\pi\varepsilon_0 d^2}$ (2) $\frac{3\sqrt{3}q}{4\pi\varepsilon_0 d^2}$ (3) $\frac{\sqrt{3}q}{4\pi\varepsilon_0 d^2}$ (4) $\frac{2\sqrt{3}q}{\pi\varepsilon_0 d^2}$

13. A charged particle (mass m and charge q) moves along X-axis with velocity V_0. When it passes through the origin it enters a region having uniform electric field $\vec{E} = -E\hat{j}$ which extends upto x = d. Equation of path of charge in the region x > d is **[JEE-MAIN_(S1)_020920]**



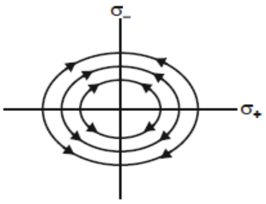
(1) $y = \frac{qEd}{mV_0^2}(x-d)$ (2) $y = \frac{qEd^2}{mV_0^2}x$ (3) $y = \frac{qEd}{mV_0^2}\left(\frac{d}{2}-x\right)$ (4) $y = \frac{qEd}{mV_0^2}x$

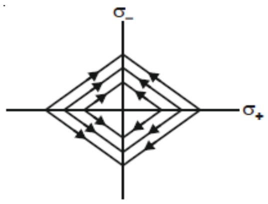
14. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R (R > r). If the surface charge densities on the two shells are equal, the electric potential at the common centre is **[JEE-MAIN_{S2}_020920]**

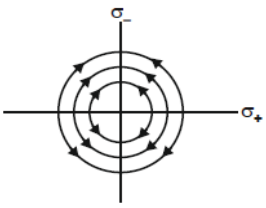


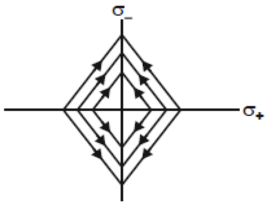
(1) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$ (2) $\frac{1}{4\pi\varepsilon_0}\frac{(R+2r)Q}{2(R^2+r^2)}$ (3) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{2(R^2+r^2)}Q$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{(2R+r)}{(R^2+r^2)}Q$

15. Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_-, where $|\sigma_+| > |\sigma_-|$, intersect at right angle. Which of the following best represents the electric field lines for this system? **[JEE-MAIN_{S1}_040920]**

(1) 

(2) 

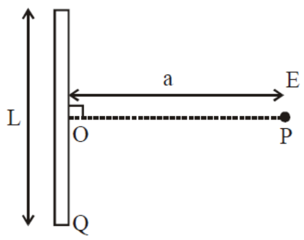
(3) 

(4) 

16. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at x = 0. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is **[JEE-MAIN_{S2}_040920]**

(1) $\sqrt{\frac{3}{a}}$ (2) $\sqrt{\frac{2}{a}}$ (3) $\sqrt{\frac{1}{a}}$ (4) a

17. Find the electric field at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q. The distance of the point P from the centre of the rod is $a = \frac{\sqrt{3}}{2}L$. **[JEE MAIN_{S1}_260221]**



(1) $\frac{\sqrt{3}Q}{4\pi\varepsilon_0 L^2}$ (2) $\frac{Q}{3\pi\varepsilon_0 L^2}$ (3) $\frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$ (4) $\frac{Q}{4\pi\varepsilon_0 L^2}$

18. Given below are two statements : **[JEE MAIN_{S2}_260221]**

Statement I : An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.

Statement II : If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius r (< R) is zero but the electric flux passing through this closed spherical surface of radius r is not zero.

In the light of the above statements, choose the correct answer from the options given below :

(1) Both Statement I and Statement II are true

(2) Statement I is true but Statement II is false

(3) Both Statement I and Statement II are false

(4) Statement I is false but Statement II is true.

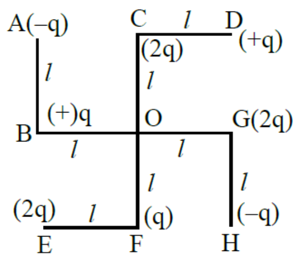
19. an electric dipole is placed on x-axis in proximity to a line charge of linear charge density 3.0×10^{-6} C/m. Line charge is placed on z-axis and positive and negative charge of dipole is at a distance of 10 mm and 12 mm from the origin respectively. If total force of 4 N is exerted on the dipole, find out the amount of positive or negative charge of the dipole. **[JEE MAIN_{S2}_220721]**

(1) 815.1 nC (2) 8.8 μC (3) 0.485 mC (4) 4.44 μC

20. Two identical tennis balls each having mass 'm' and charge 'q' are suspended from a fixed point by threads of length 'l'. What is the equilibrium separation when each thread makes a small angle 'θ' with the vertical ? **[JEE MAIN _{S1}_270721]**

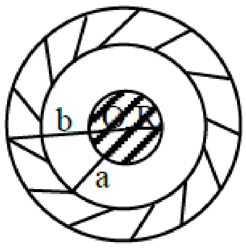
(1) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$ (2) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$ (3) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{\frac{1}{3}}$ (4) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{\frac{1}{3}}$

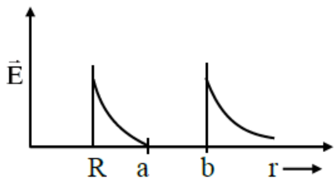
21. What will be the magnitude of electric field at point O as shown in figure? Each side of the figure is l and perpendicular to each other? **[JEE MAIN _{S2}_270721]**

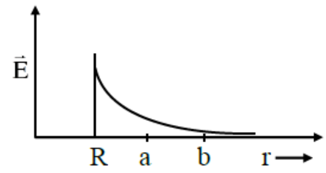


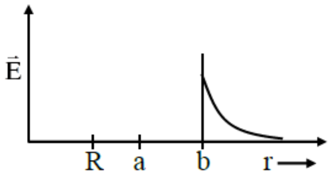
(1) $\frac{1}{4\pi\varepsilon_0}\frac{q}{l^2}$ (2) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(2l^2)}(2\sqrt{2}-1)$ (3) $\frac{q}{4\pi\varepsilon_0(2l)^2}$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{2l^2}(\sqrt{2})$

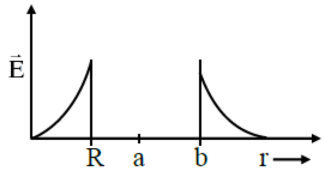
22. A solid metal sphere of radius R having charge q is enclosed inside the concentric conducting spherical shell of inner radius a and outer radius b as shown in figure. The approximate variation electric field $\vec{E}$-as a function of distance r from centre O is given by E **[JEE MAIN_{S1}_260821]**



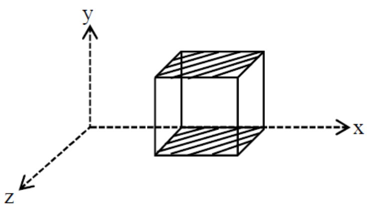
(1) 

(2) 

(3) 

(4) 

23. A cube is placed inside an electric field, $\vec{E} = 150y^2\hat{j}$. The side of the cube is 0.5 m and is placed in the field as shown in the given figure. The charge inside the cube is : **[JEE MAIN_{S2}_010921]**



(1) 3.8×10^{-11} C (2) 8.3×10^{-11} C (3) 3.8×10^{-12} C (4) 8.3×10^{-12} C

24. A vertical electric field of magnitude 4.9×10^5 N/C just prevents a water droplet of a mass 0.1 g from falling. The value of charge on the droplet will be : (Given g = 9.8 m/s^2) **[JEE MAIN_{S1}_240622]**

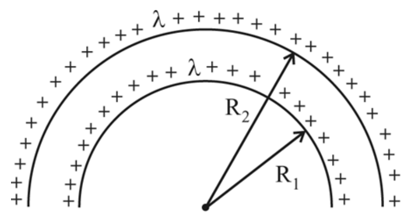
(1) 1.6×10^{-9} C (2) 2.0×10^{-9} C (3) 3.2×10^{-9} C (4) 0.5×10^{-9} C

25. If two charges q_1 and q_2 are separated with distance 'd' and placed in a medium of dielectric constant K. What will be the equivalent distance between charges in air for the same electrostatic force ?

[JEE MAIN_{S1}_240123]

(1) $d\sqrt{k}$ (2) $k\sqrt{d}$ (3) $1.5d\sqrt{k}$ (4) $2d\sqrt{k}$

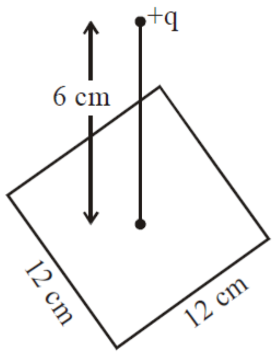
26. The electric potential at the centre of two concentric half rings of radii R_1 and R_2, having same linear charge density λ is **[JEE MAIN_{S2}_240123]**



(1) $\frac{2\lambda}{\epsilon_0}$ (2) $\frac{\lambda}{2\epsilon_0}$ (3) $\frac{\lambda}{4\epsilon_0}$ (4) $\frac{\lambda}{\epsilon_0}$

27. A point charge of +12 μC is at a distance 6 cm vertically above the centre of a square of side 12 cm as shown in figure. The magnitude of the electric flux through the square will be______ × 10^3 Nm^2/C.

[JEE-MAIN_{S2}_240221]



28. 27 similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is .... times that of a smaller drop.

[JEE MAIN_{S2}_260221]

29. An infinite number of point charges, each carrying 1 μ C charge, are placed along the y-axis at y = 1 m, 2 m, 4 m, 8 m.................

The total force on a 1 C point charge, placed at the origin, is x × 10^3 N. The value of x, to the nearest integer, is________. [Take $\frac{1}{4\pi \in_0} = 9 \times 10^9$ Nm^2/C^2] **[JEE MAIN_{S1}_180321]**

30. The total charge enclosed in an incremental volume of 2 × 10^{-9} m^3 located at the origin is _________nC, if electric flux density of its field is found as $D = e^{-x}\sin y\hat{i} - e^{-x}\cos y\hat{j} + 2z\hat{k}\, C/m^2$.

[JEE MAIN_{S2}_220721]

ANSWER KEY

1.	(4)	2.	(1)	3.	(1)	4.	(4)	5.	(4)	6.	(1)	7.	(1)
8.	(1)	9.	(3)	10.	(3)	11.	(3)	12.	(1)	13.	(3)	14.	(1)
15.	(4)	16.	(1)	17.	(3)	18.	(2)	19.	(4)	20.	(2)	21.	(2)
22.	(1)	23.	(2)	24.	(2)	25.	(1)	26.	(2)	27.	226	28.	243
29.	12	30.	4										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- GRAVITATION

(Important Questions Only)

1. The energy required to take a satellite to a height 'h' above Earth surface (radius of Earth = 6.4×10^3 km) is E_1 and kinetic energy required for the satellite to be in a circular orbit at this height is E_2. The value of h for which E_1 and E_2 are equal, is **[JEE MAIN_{S1}_090119]**

(1) 3.2×10^3 km (2) 1.6×10^3 km (3) 1.28×10^4 km (4) 6.4×10^3 km

2. Two stars of masses 3×10^{31} kg each, and at distance 2×10^{11} m rotate in a plane about their common centre of mass O. A meteorite passes through O moving perpendicular to the star's rotation plane. In order to escape from the gravitational field of this double star, the minimum speed that meteorite should have at O is: **[JEE MAIN_{S2}_100119]**

(Take Gravitational constant

$G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2})

(1) 2.8×10^5 m/s (2) 1.4×10^5 m/s (3) 2.4×10^4 m/s (4) 3.8×10^4 m/s

3. A satellite is revolving in a circular orbit at a height h from the earth surface, such that h << R where R is the radius of the earth. Assuming that the effect of earth's atmosphere can be neglected the minimum increase in the speed required so that the satellite could escape from the gravitational field of eath is **[JEE MAIN_{S1}_110119]**

(1) $\sqrt{2gR}$ (2) $\sqrt{gR}\left(\sqrt{2}-1\right)$ (3) $\sqrt{gR}$ (4) $\sqrt{\frac{gR}{2}}$

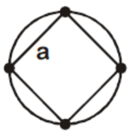
4. A straight rod of length L extends from x = a to x = L + a. The gravitational force it exerts on a point mass 'm' at x = 0, if the mass per unit length of the rod is $A + Bx^2$, is given by

[JEE MAIN {S1}_120119]

(1) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)+BL\right]$ (2) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)-BL\right]$

(3) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)+BL\right]$ (4) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)-BL\right]$

5. Four identical particles of mass M are located at the corners of a square of side 'a'. What should be their speed if each of them revolves under the influence of others' gravitational field in a circular orbit circumscribing the square? **[JEE-MAIN_{S1}_080419]**



(1) $1.41\sqrt{\frac{GM}{a}}$ (2) $1.16\sqrt{\frac{GM}{a}}$ (3) $1.21\sqrt{\frac{GM}{a}}$ (4) $1.35\sqrt{\frac{GM}{a}}$

6. A rocket has to be launched from earth in such a way that it never returns. If E is the minimum energy delivered by the rocket launcher, what should be the minimum energy that the launcher should have if the same rocket is to be launched from the surface of the moon? Assume that the density of the earth and the moon are equal and that the earth's volume is 64 times the volume of the moon.

[JEE-MAIN_{S2}_080419]

(1) $\frac{E}{64}$ (2) $\frac{E}{4}$ (3) $\frac{E}{16}$ (4) $\frac{E}{32}$

7. A test particle is moving in a circular orbit in the gravitational field produced by a mass density $\rho(r) = \frac{K}{r^2}$. Identify the correct relation between the radius R of the particle's orbit and its period T :

[JEE-MAIN_{S2}_090419]

(1) T/R is a constant (2) TR is a constant (3) T/R^2 is a constant (4) T^2/R^3 is a constant

8. A person of mass M is, sitting on a swing of length L and swinging with an angular amplitude θ_0. If the person stands up when the swing passes through its lowest point, the work done by him, assuming that his centre of mass moves by a distance l (l<<L), is close to : **[JEE-MAIN_{S1}_120419]**

(1) Mgl (2) $Mgl\left(1+\theta_0^2\right)$ (3) $Mgl\left(1+\frac{\theta_0^2}{2}\right)$ (4) $Mgl\left(1-\theta_0^2\right)$

9. A stellite of mass m is launched vertically upwards with an initial speed u from the surface of the earth. After it reaches height R(R = radius of the earth), it ejects a rocket of mass $\frac{m}{10}$ so that subsequently the satellite moves in a circular orbit. The kinetic energy of the rocket is (G is the gravitational constant; M is the mass of the earth): **[JEE-MAIN_{S1} _070120]**

(1) $5m\left(u^2 - \frac{119}{200}\frac{GM}{R}\right)$ (2) $\frac{3m}{8}\left(u+\sqrt{\frac{5GM}{6R}}\right)^2$

(3) $\frac{m}{20}\left(u-\sqrt{\frac{2GM}{3R}}\right)^2$ (4) $\frac{m}{20}\left(u^2+\frac{113}{200}\frac{GM}{R}\right)$

10. A satellite is moving in a low nearly circular orbit around the earth. Its radius is roughly equal to that of the earth's radius Re. By firing rockets attached to it, its speed is instantaneously increased in the direction of its motion so that it become $\sqrt{\frac{3}{2}}$ times larger. Due to this the farthest distance from the centre of the earth that the satellite reaches is R. Value of R is **[JEE-Main_{S1}_030920]**

(1) $3R_e$ (2) $4R_e$ (3) $2.5R_e$ (4) $2R_e$

11. The acceleration due to gravity on the earth's surface at the poles is g and angular velocity of the earth about the axis passing through the pole is ω. An object is weighed at the equator and at a height h above the poles by using a spring balance. If the weights are found to be same, then h is (h << R, where R is the radius of the earth) **[JEE MAIN_{S2} _050920]**

(1) $\frac{R^2\omega^2}{2g}$ (2) $\frac{R^2\omega^2}{g}$ (3) $\frac{R^2\omega^2}{8g}$ (4) $\frac{R^2\omega^2}{4g}$

12. A satellite is in an elliptical orbit around a planet P. It is observed that the velocity of the satellite when it is farthest from the planet is 6 times less than that when it is closest to the planet. The ratio of distances between the satellite and the planet at closest and farthest points is

[JEE MAIN_(S1)_060920]

(1) 1 : 6 (2) 1 : 2 (3) 3 : 4 (4) 1 : 3

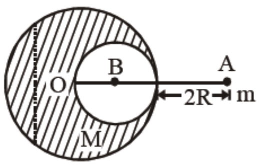
13. Two stars of masses m and 2m at a distance d rotate about their common centre of mass in free space. The period of revolution is : **[JEE-Main_{S1}_240221]**

(1) $\frac{1}{2\pi}\sqrt{\frac{d^3}{3Gm}}$ (2) $2\pi\sqrt{\frac{d^3}{3Gm}}$ (3) $\frac{1}{2\pi}\sqrt{\frac{3Gm}{d^3}}$ (4) $2\pi\sqrt{\frac{3Gm}{d^3}}$

14. Four identical particles of equal masses 1kg made to move along the circumference of a circle of radius 1 m under the action of their own mutual gravitational attraction. The speed of each particle will be : **[JEE-Main_{S1}_240221]**

(1) $\sqrt{\frac{G}{2}\left(1+2\sqrt{2}\right)}$ (2) $\sqrt{G\left(1+2\sqrt{2}\right)}$ (3) $\sqrt{\frac{G}{2}\left(2\sqrt{2}-1\right)}$ (4) $\frac{\sqrt{(1+2\sqrt{2})G}}{2}$

15. A solid sphere of radius R gravitationally attracts a particle placed at 3 R form its centre with a force F_1. Now a spherical cavity of radius $\left(\frac{R}{2}\right)$ is made in the sphere (as shown in figure) and the force becomes F_2. The value of $F_1 : F_2$ is : **[JEE MAIN_{S1}_020221]**



(1) 25 : 36 (2) 36 : 25 (3) 50 : 41 (4) 41 : 50

16. Assume that a tunnel is dug along a chord of the earth, at a perpendicular distance (R/2) from the earth's centre, where 'R' is the radius of the Earth. The wall of the tunnel is frictionless. If a particle is released in this tunnel, it will execute a simple harmonic motion with a time period :

[JEE MAIN_{S1}_260221]

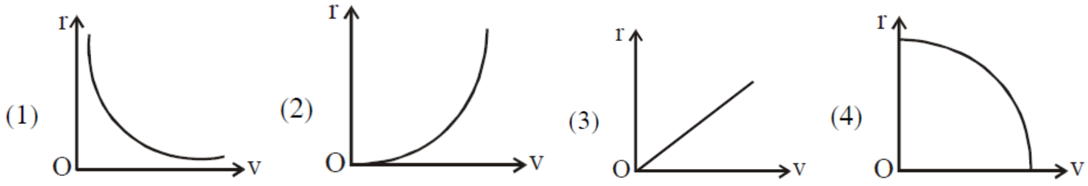
(1) $\frac{2\pi R}{g}$ (2) $\frac{g}{2\pi R}$ (3) $\frac{1}{2\pi}\sqrt{\frac{g}{R}}$ (4) $2\pi\sqrt{\frac{R}{g}}$

17. The angular momentum of a planet of mass M moving around the sun in an elliptical orbit is $\vec{L}$. The magnitude of the areal velocity of the planet is : **[JEE MAIN {S1}_180321]**

(1) $\frac{4L}{M}$ (2) $\frac{L}{M}$ (3) $\frac{2L}{M}$ (4) $\frac{L}{2M}$

18. A particle of mass m moves in a circular orbit under the central potential field, $U(r) = \frac{-C}{r}$, where C is a positive constant,

The correct radius – velocity graph of the particle's motion is : **[JEE MAIN_{S1}_180321]**



19. A body is projected vertically upwards from the surface of earth with a velocity sufficient enough to carry it to infinity. The time taken by it to reach height h is ________S. **[JEE MAIN_{S2}_220721]**

(1) $\sqrt{\frac{R_e}{2g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$ (2) $\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$

(3) $\frac{1}{3}\sqrt{\frac{R_e}{2g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$ (4) $\frac{1}{3}\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$

20. The masses and radii of the earth and moon are (M_1, R_1) and (M_2, R_2) respectively. Their centres are at a distance 'r' apart. Find the minimum escape velocity for a particle of mass 'm' to be projected from the middle of these two masses: **[JEE MAIN_{S2}_310821]**

(1) $V = \frac{1}{2}\sqrt{\frac{4G(M_1+M_2)}{r}}$ (2) $V = \sqrt{\frac{4G(M_1+M_2)}{r}}$

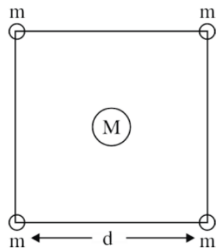
(3) $V = \frac{1}{2}\sqrt{\frac{2G(M_1+M_2)}{r}}$ (4) $V = \frac{\sqrt{2G}(M_1+M_2)}{r}$

21. The distance of the Sun from earth is 1.5×10^{11} m and its angular diameter is (2000) s when observed from the earth. The diameter of the Sun will be : **[JEE MAIN_{S2}_270622]**

(1) 2.45×10^{10} m (2) 1.45×10^{10} m (3) 1.45×10^{9} m (4) 0.14×10^{9} m

22. Four spheres each of mass m form a square of side d (as shown in figure). A fifth sphere of mass M is situated at the centre of square. The total gravitational potential energy of the system is :

[JEE MAIN_{S2}_270622]



(1) $-\frac{Gm}{d}\left[(4+\sqrt{2})m+4\sqrt{2}M\right]$ (2) $-\frac{Gm}{d}\left[(4+\sqrt{2})M+4\sqrt{2}m\right]$

(3) $-\frac{Gm}{d}\left[3m^2+4\sqrt{2}M\right]$ (4) $-\frac{Gm}{d}\left[6m^2+4\sqrt{2}M\right]$

23. Three identical particle A, B and C of mass 100 kg each are placed in a straight line with AB = BC = 13 m. The gravitational force on a fourth particle P of the same mass is F, when placed at a distance 13 m from the particle B on the perpendicular bisector of the line AC. The value of F will be approximately : **[JEE MAIN_{S1}_250722]**

(1) 21 G (2) 100 G (3) 59 G (4) 42 G

24. A body of mass m is projected with velocity λv_e in vertically upward direction from the surface of the earth into space. It is given that v_e is escape velocity and $\lambda < 1$. If air resistance is considered to the negligible, then the maximum height from the centre of earth, to which the body can go, will be (R : radius of earth) **[JEE MAIN_{S2}_270722]**

(1) $\frac{R}{1+\lambda^2}$ (2) $\frac{R}{1-\lambda^2}$ (3) $\frac{R}{1-\lambda}$ (4) $\frac{\lambda^2 R}{1-\lambda^2}$

25. If the distance of the earth from Sun is 1.5×10^6 km. Then the distance of an imaginary planet from Sun, if its period of revolution is 2.83 years is: **[JEE MAIN_{S2}_240123]**

(1) 6×10^7 km (2) 6×10^6 km (3) 3×10^6 km (4) 3×10^7 km

26. Given below are two statements: **[JEE MAIN_{S2}_240123]**

Statement I: Acceleration due to earth's gravity decreases as you go 'up' or 'down' from earth's surface.

Statement II: Acceleration due to earth's gravity is same at a height 'h' and depth 'd' from earth's surface, if h = d.

In the light of above statements, choose the most appropriate answer form the options given below

(1) Statement I is incorrect but statement II is correct

(2) Both Statement I and Statement II are incorrect

(3) Statement I is correct but statement II is incorrect

(4) Both Statement I and II are correct

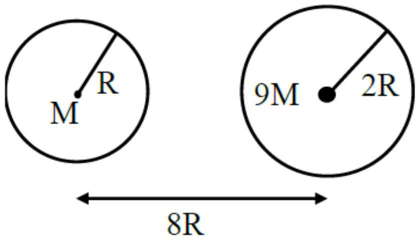
27. The weight of a body at the surface of earth is 18 N. The weight of the body at an altitude of 3200 km above the earth's surface is (given, radius of earth R_e = 6400 km) **[JEE MAIN_{S1}_240123]**

(1) 9.8 N (2) 4.9 N (3) 19.6 N (4) 8 N

28. An asteroid is moving directly towards the centre of the earth. When at a distance of 10 R (R is the radius of the earth) from the earths centre, it has a speed of 12 km/s. Neglecting the effect of earths atmosphere, what will be the speed of the asteroid when it hits the surface of the earth (escape velocity from the earth is 11.2 km/s)? Give your answer to the nearest integer in kilometer/s ________.

[JEE MAIN_{S2}_080120]

29. Suppose two planets (spherical in shape) of radii R and 2R, but mass M and 9 M respectively have a centre to centre separation 8 R as shown in the figure. A satellite of mass 'm' is projected from the surface of the planet of mass 'M' directly towards the centre of the second planet. The minimum speed 'v' required for the satellite to reach the surface of the second planet is $\sqrt{\frac{a}{7}\frac{GM}{R}}$ then the value of 'a' is ________. [Given : The two planets are fixed in their position] **[JEE MAIN_{S1}_270721]**



30. Two satellites revolve around a planet in coplanar circular orbits in anticlockwise direction. Their period of revolutions are 1 hour and 8 hours respectively. The radius of the orbit of nearer satellite is 2 × 10^3 km. The angular speed of the farther satellite as observed from the nearer satellite at the instant when both the satellites are closest is $\frac{\pi}{x}$ rad h^{-1} where x is .... **[JEE MAIN_{S2}_010921]**

ANSWER KEY

1.	**(1)**	**2.**	**(1)**	**3.**	**(2)**	**4.**	**(3)**	**5.**	**(2)**	**6.**	**(3)**	**7.**	**(1)**
8.	**(2)**	**9.**	**(1)**	**10.**	**(1)**	**11.**	**(1)**	**12.**	**(1)**	**13.**	**(2)**	**14.**	**(4)**
15.	**(3)**	**16.**	**(4)**	**17.**	**(4)**	**18.**	**(1)**	**19.**	**(4)**	**20.**	**(2)**	**21.**	**(3)**
22.	**(1)**	**23.**	**(2)**	**24.**	**(2)**	**25.**	**(3)**	**26.**	**(3)**	**27.**	**(4)**		
28.	**16.00**	**29.**	**4**	**30.**	**3**								

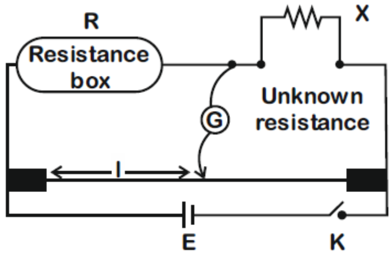
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- CURRENT ELECTRICITY

(Important Questions Only)

1. In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure. **[JEE MAIN_{S2}_100419]**

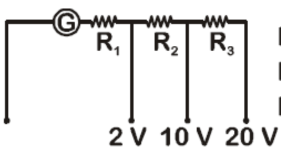


Sl. No	R (Ω)	l (cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

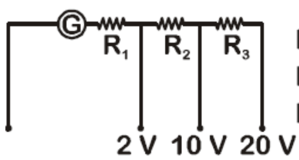
Which of the readings is inconsistent ?

(1) 3 (2) 2 (3) 1 (4) 4

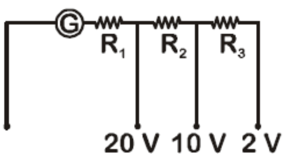
2. A galvanometer of resistance 100 Ω has 50 divisions on its scale and has sensitivity of 20 μA/division. It is to be converted to a voltmeter with three ranges, of 0-2 V, 0-10 V and 0-20 V. The appropriate circuit to do so is : **[JEE MAIN_{S1}_120419]**

(1)


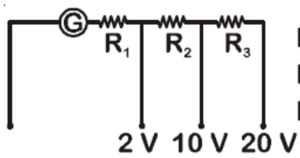
$R_1 = 1900\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

(2)


$R_1 = 1900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 19900\ \Omega$

(3)


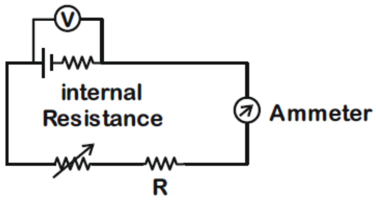
$R_1 = 19900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 1900\ \Omega$

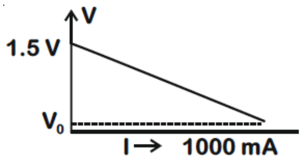
(4)


$R_1 = 2000\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

3. To verify Ohm's law, a student connects the voltmeter across the battery as, shown in the figure. The measured voltage is plotted as a function of the current, and the following graph is obtained :

[JEE MAIN_{S1}_120419]





If V_0 is almost zero, identify the correct statement :

(1) The emf of the battery is 1.5 V and its internal resistance is 1.5 Ω

(2) The emf of the battery is 1.5 V and the value of R is 1.5 Ω

(3) The value of the resitance R is 1.5 Ω

(4) The potential difference across the battery is 1.5 V when it sends a current of 1000 mA

4. A moving coil galvanometer, having a resistance G, produces full scale deflection when a current Ig flows through it. This galvanometer can be converted into (i) an ammeter of range 0 to $I_0(I_0 > I_g)$ by connecting a shunt resistance R_A to it and (ii) into a voltmeter of range 0 to $V(V = GI_0)$ by connecting a series resistance R_V to it. Then,

[JEE MAIN_{S2}_120419]

(1) $R_AR_V = G^2 \text{and} \frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

(2) $R_AR_V = G^2\left(\frac{I_g}{I_0 - I_g}\right) \text{and} \frac{R_A}{R_V} = \left(\frac{I_0 - I_g}{I_g}\right)^2$

(3) $R_AR_V = G^2 \text{and} \frac{R_A}{R_V} = \frac{I_g}{(I_0 - I_g)}$

(4) $R_AR_V = G^2\left(\frac{(I_0 - I_g)}{I_g}\right) \text{and} \frac{R_A}{R_V} = \left(\frac{I_g}{(I_0 - I_g)}\right)^2$

5. The length of a potentiometer wire is 1200 cm and it carries a current of 60 mA. For a cell of emf 5 V and internal resistance of 20 Ω, the null point on it is found to be at 1000 cm. The resistance of whole wire is :

[JEE MAIN_(S1)_080120]

(1) 80 Ω (2) 100 Ω (3) 60 Ω (4) 120 Ω

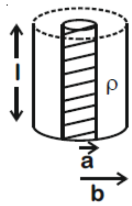
6. Consider four conducting materials copper, tungsten, mercury and aluminium with resistivity ρ_C, ρ_T, ρ_M and ρ_M respectively

[JEE MAIN_{S1}_020920]

(1) $\rho_M > \rho_A > \rho_C$ (2) $\rho_C > \rho_A > \rho_T$ (3) $\rho_A > \rho_M > \rho_C$ (4) $\rho_A > \rho_T > \rho_C$

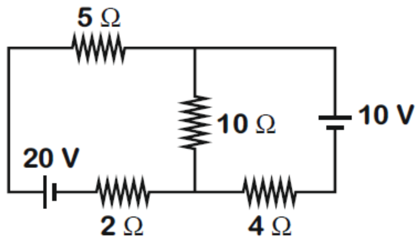
7. Model a torch battery of length l to be made up of a thin cylindrical bar of radius 'a' and a concentric thin cylindrical shell of radius 'b' filled in between with an electrolyte of resistivity ρ (see figure). If the battery is connected to a resistance of value R, the maximum Joule heating in R will take place for

[JEE MAIN_{S1}_030920]



(1) $R=\frac{\rho}{\pi l}\ln\left(\frac{b}{a}\right)$ (2) $R=\frac{2\rho}{\pi l}\ln\left(\frac{b}{a}\right)$ (3) $R=\frac{\rho}{2\pi l}\ln\left(\frac{b}{a}\right)$ (4) $R=\frac{\rho}{2\pi l}\left(\frac{b}{a}\right)$

8. **[JEE-MAIN_{S2}_060920]**



In the figure shown, the current in the 10 V battery is close to

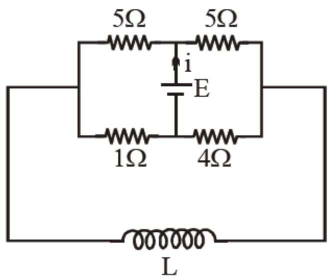
(1) 0.36 A from negative to positive terminal (2) 0.42 A from positive to negative terminal

(3) 0.71 A from positive to negative terminal (4) 0.21 A from positive to negative terminal

9. A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$ where α_0 = 20 A/s and β = 8 As^{-2}. Find the charge crossed through a section of the wire in 15s. **[JEE MAIN_{S1}_240221]**

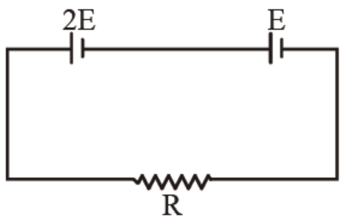
(1) 2250 C (2) 11250 C (3) 2100 C (4) 260 C

10. The current (i) at time t = 0 and t = ∞ respectively for the given circuit is : **[JEE MAIN_{S1}_020221]**



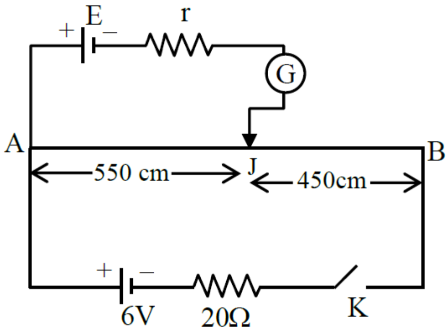
(1) $\frac{18E}{55},\frac{5E}{18}$ (2) $\frac{10E}{33},\frac{5E}{18}$ (3) $\frac{5E}{18},\frac{18E}{55}$ (4) $\frac{5E}{18},\frac{10E}{33}$

11. Two cells of emf 2E and E with internal resistance r_1 and r_2 respectively are connected in series to an external resistor R (see figure). The value of R, at which the potential difference across the terminals of the first cell becomes zero is **[JEE MAIN_{S2}_170321]**



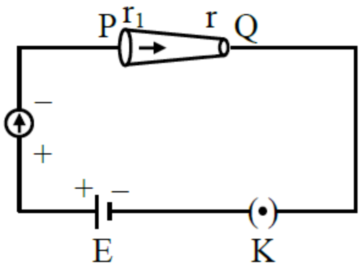
(1) r_1+r_2 (2) $\frac{r_1}{2}-r_2$ (3) $\frac{r_1}{2}+r_2$ (4) r_1-r_2

12. In the given figure, there is a circuit of potentiometer of length AB = 10 m. The resistance per unit length is 0.1 Ω per cm. Across AB, a battery of emf E and internal resistance 'r' is connected. The maximum value of emf measured by this potentiometer is : **[JEE MAIN_{S1}_250721]**



(1) 5 V (2) 2.25 V (3) 6 V (4) 2.75 V

13. In the given figure, a battery of emf E is connected across a conductor PQ of length 'l' and different area of cross-sections having radii r_1 and r_2 ($r_2 < r_1$). **[JEE MAIN_{S1}_270721]**

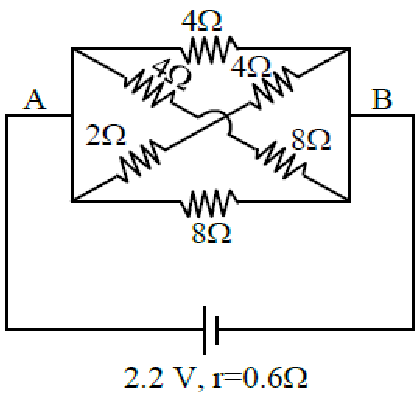


Choose the correct option as one moves from P to Q :

(1) Drift velocity of electron increases. (2) Electric field decreases.

(3) Electron current decreases. (4) All of these

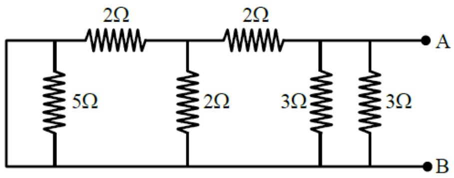
14. In the given figure, the emf of the cell is 2.2 V and if internal resistance is 0.6Ω. Calculate the power dissipated in the whole circuit : **[JEE Main_{S1}_260821]**



(1) 1.32 W (2) 0.65 W (3) 2.2 W (4) 4.4 W

15. The equivalent resistance of the given circuit between the terminals A and B is :

[JEE MAIN_{S1}_310821]



(1) 0Ω (2) 3Ω (3) $\frac{9}{2}\Omega$ (4) 1Ω

16. Identify the pair of physical quantities that have same dimensions : [JEE MAIN_{S2}_24_0622]

(1) velocity gradient and decay constant

(2) wien's constant and Stefan constant

(3) angular frequency and angular momentum

(4) wave number and Avogadro number

17. If n represents the actual number of deflections in a converted galvanometer of resistance G and shunt resistance S. Then the total current I when its figure of merit is K will be :

[JEE MAIN_{S2}_250622]

(1) $\frac{KS}{(S+G)}$ (2) $\frac{(G+S)}{nKS}$ (3) $\frac{nKS}{(G+S)}$ (4) $\frac{nK(G+S)}{s}$

18. Which of the following physical quantities have the same dimensions ? [JEE MAIN_{S1}_250722]

(1) Electric displacement ($\vec{D}$) and surface charge density

(2) Displacement current and electric field

(3) Current density and surface charge density

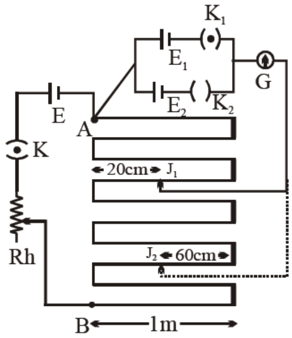
(4) Electric potential and energy

19. A cell of emf 90 V is connected across series combination of two resistors each of 100Ω resistance. A voltmeter of resistance 400 Ω is used to measure the potential difference across each resistor. The reading of the voltmeter will be : [JEE MAIN_{S2}_240123]

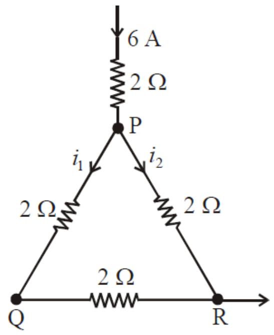
(1) 40 V (2) 45 V (3) 80 V (4) 90 V

20. In the given circuit of potentiometer, the potential difference E across AB (10m length) is larger than E_1 and E_2 as well. For key K_1 (closed), the jockey is adjusted to touch the wire at point J_1 so that there is no deflection in the galvanometer. Now the first battery (E_1) is replaced by second battery (E_2) for working by making K_1 open and K_2 closed. The galvanometer gives then null deflection at J_2.

The value of $\frac{E_1}{E_2}$ is $\frac{a}{b}$, where a = _____. [JEE MAIN_{S1}_020221]

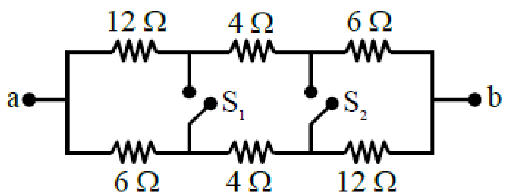


21. A current of 6 A enters one corner P of an equilateral triangle PQR having 3 wires of resistance 2Ω each and leaves by the corner R. The currents i_1 in ampere is ________. **[JEE MAIN_{S2}_250221]**

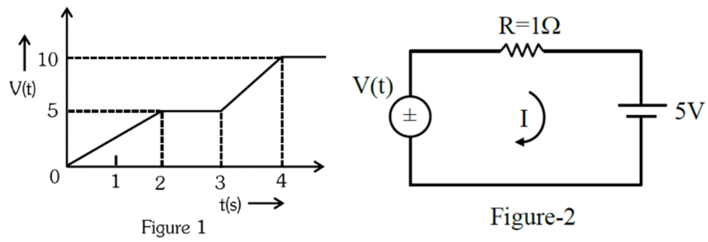


22. Two wires of same length and thickness having specific resistances 6 Ω cm and 3 Ω cm respectively are connected in parallel. The effective resistivity is ρ Ω cm. The value of ρ, to the nearest integer, is_____. **[JEE MAIN_{S1}_180321]**

23. In the given figure switches S_1 and S_2 are in open condition. The resistance across ab when the switches S_1 and S_2 are closed is __________Ω. **[JEE MAIN_{S2}_200721]**



24. For the circuit shown, the value of current at time t = 3.2 s will be _____A.
[JEE MAIN_{S2}_270721]



[Voltage distribution V (t) is shown by Fig. (i) and the circuit is shown in fig. (2)]

25. First, a set of n equal resistors of 10 Ω each are connected in series to a battery of emf 20V and internal resistance 10 Ω. A current I is observed to flow. Then, the n resistors are connected in parallel to the same battery. It is observed that the current is increased 20 times, then the value of n is ....

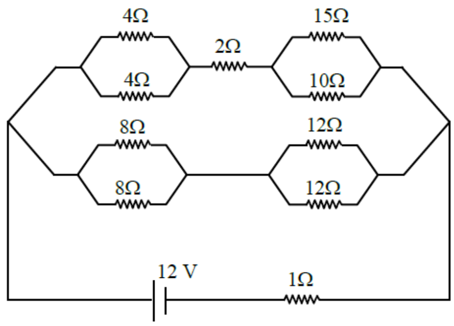
[JEE MAIN_{S1}_270821]

26. A square shaped wire with resistance of each side 3Ω is bent to form a complete circle. The resistance between two diametrically opposite points of the circle in unit of Ω will be _____.

[JEE MAIN_{S2}_310821]

27. The voltage drop across 15Ω resistance in the given figure will be _____V.

[JEE MAIN_{S2}_310821]

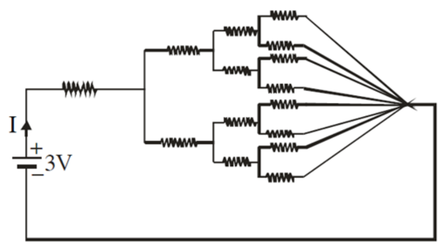


28. A potentiometer wire of length 10 m and resistance 20 Ω is connected in series with a 25 V battery and an external resistance 30 Ω. A cell of emf E in secondary circuit is balanced by 250 cm long potentiometer wire. The value of E (in volt) is $\frac{x}{10}$. The value of x is _______.

[JEE MAIN_{S2}_240622]

29. All resistances in figure are 1Ω each. The value of current 'I' is $\frac{a}{5}$A . The value of a is ______

[JEE MAIN_{S2}_280622]



30. If a copper wire is stretched to increase its length by 20°%. The percentage increase in resistance of the wire is __________ %. **[JEE MAIN_{S2}_240123]**

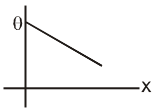
ANSWER KEY

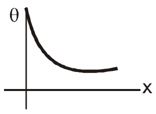
1.	(4)	2.	(1)	3.	(1)	4.	(1)	5.	(2)	6.	(1)	7.	(3)
8.	(4)	9.	(2)	10.	(4)	11.	(2)	12.	(1)	13.	(1)	14.	(3)
15.	(4)	16.	(1)	17.	(4)	18.	(1)	19.	(1)	20.	1	21.	2
22.	4	23.	10	24.	1	25.	20	26.	3	27.	6	28.	25
29.	8	30.	44										

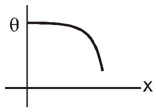
PHYSICS
JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023
Chapter Name :- HEAT TRANSFER
(Important Questions Only)

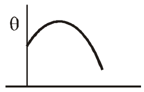
1. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figures

[AIEEE_2009]

(1) 

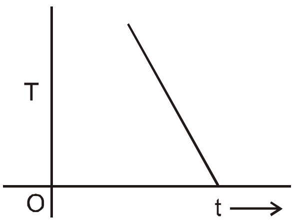
(2) 

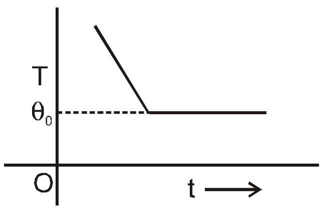
(3) 

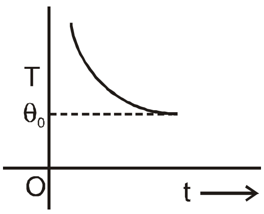
(4) 

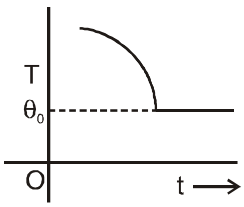
2. If a piece of metal is heated to temperature θ and then allowed to cool in a room which is at temperature θ_0, the graph between the temperature T of the metal and time t will be closest to :

[JEE-MAIN_2013]

(1) 

(2) 

(3) 

(4) 

3. Three rods of Copper, brass and steel are welded together to form a Y-shaped structure. Area of cross-section of each rod = 4 cm^2. End of copper rod is maintained at 100°C where as ends of brass and steel are kept at 0°C. Lengths of the copper, brass and steel rods are 46, 13 and 12 cms respectively. The rods are thermally insulated from surroundings except at ends. Thermal conductivities of copper, brass and steel are 0.92, 0.26 and 0.12 CGS units respectively. Rate of heat flow through copper rod is :

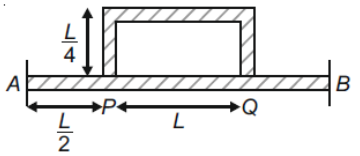
[JEE-MAIN_2014]

(1) 1.2 cal/s (2) 2.4 cal/s (3) 4.8 cal/s (4) 6.0 cal/s

4. An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure P and volume V is given by PV^n = constant, then n is given by (Here C_p and C_V are molar specific heat at constant pressure and constant volume, respectively) : **[JEE MAIN_2016]**

(1) $n = \frac{C - C_p}{C - C_V}$ (2) $n = \frac{C_p - C}{C - C_V}$ (3) $n = \frac{C - C_V}{C - Cp}$ (4) $n = \frac{C_p}{C_V}$

5. Temperature difference of 120°C is maintained between two ends of a uniform rod AB of length 2L. Another bent rod PQ, of same cross-section as AB and length $\frac{3L}{2}$, is connected across AB (see figure). In steady state, temperature difference between P and Q will be close to **[JEE MAIN_{S1}_ 090119]**



(1) 35ºC (2) 45ºC (3) 60ºC (4) 75º

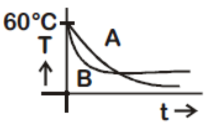
6. A heat source at T = 10^3 K is connected to another heat reservoir at T = 10^2 K by a copper slab which is 1 m thick. Given that the thermal conductivity of copper is 0.1 $WK^{-1}m^{-1}$, the energy flux through it in the steady state is **[JEE MAIN_{S1}_100119]**

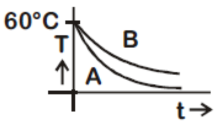
(1) 200 Wm^{-2} (2) 65 Wm^{-2} (3) 120 Wm^{-2} (4) 90 Wm^{-2}

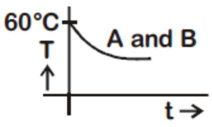
7. A cylinder of radius R is surrounded by a cylindrical shell of inner radius R and outer radius 2R. The thermal conductivity of the material of the inner cylinder is K_1 and that of the outer cylinder is K_2. Assuming no loss of heat, the effective thermal conductivity of the system for heat flowing along the length of the cylinder is **[JEE MAIN _{S1}_120119]**

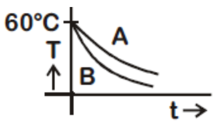
(1) $\frac{K_1 + K_2}{2}$ (2) $\frac{K_1 + 3K_2}{4}$ (3) $K_1 + K_2$ (4) $\frac{2K_1 + 3K_2}{5}$

8. Two identical beakers A and B contain equal volumes of two different liquids at 60°C each and left to cool down. Liquid in A has density of 8 × 10^2 kg/m^3 and specific heat of 2000 $Jkg^{-1}K^{-1}$ while liquid in B has density of 103 kgm–3 and specific heat of 4000 $Jkg^{-1}K^{-1}$. Which of the following best describes their temperature versus time graph schematically? (assume the emissivity of both the beakers to be the same) **[JEE-MAIN_{S1}_080419]**

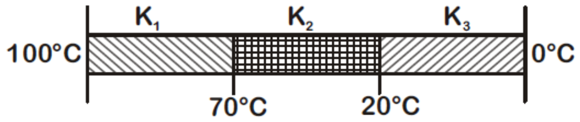
(1) 

(2) 

(3) 

(4) 

9. Three rods of identical cross-section and lengths are made of three different materials of thermal conductivity K_1, K_2 and K_3, respectively. They are joined together at their ends to make a long rod (see figure). One end of the long rod is maintained at 100°C and the other at 0°C (see figure). If the joints of the rod are at 70°C and 20°C in steady state and there is no loss of energy from the surface of the rod, the correct relationship between K_1, K_2 and K_3 is **[JEE-MAIN_{S2}_060920]**



(1) $K_1 : K_3 = 2 : 3$,
$K_2 : K_3 = 2 : 5$
(2) $K_1 < K_2 < K_3$
(3) $K_1 : K_2 = 5 : 2$,
$K_1 : K_3 = 3 : 5$
(4) $K_1 > K_2 > K_3$

10. A metallic sphere cools from 50°C to 40°C in 300 s. If atmospheric temperature around is 20°C, then the sphere's temperature after the next 5 minutes will be close to **[JEE-MAIN_{S2}_030920]**
(1) 28°C (2) 35°C (3) 33°C (4) 31°C

11. Given below are two statement : one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A : When a rod lying freely is heated, no thermal stress is developed in it.
Reason R : On heating the length of the rod increases. **[JEE MAIN_{S1}_020221]**
In the light of the above statements, choose the correct answer from the options given below:
(1) Both A and R are true but R is NOT the correct explanation of A
(2) A is false but R is true
(3) A is true but R is false
(4) Both A and R are true and R is the correct explanation of A

12. A large number of water drops, each of radius r, combine to have a drop of radius R. If the surface tension is T and mechanical equivalent of heat is J, the rise in heat energy per unit volume will be:
[JEE MAIN_{S1}_260221]
(1) $\frac{2T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$ (2) $\frac{2T}{rJ}$ (3) $\frac{3T}{rJ}$ (4) $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

13. What will be the average value of energy along one degree of freedom for an ideal gas in thermal equilibrium at a temperature T? (k_B is Boltzmann constant) **[JEE MAIN_{S1}_180321]**
(1) $\frac{1}{2}k_aT$ (2) $\frac{2}{3}k_aT$ (3) $\frac{3}{2}k_aT$ (4) k_aT

14. A body takes 4 min. to cool from 61° C to 59°C. If the temperature of the surroundings is 30°C, the time taken by the body to cool from 51°C to 49° C is : **[JEE MAIN_{S1}_270721]**
(1) 4 min. (2) 3 min. (3) 8 min. (4) 6 min.

15. Two thin metallic spherical shells of radii r_1 and r_2 ($r_1 < r_2$) are placed with their centres coinciding. A material of thermal conductivity K is filled in the space between the shells. The inner shell is maintained at temperature θ_1 and the outer shell at temperature θ_2 ($\theta_1 < \theta_2$). The rate at which heat flows radially through the material is :- **[JEE MAIN_{S1}_310821]**

(1) $\frac{4\pi K r_1 r_2(\theta_2-\theta_1)}{r_2-r_1}$ (2) $\frac{\pi r_1 r_2(\theta_2-\theta_1)}{r_2-r_1}$ (3) $\frac{K(\theta_2-\theta_1)}{r_2-r_1}$ (4) $\frac{K(\theta_2-\theta_1)(r_2-r_1)}{4\pi r_1 r_2}$

16. An expression for a dimensionless quantity P is given by $P=\frac{\alpha}{\beta}\log_e\left(\frac{kt}{\beta x}\right)$; where α and β are constants, x is distance ; k is Boltzmann constant and t is the temperature. Then the dimensions of α will be : **[JEE MAIN_{S1}_260622]**

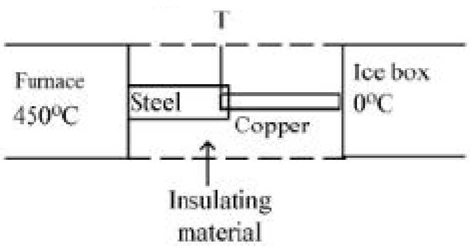
(1) $[M^0L^{-1}T^0]$ (2) $[ML^0T^{-2}]$ (3) $[MLT^{-2}]$ (4) $[ML^2T^{-2}]$

17. An ice cube of dimensions 60 cm × 50 cm × 20 cm is placed in an insulation box of wall thickness 1 cm. The box keeping the ice cube at 0°C of temperature is brought to a room of temperature 40°C. The rate of melting of ice is approximately: **[JEE MAIN_{S2}_260722]**

(Latent heat of fusion of ice is 3.4×10^5 J kg^{-1} and thermal conducting of insulation wall is 0.05 $Wm^{-1}\,{}^oC^{-1}$)

(1) 61×10^{-1} kg s^{-1} (2) 61×10^{-5} kg s^{-1} (3) 208 kg s^{-1} (4) 30×10^{-5} kg s^{-1}

18. If K_1 and K_2 are the thermal conductivities L_1 and L_2 are the lengths and A_1 and A_2 are the cross sectional areas of steel and copper rods respectively such that $\frac{K_2}{K_1}=9, \frac{A_1}{A_2}=2, \frac{L_1}{L_2}=2$. Then for the arrangement as shown in the figure. The value of temperature T of the steel – copper junction in the steady state will be : **[JEE MAIN_{S1}_270722]**



(1) 18 °C (2) 14 °C (3) 45 °C (4) 150 °C

19. Read the following statements :

A. When small temperature difference between a liquid and its surrounding is doubled the rate of loss of heat of the liquid becomes twice.

B. Two bodies P and Q having equal surface areas are maintained at temperature 10°C and 20°C. The thermal radiation emitted in a given time by P and Q are in the ratio 1 : 1.15

C. A carnot Engine working between 100 K and 400 K has an efficiency of 75%

D. When small temperature difference between a liquid and its surrounding is quadrupled, the rate of loos of heat of the liquid becomes twice.

Choose the correct answer from the options given below : **[JEE MAIN_{S1}_270722]**

(1) A, B, C only (2) A, B only (3) A, C only (4) B, C, D only

20. Two metallic wires of identical dimensions are connected is series. If σ_1 and σ_2 are the conductivities of the these wires respectively, the effective conductivity of the combination is : **[JEE MAIN_{S1}_290722]**

(1) $\frac{\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (2) $\frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (3) $\frac{\sigma_1+\sigma_2}{2\sigma_1\sigma_2}$ (4) $\frac{\sigma_1+\sigma_2}{\sigma_1\sigma_2}$

21. The resistance of a wire is 5 Ω. It's new resistance in ohm if stretched to 5 times of it's original length will be : **[JEE MAIN_{S1}_250123]**

(1) 625 (2) 5 (3) 125 (4) 25

22. The average kinetic energy of a molecule of the gas is **[JEE MAIN_{S1}_010223]**

(1) proportional to absolute temperature (2) proportional to volume

(3) proportional to pressure (4) dependent on the nature of the gas

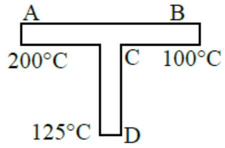
23. Ratio of thermal energy released in two resistor R and 3R connected in parallel in an electric circuit is : **[JEE MAIN_{S1}_290223]**

(1) 3 : 1 (2) 1 : 1 (3) 1 : 3 (4) 1 : 27

24. The electric field intensity produced by the radiation coming from a 100 W bulb at a distance of 3m is E. The electric field intensity produced by the radiation coming from 60 W at the same distance is $\sqrt{\frac{x}{5}}E$ Where the value of x = _______ **[JEE MAIN_{S2}_170321]**

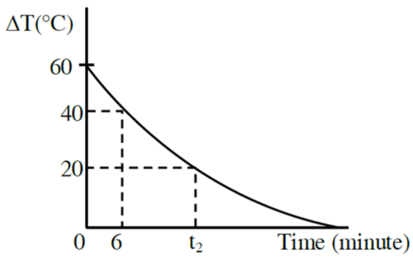
25. In 5 minutes, a body cools from 75ºC to 65ºC at room temperature of 25ºC. The temperature of body at the end of next 5 minutes is ________ºC. **[JEE_MAIN_{S2}_220721]**

26. A rod CD of thermal resistance 10.0 KW^{-1} is joined at the middle of an identical rod AB as shown in figure, The end A, B and D are maintained at 200°C, 100°C and 125°C respectively. The heat current in CD is P watt. The value of P is .... **[JEE MAIN_{S1}_270821]**



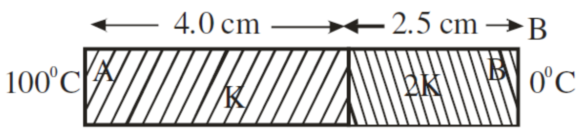
27. In an experiment of verify Newton's law of cooling, a graph is plotted between, the temperature difference (ΔT) of the water and surroundings and time as shown in figure. The initial temperature of water is taken as 80°C. The value of t_2 as mentioned in the graph will be ________.

[JEE MAIN_{S2}_240622]



28. Two coils require 20 minutes and 60 minutes respectively to produce same amount of heat energy when connected separately to the same source. If they are connected in parallel arrangement to the same source; the time required to produce same amount of heat by the combination of coils, will be___________min. **[JEE MAIN_{S1}_290622]**

29. As per the given figure, two plates A and B of thermal conductivity K and 2 K are joined together to form a compound plate. The thickness of plates are 4.0 cm and 2.5 cm respectively and the area of cross-section is 120 cm² for each plate. The equivalent thermal conductivity of the compound plate is $\left(1+\frac{5}{\alpha}\right)$ K, then the value of α will be ___________. **[JEE MAIN_{S1}_290622]**



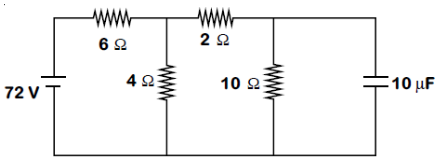
30. Nearly 10% of the power of a 110 W light bulb is converted to visible radiation. The change in average intensities of visible radiation, at a distance of 1 m from the bulb to a distance of 5 m is a × 10^{-2} W/m². The value of 'a' will be **[JEE MAIN_{S2}_290722]**

ANSWER KEY

1.	**(1)**	**2.**	**(3)**	**3.**	**(3)**	**4.**	**(1)**	**5.**	**(2)**	**6.**	**(4)**	**7.**	**(2)**
8.	**(2)**	**9.**	**(1)**	**10.**	**(3)**	**11.**	**(1)**	**12.**	**(4)**	**13.**	**(1)**	**14.**	**(4)**
15.	**(1)**	**16.**	**(3)**	**17.**	**(2)**	**18.**	**(3)**	**19.**	**(1)**	**20.**	**(2)**	**21.**	**(3)**
22.	**(1)**	**23.**	**(1)**	**24.**	**3**	**25.**	**57**	**26.**	**2**	**27.**	**16**	**28.**	**15**
29.	**21**	**30.**	**84**										

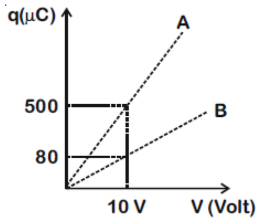
PHYSICS
JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023
Chapter Name :- CAPACITANCE
(Important Questions Only)

1. Determine the charge on the capacitor in the following circuit : **[JEE MAIN {S1}_09042019]**



(1) 200 μC (2) 60 μC (3) 10 μC (4) 2 μC

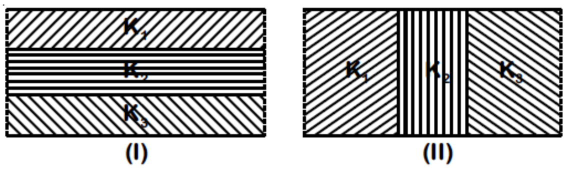
2. Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors. The capacitances are : **[JEE-MAIN_{S2}_100419]**



(1) 40 μF and 10 μF (2) 20 μF and 30 μF (3) 60 μF and 40 μF (4) 50 μF and 30 μF

3. Two identical parallel plate capacitors, of capacitance C each, have plates of area A, separated by a distance d. The space between the plates of the two capacitors, is filled with three dielectrics, of equal thickness and dielectric constants K_1, K_2 and K_3. The first capacitor is filled as shown in fig. I, and the second one is filled as shown in fig II.

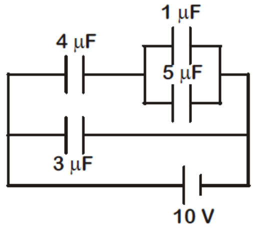
If these two modified capacitors are charged by the same potential V, the ratio of the energy stored in the two, would be (E_1 refers to capacitor (I) and E_2 to capacitor (II)): **[JEE-MAIN_{S1}_120419]**



(1) $\frac{E_1}{E_2}=\frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{K_1K_2K_3}$ (2) $\frac{E_1}{E_2}=\frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{9K_1K_2K_3}$

(3) $\frac{E_1}{E_2}=\frac{9K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$ (4) $\frac{E_1}{E_2}=\frac{K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

4. In the given circuit, the charge on 4 μF capacitor will be **[JEE MAIN_{S2}_120419]**



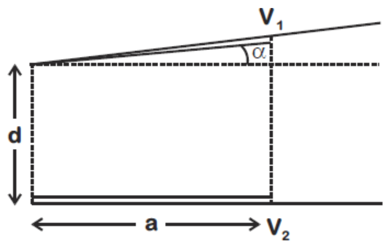
(1) 5.4 μC (2) 9.6 μC (3) 13.4 μC (4) 24 μC

5.

A parallel plate capacitor has plates of area A separated by distance 'd' between them. It is filled with a dielectric which has a dielectric constant that varies as k(x) = K(1 + αx) where 'x' is the distance measured from one of the plates. If (αd) << 1, the total capacitance of the system is best given by the expression **[JEE MAIN_(S1) _070120]**

(1) $\frac{AK\varepsilon_0}{d}(1+\alpha d)$ (2) $\frac{A\varepsilon_0 K}{d}\left(1+\frac{\alpha^2 d^2}{2}\right)$ (3) $\frac{AK\varepsilon_0}{d}\left(1+\frac{\alpha d}{2}\right)$ (4) $\frac{A\varepsilon_0 K}{d}\left(1+\left(\frac{\alpha d}{2}\right)^2\right)$

6. A capacitor is made of two square plates each of side 'a' making a very small angle α between them, as shown in figure. The capacitance will be close to **[JEE MAIN_{S2}_080120]**

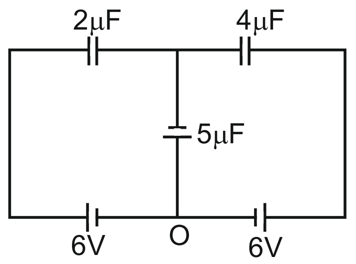


(1) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{3\alpha a}{2d}\right)$ (2) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$ (3) $\frac{\varepsilon_0 a^2}{d}\left(1+\frac{\alpha a}{d}\right)$ (4) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{4d}\right)$

7. A parallel plate capacitor has plate of length 'ℓ', width 'w' and separation of plates is 'd'. It is connected to a battery of emf V. A dielectric slab of the same thickness 'd' and of dielectric constant k = 4 is being inserted between the plates of the capacitor. At what length of the slab inside plates, will the energy stored in the capacitor be two times the initial energy stored? **[JEE MAIN_{S2} _050920]**

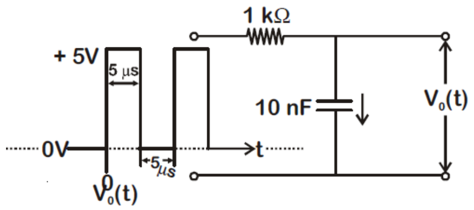
(1) $\frac{\ell}{4}$ (2) $\frac{\ell}{2}$ (3) $\frac{2\ell}{3}$ (4) $\frac{\ell}{3}$

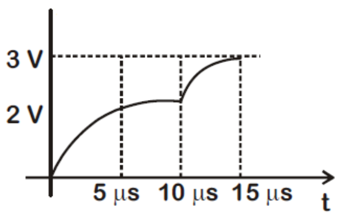
8. In the circuit shown, charge on the 5 μF capacitor is **[JEE MAIN_{S2}_050920]**



(1) 16.36 μC (2) 18.00 μC (3) 5.45 μC (4) 10.90 μC

9. For the given input voltage waveform $V_{in}(t)$, the output voltage waveform $V_0(t)$, across the capacitor is correctly depicted by **[JEE MAIN_(S1)_060920]**



(1)


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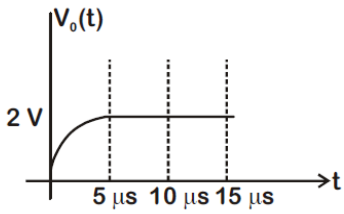

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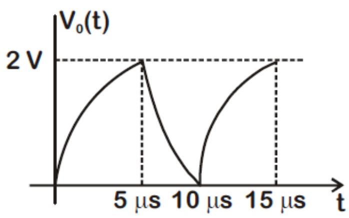
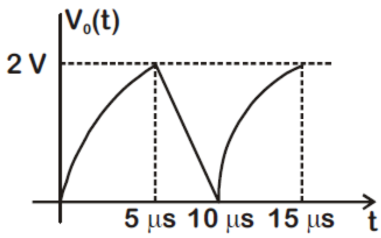


(4)


10. An electron with kinetic energy K_1 enters between parallel plates of a capacitor at an angle 'α' with the plates. It leaves the plates at angle 'β' with kinetic energy K_2. Then the ratio of kinetic energies $K_1 : K_2$ will be : **[JEE MAIN_{S2}_250221]**

(1) $\dfrac{\sin^2\beta}{\cos^2\alpha}$ (2) $\dfrac{\cos^2\beta}{\cos^2\alpha}$ (3) $\dfrac{\cos\beta}{\cos\alpha}$ (4) $\dfrac{\cos\beta}{\sin\alpha}$

11. Consider the combination of 2 capacitors C_1 and C_2, with $C_2 > C_1$, when connected in parallel, the equivalent capacitance is $\dfrac{15}{4}$ time the equivalent capacitance of the same connected in series. Calculate the ratio of capacitors, $\dfrac{C_2}{C_1}$. **[JEE MAIN_{S1}_260221]**

(1) $\dfrac{15}{11}$ (2) $\dfrac{111}{80}$ (3) $\dfrac{29}{15}$ (4) None of these

12. A parallel plate capacitor with plate area 'A' and distance of separation 'd' is filled with a dielectric. What is the capacity of the capacitor when permittivity of the dielectric varies as : **[JEE MAIN_{S1}_250721]**

$$\varepsilon(x) = \varepsilon_0 + kx, \text{for} \left(0 < x \le \frac{d}{2}\right)$$

$$\varepsilon(x) = \varepsilon_0 + k(d-x), \text{for} \left(\frac{d}{2} \le x \le d\right)$$

(1) $\left(\varepsilon_0 + \frac{kd}{2}\right)^{2/kA}$ (2) $\dfrac{kA}{2\ln\left(\frac{2\varepsilon_0 + kd}{2\varepsilon_0}\right)}$ (3) 0 (4) $\frac{kA}{2}\ln\left(\frac{2\varepsilon_0}{2\varepsilon_0 - kd}\right)$

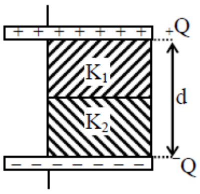
13. If q_f is the free charge on the capacitor plates and q_b is the bound charge on the dielectric slab of dielectric constant k placed between the capacitor plates, then bound charge q_b can be expressed as :

[JEE MAIN_{S2}_250721]

(1) $q_b = q_f\left(1 - \frac{1}{\sqrt{k}}\right)$ (2) $q_b = q_f\left(1 - \frac{1}{k}\right)$ (3) $q_b = q_f\left(1 + \frac{1}{\sqrt{k}}\right)$ (4) $q_b = q_f\left(1 + \frac{1}{k}\right)$

14. A parallel - plate capacitor with plate area A has separation d between the plates. Two dielectric slabs of dielectric constant K_1 and K_2 of same area A/2 and thickness d/2 are inserted in the space between the plates. The capacitance of the capacitor will be given by :

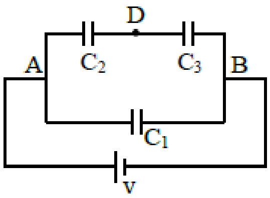
[JEE MAIN_{S2}_260821]



(1) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2} + \frac{K_1K_2}{K_1+K_2}\right)$ (2) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2} + \frac{K_1K_2}{2(K_1+K_2)}\right)$

(3) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2} + \frac{K_1+K_2}{K_1K_2}\right)$ (4) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2} + \frac{2(K_1+K_2)}{K_1K_2}\right)$

15. Three capacitors $C_1 = 2\mu F$, $C_2 = 6\ \mu F$ and $C_3 = 12\ \mu F$ are connected as shown in figure. Find the ratio of the charges on capacitors C_1, C_2 and C_3 respectively : **[JEE MAIN_{S2}_270821]**



(1) 2 : 1 : 1 (2) 2 : 3 : 3 (3) 1 : 2 : 2 (4) 3 : 4 : 4

16. A capacitor is connected to a 20 V battery through a resistance of 10Ω. It is found that the potential difference across the capacitor rises to 2 V in 1 μs. The capacitance of the capacitor is ....μF.

Given : $\ln\left(\frac{10}{9}\right) = 0.105$ **[JEE MAIN_{S2}_010921]**

(1) 9.52 (2) 0.95 (3) 0.105 (4) 1.85

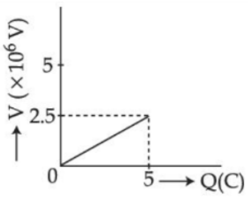
17. A force of 10N acts on a charged particle placed between two plates of a charged capacitor. If one plate of capacitor is removed, then the force acting on that particle will be : **[JEE MAIN_{S1}_270622]**

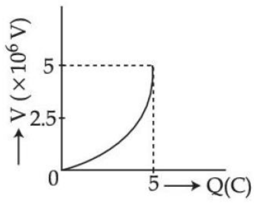
(1) 5 N (2) 10 N (3) 20 N (4) Zero

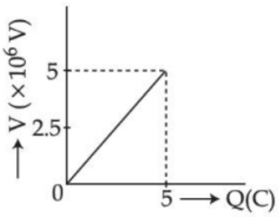
18. A capacitor is discharging through a resistor R. Consider in time t_1, the energy stored in the capacitor reduces to half of its initial value and in time t_2, the charge stored reduces to one eighth of its initial value. The ratio t_1/t_2 will be : **[JEE MAIN_{S2}_290622]**

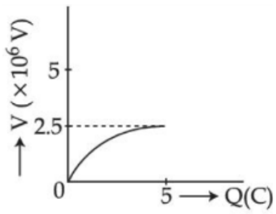
(1) 1/2 (2) 1/3 (3) 1/4 (4) 1/6

19. A condenser of 2 μF capacitance is charged steadily from 0 to 5C. Which of the following graph represents correctly the variation of potential difference (V) across it's plates with respect to the charge (Q) on the condenser ? **[JEE MAIN_{S1}_250722]**

(1) 

(2) 

(3) 

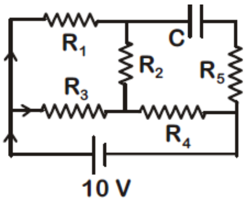
(4) 

20. Capacitance of an isolated conducting sphere of radius R_1 becomes n times when it is enclosed by a concentric conducting sphere of radius R_2 connected to earth. The ratio of their radii $\left(\frac{R_2}{R_1}\right)$ is :

[JEE MAIN_{S2}_250722]

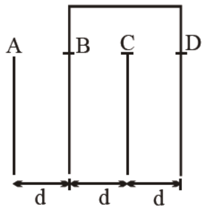
(1) $\frac{n}{n-1}$ (2) $\frac{2n}{2n+1}$ (3) $\frac{n+1}{n}$ (4) $\frac{2n+1}{n}$

21. An ideal cell of emf 10 V is connected in circuit shown in figure. Each resistance is 2 Ω. The potential difference (in V) across the capacitor when it is fully charged is _______. **[JEE MAIN_{S2}_020920]**



22. Four identical rectangular plates with length, l = 2 cm and breadth, $b = \frac{3}{2}$ cm are arranged as shown in figure. The equivalent capacitance between A and C is $\frac{x \epsilon_0}{d}$. The value of x is ___.

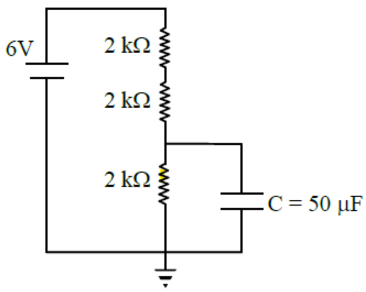
(Round off to the Nearest Integer) **[JEE_MAIN_{S1}_170321]**



23. A parallel plate capacitor whose capacitance C is 14 pF is charged by a battery to a potential difference V = 12V between its plates. The charging battery is now disconnected and a porcelin plate with k = 7 is inserted between the plates, then the plate would oscillate back and forth between the plates with a constant mechanical energy of _______ pJ.

(Assume no friction) **[JEE MAIN {S1}_170321]**

24. A capacitor of 50 μF is connected in a circuit as shown in figure. The charge on the upper plate of the capacitor is___________μC. **[JEE MAIN_{S2}_310821]**

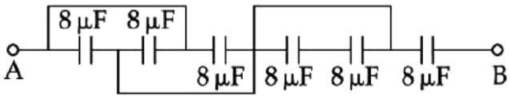


25. A parallel plate capacitor of capacitance 200 μF is connected to a battery of 200 V. A dielectric slab of dielectric constant 2 is now inserted into the space between plates of capacitor while the battery remain connected. The change in the electrostatic energy in the capacitor will be_____J.

[JEE MAIN_{S1}_310821]

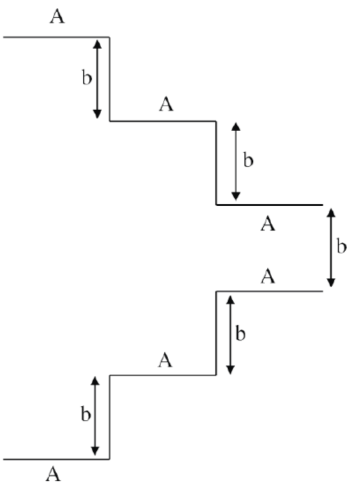
26. The equivalent capacitance between points A and B in below shown figure will be _____μF.

[JEE MAIN_{S1}_250622]



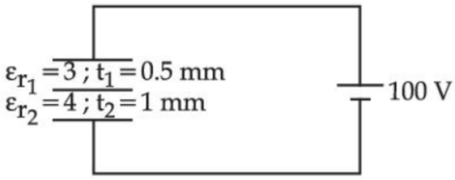
27. A paralle plate capacitor is made up of stair like structure with a palte area A of each stair and that is connected with a wire of length b, as shown in the figure. The capacitance of the arrangement is $\frac{x}{15}\frac{\varepsilon_0 A}{b}$. The value of x is _______ .

[JEE MAIN_{S2}_270622]



28. A composite parallel plate capacitor is made up of two different dielectric materials with different thickness (t_1 and t_2) as shown in figure. The two different dielectric material are separated by a conducting foil F. The voltage of the conducting foil is ____V.

[JEE MAIN_{S1}_260722]



29. A parallel plate capacitor with air between the plate has a capacitance of 15pF. The separation between the plate becomes twice and the space between them is filled with a medium of dielectric constant 3.5. Then the capacitance becomes $\frac{x}{4}$pF . The value of x is __________.

[JEE MAIN_{S2}_240123]

30. A capacitor has capacitance 5μF when it's parallel plates are separated by air medium of thickness d. A slab of material of dielectric constant 1.5 having area equal to that of plates but thickness $\frac{d}{2}$ is inserted between the plates. Capacitance of the capacitor in the presence of slab will be _____μF.

[JEE MAIN_{S2}_250123]

ANSWER KEY

1.	(1)	2.	(1)	3.	(3)	4.	(4)	5.	(3)	6.	(2)	7.	(4)
8.	(1)	9.	(1)	10.	(2)	11.	(4)	12.	(2)	13.	(2)	14.	(1)
15.	(3)	16.	(2)	17.	(1)	18.	(4)	19.	(1)	20.	(1)	21.	8
22.	2	23.	864	24.	100	25.	4	26.	6	27.	23	28.	60
29.	105	30.	6										

PHYSICS
JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023
Chapter Name :- EMF
(Important Questions Only)

1. A soft ferromagnetic material is placed in an external magnetic field. The magnetic domains :

[JEE MAIN_{S2}_240221

(1) increase in size but no change in orientation.
(2) have no relation with external magnetic field.
(3) decrease in size and changes orientation.
(4) may increase or decrease in size and change its orientation.

2. A proton, a deuteron and an α particle are moving with same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them is ____ and their speed is ____ in the ratio.

[JEE MAIN_{S1}_020221

(1) 1 : 2 : 4 and 2 : 1 : 1 (2) 2 : 1 : 1 and 4 : 2 : 1
(3) 4 : 2 : 1 and 2 : 1 : 1 (4) 1 : 2 : 4 and 1 : 1 : 2

3. A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the center of the magnet. If B_H = 0.4 G, the magnetic moment of the magnet is (1 G = 10^{-4}T) **[JEE MAIN_{S1}_160321]**

(1) 2.880×10^3 J T^{-1} (2) 2.880×10^2 J T^{-1}
(3) 2.880 J T^{-1} (4) 28.80 J T^{-1}

4. A coil having N turns is wound tightly in the form of a spiral with inner and outer radii 'a' and 'b' respectively. Find the magnetic field at centre, when a current I passes through coil :

[JEE MAIN_{S2}_310821]

(1) $\frac{\mu_0 IN}{2(b-a)}\log_e\left(\frac{b}{a}\right)$ (2) $\frac{\mu_0 I}{8}\left[\frac{a+b}{a-b}\right]$ (3) $\frac{\mu_0 I}{4(a-b)}\left[\frac{1}{a}-\frac{1}{b}\right]$ (4) $\frac{\mu_0 I}{8}\left[\frac{1-b}{a+b}\right]$

5. A small square loop of side 'a' and one turn is placed inside a larger square loop of side b and one turn (b >> a). The two loops are coplanar with their centres coinciding. If a current I is passed in the square loop of side 'b', then the coefficient of mutual inductance between the two loops is :

[JEE MAIN_{S2}_310821]

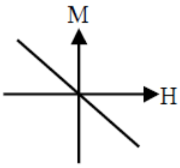
(1) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$ (2) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{a}$ (3) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{b^2}{a}$ (4) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{b}$

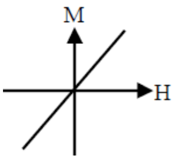
6. A current of 1.5 A is flowing through a triangle, of side 9 cm each. The magnetic field at the centroid of the triangle is : (Assume that the current is flowing in the clockwise direction.)

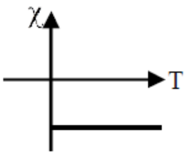
[JEE MAIN_{S1}_310821]

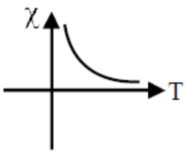
(1) 3×10^{-7} T, Outside the plane of triangle
(2) $2\sqrt{3} \times 10^{-7}$ T, Outside the plane of triangle
(3) $2\sqrt{3} \times 10^{-5}$ T, Outside the plane of triangle
(4) 3×10^{-5} T, Outside the plane of triangle

7. Following plots show Magnetization (M) vs Magnetising field (H) and Magnetic susceptibility (χ) vs temperature (T) graph : **[JEE MAIN_{S2}_010921]**

(a) 

(b) 

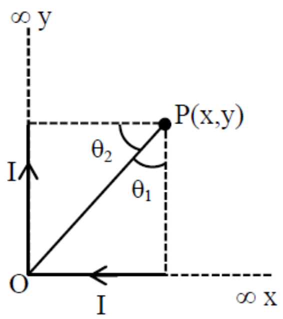
(c) 

(d) 

Which of the following combination will be represented by a diamagnetic material?

(1) (a), (c)
(2) (a), (d)
(3) (b), (d)
(4) (b), (c)

8. There are two infinitely long straight current carrying conductors and they are held at right angles to each other so that their common ends meet at the origin as shown in the figure given below. The ratio of current in both conductor is 1 : 1. The magnetic field at point P is _____. **[JEE MAIN_{S2}_010921]**



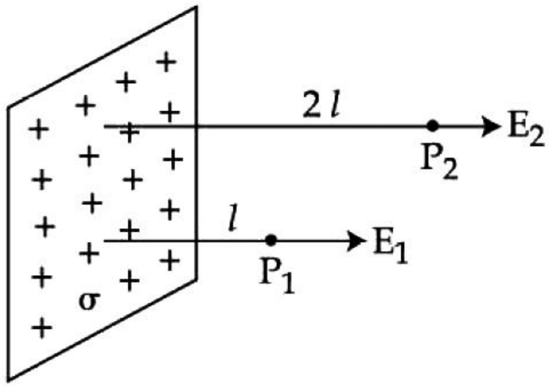
(1) $\frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2}+(x+y)\right]$
(2) $\frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2}-(x+y)\right]$
(3) $\frac{\mu_0 Ixy}{4\pi}\left[\sqrt{x^2+y^2}-(x+y)\right]$
(4) $\frac{\mu_0 Ixy}{4\pi}\left[\sqrt{x^2+y^2}+(x+y)\right]$

9. The magnetic field at the centre of a circular coil of radius r, due to current I flowing through it, is B. The magnetic field at a point along the axis at a distance $\frac{r}{2}$ from the centre is :

[JEE MAIN_{S1}_240622]

(1) B/2
(2) 2B
(3) $\left(\frac{2}{\sqrt{5}}\right)^3 B$
(4) $\left(\frac{2}{\sqrt{3}}\right)^3 B$

10. In the figure, a very large plane sheet of positive charge is shown. P_1 and P_2 are two points at distance ℓ and 2ℓ from the charge distribution. If s is the surface charge density, then the magnitude of electric fields E_1 and E_2 at P_1 and P_2 respectively are : **[JEE MAIN_{S1}_250622]**



(1) $E_1 = \sigma / \varepsilon_0$, $E_2 = \sigma / 2\varepsilon_0$ (2) $E_1 = 2\sigma / \varepsilon_0$, $E_2 = \sigma / \varepsilon_0$

(3) $E_1 = E_2 = \sigma / 2\varepsilon_0$ (4) $E_1 = E_2 = \sigma / \varepsilon_0$

11. A long straight wire with a circular crosssection having radius R, is carrying a steady current I. The current I is uniformly distributed across this cross-section. Then the variation of magnetic field due to current I with distance r (r < R) from its centre will be :- **[JEE MAIN_{S1}_250622]**

(1) $B \propto r^2$ (2) $B \propto r$ (3) $B \propto \frac{1}{r^2}$ (4) $B \propto \frac{1}{r}$

12. Given below are two statements : One is labeled as Assertion A and the other is labelled as Reason R.

Assertion A : If we move from poles to equator, the direction of acceleration due to gravity of earth always points towards the center of earth without any variation in its magnitude.

Reason R : At equator, the direction of acceleration due to the gravity is towards the center of earth. In the light of above statements, choose the correct answer from the options given below :

[JEE MAIN_{S2}_260622]

(1) Both A and R are true and R is the correct explanation of A.

(2) Both A and R are true but R is NOT the correct explanation of A.

(3) A is true but R is false

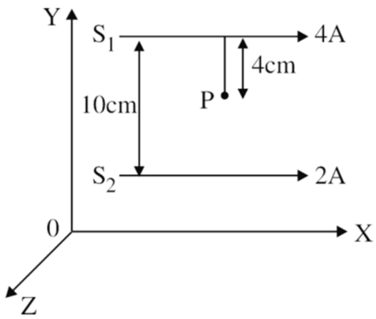
(4) A is false but R is true

13. Two long parallel conductors S_1 and S_2 are separated by a distance 10 cm and carrying currents of 4A and 2A respectively. The conductors are placed along x-axis in X-Y plane. There is a point P located between the conductors (as shown in figure). **[JEE MAIN_{S2}_270622]**

A charge particle of 3π coulomb is passing through the point P with velocity

$\vec{v} = (2\hat{i} + 3\hat{j})$m/s; where $\hat{i}$ & $\hat{j}$ represents unit vector along x & y axis respectively.

The force acting on the charge particle is $4\pi \times 10^{-5}(-x\hat{i} + 2\hat{j})$N . The value of x is :



(1) 2 (2) 1 (3) 3 (4) –3

14. Motion of a particle in x-y plane is described by a set of following equations $x = 4\sin\left(\frac{\pi}{2} - \omega t\right)$ m and $y = 4\sin(\omega t)$ m. The path of particle will be – **[JEE MAIN_{S1}_280622]**

(1) circular (2) helical (3) parabolic (4) elliptical

15. The space inside a straight current carrying solenoid is filled with a magnetic material having magnetic susceptibility equal to 1.2×10^{-5}. What is fractional increase in the magnetic field inside solenoid with respect to air as medium inside the solenoid? **[JEE MAIN_{S2}_280622]**

(1) 1.2×10^{-5} (2) 1.2×10^{-3} (3) 1.8×10^{-3} (4) 2.4×10^{-5}

16. Two parallel, long wires are kept 0.20 m apart in vacuum, each carrying current of x A in the same direction. If the force of attraction per meter of each wire is 2×10^{-6} N, then the value of x is approximately: **[JEE MAIN_{S2}_280622]**

(1) 1 (2) 2.4 (3) 1.4 (4) 2

17. An electron with energy 0.1 keV moves at right angle to the earth's magnetic field of 1×10^{-4} Wbm^{-2}. The frequency of revolution of the electron will be (Take mass of electron = 9.0×10^{-31} kg)

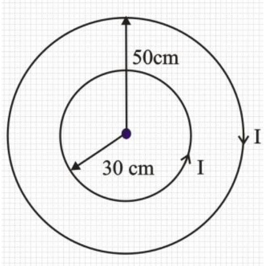
[JEE MAIN_{S2}_250722]

(1) 1.6×10^5 Hz (2) 5.6×10^5 Hz (3) 2.8×10^6 Hz (4) 1.8×10^6 Hz

18. A charge particle is moving in a uniform magnetic field $(2\hat{i} + 3\hat{j})$T. If it has an acceleration of $(\alpha\hat{i} - 4\hat{j})$m/s^2, then the value of α will be **[JEE MAIN_{S1}_260722]**

(1) 3 (2) 6 (3) 12 (4) 2

19. Two concentric circular loops of radii r_1 = 30 cm and r_2 = 50 cm are placed in X-Y plane as shown in the figure. A current **I** = 7A is flowing through them in the direction as shown in figure. The net magnetic moment of this system of two circular loops is approximately : **[JEE MAIN_{S2}_260722]**



(1) $\frac{7}{2}\hat{k}\,Am^2$ (2) $-\frac{7}{2}\hat{k}\,Am^2$ (3) $7\hat{k}\,Am^2$ (4) $-7\hat{k}\,Am^2$

20. A velocity selector consists of electric field $\vec{E} = E\hat{k}$ and magnetic field $\vec{B} = B\hat{j}$ with B = 12 mT. The value E required for an electron of energy 728 eV moving along the positive x-axis to pass undeflected is : **[JEE MAIN_{S2}_260722]**

(Given, mass of electron = 9.1×10^{-31}kg)

(1) 192 kVm^{-1} (2) 192 m Vm^{-1} (3) 9600 kVm^{-1} (4) 16 kVm^{-1}

21. Two bar magnets oscillate in a horizontal plane in earth's magnetic field with time periods of 3 s and 4 s respectively. If their moments of inertia are in the ratio of 3 : 2 then the ratio of their magnetic moments will be : **[JEE MAIN_{S1}_270722]**

(1) 2 : 1 (2) 8 : 3 (3) 1 : 3 (4) 27 : 16

22. A magnet hung at 45° with magnetic meridian makes an angle of 60° with the horizontal. The actual value of the angle of dip is **[JEE MAIN_{S1}_270722]**

(1) $\tan^{-1}\left(\sqrt{\frac{3}{2}}\right)$ (2) $\tan^{-1}\left(\sqrt{6}\right)$ (3) $\tan^{-1}\left(\sqrt{\frac{2}{3}}\right)$ (4) $\tan^{-1}\left(\sqrt{\frac{1}{2}}\right)$

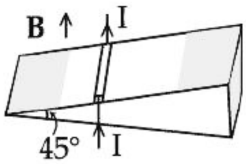
23. A beam of light travelling along X-axis is described by the electric field $E_y = 900 \sin \omega(t-x/c)$. The ratio of electric force of magnetic force on a charge q moving along Y-axis with a speed of 3×10^7 ms^{-1} will be : [Given speed of light = 3×10^8 ms^{-1}] **[JEE MAIN_{S1}_270722]**

(1) 1 : 1 (2) 1 : 10 (3) 10 : 1 (4) 1 : 2

24. A compass needle of oscillation magnetometer oscillates 20 times per minute at a place P of dip 30°. The number of oscillations per minute become 10 at another place Q of 60° dip. The ratio of the total magnetic field at the two places ($B_Q : B_P$) is : **[JEE MAIN_{S2}_270722]**

(1) $\sqrt{3} : 4$ (2) $4 : \sqrt{3}$ (3) $\sqrt{3} : 2$ (4) $2 : \sqrt{3}$

25. As shown in the figure, a metallic rod of linear density 0.45 kg m^{-1} is lying horizontally on a smooth incline plane which makes an angle of 45° with the horizontal. The minimum current flowing in the rod required to keep it stationary, when 0.15 T magnetic field is acting on it in the vertical upward direction, will be : **[JEE MAIN_{S1}_280722]**



(1) 30 A (2) 15 A (3) 10 A (4) 3 A

26. The electric current in a circular coil of four turns produces a magnetic induction 32 T at its centre. The coil is unwound and is rewound into a circular coil of single turn, the magnetic induction at the centre of the coil by the same current will be : **[JEE MAIN_{S2}_290123]**

(1) 8T (2) 4T (3) 2T (4) 16T

27. A long solenoid with 1000 turns/m has a core material with relative permeability 500 and volume 10^3 cm^3. If the core material is replaced by another material having relative permeability of 750 with same volume maintaining same current of 0.75 A in the solenoid, the fractional change in the magnetic moment of the core would be approximately $\left(\frac{x}{499}\right)$. Find the value of x. **[JEE MAIN_{S1}_310821]**

28. A deuteron and a proton moving with equal kinetic energy enter into to a uniform magnetic field at right angle to the field. If r_d and r_p are the radii of their circular paths respectively, then the ratio $\frac{r_d}{r_p}$ will be $\sqrt{x}:1$ where x is ______ . **[JEE MAIN_{S2}_270622]**

29. A singly ionized magnesium atom (A = 24) ion is accelerated to kinetic energy 5 keV and is projected perpendicularly into a magnetic field B of the magnitude 0.5 T. The radius of path formed will be ______________ cm. **[JEE MAIN_{S1}_280622]**

30. A closely wounded circular coil of radius 5 cm produces a magnetic field of 37.68×10^{-4} T at its center. The current through the coil is __________A. [Given, number of turns in the coil is 100 and $\pi = 3.14$] **[JEE MAIN_{S1}_290722]**

ANSWER KEY

1.	(4)	2.	(2)	3.	(3)	4.	(1)	5.	(1)	6.	(4)	7.	(1)
8.	(1)	9.	(3)	10.	(3)	11.	(2)	12.	(4)	13.	(3)	14.	(1)
15.	(1)	16.	(3)	17.	(3)	18.	(2)	19.	(2)	20.	(1)	21.	(2)
22.	(1)	23.	(3)	24.	(1)	25.	(1)	26.	(3)	27.	250	28.	2
29.	10	30.	3										

PHYSICS
JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023
Chapter Name :- EMI
(Important Questions Only)

1. A square loop is carrying a steady current I and the magnitude of its magnetic dipole moment is m. If this square loop is changed to a circular loop and it carries the same current, the magnitude of the magnetic dipole moment of circular loop will be : **[JEE MAIN_{S2}_100419]**

(1) $\frac{2m}{\pi}$ (2) $\frac{4m}{\pi}$ (3) $\frac{m}{\pi}$ (4) $\frac{3m}{\pi}$

2. A long solenoid of radius R carries a time (t) dependent current $I(t) = I_0t(1 - t)$. A ring of radius 2R is placed coaxially near its middle. During the time interval $0 \le t \le 1$, the induced current (I_R) and the induced EMF(V_R) in the ring change as: **[JEE-MAIN_M_(S1) _070120]**

(1) Direction of I_R remains unchanged and V_R is zero at t = 0.25

(2) Direction of I_R remains unchanged and V_R is maximum at t = 0.5

(3) At t = 0.5 direction of I_R reverses and V_R is zero

(4) At t = 0.25 direction of I_R reverses and V_R is maximum

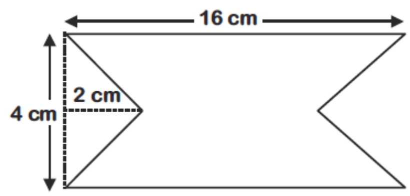
3. A LCR circuit behaves like a damped harmonic oscillator. Comparing it with a physical springmass damped oscillator having damping constant 'b' the correct equivalence would be

[JEE-MAIN_{S1}_070120]

(1) $L \leftrightarrow m, C \leftrightarrow \frac{1}{k}, R \leftrightarrow b$ (2) $L \leftrightarrow k, C \leftrightarrow b, R \leftrightarrow m$

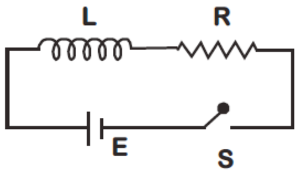
(3) $L \leftrightarrow \frac{1}{b}, C \leftrightarrow \frac{1}{m}, R \leftrightarrow \frac{1}{k}$ (4) $L \leftrightarrow m, C \leftrightarrow k, R \leftrightarrow b$

4. At time t = 0 magnetic field of 1000 Gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 Gauss, in the next 5 s, then induced EMF in the loop is **[JEE MAIN_(S1)_080120]**



(1) 48 μV (2) 36 μV (3) 56 μV (4) 28 μV

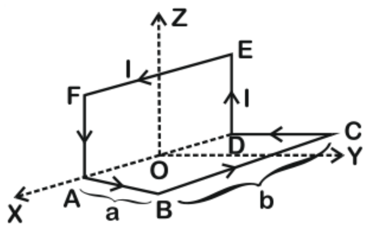
5.



As shown in the figure, a battery of emf E is connected to an inductor L and resistance R in series. The switch is closed at t = 0. The total charge that flows from the battery, between t = 0 and t = t_C (t_C is the time constant of the circuit) is : **[JEE MAIN_(S2) _080120]**

(1) $\frac{EL}{R^2}$ (2) $\frac{EL}{eL^2}$ (3) $\frac{EL}{R^2}\left(1-\frac{1}{e}\right)$ (4) $\frac{EL}{eR^2}$

6. A wire carrying current I is bent in the shape ABCDEFA as shown, where rectangle ABCDA and ADEFA are perpendicular to each other. If the sides of the rectangles are of lengths a and b, then the magnitude and direction of magnetic moment of the loop ABCDEFA is **[JEE-MAIN_{S2}_020920]**



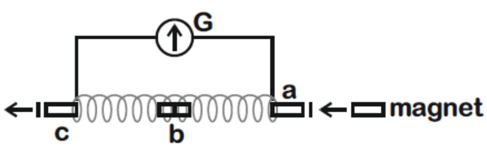
(1) abI, along $\left(\frac{\hat{j}}{\sqrt{5}}+\frac{2\hat{k}}{\sqrt{5}}\right)$ (2) $\sqrt{2}$ abI, along $\left(\frac{\hat{j}}{\sqrt{2}}+\frac{\hat{k}}{\sqrt{2}}\right)$

(3) abI, along $\left(\frac{\hat{j}}{\sqrt{2}}+\frac{\hat{k}}{\sqrt{2}}\right)$ (4) $\sqrt{2}$ abI, along $\left(\frac{\hat{j}}{\sqrt{5}}+\frac{2\hat{k}}{\sqrt{5}}\right)$

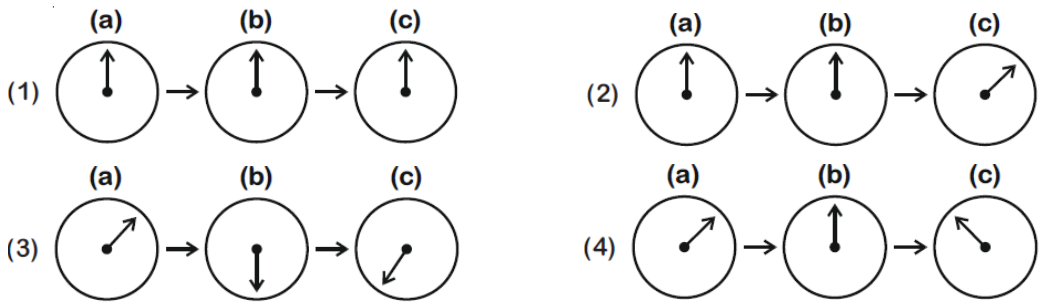
7. A uniform magnetic field B exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate dB/dt = 0.032 Ts^{-1}. The induced current in the loop is close to (Resistivity of the metal wire is 1.23×10^{-8} Ωm) **[JEE-MAIN_(S2) _030920]**

(1) 0.34 A (2) 0.61 A (3) 0.53 A (4) 0.43 A

8. A small bar magnet is moved through a coil at constant speed from one end to the other. Which of the following series of observations will be seen on the galvanometer G attached across the coil?



Three positions shown describe : (a) the magnet's entry (b) magnet is completely inside and (c) magnet's exit. **[JEE-MAIN_(S1)_040920]**



9. 0.8 kg m² around any diameter and is carrying current to produce a magnetic moment of 20 Am². The coil is kept initially in a vertical position and it can rotate freely around a horizontal diameter. When a uniform magnetic field of 4 T is applied along the vertical, it starts rotating, around its horizontal diameter. The angular speed the coil acquires after rotating by 60° will be **[JEE MAIN_(S2) _040920]**

(1) 13.16 rad s^{-1} (2) 10π rad s^{-1}

(3) 20 rad s^{-1} (4) 20π rad s^{-1}

10. A series L-R circuit is connected to a battery of emf V. If the circuit is switched on at t = 0, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is

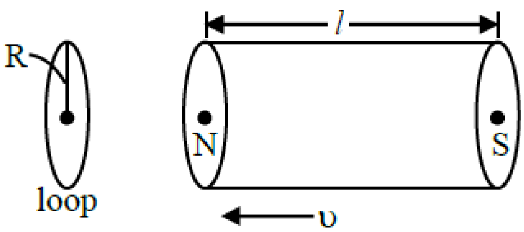
[JEE-MAIN_{S2}_040920]

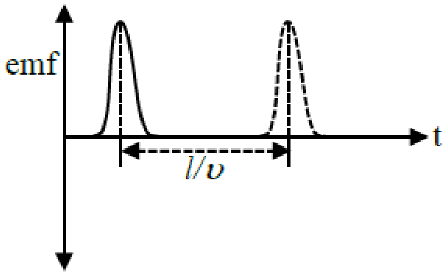
(1) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$ (2) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$ (3) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$ (4) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$

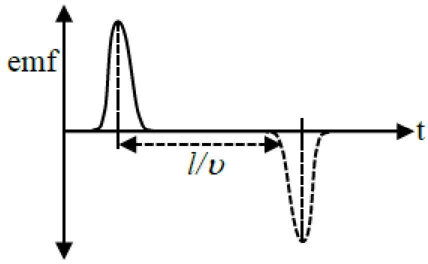
11. An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit in seconds : **[JEE MAIN_{S1}_260821]**

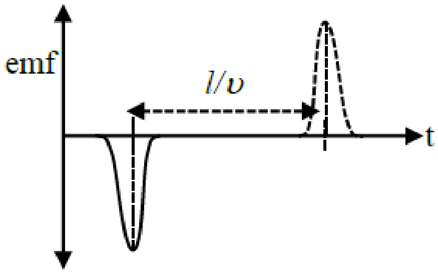
(1) 0.4 (2) 0.8 (3) 0.125 (4) 0.2

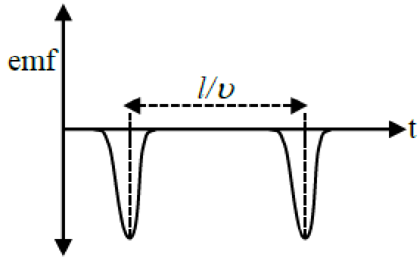
12. A bar magnet is passing through a conducting loop of radius R with velocity υ. The radius of the bar magnet is such that it just passes through the loop. The induced e.m.f. in the loop can be represented by the approximate curve : **[JEE MAIN_{S1}_270821]**



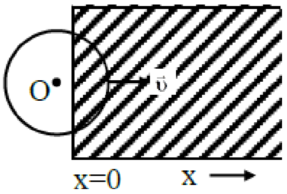
(1) 

(2) 

(3) 

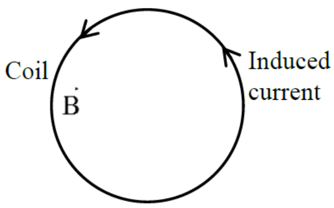
(4) 

13. A constant magnetic field of 1 T is applied in the x > 0 region. A metallic circular ring of radius 1m is moving with a constant velocity of 1 m/s along the x-axis. At t = 0s, the centre of O of the ring is at x = –1m. What will be the value of the induced emf in the ring at t = 1s? (Assume the velocity of the ring does not change.) **[JEE MAIN_{S2}_270821]**



(1) 1 V (2) 2 πV (3) 2 V (4) 0 V

14. A coil is placed in a magnetic field B as shown below : **[JEE MAIN_{S1}_310821]**



A current is induced in the coil because B is :

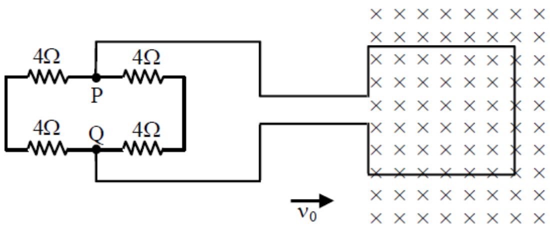
(1) Outward and decreasing with time

(2) Parallel to the plane of coil and decreasing with time

(3) Outward and increasing with time

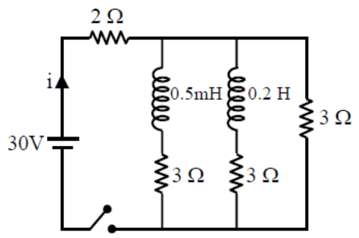
(4) Parallel to the plane of coil and increasing with time

15. A square loop of side 20 cm and resistance 1Ω is moved towards right with a constant speed v0. The right arm of the loop is in a uniform magnetic field of 5T. The field is perpendicular to the plane of the loop and is going into it. The loop is connected to a network of resistors each of value 4Ω. What should be the value of v0 so that a steady current of 2 mA flows in the loop ? **[JEE MAIN_{S2}_010921]**



(1) 1 m/s (2) 1 cm/s (3) 10^2 m/s (4) 10^{-2} cm/s

16. For the given circuit the current *i* through the battery when the key in closed and the steady state has been reached is_________. **[JEE MAIN_{S2}_010921]**



(1) 6 A (2) 25 A (3) 10 A (4) 0 A

17. The dimension of mutual inductance is : **[JEE MAIN_{S2}_260622]**

(1) $[ML^2 T^{-2} A^{-1}]$ (2) $[ML^2T^{-3}A^{-1}]$ (3) $[ML^2T^{-2}A^{-2}]$ (4) $[ML^2T^{-3}A^{-2}]$

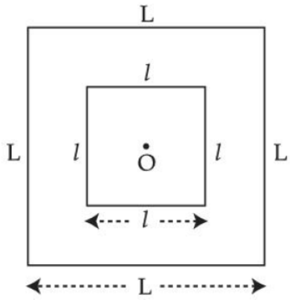
18. Two coils of self inductance L_1 and L_2 are connected in series combination having mutual inductance of the coils as M. The equivalent self inductance of the combination will be : **[JEE MAIN_{S2}_260622]**

(1) $\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{M}$ (2) $L_1 + L_2 + M$ (3) $L_1 + L_2 + 2M$ (4) $L_1 + L_2 - 2M$

19. A metallic conductor of length 1m rotates in a vertical plane parallel to east-west direction about one of its end with angular velocity 5 rad/s. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then emf induced between the two ends of the conductor is : **[JEE MAIN_{S2}_260622]**

(1) 5 μF (2) 50 μV (3) 5 mV (4) 50 mV

20. A small square loop of wire of side l is placed inside a large square loop of wire L (L >> l). Both loops are coplanar and their centres coincide at point O as shown in figure. The mutual inductance of the system is : **[JEE MAIN_{S1}_250722]**



(1) $\frac{2\sqrt{2}\mu_0 L^2}{\pi\ell}$ (2) $\frac{\mu_0\ell^2}{2\sqrt{2}\pi L}$ (3) $\frac{2\sqrt{2}\mu_0\ell^2}{\pi L}$ (4) $\frac{\mu_0\ell^2}{2\sqrt{2}\pi\ell}$

21. A coil of inductance 1H and resistance 100 Ω is connected to a battery of 6 v. Determine approximately :

(a) The time elapsed before the current acquires half of its steady – state value

(b) The energy stored in the magnetic field associated with the coil at an instant 15 ms after the circuit is switched on. (Given In 2 = 0.693, $e^{-3/2} = 0.25$) **[JEE MAIN_{S1}_290722]**

(1) t = 10 ms; U = 2 mJ (2) t = 10 ms; U = 1 mJ

(3) t = 7 ms; U = 1 mJ (4) t = 7 ms; U = 2 mJ

22. A long solenoid is formed by winding 70 turns cm^{-1}. If 2.0 A current flows, then the magnetic field produced inside the solenoid is ____________. ($\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}) **[JEE MAIN_{S2}_240123**

(1) 1232×10^{-4} T (2) 176×10^{-4} T (3) 352×10^{-4} T (4) 88×10^{-4} T

23. A circular coil of radius 10 cm is placed in a uniform magnetic field of 3.0×10^{-5} T with its plane perpendicular to the field initially. It is rotated at constant angular speed about an axis along the diameter of coil and perpendicular to magnetic field so that it undergoes half of rotation in 0.2 s. The maximum value of EMF induced (in μV) in the coil will be close to the integer ________.

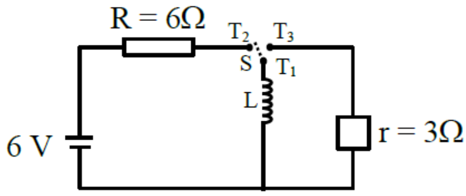
[JEE MAIN_(S1) _020920]

24. A circular conducting coil of radius 1 m is being heated by the change of magnetic field $\vec{B}$ passing perpendicular to the plane in which the coil is laid. The resistance of the coil is 2 $\mu\Omega$. The magnetic field is slowly switched off that its magnitude changes in time as **[JEE MAIN_{S1}_250721]**

$$B = \frac{4}{\pi} \times 10^{-3} T\left(1 - \frac{t}{100}\right)$$

The energy dissipated by the coil before the magnetic field is switched off completely is E = _______mJ.

25. Consider an electrical circuit containing a two way switch 'S'. Initially S is open and then T_1 is connected to T_2. As the current in R = 6 Ω attains a maximum value of steady state level, T_1 is disconnected from T_2 and immediately connected to T_3. Potential drop across r = 3 Ω resistor immediately after T_1 is connected to T_3 is______V. (Round off to the Nearest Integer) **[JEE MAIN_{S1}_270721]**



26. The current in a coil of self inductance 2.0 H is increasing according to I = 2sin(t^2)A. The amount of energy spent during the period when current changes from 0 to 2A is ________ J.

[JEE MAIN_{S1}_250622]

27. A 10Ω, 20 mH coil carrying constant current is connected to a battery of 20 V through a switch is opened current becomes zero in 100μs. The average emf induced in the coil is .... V.

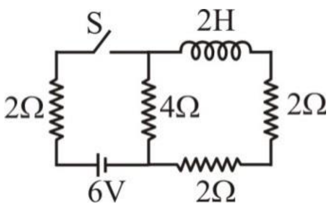
[JEE MAIN_{S1}_260622]

28. In a coil of resistance 8Ω, the magnetic flux due to an external magnetic field varies with time as $\phi = \frac{2}{3}(9 - t^2)$. The value of total heat produced in the coil, till the flux becomes zero, will be ----------J.

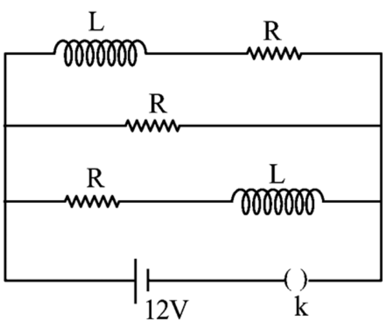
[JEE MAIN_{S2}_260722]

29. For the given circuit the current through battery of 6V just after closing the switch 'S' will be ……….A.

[JEE MAIN_{S2}_280722]



30. Three identical resistors with resistance R = 12Ω and two identical inductors with sell inductance L = 5 mH are connected to an ideal battery with emf of 12 V as shown in figure. The current through the battery long after the switch has been closed will be _________A. **[JEE MAIN_{S2}_240123]**



ANSWER KEY

1.	(2)	2.	(3)	3.	(1)	4.	(3)	5.	(4)	6.	(2)	7.	(2)
8.	(4)	9.	(1)	10.	(2)	11.	(4)	12.	(3)	13.	(3)	14.	(1)
15.	(2)	16.	(3)	17.	(3)	18.	(4)	19.	(2)	20.	(3)	21.	(3)
22.	(2)	23.	15	24.	80	25.	3	26.	4	27.	400	28.	2
29.	1	30.	3										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- ALTERNATING CURRENT

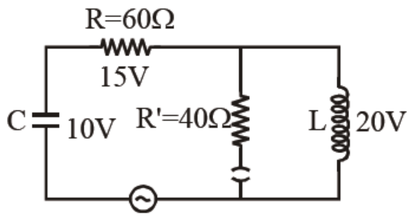
(Important Questions Only)

1. An alternating voltage v(t) = 220 sin 100πt volt is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value to the peak value is **[JEE MAIN_{S1}_080419]**

(1) 2.2 ms (2) 7.2 ms (3) 5 ms (4) 3.3 ms

2. The angular frequency of alternating current in a L-C-R circuit is 100 rad/s. The components connected are shown in the figure. Find the value of inductance of the coil and capacity of condenser.

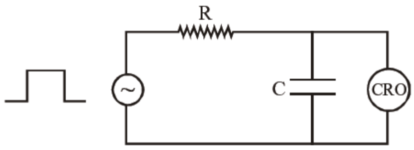
[JEE MAIN_{S1}_020221]



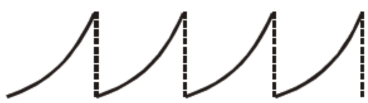
(1) 0.8 H and 150 μF (2) 0.8 H and 250 μF

(3) 1.33 H and 250 μF (4) 1.33 H and 150 μF

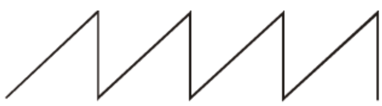
3. An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to : **[JEE MAIN_ {S1}_160321]**



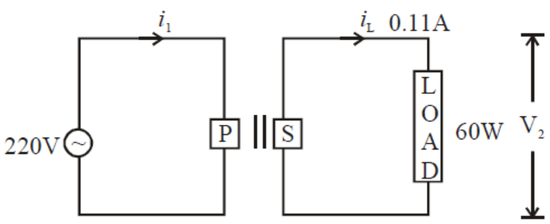
(1) 

(2) 

(3) 

(4) 

4. For the given circuit, comment on the type of transformer used : **[JEE MAIN_{S2}_160321]**



(1) Auxilliary transformer (2) Auto transformer

(3) Step-up transformer (4) Step down transformer

5. An AC current is given by $I = I_1 \sin\omega t + I_2 \cos\omega t$. A hot wire ammeter will give a reading :

[JEE MAIN_{S1}_170321]

(1) $\sqrt{\dfrac{I_1^2 - I_2^2}{2}}$ (2) $\sqrt{\dfrac{I_1^2 + I_2^2}{2}}$ (3) $\dfrac{I_1^2 + I_2^2}{\sqrt{2}}$ (4) $\dfrac{I_1^2 + I_2^2}{2\sqrt{2}}$

6. Match list I with List II **[JEE MAIN_{S2}_170321]**

List - I		**List - II**	
(a)	Phase difference between current and voltage in a purely resistive AC circuit	(i)	$\frac{\pi}{2}$; current leads voltage
(b)	Phase difference between current and voltage in a pure inductive AC circuit	(ii)	Zero
(c)	Phase difference between current and voltage in a pure capacitive AC circuit	(iii)	$\frac{\pi}{2}$; current lags voltage
(d)	Phase difference between current and voltage in an LCR series circuit	(iv)	$\tan^{-1}\left(\frac{X_C - X_t}{R}\right)$

Choose the most appropriate answer from the options given below :

(1) (a)–(i),(b)–(iii),(c)–(iv),(d)–(ii) (2) (a)–(ii),(b)–(iv),(c)–(iii),(d)–(i)

(3) (a)–(ii),(b)–(iii),(c)–(iv),(d)–(i) (4) (a)–(ii),(b)–(iii),(c)–(i),(d)–(iv)

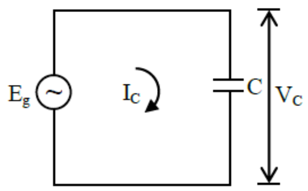
7. An AC source rated 220 V, 50 Hz is connected to a resistor. The time taken by the current to change from its maximum to the rms value is : **[JEE MAIN_{S1}_180321]**

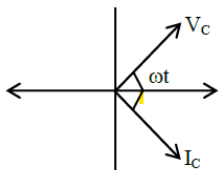
(1) 2.5 ms (2) 25 ms (3) 2.5 s (4) 0.25 ms

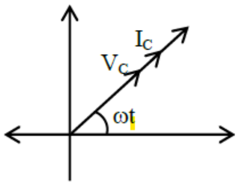
8. In a series LCR circuit, the inductive reactance (X_L) is 10 Ω and the capacitive reactance (X_C) is 4 Ω. The resistance (R) in the circuit is 6 Ω. The power factor of the circuit is : **[JEE MAIN_ {S1}_180321]**

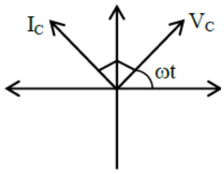
(1) $\frac{1}{2}$ (2) $\frac{1}{2\sqrt{2}}$ (3) $\frac{1}{\sqrt{2}}$ (4) $\frac{\sqrt{3}}{2}$

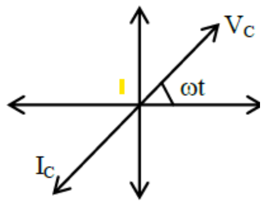
9. In a circuit consisting of a capacitance and a generator with alternating emf $E_g = E_{g0} \sin \omega t$, V_C and I_C are the voltage and current. Correct phasor diagram for such circuit is : **[JEE MAIN_{S2}_220721]**



(1) 

(2) 

(3) 

(4) 

10. Match List-I with List-II : **[JEE MAIN_{S2}_220721]**

	List–I		List–II
(a)	$\omega L > \frac{1}{\omega C}$	(i)	Current is in phase with emf
(b)	$\omega L = \frac{1}{\omega C}$	(ii)	Current lags behind the applied emf
(c)	$\omega L < \frac{1}{\omega C}$	(iii)	Maximum current occurs
(d)	Resonant frequency	(iv)	Current leads the emf

Choose the correct answer from the options given below :

(1) (a) -(ii); (b)-(i); (c)-(iv); (d) -(iii)
(2) (a) -(ii); (b)-(i); (c)-(iii); (d) -(iv)
(3) (a) -(iii); (b)-(i); (c)-(iv); (d) -(ii)
(4) (a) -(iv); (b)-(iii); (c)-(ii); (d) -(i)

11. A 10 Ω resistance is connected across 220V – 50 Hz AC supply. The time taken by the current to change from its maximum value to the rms value is : **[JEE MAIN_{S2}_250721]**

(1) 2.5 ms (2) 1.5 ms (3) 3.0 ms (4) 4.5 ms

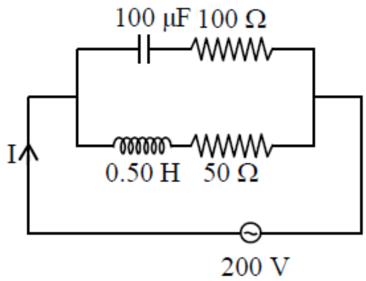
12. A 0.07 H inductor and a 12 Ω resistor are connected in series to a 220 V, 50 Hz ac source. The approximate current in the circuit and the phase angle between current and source voltage are respectively. [Take π as $\frac{22}{7}$] **[JEE MAIN_{S1}_270721]**

(1) 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$
(2) 88 A and $\tan^{-1}\left(\frac{11}{6}\right)$
(3) 0.88 A and $\tan^{-1}\left(\frac{11}{6}\right)$
(4) 8.8 A and $\tan^{-1}\left(\frac{6}{11}\right)$

13. A series LCR circuit driven by 300 V at a frequency of 50 Hz contains a resistance R = 3 kΩ, an inductor of inductive reactance XL = 250 $\pi\Omega$ and an unknown capacitor. The value of capacitance to maximize the average power should be : (Take π^2 = 10) **[JEE MAIN_{S1}_260821]**

(1) 4 μF (2) 25 μF (3) 400 μF (4) 40 μF

14. In the given circuit the AC source has ω = 100 rad s^{-1}. Considering the inductor and capacitor to be ideal, what will be the current I flowing through the circuit? **[JEE MAIN_{S2}_260821]**



(1) 5.9 A (2) 4.24 A (3) 0.94 A (4) 6 A

15. Given below are two statements : **[JEE MAIN_{S2}_240622]**

Statement-I : The reactance of an ac circuit is zero. It is possible that the circuit contains a capacitor and an inductor.

Statement-II : In ac circuit, the average poser delivered by the source never becomes zero. In the light of the above statements, choose the correct answer from the options given below :

(1) Both Statement I and Statement II are true. (2) Both Statement I and Statement II are false.

(3) Statement I is true but Statement II in false. (4) Statement I is false but Statement II is true.

16. A sinusoidal voltage V(t) = 210 sin 3000t volt is applied to a series LCR circuit in which L = 10 mH, C = 25 μF and R = 100Ω. The phase difference (Φ) between the applied voltage and resultant current will be : **[JEE MAIN_{S2}_250622]**

(1) $\tan^{-1}$ (0.17) (2) $\tan^{-1}$ (9.46) (3) $\tan^{-1}$ (0.30) (4) $\tan^{-1}$ (13.33)

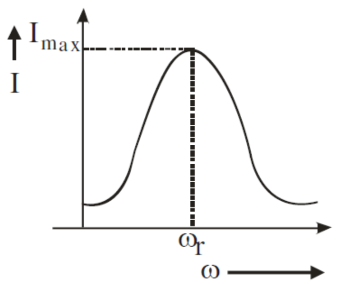
17. For a series LCR circuit, I vs ω curve is shown : **[JEE MAIN_{S1}_290622]**

(a) To the left of ω_r, the circuit is mainly capacitive.

(b) To the left of ω_r, the circuit is mainly inductive.

(c) At ω_r, impedance of the circuit is equal to the resistance of the circuit.

(d) At ω_r, impedance of the circuit is 0.



Choose the most appropriate answer from the options given below :

(1) (a) and (d) only (2) (b) and (d) only (3) (a) and (c) only (4) (b) and (c) only

18. In a series LR circuit X_L = R and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. The ratio $\frac{P_1}{P_2}$ is

[JEE MAIN_{S1}_260722]

(1) $\frac{1}{2}$ (2) $\frac{1}{\sqrt{2}}$ (3) $\frac{\sqrt{3}}{\sqrt{2}}$ (4) 2 : 1

19. Seawater at a frequency f = 9 × 10^2 Hz, has permittivity $\varepsilon = 80\,\varepsilon_0$ and resistivity r = 0.25 Ωm. Imagine a parallel plate capacitor is immersed in seawater and is driven by an alternating voltage source $V(t)=V_0 \sin(2\pi ft)$. Then the conduction current density becomes 10^x times the displacement current density after time $t = \frac{1}{800}$ s . The value of x is __________. [JEE MAIN_{S2}_170321]

(Given : $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2C^{-2}$)

20. In an LCR series circuit, an inductor 30 mH and a resistor 1Ω are connected to an AC source of angular frequency 300 rad/s. The value of capacitance for which, the current leads the voltage by 45º is $\frac{1}{x} \times 10^{-3}$ F. Then the value of x is _____. [JEE MAIN_{S1}_200721]

21. Two circuits are shown in the figure (a) & (b). At a frequency of _________rad/s the average power dissipated in one cycle will be same in both the circuits. [JEE MAIN_{S2}_250721]

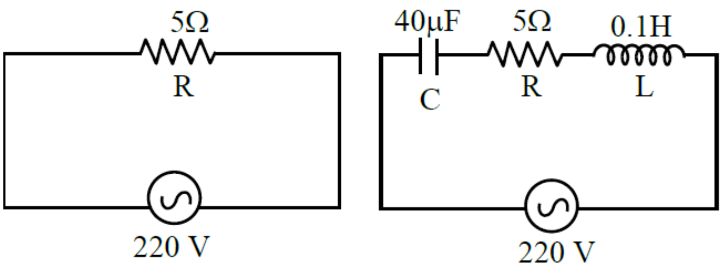


figure (a) figure (b)

22. The alternating current is given by [JEE MAIN_{S1}_270821]

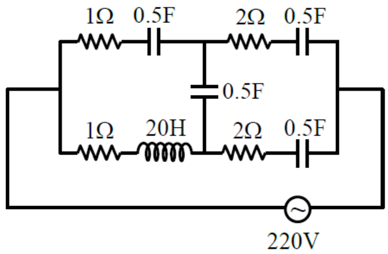
$$i = \left\{\sqrt{42}\sin\left(\frac{2\pi}{T}t\right) + 10\right\}A$$

The r.m.s. value of this current is ……A.

23. An ac circuit has an inductor and a resistor of resistance R in series, such that XL = 3R. Now, a capacitor is added in series such that XC = 2R. The ratio of new power factor with the old power factor of the circuit is $\sqrt{5} : x$. The value of x is ______. 5:x [JEE MAIN_{S2}_270821]

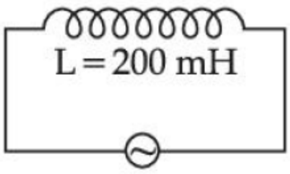
24. At very high frequencies, the effective impendance of the given circuit will be______Ω.

[JEE MAIN_{S1}_310821]



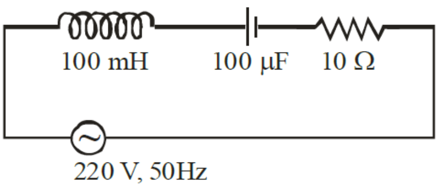
25. As shown in the figure an inductor of inductance 200 mH is connected to an AC source of emf 220 V and frequency 50 Hz. The instantaneous voltage of the source is 0 V when the peak value of current is $\frac{\sqrt{a}}{\pi}$ A. The value of a is_______.

[JEE MAIN_{S1}_240622]



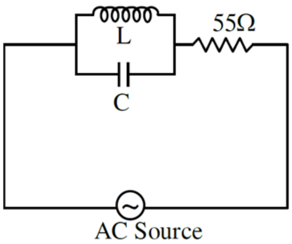
26. In a series LCR circuit, the inductance, capacitance and resistance are L = 100mH, C = 100μF and R = 10Ω respectively. They are connected to an AC source of voltage 220V and frequency of 50 Hz. The approximate value of current in the circuit will be____ A.

[JEE MAIN_{S2}_250622]

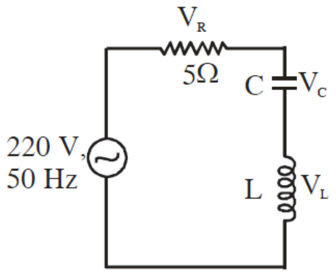


27. A 110 V, 50 Hz, AC source is connected in the circuit (as shown in figure). The current through the resistance 55 Ω, at resonance in the circuit, will be .... A.

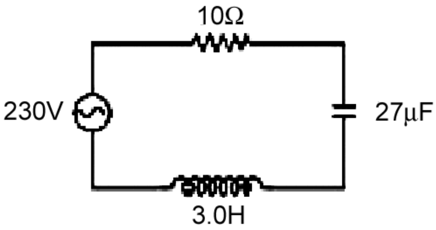
[JEE MAIN_{S1}_260622]



28. In the given circuit, the magnitude of V_L and V_C are twice that of V_R. Given that f = 50 Hz, the inductance of the coil is $\frac{1}{K\pi}$ mH. The value of K is _______ **[JEE MAIN_{S2}_280622]**



29. In the circuit shown in the figure, the ratio of the quality factor and the band width is _______ s. **[JEE MAIN_{S1}_240123]**



30. A series LCR circuit is connected to an AC source of 220 V, 50 Hz. The circuit contains a resistance R = 80Ω, an inductor of inductive reactance X_L = 70Ω, and a capacitor of capacitive reactance X_C = 130Ω. The power factor of circuit is $\frac{x}{10}$. The value of x is : **[JEE MAIN_{S2}_250123]**

ANSWER KEY

1.	(4)	2.	(2)	3.	(3)	4.	(3)	5.	(2)	6.	(4)	7.	(1)
8.	(3)	9.	(3)	10.	(1)	11.	(1)	12.	(1)	13.	(1)	14.	(2)
15.	(3)	16.	(1)	17.	(3)	18.	(2)	19.	6	20.	3	21.	500
22.	11	23.	1	24.	2	25.	242	26.	22	27.	0	28.	0
29.	10	30.	8										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- ELECTROMAGNETIC WAVE

(Important Questions Only)

1. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi v\left(\frac{z}{c}-t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos\left[k(2z-ct)\right]$ in medium, where the wave number k and frequency υ refer to their values in air. The medium is non-magnetic. If ε_{r_1} and ε_{r_2} refer to relative permittivities of air and medium respectively, which of the following options is correct? **[JEE MAIN_080418]**

(1) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$ (2) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{2}$ (3) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 4$ (4) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 2$

2. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by **[JEE MAIN_{S1}_110119]**

(1) $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$ (2) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$ (3) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (4) $\left(\sqrt{n}, \sqrt{n}\right)$

3. A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}$ V/m The corresponding magnetic field, $\vec{B}$ at that point will be **[JEE MAIN_{S1}_090119]**

(1) $18.9 \times 10^{-8}\hat{k}$ T (2) $2.1 \times 10^{-8}\hat{k}$ T (3) $6.3 \times 10^{-8}\hat{k}$ T (4) $18.9 \times 10^{-8}\hat{k}$ T

4. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space, Then **[JEE MAIN_{S2}_090119]**

(1) $U_E < U_B$ (2) $U_E = \frac{U_B}{2}$ (3) $U_E = U_B$ (4) $U_E > U_B$

5. The magnetic field of an electromagnetic wave is given by: **[JEE-MAIN_{S2}_080419]**

$\vec{B} = 1.6 \times 10^{-6}\cos(2\times10^7 z + 6\times10^{15} t)(2\hat{i}+\hat{j})\frac{Wb}{m^2}$

The associated electric field will be:

(1) $\vec{E} = 4.8 \times 10^2\cos(2\times10^7 z + 6\times10^{15} t)(-\hat{i}-2\hat{j})\frac{V}{m}$

(2) $\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z + 6 \times 10^{15} t)(2\hat{i} + \hat{j})\frac{V}{m}$

(3) $\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z - 6 \times 10^{15} t)(-2\hat{i} + \hat{j})\frac{V}{m}$

(4) $\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z + 6 \times 10^{15} t)(\hat{i} + 2\hat{j})\frac{V}{m}$

6. The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0 \hat{i} \cos(kz)\cos(\omega t)$ **[JEE-MAIN_{S2}_100419]**

The corresponding magnetic field $\vec{B}$ is then given by :

(1) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\cos(\omega t)$ (2) $\vec{B} = \frac{E_0}{C}\hat{j}\cos(kz)\sin(\omega t)$

(3) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\sin(\omega t)$ (4) $\vec{B} = \frac{E_0}{C}\hat{k}\sin(kz)\cos(\omega t)$

7. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by

[JEE MAIN_{S1}_110119]

(1) $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$ (2) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$ (3) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (4) $\left(\sqrt{n}, \sqrt{n}\right)$

8. The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0 \frac{\hat{i} + \hat{j}}{\sqrt{2}}\cos(kz + \omega t)$

At t = 0, a positively charged particle is at the point (x, y, z) = $\left(0, 0, \frac{\pi}{k}\right)$. If its instantaneous velocity at (t = 0) is $v_0\hat{k}$, the force acting on it due to the wave is: **[JEE MAIN_{S2} _070120]**

(1) Antiparallel to $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$ (2) Zero

(3) Parallel to $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$ (4) Parallel to $\hat{k}$

9. The magnetic field of a plane electromagnetic wave is

$\vec{B} = 3 \times 10^{-8} \sin[200\pi(y + ct)]\hat{i}T$

where c = 3 × 10^8 ms^{-1} is the speed of light.

The corresponding electric field is **[JEE-MAIN_{S1} _030920]**

(1) $\vec{E} = -9\sin[200\pi(y + ct)]\hat{k}V/m$ (2) $\vec{E} = 9\sin[200\pi(y + ct)]\hat{k}\,V/m$

(3) $\vec{E} = -10^{-6}\sin[200\pi(y+ct)]\hat{k}\,V/m$ (4) $\vec{E} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{k}\,V/m$

10. Choose the correct option relating wavelengths of different parts of electromagnetic wave spectrum **[JEE-MAIN_{S1}_040920]**

(1) $\lambda_{\text{x-rays}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$ (2) $\lambda_{\text{visible}} > \lambda_{\text{x-rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{micro waves}}$

(3) $\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{\text{x-rays}}$ (4) $\lambda_{\text{visible}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{x-rays}}$

11. The electric field of a plane electromagnetic wave is given by **[JEE MAIN_{S2}_040920]**

$\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$

Its magnetic field will be given by

(1) $\frac{E_0}{c}(\hat{x}-\hat{y})\cos(kz-\omega t)$ (2) $\frac{E_0}{c}(\hat{x}-\hat{y})\sin(kz-\omega t)$

(3) $\frac{E_0}{c}(-\hat{x}+\hat{y})\sin(kz-\omega t)$ (4) $\frac{E_0}{c}(\hat{x}+\hat{y})\sin(kz-\omega t)$

12. For a plane electromagnetic wave, the magnetic field at a point x and time t is

$\vec{B}(x,t) = [1.2\times10^{-7}\sin(0.5\times10^{3}x+1.5\times10^{11}t)\hat{k}]\,T$. The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is (speed of light c = 3 × 10^8 ms^{-1}) **[JEE MAIN_{S2}_060920]**

(1) $\vec{E}(x,t) = [36\sin(1\times10^{3}x+1.5\times10^{11}t)\hat{i}]\frac{V}{m}$ (2) $\vec{E}(x,t) = [36\sin(0.5\times10^{3}x+1.5\times10^{11}t)\hat{k}]\frac{V}{m}$

(3) $\vec{E}(x,t) = [-36\sin(0.5\times10^{3}x+1.5\times10^{11}t)\hat{j}]\frac{V}{m}$ (4) $\vec{E}(x,t) = [36\sin(1\times10^{3}x+0.5\times10^{11}t)\hat{j}]\frac{V}{m}$

13. A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time, $\vec{B} = 8.0\times10^{-8}\hat{z}T$. The value of electric field at this point is : (speed of light = 3 × 10^8 ms^{-1}) **[JEE MAIN_{S1}_160321]**

$\hat{x}, \hat{y}, \hat{z}$ are unit vectors along x, y and z direction.

(1) $-24\,\hat{x}$ V / m (2) 2.6 $\hat{x}$ V / m (3) 24 $\hat{x}$ V / m (4) –2.6 $\hat{y}$ V / m

14. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) fields is : **[JEE MAIN_{S1}_160321]**

(1) $U_e = U_m$ (2) $U_e > U_m$ (3) $U_e < U_m$ (4) $U_e \le U_m$

15. A light beam is described by $E = 800\sin\omega\left(t-\frac{x}{c}\right)$. An electron is allowed to move normal to the propagation of light beam with a speed of 3 × 10^7 ms^{-1}. What is the maximum magnetic force exerted on the electron ? **[JEE MAIN_{S2}_260821]**

(1) 1.28 × 10^{-18} N (2) 1.28 × 10^{-21} N (3) 12.8 × 10^{-17} N (4) 12.8 × 10^{-18} N

16. Electric field in a plane electromagnetic wave is given by E = 50 sin(500x – 10 × 10^{10}t) V/m

The velocity of electromagnetic wave in this medium is : **[JEE MAIN_{S1}_270821]**

(Given C = speed of light in vacuum)

(1) $\frac{3}{2}C$ (2) C (3) $\frac{2}{3}C$ (4) $\frac{C}{2}$

17. The magnetic field vector of an electromagnetic wave is given by $B = B_o \frac{\hat{i}+\hat{j}}{\sqrt{2}} \cos(kz - \omega t)$; where $\hat{i},\hat{j}$ represents unit vector along x and y-axis respectively. At t = 0 s, two electric charges q_1 of 4π coulomb and q_2 of 2π coulomb located at $\left(0,0,\frac{\pi}{k}\right)$ and $\left(0,0,\frac{3\pi}{k}\right)$, respectively. Have the same velocity of $0.5\, c\,\hat{i}$, (where c is the velocity of light). The ratio of the force acting on charge q_1 to q_2 is :-

[JEE MAIN_{S1}_310821]

(1) $2\sqrt{2} : 1$ (2) $1 : \sqrt{2}$ (3) 2 : 1 (4) $\sqrt{2} : 1$

18. The electromagnetic waves travel in a medium at a speed of 2.0 × 10^8 m/s. The relative permeability of the medium is 1.0. The relative permittivity of the medium will be: **[JEE MAIN_{S2}_250622]**

(1) 2.25 (2) 4.25 (3) 6.25 (4) 8.25

19. If electric field intensity of a uniform plane electro magnetic wave is given as

$E = -301.6 \sin(kz - \omega t)\, \hat{a}_x + 452.4 \sin(kz - \omega t)\, \hat{a}_y \frac{V}{m}$ **[JEE MAIN_{S1}_260622]**

Then, magnetic intensity H of this wave in Am^{-1} will be:'

[Given: Speed of light in vacuum c = 3 × 10^8 ms^{-1},

permeability of vacuum $\mu_0 = 4\pi \times 10^{-7}$ NA^{-2}]

(1) $+0.8\sin(kz - \omega t)\, \hat{a}_y + 0.8\sin(kz - \omega t)\, \hat{a}_x$

(2) $+1.0 \times 10^{-6} \sin(kz - \omega t)\, \hat{a}_y + 1.5 \times 10^{-6} (kz - \omega t)\, \hat{a}_x$

(3) $-0.8\sin(kz - \omega t)\, \hat{a}_y - 1.2\sin(kz - \omega t)\, \hat{a}_x$

(4) $-1.0 \times 10^{-6} \sin(kz - \omega t)\, \hat{a}_y - 1.5 \times 10^{-6} \sin(kz - \omega t)\, \hat{a}_x$

20. Given below are two statements: **[JEE MAIN_{S2}_270622]**

Statement I : A time varying electric field is a source of changing magnetic field and vice-versa. Thus a disturbance in electric or magnetic field creates EM waves.

Statement II : In a material medium. The EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$.

In the light of the above statements, choose the correct answer from the options given below:

(1) Both statement I and statement II are true.

(2) Both statement I and statement II are false.

(3) Statement I is correct but statement II is false.

(4) Statement I is incorrect but statement II is true.

21. The magnetic field of a plane electromagnetic wave is given by **[JEE MAIN_{S1}_260722]**

$\vec{B} - = 2 \times 10^{-8} \sin(0.5 \times 10^{3} x + 1.5 \times 10^{11} t)\hat{j}\,T$

The amplitude of the electric field would be

(1) 6 Vm^{-1} along x-axis

(2) 3 Vm^{-1} along x-axis

(3) 6 Vm^{-1} along z-axis

(4) 2 × 10^{-8} Vm^{-1} along z-axis

22. The electric field and magnetic field components of an electromagnetic wave going through vacuum is described by **[JEE MAIN_{S2}_240123]**

$E_x = E_0 \sin(kz - \omega t)$

$B_y = B_0 \sin(kz - \omega t)$

Then the correct relation between E_0 and B_0 is given by

(1) $kE_0 = \omega B_0$

(2) $E_0B_0 = \omega k$

(3) $\omega E_0 = kB_0$

(4) $E_0 = kB_0$

23. If $\vec{E}$ and $\vec{K}$ represent electric field and propagation vectors of the EM waves in vacuum, then magnetic field vector is given by : (ω - angular frequency) : **[JEE MAIN_{S1}_240123]**

(1) $\frac{1}{\omega}(\vec{K} \times \vec{E})$

(2) $\omega(\vec{E} \times \vec{K})$

(3) $\omega(\vec{K} \times \vec{E})$

(4) $\vec{K} \times \vec{E}$

24. All electromagnetic wave is transporting energy in the negative z direction. At a certain point and certain time the direction of electric field of the wave is along positive y direction. What will be the direction of the magnetic field of the wave at that point and instant? **[JEE MAIN_{S1}_250123]**

(1) Positive direction of x

(2) Positive direction of z

(3) Negative direction of x

(4) Negative direction of y

25. Given below are two statements: **[JEE MAIN_{S2}_290123]**

Statement I : Electromagnetic waves are not deflected by electric and magnetic field.

Statement II : The amplitude of electric field and the magnetic field in electromagnetic waves are related to each other as $E_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} B_0$

In the light of the above statements, choose the correct answer from the options given below:

(1) Statement I is true but statement II is false

(2) Both Statement I and Statement II are true

(3) Statement I is false but statement II is true

(4) Both Statement I and Statement II are false

26. An electromagnetic wave of frequency 3 GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be ____ $\times 10^{-2}$ cm.

[JEE MAIN_{S2}_240221]

27. The peak electric field produced by the radiation coming from the 80 W bulb at a distance of 10 m is $\frac{x}{10}\sqrt{\frac{\mu_0 c}{\pi}}\frac{V}{m}$. The efficiency of the bulb is 10% and it is a point source. The value of x is________.

[JEE MAIN_{S2}_250221]

28. The electric field in an electromagnetic wave is given by $E = (50\ NC^{-1}) \sin\omega\ (t\text{-}x/c)$

The energy contained in a cylinder of volume V is 5.5×10^{-12} J. The value of V is _____cm^3.

(given $\in_0 = 8.8 \times 10^{-12} C^2N^{-1}m^{-2}$) **[JEE MAIN_{S2}_310821]**

29. The intensity of the light from a bulb incident on a surface is 0.22 W/m^2. The amplitude of the magnetic field in this light-wave is______$\times 10^{-9}$ T. **[JEE MAIN_{S1}_290622]**

(Given : Permittivity of vacuum $\in_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$, speed of light in vacuum $c = 3 \times 10^8\ ms^{-1}$)

30. The displacement current of 4.425 μA is developed in the space between the plates of parallel plate capacitor when voltage is changing at a rate of $10^6\ Vs^{-1}$. The area of each plate of the capacitor is 40 cm^2. The distance between each plate of the capacitor is $x \times 10^{-3}$ m. The value of x is,

(Permittivity of free space, $E_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$) **[JEE MAIN_{S2}_290622]**

ANSWER KEY

1.	(1)	2.	(2)	3.	(2)	4.	(3)	5.	(1)	6.	(3)	7.	(2)
8.	(1)	9.	(1)	10.	(3)	11.	(3)	12.	(3)	13.	(1)	14.	(1)
15.	(4)	16.	(3)	17.	(3)	18.	(1)	19.	(3)	20.	(3)	21.	(3)
22.	(1)	23.	(1)	24.	(1)	25.	(1)	26.	667	27.	2	28.	500
29.	43	30.	8										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- MODERN PHYSICS_I (ATOMIC PHYSICS)

(Important Questions Only)

1. An electron of mass m and magnitude of charge |e| initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of this electron at time t ignoring relativistic effects is **[JEE MAIN_{S2} _090120]**

(1) $-\frac{h}{|e|E\sqrt{t}}$ (2) $\frac{-h}{|e|Et^2}$ (3) $\frac{|e|Et^2}{h}$ (4) $-\frac{h}{|e|Et}$

2. In a hydrogen atom the electron makes a transition from $(n + 1)^{th}$ level to the n^{th} level. If n >> 1, the frequency of radiation emitted is proportional to **[JEE MAIN_{S2}_020920]**

(1) $\frac{1}{n}$ (2) $\frac{1}{n^2}$ (3) $\frac{1}{n^3}$ (4) $\frac{1}{n^4}$

3. If an electron is moving in the n^{th} orbit of the hydrogen atom, then its velocity (v_n) for the nth orbit is given as : **[JEE MAIN_{S1}_170321]**

(1) $v_n \propto n$ (2) $v_n \propto \frac{1}{n}$ (3) $v_n \propto n^2$ (4) $v_n \propto \frac{1}{n^2}$

4. The radiation corresponding to $3 \to 2$ transition of a hydrogen atom falls on a gold surface to generate photoelectrons. These electrons are passed through a magnetic field of 5×10^{-4} T. Assume that the radius of the largest circular path followed by these electrons is 7 mm, the work function of the metal is : (Mass of electron = 9.1×10^{-31}kg) **[JEE MAIN_{S1}_200721]**

(1) 1.36 eV (2) 1.88 eV (3) 0.16 eV (4) 0.82 eV

5. With what speed should a galaxy move outward with respect to earth so that the sodium-D line at wavelength 5890 Å is observed at 5896 Å ? **[JEE MAIN_{S2}_200721]**

(1) 306 km/sec (2) 322 km/sec (3) 296 km/sec (4) 336 km/sec

6. An electron having de- Broglie wavelength λ is incident on a target in a X-ray tube. Cut – off wavelength of emitted X-ray is : **[JEE MAIN_{S2}_200721]**

(1) 0 (2) $\frac{2m^2c^2\lambda^2}{h^2}$ (3) $\frac{2mc\lambda^2}{h}$ (4) $\frac{hc}{mc}$

7. An electron moving with speed v and a photon moving with speed c, have same D-Broglie wavelength. The ratio of kinetic energy of electron to that of photon is : **[JEE MAIN_{S2}_250721]**

(1) $\frac{3c}{v}$ (2) $\frac{v}{3c}$ (3) $\frac{v}{2c}$ (4) $\frac{2c}{v}$

8. When radiation of wavelength λ is incident on a metallic surface, the stopping potential of ejected photoelectrons is 4.8 V. If the same surface is illuminated by radiation of double the previous wavelength, then the stopping potential becomes 1.6 V. The threshold wavelength of the metal is :

[JEE MAIN_{S2}_250721]

(1) 2 λ (2) 4 λ (3) 8 λ (4) 6 λ

9. Consider two separate ideal gases of electrons and protons having same number of particles. The temperature of both the gases are same. The ratio of the uncertainty in determining the position of an electron to that of a proton is proportional to :- **[JEE MAIN_{S1}_310821]**

(1) $\left(\frac{m_p}{m_e}\right)^{3/2}$ (2) $\sqrt{\frac{m_e}{m_p}}$ (3) $\sqrt{\frac{m_p}{m_e}}$ (4) $\frac{m_e}{m_p}$

10. In Bohr's atomic model of hydrogen, let K. P and E are the kinetic energy, potential energy and total energy of the electron respectively. Choose the correct option when the electron undergoes transitions to a higher level : **[JEE MAIN_{S2}_240622]**

(1) All K. P and E increase. (2) K decreases. P and E increase.

(3) P decreases. K and E increase. (4) K increases. P and E decrease.

11. An electron with speed v and a photon with speed c have the same de-Broglie wavelength. If the kinetic energy and momentum of electron are E_e and p_e and that of photon are E_{ph} and p_{ph} respectively. Which of the following is correct? **[JEE MAIN_{S1}_260622]**

(1) $\frac{E_e}{E_{ph}} = \frac{2c}{v}$ (2) $\frac{E_e}{E_{ph}} = \frac{v}{2c}$ (3) $\frac{p_e}{p_{ph}} = \frac{2c}{v}$ (4) $\frac{p_e}{p_{ph}} = \frac{v}{2c}$

12. A metal surface is illuminated by a radiation of wavelength 4500 Å. the ejected photo-electron enters a constant magnetic field of 2 mT making an angle of 90º with the magnetic field. If it starts revolving in a circular path of radius 2 mm, the work function of the metal is approximately :**[JEE MAIN_{S2}_260622]**

(1) 1.36 eV (2) 1.69 eV (3) 2.78 eV (4) 2.23 eV

13. Mach List-I with List – II : **[JEE MAIN_{S1}_270622]**

	List-I		List-Ii
(a)	Ultraviolet rays	(i)	Study crystal structure
(b)	Microwaves	(ii)	Greenhouse effect
(c)	Infrared waves	(iii)	Sterilizing surgical instrument
(d)	X-rays	(iv)	Radar system

Choose the correct answer from the options given below :

(1) (a) – (iii), (b) – (iv), (c) – (ii), (d) – (i) (2) (a) – (iii), (b) – (i), (c) – (ii), (d) – (iv)

(3) (a) – (iv), (b) – (iii), (c) – (ii), (d) – (i) (4) (a) – (iii), (b) – (iv), (c) – (i), (d) – (ii)

14. An α particle and a carbon 12 atom has same kinetic energy K. The ratio of their de-Broglie wavelength ($\lambda_a : \lambda_{C12}$) is : **[JEE MAIN_{S1}_270622]**

(1) $1 : \sqrt{3}$ (2) $\sqrt{3} : 1$ (3) 3 : 1 (4) $2 : \sqrt{3}$

15. The de Brogue wavelengths for an electron and a photon are λ_e and λ_p respectively. For the same kinetic energy of electron and photon. which of the following presents the correct relation between the de Brogue wavelengths of two ? **[JEE MAIN_{S1}_280622]**

(1) $\lambda_p \propto \lambda_e^2$ (2) $\lambda_p \propto \lambda_e$ (3) $\lambda_p \propto \sqrt{\lambda_e}$ (4) $\lambda_p \propto \sqrt{\frac{1}{\lambda_e}}$

16. A charged particle moves along circular path in a uniform magnetic field in a cyclotron. The kinetic energy of the charged particle increases to 4 times its initial value. What will be the ratio of new radius to the original radius of circular path of the charged particle : **[JEE MAIN_{S1}_290622]**

(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) 1 : 4

17. The momentum of an electron revolving in n^{th} orbit is given by : (Symbols have their usual meanings) **[JEE MAIN_{S1}_250722]**

(1) $\frac{nh}{2\pi r}$ (2) $\frac{nh}{2r}$ (3) $\frac{nh}{2\pi}$ (4) $\frac{2\pi r}{nh}$

18. The magnetic moment of an electron (e) revolving in an orbit around nucleus with an orbital angular momentum is given by : **[JEE MAIN_{S1}_250722]**

(1) $\vec{\mu}_L = \frac{e\vec{L}}{2m}$ (2) $\vec{\mu}_L = -\frac{e\vec{L}}{2m}$ (3) $\vec{\mu}_1 = -\frac{e\vec{L}}{m}$ (4) $\vec{\mu}_1 = \frac{2e\vec{L}}{m}$

19. The ratio of wavelengths of proton and deuteron accelerated by potential V_p and V_d is $1:\sqrt{2}$. Then, the ratio of V_p to V_d will be **[JEE MAIN_{S2}_250722]**

(1) 1 : 1 (2) $\sqrt{2}:1$ (3) 2 : 1 (4) 4 : 1

20. Hydrogen atom from excited state comes to the ground by emitting a photon of wavelength λ. The value of principal quantum number 'n' of the excited state will be (R : Rydberg constant) **[JEE MAIN_{S2}_250722]**

(1) $\sqrt{\frac{\lambda R}{\lambda - 1}}$ (2) $\sqrt{\frac{\lambda R}{\lambda R - 1}}$ (3) $\sqrt{\frac{\lambda}{\lambda R - 1}}$ (4) $\sqrt{\frac{\lambda R^2}{\lambda R - 1}}$

21. A parallel beam of light of wavelength 900 nm and intensity 100 Wm^{-2} is incident on a surface perpendicular to the beam. The number of photons crossing 1 cm^2 area perpendicular to the beam in one second is : **[JEE MAIN_{S1}_260722]**

(1) 3×10^{16} (2) 4.5×10^{16} (3) 4.5×10^{17} (4) 4.5×10^{20}

22. An electron (mass m) with an initial velocity $\vec{v} = v_0\hat{i}(v_0 > 0)$ is moving in an electric field $\vec{E} = -E_0\hat{i}(E_0 > 0)$ where E_0 is constant. If at t = 0 de Broglie wavelength is $\lambda_0 = \frac{h}{mv_0}$, then its de Broglie wavelength after time t is given by **[JEE MAIN_{S1}_270722]**

(1) λ_0 (2) $\lambda_0\left(1+\frac{eE_0t}{mv_0}\right)$ (3) $\lambda_0 t$ (4) $\frac{\lambda_0}{\left(1+\frac{eE_0t}{mv_0}\right)}$

23. Sun light falls normally on a surface of area 36 cm^2 and exerts an average force of 7.2×10^{-9} N within a time period of 20 minutes. Considering a case of complete absorption, the energy flux of incident light is **[JEE MAIN_{S2}_280722]**

(1) 25.92×10^2 W/cm^2 (2) 8.64×10^{-6} W/cm^2 (3) 6.0 W/cm^2 (4) 0.06 W/cm^2

24. The kinetic energy of emitted electron is E when the light incident on the metal has wavelength λ. To double the kinetic energy, the incident light must have wavelength : **[JEE MAIN_{S1}_290722]**

(1) $\frac{hc}{E\lambda - hc}$ (2) $\frac{hc\lambda}{E\lambda + hc}$ (3) $\frac{h\lambda}{E\lambda + hc}$ (4) $\frac{hc\lambda}{E\lambda - hc}$

25. A photon is emitted in transition from n = 4 to n = 1 level in hydrogen atom. The corresponding wavelength for this transition is (given, h = 4×10^{-15} eVs) : **[JEE MAIN_{S2}_240123]**

(1) 94.1 nm (2) 941 nm (3) 97.4 nm (4) 99.3 nm

26. From the photoelectric effect experiment, following observations are made. Identify which of these are correct **[JEE MAIN_{S1}_240123]**

A. The stopping potential depends only on the work function of the metal.

B. The saturation current increases as the intensity of incident light increases.

C. The maximum kinetic energy of a photo electron depends on the intensity of the incident light.

D. Photoelectric effect can be explained using wave theory of light.

Choose the correct answer from the options given below:

(1) B, C only (2) A, C, D only (3) B only (4) A, B, D only

27. A galaxy is moving away from the earth at a speed of 286 kms^{-1}. The shift in the wavelength of a red line at 630 nm is x × $l0^{-10}$ m. The value of x, to the nearest integer, is_____.

[Take the value of speed of light c, as 3×10^8 ms^{-1}] **[JEE MAIN_{S1}_180321]**

28. In Bohr's atomic model, the electron is assumed to revolve in a circular orbit of radius 0.5 Å. If the speed of electron is 2.2×16^6 m/s, then the current associated with the electron will be ___________ × 10^{-2} mA. [Take π as $\frac{22}{7}$] **[JEE MAIN _{S1}_270721]**

29. The K_α X-ray of molybdenum has wavelength 0.071 nm. If the energy of a molybdenum atoms with a K electron knocked out is 27.5 KeV, the energy of this atoms when an L electron is knocked out will be _____keV. (Round off to the nearest integer) [h = 4.14×10^{-15} eVs, c = 3×10^8 ms^{-1}]

[JEE MAIN_{S2}_270721]

30. In a hydrogen spectrum, λ be the wavelength of first transition line of Lyman series. The wavelength difference will be "aλ" between the wavelength of 3rd transition line of Paschen series and that of 2nd transition line of Balmer Series where a = _______ **[JEE MAIN_{S1}_260722]**

ANSWER KEY

1.	(2)	2.	(3)	3.	(2)	4.	(4)	5.	(1)	6.	(3)	7.	(3)
8.	(2)	9.	(3)	10.	(2)	11.	(2)	12.	(1)	13.	(1)	14.	(2)
15.	(1)	16.	(3)	17.	(1)	18.	(2)	19.	(4)	20.	(2)	21.	(2)
22.	(4)	23.	(4)	24.	(2)	25.	(1)	26.	(3)	27.	6	28.	112
29.	10	30.	5										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- MODERN PHYSICS_II (NUCLEAR PHYSICS)

(Important Questions Only)

1. A sample of radioactive material A, that has an activity of 10 mCi(1 Ci = 3.7×10^{10} decays/s), has twice the number of nuclei as another sample of a different radioactive material B which has an activity of 20 mCi. The correct choices for half-lives of A and B would then be respectively:

[JEE MAIN_{S1}_090119]

(1) 10 day and 40 days (2) 20 day and 5 days
(3) 20 day and 10 days (4) 5 day and 10 days

2. Using a nuclear counter the count rate of emitted particles from a radioactive source is measured. At t = 0 it was 1600 counts per second and t = 8 seconds it was 100 counts per second. The count rate observed, as counts per second, at t = 6 seconds is close to **[JEE MAIN_{S1}_100119]**

(1) 400 (2) 360 (3) 150 (4) 200

3. In a radioactive decay chain, the initial nucleus is $^{232}_{90}Th$ at the end there are 6 α-particles and 4 β^- particles which are emitted. If the end nucleus is $^{A}_{Z}X$, A and Z are given by:

[JEE MAIN_{S2}_120119]

(1) A = 200; Z = 81 (2) A = 202; Z = 80
(3) A = 208; Z = 80 (4) A = 208; Z = 82

4. A nucleus A, with a finite de-Broglie wavelength λ_A, undergoes spontaneous fission into two nuclei B and C of equal mass. B flies in the same direction as that of A, while C flies in the opposite direction with a velocity equal to half of that of B. The de-Broglie wavelength λ_B and λ_C of B and C are respectively: **[JEE MAIN_{S2}_080419]**

(1) $2\lambda_A, \lambda_A$ (2) $\lambda_A, \frac{\lambda_A}{2}$ (3) $\frac{\lambda_A}{2}, \lambda_A$ (4) $\lambda_A, 2\lambda_A$

5. Two radioactive materials A and B have decay constants 10λ and λ, respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time : **[JEE MAIN_{S2}_100419]**

(1) $\frac{1}{10\lambda}$ (2) $\frac{11}{10\lambda}$ (3) $\frac{1}{9\lambda}$ (4) $\frac{1}{11\lambda}$

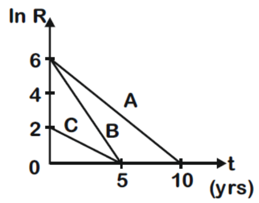
6. The number density of molecules of a gas depends on their distance r from the origin as $n(r) = n_0 e^{\alpha r^4}$. Then the total number of molecules is proportional to **[JEE MAIN_{S2}_120419]**

(1) $n_0\alpha^{-3/4}$ (2) $\sqrt{n_0}\,\alpha^{1/2}$ (3) $n_0\alpha^{1/4}$ (4) $n_0\alpha^{-3}$

7. In a reactor, 2 kg of $_{92}U^{235}$ fuel is fully used up in 30 days. The energy released per fission is 200 MeV. Given that the Avogadro number, N = 6.023×10^{26} per kilo mole and 1 eV = 1.6×10^{-19} J. The power output of the reactor is close to **[JEE MAIN_{S1}_020920]**

(1) 125 MW (2) 35 MW (3) 60 MW (4) 54 MW

8. Activities of three radioactive substances A, B and C are represented by the curves A, B and C, in the figure. Then their half-lives $T_{\frac{1}{2}}(A) : T_{\frac{1}{2}}(B) : T_{\frac{1}{2}}(C)$ are in the ratio **[JEE MAIN_(S1)_050920]**



(1) 2 : 1 : 3 (2) 4 : 3 : 1 (3) 2 : 1 : 1 (4) 3 : 2 : 1

9. Given the masses of various atomic particles m_p = 1.0072 u, m_n = 1.0087 u, m_e = 0.000548 u, $m_{\bar{\nu}} = 0$, m_d = 2.0141 u, where p ≡ proton, n ≡ neutron, e ≡ electron, $\bar{\nu}$ ≡ antineutrino and d ≡ deuteron. Which of the following process is allowed by momentum and energy conservation? **[JEE MAIN_{S2}_060920]**

(1) n + n → deuterium atom (electron bound to the nucleus)

(2) n + p → d + γ

(3) $p \rightarrow n + e^{+} + \bar{\nu}$

(4) $e^{+} + e^{-} \rightarrow \gamma$

10. A radioactive sample is undergoing α decay. At any time t_1, its activity is A and another time t_2, the activity is $\frac{A}{5}$. What is the average life time for the sample? **[JEE MAIN_{S2}_260221]**

(1) $\frac{\ell n5}{t_2 - t_1}$ (2) $\frac{t_1 - t_2}{\ell n5}$ (3) $\frac{t_2 - t_1}{\ell n5}$ (4) $\frac{\ell n(t_2 + t_1)}{2}$

11. Calculate the time interval between 33% decay and 67% decay if half-life of a substance is 20 minutes.
[JEE MAIN _{S2}_160321]

(1) 60 minutes (2) 20 minutes (3) 40 minutes (4) 13 minutes

12. The decay of a proton to neutron is : **[JEE MAIN_{S1}_180321]**

(1) not possible as proton mass is less than the neutron mass

(2) possible only inside the nucleus

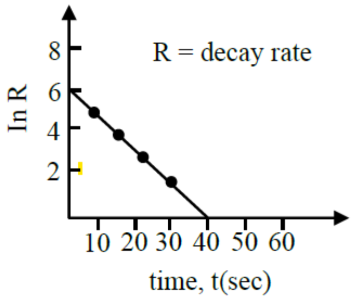
(3) not possible but neutron to proton conversion is possible

(4) always possible as it is associated only with β^{+} decay

13. A nucleus of mass M emits γ-ray photon of frequency 'v'. The loss of internal energy by the nucleus is : [Take 'c' as the speed of electromagnetic wave] **[JEE MAIN_{S1}_200721]**

(1) hv (2) 0 (3) $hv\left[1 - \frac{hv}{2Mc^2}\right]$ (4) $hv\left[1 + \frac{hv}{2Mc^2}\right]$

14. For a certain radioactive process the graph between In R and t(sec) is obtained as shown in the figure. Then the value of half life for the unknown radioactive material is approximately :
[JEE MAIN_{S2}_200721]



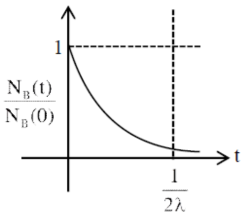
(1) 9.15 sec (2) 6.93 sec (3) 2.62 sec (4) 4.62 sec

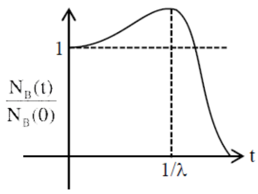
15. A nucleus with mass number 184 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, calculate the kinetic energy of the α-particle. **[JEE MAIN_{S2}_220721]**

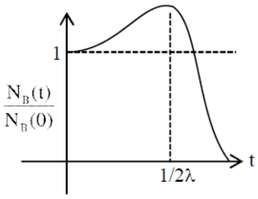
(1) 5.0 MeV (2) 5.5 MeV (3) 0.12 MeV (4) 5.38 MeV

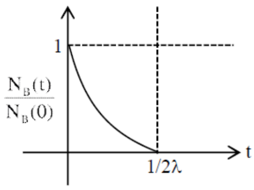
16. At time t = 0, a material is composed of two radioactive atoms A and B, where NA(0) = 2NB(0). The decay constant of both kind of radioactive atoms is λ. However, A disintegrates to B and B disintegrates to C. Which of the following figures represents the evolution of NB(t) / NB(0) with respect to time t ? **[JEE MAIN_{S2}_260821]**

$$\begin{bmatrix} N_A(0) = \text{No. of A atoms at } t = 0 \\ N_B(0) = \text{No. of B atoms at } t = 0 \end{bmatrix}$$

(1) 

(2) 

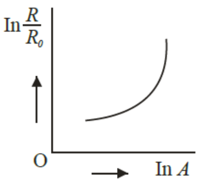
(3) 

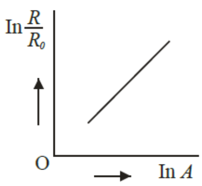
(4) 

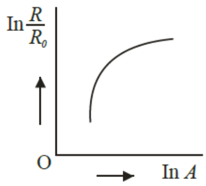
17. Nucleus A is having mass number 220 and its binding energy per nucleon is 5.6 MeV. It splits in two fragments 'B' and 'C' of mass numbers 105 and 115. The binding energy of nucleons in 'B' and 'C' is 6.4 MeV per nucleon. The energy Q released per fission will be : **[JEE MAIN_{S1}_240622]**

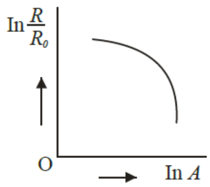
(1) 0.8 MeV (2) 275 MeV (3) 220 MeV (4) 176 MeV

18. Which of the following figure represents the variation of $\ln\left(\frac{R}{R_0}\right)$ with ln A(If R = radius of a nucleus and A = its mass number) **[JEE MAIN_{S2}_250622]**

(1) 

(2) 

(3) 

(4) 

19. A radioactive nucleus can decay by two different processes. Half-life for the first process is 3.0 hours while it is 4.5 hours for the second process. The effective half-life of the nucleus will be :

[JEE MAIN_{S2}_260622]

(1) 3.75 hours (2) 0.56 hours (3) 0.26 hours (4) 1.80 hours

20. The Q-value of a nuclear reaction and kinetic energy of the projectile particle, K_p are related as :

[JEE MAIN_{S1}_280622]

(1) $Q = K_p$ (2) $(K_p + Q) < O$ (3) $Q < K_p$ (4) $(K_p + Q) > 0$

21. In the following nuclear rection, **[JEE MAIN_{S2}_290622]**

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2 \xrightarrow{\alpha} D_3 \xrightarrow{\gamma} D_4$$

Mass number of D is 182 and atomic number is 74. Mass number and atomic number of D_4 respectively will be___.

(1) 174 and 71 (2) 174 and 69 (3) 172 and 69 (4) 172 and 71

22. A nucleus of mass M at rest splits into two parts having masses $\frac{M'}{3}$ and $\frac{2M'}{3}(M' < M)$. The ratio of de Broglie wavelength of two parts will be **[JEE MAIN_{S2}_260722]**

wavelength of two parts will be :

(1) 1 : 2 (2) 2 : 1 (3) 1 : 1 (4) 2 : 3

23. Read the following statements : **[JEE MAIN_{S2}_290722]**

(A) Volume of the nucleus is directly proportional to the mass number.

(B) volume o the nucleus is independent of mass number.

(C) Density of the nucleus is directly proportional to the mass number.

(D) Density of the nucleus is directly proportional to the cube root of the mass number.

(E) Density of the nucleus is independent of the mass number.

Choose the correct option from the following options.

(1) (A) and (D) only (2) (A) and (E) only (3) (B) and (E) only (4) (A) and (C) only

24. An α-particle, a proton and an electron have the same kinetic energy. Which one of the following is correct in case of their De-Broglie wavelength: **[JEE MAIN_{S2}_240123**

(1) $\lambda_\alpha > \lambda_p > \lambda_e$ (2) $\lambda_\alpha < \lambda_p < \lambda_e$ (3) $\lambda_\alpha = \lambda_p = \lambda_e$ (4) $\lambda_\alpha > \lambda_p < \lambda_e$

25. From the given data, the amount of energy required break the nucleus of aluminium ${}^{27}_{13}Al$ is ______ x × 10^{-3} J.

Mass of neutron = 1.00566 u **[JEE MAIN_{S2}_250721]**

Mass of proton = 1.00726 u

Mass of Aluminium nucleus = 27.18846 u

(Assume 1 u corresponds to x J of energy)

(Round off to the nearest integer)

26. A radioactive sample has an average life of 30 ms and is decaying. A capacitor of capacitance 200 μF is first charged and later connected with resistor 'R'. If the ratio of charge on capacitor to the activity of radioactive sample is fixed with respect to time then the value of 'R' should be _______Ω.

[JEE MAIN_{S1}_270721]

27. Two lighter nuclei combine to form a comparatively heavier nucleus by the relation given below:

${}^{2}_{1}X + {}^{2}_{1}X = {}^{4}_{2}Y$ **[JEE MAIN_{S2}_260722]**

The binding energies per nucleon ${}^{2}_{1}X$ and ${}^{4}_{2}Y$ are 1.1 MeV and 7.6 MeV respectively. The energy released in this process is________ . MeV.

28. A freshly prepared radioactive source of half life 2 hours 30 minutes emits radiation which is 64 times the permissible safe level. The minimum time, after which it would be possible to work safely with source, will be _________hours. **[JEE MAIN_{S1}_280722]**

29. Two radioactive materials A and B have decay constants 25λ and 16λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of B to that of A will be 'e' after a time $\frac{1}{a\lambda}$. The value of a is ______________. **[JEE MAIN_{S2}_290722]**

30. The energy released per fission of nucleus of ${}^{240}X$ is 200 MeV. The energy released if all the atoms in 120g of pure ${}^{240}X$ undergo fission is ______ × 10^{25} MeV. (Given NA = 6 × 10^{23})

[JEE MAIN_{S2}_240123]

ANSWER KEY

1.	(2)	2.	(4)	3.	(4)	4.	(3)	5.	(3)	6.	(1)	7.	(3)
8.	(1)	9.	(2)	10.	(3)	11.	(2)	12.	(2)	13.	(4)	14.	(4)
15.	(4)	16.	(3)	17.	(4)	18.	(2)	19.	(4)	20.	(4)	21.	(1)
22.	(3)	23.	(2)	24.	(2)	25.	27	26.	150	27.	26	28.	15
29.	9	30.	6										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- WAVE OPTICS

(Important Questions Only)

1. Unpolarized light of intensity I passes through an ideal polarizer A. another identical polarizer B is placed behind A. The intensity of light beyond B is found to be $\frac{I}{2}$. Now another identical polarizer C is placed between A and B. The intensity beyond B is now found to be $\frac{I}{8}$. The angle between polarizer A and C is : **[JEE MAIN_08042018]**

(1) 45º (2) 60º (3) 0º (4) 30º

2. The angular width of the central maximum in a single slit diffraction pattern is 60°. The width of the slit is 1 μm. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what is slit separation distance? **[JEE MAIN_08042018]**
(i.e. distance between the centres of each slit.)

(1) 75 μm (2) 100 μm (3) 25 μm (4) 50 μm

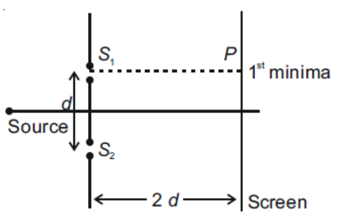
3 Two coherent sources produce waves of different intensities which interfere. After interference, the ratio of the maximum intensity to the minimum intensity is 16. The intensity of the waves are in the ratio: **[JEE MAIN {S1}_090119]**

(1) 25 : 9 (2) 4 : 1 (3) 16 : 9 (4) 5 : 3

4 In a Young's double slit experiment, the slits are placed 0.320 mm apart. Light of wavelength λ = 500 nm is incident on the slits. The total number of bright fringes that are observed in the angular range – 30° $\leq \theta \leq$ 30° is **[JEE MAIN {S2}_090119]**

(1) 640 (2) 320 (3) 321 (4) 641

5. Consider a Young's double slit experiment as shown in figure. What should be the slit separation d in terms wavelength λ such that the first minima occurs directly in front of the slit (S_1)? **[JEE MAIN {S2}_100119]**



(1) $\frac{\lambda}{2(\sqrt{5}-2)}$ (2) $\frac{\lambda}{2(5-\sqrt{2})}$ (3) $\frac{\lambda}{(5-\sqrt{2})}$ (4) $\frac{\lambda}{(\sqrt{5}-2)}$

6. In a Young's double slit experiment, the path difference, at a certain point on the screen, between two interfering waves is $\frac{1}{8}$th of wavelength. The ratio of the intensity at this point to that at the centre of a bright fringe is close to **[JEE MAIN_{S1}_110119]**

(1) 0.74 (2) 0.94 (3) 0.80 (4) 0.85

7. In a double slit experiment, when a thin film of thickness t having refractive index μ is introduced in front of one of the slits, the maximum at the centre of the fringe pattern shifts by one fringe width. The value of t is (λ is the wavelength of the light used) : **[JEE-MAIN_{S1}_120419]**

(1) $\frac{2\lambda}{(\mu-1)}$ (2) $\frac{\lambda}{3(\mu-1)}$ (3) $\frac{\lambda}{(2\mu-1)}$ (4) $\frac{\lambda}{(\mu-1)}$

8. A system of three polarizers P_1, P_2, P_3 is set up such that the pass axis of P_3 is crossed with respect to that of P_1. The pass axis of P_2 is inclined at 60°C to the pass axis of P_3. When a beam of unpolarized light of intensity I_0 is incident on P_1, the intensity of light transmitted by the three polarizers is I. The ratio (I_0/I) equals (nearly) : **[JEE-MAIN_{S2}_120419]**

(1) 1.80 (2) 5.33 (3) 10.67 (4) 16.00

9. The aperture diameter of a telescope is 5 m. The separation between the moon and the earth is 4×10^5 km. With light of wavelength of 5500 Å, the minimum separation between objects on the surface of moon, so that they are just resolved, is close to: **[JEE MAIN_(S1) _090120]**

(1) 20 m (2) 200 m (3) 600 m (4) 60 m

10. In a Young's double slit experiment, 16 fringes are observed in a certain segment of the screen when light of a wavelength 700 nm is used. If the wavelength of light is changed to 400 nm, the number of fringes observed in the same segment of the screen would be **[JEE MAIN_{S2}_020920]**

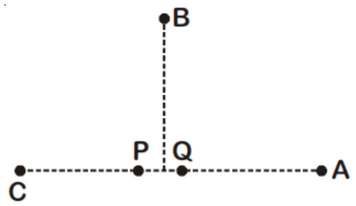
(1) 28 (2) 24 (3) 30 (4) 18

11. Two light waves having the same wavelength λ in vacuum are in phase initially. Then the first wave travels a path L_1 through a medium of refractive index n_1 while the second wave travels a path of length L_2 through a medium of refractive index n_2. After this the phase difference between the two waves is

[JEE MAIN_(S2) _030920]

(1) $\frac{2\pi}{\lambda}(n_2L_1 - n_1L_2)$ (2) $\frac{2\pi}{\lambda}\left(\frac{L_1}{n_1} - \frac{L_2}{n_2}\right)$ (3) $\frac{2\pi}{\lambda}(n_1L_1 - n_2L_2)$ (4) $\frac{2\pi}{\lambda}\left(\frac{L_2}{n_1} - \frac{L_1}{n_2}\right)$

12. In the figure below, P and Q are two equally intense coherent sources emitting radiation of wavelength 20 m. The separation between P and Q is 5 m and the phase of P is ahead of that of Q by 90°. A, B and C are three distinct points of observation, each equidistant from the midpoint of PQ. The intensities of radiation at A, B, C will be in the ratio **[JEE-MAIN_{S1}_060920]**



(1) 0 : 1 : 2 (2) 4 : 1 : 0 (3) 2 : 1 : 0 (4) 0 : 1 : 4

13. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R. **[JEE MAIN_{S1}_260221]**

Assertion A : An electron microscope can achieve better resolving power than an optical microscope.

Reason R : The de Broglie's wavelength of the electrons emitted from an electron gun is much less than wavelength of visible light.

In the light of the above statements, choose the correct answer from the options given below:

(1) A is true but R is false.

(2) Both A and R are true and R is the correct explanation of A.

(3) Both A and R are true but R is NOT the correct explanation of A.

(4) A is false but R is true.

14. In the Young's double slit experiment, the distance between the slits varies in time as $d(t) = d_0 + a_0 \sin\omega t$; where d_0 ω and a_0 are constants. The difference between the largest fringe width and the smallest fringe width obtained over time is given as : **[JEE MAIN_{S1}_250721]**

(1) $\frac{2\lambda D(d_0)}{(d_0^2 - a_0^2)}$ (2) $\frac{2\lambda D a_0}{(d_0^2 - a_0^2)}$ (3) $\frac{\lambda D}{d_0^2} a_0$ (4) $\frac{\lambda D}{d_0 + a_0}$

15. The interference pattern is obtained with two coherent light sources of intensity ratio 4 :1. And the ratio $\frac{I_{max} + I_{min}}{I_{max} - I_{min}}$ is $\frac{5}{x}$. Then, the value of x will be equal to : **[JEE MAIN_{S2}_250622]**

(1) 3 (2) 4 (3) 2 (4) 1

16. In young's double slit experiment performed using a monochromatic light of wavelength λ, when a glass plate (μ = 1.5) of thickness $x\lambda$ is introduced in the path of the one of the interfering beams, the intensity at the position where the central maximum occurred previously remains unchanged. The value of x will be: **[JEE MAIN_{S2}_280622]**

(1) 3 (2) 2 (3) 1.5 (4) 0.5

17. In young's double slit experiment, the fringe width is 12 mm. If the entire arrangement is placed in water of refractive index $\frac{4}{3}$, then the fringe width becomes (in mm) **[JEE MAIN_{S1}_260722]**

(1) 16 (2) 9 (3) 48 (4) 12

18. An unpolarised light beam of intensity $2I_0$ is passed through a polaroid P and then through another polaroid Q which is oriented in such a way that its passing axis makes an angle of 30º relative to that of P. The intensity of the emergent light is **[JEE MAIN_{S2}_290722]**

(1) $\frac{I_0}{4}$ (2) $\frac{I_0}{2}$ (3) $\frac{3I_0}{4}$ (4) $\frac{3I_0}{2}$

19. In Young's double slits experiment, the position of 5th bright fringe from the central maximum is 5 cm. The distance between slits and screen is 1 m and wavelength of used monochromatic light is 600 nm. The separation between the slits is: **[JEE MAIN_{S1}_250123]**

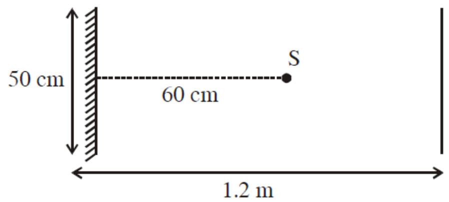
(1) 60 μm (2) 48 μm (3) 12 μm (4) 36 μm

20. Two polaroide A and B are placed in such a way that the pass-axis of polaroids are perpendicular to each other. Now, another polaroid C is placed between A and B bisecting angle between them. If intensity of unpolarised light is I_0 then intensity of transmitted light after passing through polaroid B will be : **[JEE MAIN_{S1}_310123]**

(1) $\frac{I_0}{4}$ (2) $\frac{I_0}{2}$ (3) $\frac{I_0}{8}$ (4) Zero

21. An unpolarized light beam is incident on the polarizer of a polarization experiment and the intensity of light beam emerging from the analyzer is measured as 100 Lumens. Now, if the analyzer is rotated around the horizontal axis (direction of light) by 30° in clockwise direction, the intensity of emerging light will be _______ Lumens. **[JEE MAIN_{S1}_240221]**

22. A point source of light S, placed at a distance 60 cm infront of the centre of a plane mirror of width 50 cm, hangs vertically on a wall. A man walks infront of the mirror along a line parallel to the mirror at a distance 1.2 m from it (see in the figure). The distance between the extreme points where he can see the image of the light source in the mirror is .... cm. **[JEE MAIN_{S2}_260221]**



23. The difference in the number of waves when yellow light propagates through air vacuum columns of the same thickness is one. The thickness of the air column is _______mm. **[JEE MAIN_{S2}_270721]**
[Refractive index of air = 1.0003, wavelength of yellow light in vacuum = 6000 Å]

24. White light is passed through a double slit and interference is observed on a screen 1.5 m away. The separation between the slits is 0.3 mm. The first violet and red fringes are formed 2.0 mm and 3.5 mm away from the central white fringes. The difference in wavelengths of red and voilet light is .... nm. **[JEE MAIN_{S1}_260821]**

25. In Young's double slit experiment the two slits are 0.6 mm distance apart. Interference pattern is observed on a screen at a distance 80 cm from the slits. The first dark fringe is observed on the screen directly opposite to one of the slits. The wavelength of light will be _____ nm. **[JEE MAIN_{S1}_270622]**

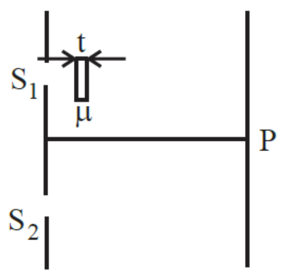
26. In a double slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the plane of slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-3} cm. If the distance between the slits is 1 mm, then the wavelength of the light will be ______nm. **[JEE MAIN_{S2}_290622]**

27. Two beam of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the two beams are $\pi/2$ and $\pi/3$ at points A and B respectively. The difference between the resultant intensities at the two points is xI. The value of x will be_______. **[JEE MAIN_{S1}_270722]**

28. Two coherent sources of light interfere. The intensity ratio of two sources is 1 : 4. For this interference pattern if the value of $\frac{I_{max} + I_{min}}{I_{max} - I_{min}}$ is equal to $\frac{2\alpha + 1}{\beta + 3}$, then $\frac{\alpha}{\beta}$ will be : **[JEE MAIN_{S2}_270722]**

29. The distance between two consecutive points with phase difference of 60° in a wave of frequency 500 Hz is 6.0 m. The velocity with which wave is traveling is______ km/s **[JEE MAIN_{S1}_250123]**

30. As shown in the figure, in Young's double slit experiment, a thin plate of thickness t = 10 μm and refractive index $\mu = 1.2$ is inserted infront of slit S_1. The experiment is conducted in air (μ = 1) and uses a monochromatic light of wavelength λ = 500 nm. Due to the insertion of the plate, central maxima is shifted by a distance of $x\beta_0$. β_0 is the fringe-width before the insertion of the plate. The value of the x is_____. **[JEE MAIN_{S2}_010223]**



ANSWER KEY

1.	(1)	2.	(3)	3	(1)	4	(4)	5.	(1)	6.	(4)	7.	(4)
8.	(3)	9.	(4)	10.	(1)	11.	(3)	12.	(1)	13.	(2)	14.	(2)
15.	(2)	16.	(2)	17.	(2)	18.	(3)	19.	(1)	20.	(3)	21.	75
22.	150	23.	2	24.	300	25.	450	26.	600	27.	2	28.	2
29.	18	30.	4										

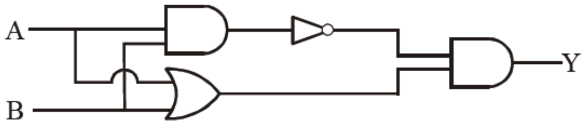
PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- SOLID & SEMICONDUCTORS

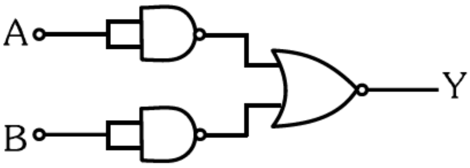
(Important Questions Only)

1. Which one of the following will be the output of the given circuit ? **[JEE MAIN_{S2}_170321]**



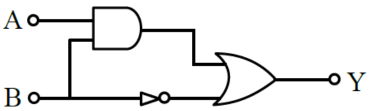
(1) NOR Gate (2) NAND Gate (3) AND Gate (4) XOR Gate

2. Identify the logic operation carried out. **[JEE MAIN_{S1}_250721]**



(1) OR (2) AND (3) NOR (4) NAND

3. Find the truth table for the function Y of A and B represented in the following figure. **[JEE MAIN_{S2}_270721]**



(1)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0

(2)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

(3)

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

(4)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

4. **Statement-I :** By doping silicon semiconductor with pentavalent material, the electrons density increases. **[JEE MAIN_{S1}_260821]**

Statement-II : The n-type semiconductor has net negative charge.

In the light of the above statements, choose the most appropriate answer from the options given below :

(1) Statement-I is true but Statement-II is false.

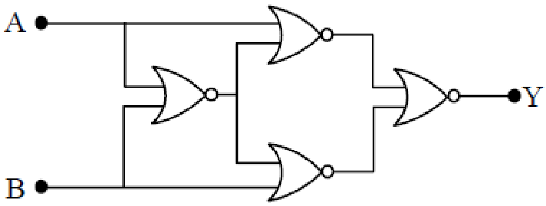
(2) Statement-I is false but Statement-II is true.

(3) Both Statement-I and Statement-II are true.

(4) Both Statement-I and Statement-II are false.

5. Four NOR gates are connected as shown in figure. The truth table for the given figure is :

[JEE MAIN_{S2}_260821]



(1)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

(2)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(3)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

(4)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

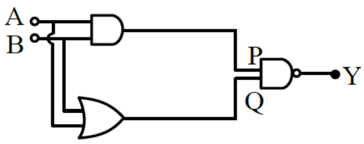
6. For a transistor α and β are given as $\alpha = \frac{I_C}{I_E}$ and $\beta = \frac{I_C}{I_B}$. Then the correct relation between α and β will be :

[JEE MAIN_{S2}_270821]

(1) $\alpha = \frac{1-\beta}{\beta}$ (2) $\beta = \frac{\alpha}{1-\alpha}$ (3) $\alpha\beta = 1$ (4) $\alpha = \frac{\beta}{1-\beta}$

7. In the following logic circuit the sequence of the inputs A, B are (0, 0), (0, 1), (1, 0) and (1, 1). The output Y for this sequence will be :

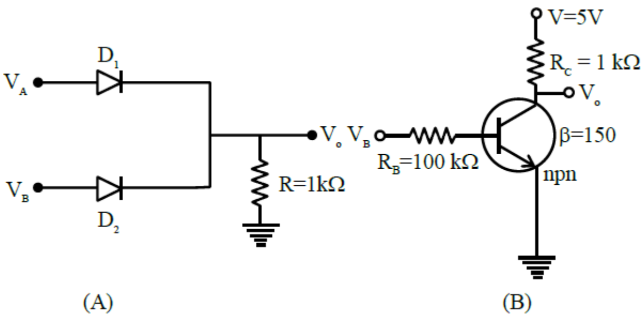
[JEE MAIN_{S2}_310821]



(1)1, 0, 1, 0 (2) 0, 1, 0, 1 (3) 1, 1, 1, 0 (4) 0, 0, 1, 1

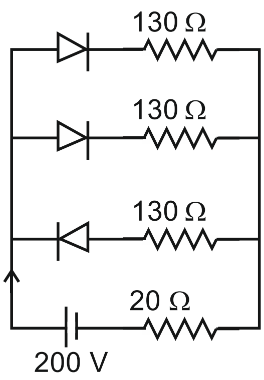
8. If V_A and V_B are the input voltages (either 5V or 0V) and V_o is the output voltage then the two gates represented in the following circuit (A) and (B) are:-

[JEE MAIN_{S1}_310821]



(1) AND and OR Gate (2) OR and NOT Gate (3) NAND and NOR Gate (4) AND and NOT Gate

9. In the given figure, each diode has a forward bias resistance of 30 Ω and infinite resistance in reverse bias. The current I1 will be : **[JEE MAIN_{S2}_010921]**



(1) 3.75 A (2) 2.35 A (3) 2 A (4) 2.73 A

10. The positive feedback is required by an amplifier to act an oscillator. The feedback here means : **[JEE MAIN_{S2}_260622]**

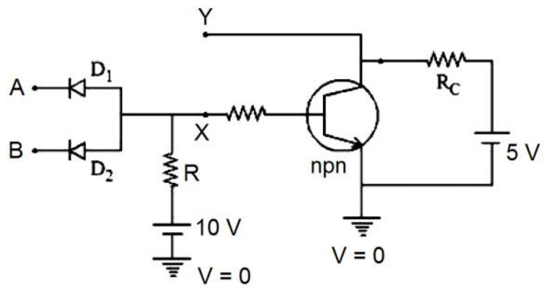
(1) External input is necessary to sustain ac signal in output

(2) A portion of the output power is returned back to the input.

(3) Feedback can be achieved by LR network

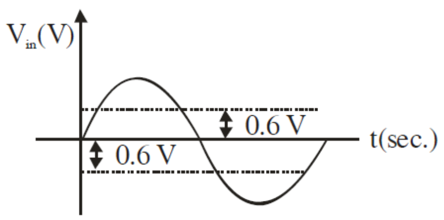
(4) the base-collector junction must be forward biased.

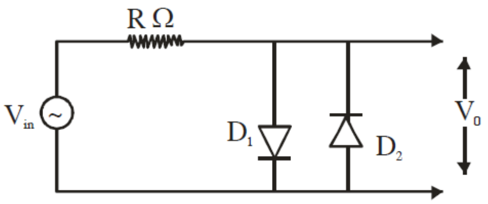
11. In the following circuit, the correct relation between output (Y) and inputs A and B will be : **[JEE MAIN_{S1}_280622]**

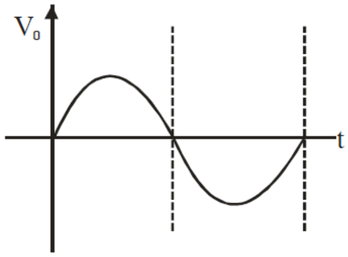


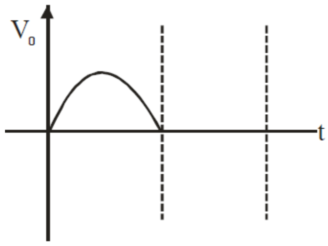
(1) Y = AB (2) Y = A + B (3) $Y = \overline{AB}$ (4) $Y = \overline{A + B}$

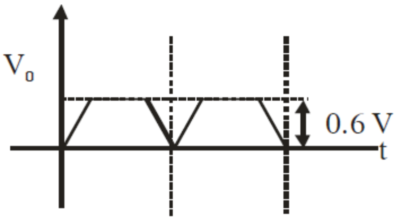
12. In the given circuit the input voltage V_{in} is shown in figure. The cut–in voltage of p–n junction diode (D_1 or D_2) is 0.6 V. Which of the following output voltage (V_0) waveform across the diode is correct? **[JEE MAIN_{S2}_280622]**

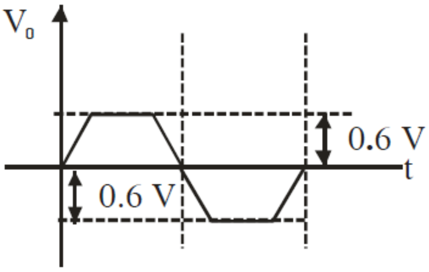




(1) 

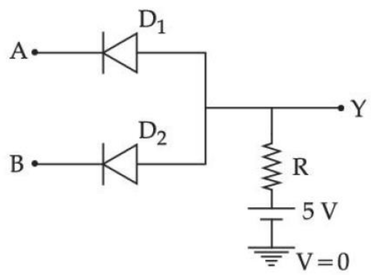
(2) 

(3) 

(4) 

13. In the circuit, the logical value of A = 1 or B = 1 when potential at A or B is 5V and the logical value of A = 0 or B = 0 when potential at A or B is 0 V. The truth table of the given circuit will be :

[JEE MAIN_{S1}_250722]



(1)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

(2)

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

(3)

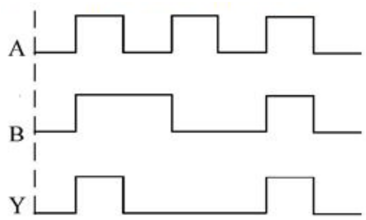
A	B	Y
0	0	0
1	0	0
0	1	0
1	1	0

(4)

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

14. A logic gate circuit has two inputs A and B and output Y. The voltage waveforms of A, B and Y are shown below

[JEE MAIN_{S1}_270722]



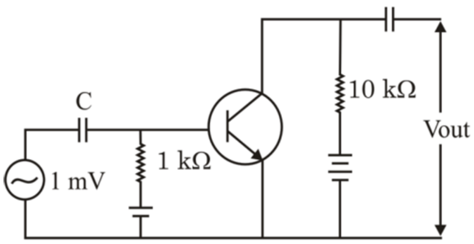
The logic gate circuit is

(1) AND gate (2) OR gate (3) NOR gate (4) NAND gate

15. For a constant collector-emitter voltage of 8V, the collector current of a transistor reached to the value of 6 mA from 4 mA, whereas base current changed from 20 μA to 25 μA value. If transistor is in active state, small signal current gain (current amplification factor) will be : **[JEE MAIN_{S2}_270722]**

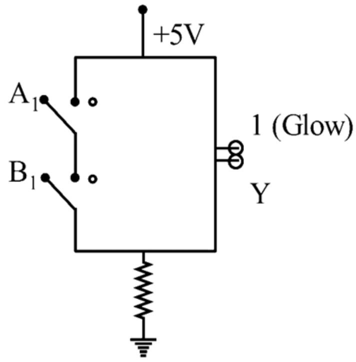
(1) 240 (2) 400 (3) 0.0025 (4) 200

16. An n.p.n transistor with current gain β = 100 in common emitter configuration is shown in figure. The output voltage of the amplifier will be **[JEE MAIN_{S2}_280722]**



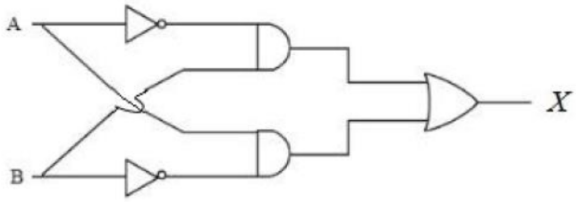
(1) 0.1 V (2) 1.0 V (3) 10 V (4) 100 V

17. The logic gate equivalent to the given circuit diagram is : **[JEE MAIN_{S2}_240123]**



(1) OR (2) NAND (3) NOR (4) AND

18. For the given logic gates combination, the correct truth table will be **[JEE MAIN_{S2}_290123]**



(1)

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

(2)

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

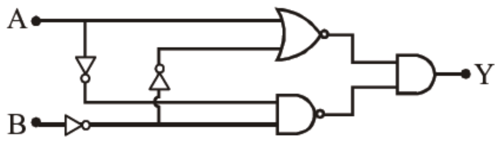
(3)

A	B	X
0	0	1
0	1	0
1	0	1
1	1	0

(4)

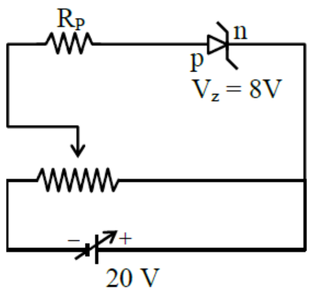
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

19. In the logic circuit shown in the figure, if input A and B are 0 to 1 respectively, the output at Y would be 'x'. The value of x is ________. **[JEE MAIN_{S1}_160321]**



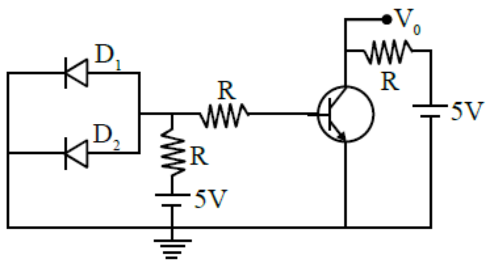
20. An npn transistor operates as a common emitter amplifier with a power gain of 10^6. The input circuit resistance is 100Ω and the output load resistance is $10\ K\ \Omega$. The common emitter current gain 'β' will be ______. (Round off to the Nearest Integer) **[JEE MAIN_{S1}_180321]**

21. A zener diode having zener voltage 8 V and power dissipation rating of 0.5 W is connected across a potential divider arranged with maximum potential drop across zener diode is as shown in the diagram. The value of protective resistance R_p is ....Ω. **[JEE MAIN_{S2}_200721]**

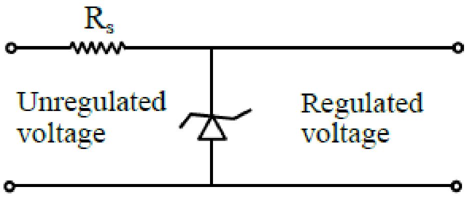


22. In a semiconductor, the number density of intrinsic charge carriers at 27ºC is 1.5×10^{16} /m^3. If the semiconductor is doped with impurity atoms, the hole density increases to 4.5×10^{22} /m^3. The electron density in the doped semiconductor is ______ $\times 10^9$/m^3. **[JEE MAIN_{S2}_250721]**

23. A circuit is arranged as shown in figure. The output voltage V_0 is equal to …..V. **[JEE MAIN_{S1}_270821]**



24. A zener diode of power rating 2Ω is to be used as a voltage regulator. If the zener diode has a breakdown of 10 V and it has to regulate voltage fluctuated between 6 V and 14 V, the value of Rs for safe operation should be _______ Ω. **[JEE MAIN_{S2}_270821]**



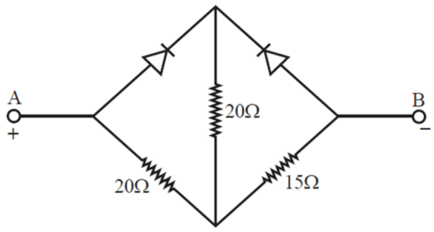
25. A transistor is used in common-emitter mode in an amplifier circuit. When a signal of 10 mV is added to the base-emitter voltage, the base current changes by 10 μA and the collector current changes by 1.5 mA. The load resistance is 5 kΩ. The voltage gain of the transistor will be ______ .

[JEE MAIN_{S1}_240622]

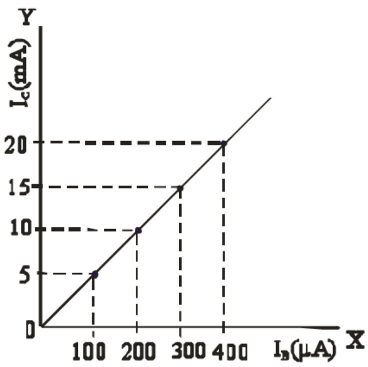
26. A potential barrier of 0.4 V exists across a p-n junction. An electron enters the junction from the n-side with a speed of 6.0×10^5 ms^{-1}. The speed with which electron enters the p side will be $\frac{x}{3} \times 10^5\,\text{ms}^{-1}$ the value of x is ________. **[JEE MAIN_{S2}_290622]**

(Given mass of electron = 9×10^{-31} kg, charge on electron = 1.6×10^{-19}C.)

27. Two ideal diodes are connected in the network as shown in figure. The equivalent resistance between A and B is _______Ω. **[JEE MAIN_{S2}_250722]**

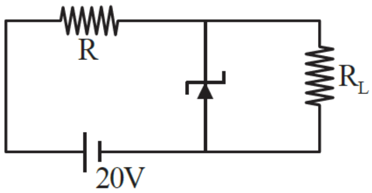


28. The typical transfer characteristic of a transistor in CE configuration is shown in figure. A load resistor of 2 kΩ is connected in the collector branch of the circuit used. The input resistance of the transistor is 0.50 kΩ . The voltage gain of the transistor is **[JEE MAIN_{S2}_260722]**



29. If the potential barrier across a p-n junction is 0.6 V. Then the electric field intensity, in the depletion region having the width of 6×10^{-6} m, will be ________ $\times 10^5$ N/C. **[JEE MAIN_{S1}_290722]**

30. A 8 V Zener diode along with a series resistance R is connected across a 20 V supply (as shown in the figure). If the maximum Zener current is 25 mA, then the minimum value of R will be_____Ω.
[JEE MAIN_{S2}_290722]



ANSWER KEY

1.	(4)	2.	(2)	3.	(2)	4.	(1)	5.	(4)	6.	(2)	7.	(3)
8.	(2)	9.	(3)	10.	(2)	11.	(3)	12.	(4)	13.	(1)	14.	(1)
15.	(2)	16.	(2)	17.	(2)	18.	(2)	19.	0	20.	100	21.	192
22.	5	23.	5	24.	20	25.	750	26.	14	27.	25	28.	200
29.	1	30.	480										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- PRINCIPLE OF COMMUNICATION

(Important Questions Only)

1. A telephonic communication service is working at carrier frequency of 10 GHz. Only 10% of it is utilized for transmission. How many telephonic channels can be transmitted simultaneously if each channel requires a bandwidth of 5 kHz? **[JEE MAIN_08042018]**

(1) 2×10^5 (2) 2×10^6 (3) 2×10^3 (4) 2×10^4

2. In a communication system operating at wavelength 800 nm, only one percent of source frequency is available as signal bandwidth. The number of channels accomodated for transmitting TV signals of band width 6 MHz are (take velocity of light c = 3 × 108m/s,h = 6.6×10^{-34} J-s)

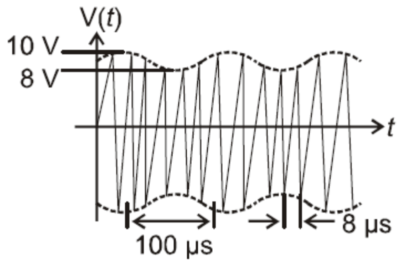
[JEE MAIN_{S2}_090119]

(1) 3.75×10^6 (2) 3.86×10^6 (3) 6.25×10^5 (4) 4.87×10^5

3. An amplitude modulated signal is given by $V_{(t)} = 10\,[1 + 0.3\cos(2.2 \times 10^4 t)]\sin(5.5 \times 10^5 t)$. Here t is in seconds. The sideband frequencies (in kHz) are, [Given π =22/7] **[JEE MAIN_{S1}_110119]**

(1) 1785 and 1715 (2) 178.5 and 171.5 (3) 89.25 and 85.75 (4) 892.5 and 857.5

4. An amplitude modulated signal is plotted below: **[JEE MAIN_{S2}_110119]**



Which one of the following best describes the above signal?

(1) $(9 + \sin(2\pi \times 10^4 t))\sin(2.5\pi \times 10^5 t)$ V (2) $(9 + \sin(4\pi \times 10^4 t))\sin(5\pi \times 10^5 t)$ V

(3) $(1 + 9\sin(2\pi \times 10^4 t))\sin(2.5\pi \times 10^5 t)$ V (4) $(9 + \sin(2.5\pi \times 10^5 t))\sin(2\pi \times 10^4 t)$ V

5. A signal $A\cos\omega t$ is transmitted using $v_0 \sin\omega_0 t$ as carrier wave. The correct amplitude modulated (AM) signal is: **[JEE MAIN_{S1}_09042019]**

(1) $v_0 \sin\omega_0 t + \frac{A}{2}\sin(\omega_0 - \omega)t + \frac{A}{2}\sin(\omega_0 + \omega)t$ (2) $(v_0 + A)\cos\omega t \sin\omega 0t$

(3) $v_0\sin\omega_0 t + A\cos\omega t$ (4) $v_0\sin[\omega_0(1 + 0.01 A\sin\omega t)t]$

6. Given below in the left column are different modes of communication using the kinds of waves given in the right column. **[JEE MAIN_{S2}_100419]**

A. Optical Fibre Communication — P. Ultrasound

B. Radar — Q. Infrared Light

C. Sonar — R. Microwaves

D. Mobile Phones — S. Radio Waves

From the options given below, find the most appropriate match between entries in the left and the right column.

(1) A-Q, B-S, C-P, D-R (2) A-Q, B-S, C-R, D-P

(3) A-S, B-Q, C-R, D-P (4) A-R, B-P, C-S, D-Q

7. The correct match between the entries in column I and column II are **[JEE MAIN_{S2}_050920]**

I **Radiation**	II **Wavelength**
(a) Microwave	(i) 100 m
(b) Gamma rays	(ii) 10^{-15} m
(c) A.M. radio waves	(iii) 10^{-10} m
(d) X = rays	(iv) 10^{-3} m

(1) (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii) (2) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)

(3) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv) (4) (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

8. If a message signal of frequency 'f_m' is amplitude modulated with a carrier signal of frequency 'f_c' and radiated through an antenna, the wavelength of the corresponding signal in air is :

[JEE MAIN_{S2}_25_0221]

(1) $\frac{c}{f_c - f_m}$ (2) $\frac{c}{f_m}$ (3) $\frac{c}{f_c + f_m}$ (4) $\frac{c}{f_c}$

9. What should be the height of transmitting antenna and the population covered if the television telecast is to cover a radius of 150 km? The average population density around the tower is 2000 per km^2 and the value of $R_e = 6.5 \times 10^6$ m. **[JEE MAIN_{S2}_220721]**

(1) Height = 1731 m Population Covered = 1413×10^5

(2) Height = 1441 m Population Covered = 7×10^5

(3) Height = 1600 m Population Covered = 2×10^5

(4) Height = 1800 m Population Covered = 1413×10^8

10. A transmitting antenna at top of a tower has a height of 50 m and the height of receiving antenna is 80 m. What is range of communication for Line of Sight (LoS) mode ? [use radius of earth = 6400 km] **[JEE MAIN_{S2}_260821]**

(1) 45.5 km (2) 80.2 km (3) 144.1 km (4) 57.28 km

11. An antenna is mounted on a 400 m tall building. What will be the wavelength of signal that can be radiated effectively by the transmission tower upto a range of 44 km?

[JEE MAIN_{S2}_270821]

(1) 37.8 m (2) 605 m (3) 75.6 m (4) 302 m

12. Match List I with List II **[JEE MAIN_{S2}_250622]**

	List -I		**List – II**
(A)	Facsimile	(I)	Static Document Image
(B)	Guided media Channel	(II)	Local BroadcastRadio
(C)	Frequency Modulation	(III)	Rectangular wave
(D)	Digital Signal	(IV)	Optical Fiber

Choose the correct answer from the following options :

(1) A –IV, B-III, C-II, D-I (2) A-I, B-IV, C-II, D-III

(3) A –IV, B-II, C-III, D-I (4) A-I, B-II, C-III, D-IV

13. Choose the correct statement for amplitude modulation: **[JEE MAIN_{S1}_260622]**

(1) Amplitude of modulating is varied in accordance with the information signal.

(2) Amplitude of modulated is varied in accordance with the information signal.

(3) Amplitude of carrier signal is varied in accordance with the information signal.

(4) Amplitude of modulated is varied in accordance with the modulating signal.

14. We do not transmit low frequency signal to long distances because **[JEE MAIN_{S2}_270622]**

(a) The size of the antenna should be comparable to signal wavelength which is unreal solution for a signal of longer wavelength.

(b) Effective power radiated by a long wavelength baseband signal would be high.

(c) We want to avoid mixing up signals transmitted by different transmitter simultaneously.

(d) Low frequency signal can be sent to long distances by superimposing with a high frequency wave as well.

Therefore, the most suitable options will be :

(1) All statements are true (2) (a), (b) and (c) are true only

(3) (a), (c) and (d) are true only (4) (b), (c) and (d) are true only

15. Match List-I with List-II **[JEE MAIN_{S1}_280622]**

	List-I		List-II
A	Television signal	I	03 KHz
B	Radio signal	II	20 KHz
C	High Quality Music	III	02 MHz
D	Human speech	IV	06 MHz

Choose the correct answer from the options given below :

(1) A-I, B-II, C-III, D-IV (2) A-IV, B-III, C-I, D-II
(3) A-IV, B-III, C-II, D-I (4) A-I, B-II, C-IV, D-III

16. Amplitude modulated wave is represented by $V_{RM} = 10\left[1+0.4\cos(2\pi\times10^4 t)\right]\cos(2\pi\times10^7 t)$. The total bandwidth of the amplitude modulated wave is : **[JEE MAIN_{S2}_280622]**
(1) 10 kHz (2) 20 MHz (3) 20 kHz (4) 10 MHz

17. When you walk through a metal detector carrying a metal object in your pocket, it raises an alarm. This phenomenon works on **[JEE MAIN_{S2}_250722]**
(1) Electromagnetic induction (2) Resonance in ac circuits
(3) Mutual induction in ac circuits (4) interference of electromagnetic waves

18. The maximum and minimum voltage of an amplitude modulated signal are 60 V and 20 V respectively. The percentage modulation index will be : **[JEE MAIN_{S2}_260722]**
(1) 0.5% (2) 50% (3) 2% (4) 30%

19. A FM Broad cast transmitter, using modulating signal of frequency 20 kHz has a deviation ratio of 10. The Bandwidth required for transmission is : **[JEE MAIN_{S2}_280722]**
(1) 220 kHz (2) 180 kHz (3) 360 kHz (4) 440 kHz

20. Match List – I with List –II **[JEE MAIN_{S1}_290722]**

	List-I		List-II
(a)	UV rays	(i)	Diagnostic tool in medicine
(b)	X-rays	(ii)	Water purification
(c)	Microwave	(iii)	Communication, Radar
(d)	Infrared wave	(iv)	Improving visibility in foggy days

Choose the correct answer from the options given below :
(1) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv) (2) (a)-(ii), (b)-(i), (c)-(iii), (d)-(iv)
(3) (a)-(ii), (b)-(iv), (c)-(iii), (d)-(i) (4) (a)-(iii), (b)-(i), (c)-(ii), (d)-(iv)

21. Find the modulation index of an AM wave having 8V variation where maximum amplitude of the AM wave is 9 V. **[JEE MAIN_{S1}_290722]**
(1) 0.8 (2) 0.5 (3) 0.2 (4) 0.1

22. Match List I with List II **[JEE MAIN_{S2}_240123]**

	LIST-I		LIST-II
A	AM Broadcast	**I**	88-108 MHz
B	FM Broadcast	**II**	540-1600 kHz
C	Television	**III**	3.7-4.2 GHz

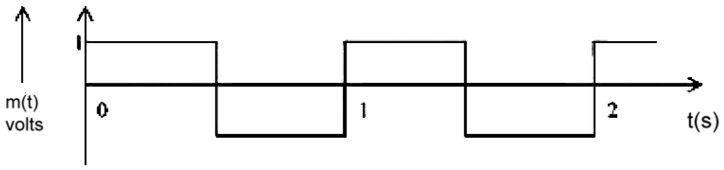
D	Satellite Communication	**IV**	54 MHz-590 MHz

Choose the correct answer from the options given below:

(1) A–II, B–I, C–IV, D–III (2) A–IV, B–III, C–I, D–II

(3) A–II, B–III, C–I, D–IV (4) A–I, B–III, C–II, D–IV

23. A modulating signal is a square wave, as shown in the figure. **[JEE MAIN_{S1}_240123]**



If the carrier wave is given as c(t) = 2 sin ($8\pi t$) volts, the modulation index is :

(1) 1/4 (2) 1 (3) 1/3 (4) ½

24. Match List I with List II **[JEE MAIN_{S2}_250123]**

	LIST-I		LIST-II
A	Troposphere	**I**	Approximate 65-75 km over Earth's surface
B	E-Part of Stratosphere	**II**	Approximate 300 km over Earth's surface
C	F_2-Part of Thermosphere	**III**	Approximate 10 km over Earth's surface
D	D-Part of Stratosphere	**IV**	Approximate 100 km over Earth's surface

Choose the correct answer from the options given below :

(1) A–III, B–IV, C–II, D–I (2) A–I, B–II, C–IV, D–III

(3) A–I, B–IV, C–III, D–II (4) A–III, B–II, C–I, D–IV

25. A message signal of frequency 5 kHz is used to modulate a carrier signal of frequency 2 MHz. The bandwidth for amplitude modulation is: **[JEE MAIN_{S1}_250123]**

(1) 5 kHz (2) 20 kHz (3) 10 kHz (4) 2.5 kHz

26. A carrier wave $V_C(t) = 160 \sin(2\pi \times 10^6 t)$ volts is made to vary between V_{max} = 200 V and V_{min} = 120 V by a message signal $V_m(t) = A_m \sin(2\pi \times 10^3 t)$ volts. The peak voltage A_m of the modulation signal is ____. **[JEE MAIN_{S1}_200721]**

27. The amplitude of upper and lower side bands of A.M. wave where a carrier signal with frequency 11.21 MHz, peak voltage 15 Volt is amplitude modulated by a 7.7 kHz sine wave of 5 Volt amplitude are $\frac{a}{10}$ Volt and $\frac{b}{10}$ Volt respectively. Then the value of $\frac{a}{b}$ is ___________. **[JEE MAIN_{S1}_270721]**

28. The height of a transmitting antenna at the top of a tower is 25 m and that of receiving antenna is, 49 m. The maximum distance between them, for satisfactory communication in LOS (Line-Of- Sight) is

$K\sqrt{5}\times10^{2}\,m$. The value of K is _______ . [Assume radius of Earth is 64 × 10^{+5} m] (Calculate upto nearest integer value) **[JEE MAIN_{S1}_270622]**

29. The required height of a TV tower which can cover the population of 6.03 lakh is h. If the average population density is 100 per square km and the radius of earth is 6400 km, then the value of h will be _______ m. **[JEE MAIN_{S1}_250722]**

30. A modulating signal 2sin (6.28 × 10^6)t is added to the carrier signal 4sin (12.56 × 10^9) t for amplitude modulation. The combined signal is passed through a non-linear square law device. The output is then passed through a band pass filter. The bandwidth of the output signal of band pass filter will be_____MHz. **[JEE MAIN_{S2}_290722]**

ANSWER KEY

1.	(1)	2.	(3)	3.	(3)	4.	(1)	5.	(1)	6.	(1)	7.	(2)
8.	(4)	9.	(1)	10.	(4)	11.	(2)	12.	(2)	13.	(3)	14.	(3)
15.	(3)	16.	(3)	17.	(2)	18.	(2)	19.	(4)	20.	(2)	21.	(1)
22.	(1)	23.	(4)	24.	(1)	25.	(3)	26.	40	27.	1	28.	192
29.	150	30.	2										

PHYSICS

JEE MAIN PREVIOUS YEARS QUESTIONS – 2018-2023

Chapter Name :- MEASUREMENT ERROR & UNIT AND DIMENSIONS

(Important Questions Only)

1. The pitch and the number of divisions, on the circular scale, for a given screw gauge are 0.5 mm and 100 respectively. When the screw gauge is fully tightened without any object, the zero of its circular scale lies 3 divisions below the mean line.

The readings of the main scale and the circular scale, for a thin sheet, are 5.5 mm and 48 respectively, the thickness of this sheet is: **[JEE MAIN_{S2}_090119]**

(1) 5.725 mm (2) 5.740 mm (3) 5.755 mm (4) 5.950 mm

2. When the temperature of a metal wire is increased from 0°C to 10°C, its length increases by 0.02%. The percentage change in its mass density will be closest to **[JEE-MAIN_{S2}_020920]**

(1) 2.3 (2) 0.06 (3) 0.8 (4) 0.008

3. In a typical combustion engine the work done by a gas molecule is given $W = \alpha^2 \beta e^{\frac{-\beta x^2}{kT}}$ where x is the displacement, k is the Boltzmann constant and T is the temperature. If α and β are constants, dimensions of α will be : **[JEE MAIN_{S1}_260221]**

(1) $[MLT^{-2}]$ (2) $[M^0LT^0]$ (3) $[M^2LT^{-2}]$ (4) $[MLT^{-1}]$

4. **Assertion A :** If in five complete rotations of the circular scale, the distance travelled on main scale of the screw gauge is 5 mm and there are 50 total divisions on circular scale, then least count is 0.001 cm.

Reason R : Least Count = $\frac{\text{Pitch}}{\text{Total division on circular scale}}$ **[JEE MAIN_{S1}_270721]**

In the light of the above statements, choose the most appropriate answer from the options given below :

(1) A is not correct but R is correct.

(2) Both A and R are correct and R is the correct explanation of A.

(3) A is correct but R is not correct.

(4) Both A and R are correct and R is NOT the correct explanation of A.

5. A screw gauge of pitch 0.5 mm is used to measure the diameter of uniform wire of length 6.8 cm, the main scale reading is 1.5 mm and circular scale reading is 7. The calculated curved surface area of wire to appropriate significant figures is : [Screw gauge has 50 divisions on the circular scale]

[JEE MAIN_{S1}_260722]

(1) 6.8 cm^2 (2) 3.4 cm^2 (3) 3.9 cm^2 (4) 2.4 cm^2

6. In a Vernier Calipers. 10 divisions of Vernier scale is equal to the 9 divisions of main scale. When both jaws of Vernier calipers touch each other, the zero of the Vernier scale is shifted to the left of zero of the main scale and 4^{th} Vernier scale division exactly coincides with the main scale reading. One main scale division is equal to 1 mm. While measuring diameter of a spherical body, the body is held between two jaws. It is now observed that zero of the Vernier scale lies between 30 and 31 divisions of main scale reading and 6^{th} Vernier scale division exactly. coincides with the main scale reading. The diameter of the spherical body will be : **[JEE MAIN_{S2}_260722]**

(1) 3.02 cm (2) 3.06 cm (3) 3.10 cm (4) 3.20 cm

7. A torque meter is calibrated to reference standards of mass, length and time each with 5% accuracy. After calibration, the measured torque with this torque meter will have net accuracy of :

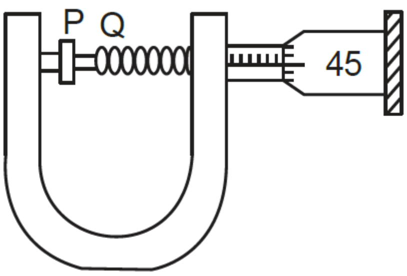
[JEE MAIN_{S1}_270722]

(1) 15% (2) 25% (3) 75% (4) 5%

8. A travelling microscope has 20 divisions per cm on the main scale while its Vernier scale has total 50 divisions and 25 Vernier scale divisions are equal to 24 main scale divisions, what is the least count of the travelling microscope? **[JEE MAIN_{S1}_290722]**

(1) 0.001 cm (2) 0.002 mm (3) 0.002 cm (4) 0.005

9. In an experiment to find out the diameter of wire using screw gauge, the following observation were noted : **[JEE MAIN_{S1}_290722]**



(a) Screw moves 0.5 mm on main scale in one complete rotation

(b) Total divisions on circular scale = 50

(c) main scale reading is 2.5 mm

(d) 45^{th} division of circular scale is in the pitch line

(e) Instrument has 0.03 mm negative error

Then the diameter of wire is :

(1) 2.92 mm (2) 2.54 mm (3) 2.98 mm (4) 3.45 mm

10. The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1% the maximum error in determining the density is : **[JEE MAIN_080418]**

(1) 4.5% (2) 6% (3) 2.5% (4) 3.5 %

11. The force of interaction between two atoms is given by $F = \alpha\beta \exp\left(-\frac{x^2}{\alpha kt}\right)$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimension of β i

[JEE MAIN_{S1}_110119]

(1) $M^0L^2T^{-4}$ (2) M^2LT^{-4} (3) MLT^{-2} (4) $M^2L^2T^{-2}$

12. Let l, r, c and v represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{1}{rcv}$ in SI units will be **[JEE MAIN_{S2}_120119]**

(1) $[A^{-1}]$ (2) $[LA^{-2}]$ (3) $[LT^2]$ (4) $[LTA]$

13. In SI units, the dimensions of $\sqrt{\frac{\epsilon_0}{\mu_0}}$ is: **[JEE MAIN_{S1}_080419]**

(1) $AT^2M^{-1}L^{-1}$ (2) $AT^{-3}ML^{3/2}$ (3) $A^{-1}TML^3$ (4) $A^2T^3M^{-1}L^{-2}$

14. A quantity x is given by (IFv^2/WL^4) in terms of moment of inertia I, force F, velocity v, work W and length L. The dimensional formula for x is same as that of **[JEE MAIN_(S2) _040920]**

(1) Coefficient of viscosity (2) Force constant

(3) Energy density (4) Planck's constant

15. The quantities $x = \frac{1}{\sqrt{\mu_0\varepsilon_0}}, y = \frac{E}{B}$ and $z = \frac{l}{CR}$ are defined where C-capacitance, R-Resistance, l-length, E-Electric field, B-magnetic field and ε_0, μ_0, - free space permittivity and permeability respectively. Then

[JEE MAIN_(S2) _050920]

(1) Only x and y have the same dimension (2) Only x and z have the same dimension

(3) x, y and z have the same dimension (4) Only y and z have the same dimension

16. The workdone by a gas molecule in an isolated system is given by, $W = \alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature, α and β are constants. Then the dimension of β will be : **[JEE MAIN_{S1}_240221]**

(1) $[M\,L^2\,T^{-2}]$ (2) $[M\,L\,T^{-2}]$ (3) $[M^2\,L\,T^2]$ (4) $[M^0\,L\,T^0]$

17. The entropy of any system is given by **[JEE MAIN_{S1}_200721]**

$$S = \alpha^2\beta\,1n\left[\frac{\mu kR}{J\beta^2} + 3\right]$$

Where α and β are the constants. μ, J, k and R are no. of moles, mechanical equivalent of heat, Boltzmann constant and gas constant respectively.

$$\left[\text{Take } S = \frac{dQ}{T}\right]$$

Choose the incorrect option from the following :

(1) α and J have the same dimensions
(2) S, β, k and μR have the same dimension
(3) S and α have different dimensions
(4) α and k have the same dimension

18. If time (t), velocity (v), and angular momentum (l) are taken as the fundamental units. Then the dimension of mass (m) in terms of t, v and l is : **[JEE MAIN_{S2}_200721]**

(1) $\left[t^{-1}v^{1}\ell^{-2}\right]$ (2) $\left[t^{1}v^{1}\ell^{-1}\right]$ (3) $\left[t^{-1}v^{-1}\ell^{1}\right]$ (4) $\left[t^{-1}v^{-2}\ell^{1}\right]$

19. If force (F), length (L) and time (T) are taken as the fundamental quantities, Then what will be the dimension of density : **[JEE MAIN_{S2}_270821]**

(1) $[FL^{-4}T^{2}]$ (2) $[FL^{-3}T^{2}]$ (3) $[FL^{-5}T^{2}]$ (4) $[FL^{-3}T^{3}]$

20. Velocity (v) and acceleration (a) in two systems of units 1 and 2 are related as $v_2 = \frac{n}{m^2}v_1$ and $a_2 = \frac{a_1}{mn}$ respectively. Here m and n are constants. The relations for distance and time in two systems respectively are: **[JEE MAIN_{S2}_280622]**

(1) $\frac{n^3}{m^3}L_1 = L_2$ and $\frac{n^2}{m}T_1 = T_2$
(2) $L_1 = \frac{n^4}{m^2}L_2$ and $T_1 = \frac{n^2}{m}T_2$
(3) $L_1 = \frac{n^2}{m}L_2$ and $T_1 = \frac{n^4}{m^2}T_2$
(4) $\frac{n^2}{m}L_1 = L_2$ and $\frac{n^4}{m^2}T_1 = T_2$

21. If momentum [P], area [A] and time [T] are taken as fundamental quantities, then the dimensional formula for coefficient of viscosity is : **[JEE MAIN_{S1}_250722]**

(1) $[P\,A^{-1}\,T^{0}]$ (2) $[P\,A\,T^{-1}]$ (3) $[P\,A^{-1}\,T]$ (4) $[P\,A^{-1}\,T^{-1}]$

22. An expression of energy density is given by $u = \frac{\alpha}{\beta}\sin\left(\frac{\alpha x}{kt}\right)$, where α, β are constants, x is displacement, k is Boltzmann constant and t is the temperature. The dimensions of β will be : **[JEE MAIN_{S2}_270722]**

(1) $[ML^{2}T^{-2}\theta^{-1}]$ (2) $[M^{0}L^{2}T^{-2}]$ (3) $[M^{0}L^{0}T^{0}]$ (4) $[M^{0}L^{2}T^{0}]$

23. Consider the efficiency of Carnot's engine is given by $\eta = \frac{\alpha\beta}{\sin\theta}\log_e\frac{\beta x}{kT}$, where α and β are constants. If T is temperature, k is Boltzman constant, θ is angular displacement and x has the dimensions of length. Then, choose the incorrect option. **[JEE MAIN_{S2}_280722]**

(1) dimension of β is same as that of force
(2) Dimension of α^{-1} x is same as that of energy.
(3) dimensions of η^{-1} sin θ is same as that of $\alpha\beta$
(4) Dimension of α is same as that of β

24. The frequency (ν) of an oscillating liquid drop may depend upon radius (r) of the drop, density (ρ) of liquid and the surface tension (s) of the liquid as : $\nu = r^a \rho^b s^c$. The values of a, b and c respectively are **[JEE MAIN_{S2}_240123]**

(1) $\left(-\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}\right)$ (2) $\left(\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}\right)$ (3) $\left(\frac{3}{2}, \frac{1}{2}, -\frac{1}{2}\right)$ (4) $\left(-\frac{3}{2}, \frac{1}{2}, \frac{1}{2}\right)$

25. A non-isotropic solid metal cube has coefficients of linear expansion as: 5×10^{-5}/°C along the x-axis and 5×10^{-6}/°C along the y and the z-axis. If the coefficent of volume expansion of the solid is C × 10^{-6}/°C then the value of C is________. **[JEE MAIN_{S1} _070120]**

26. The density of a solid metal sphere is determined by measuring its mass and its diameter. The maximum error in the density of the sphere is $\left(\frac{x}{100}\right)\%$. If the relative errors in measuring the mass and the diameter are 6.0% and 1.5% respectively, the value of x is _____. **[JEE MAIN_{S1} _060920]**

27. The radius of a sphere is measured to be (7.50 ± 0.85) cm. Suppose the percentage error in its volume is x. The value of x, to the nearest x, is_______. **[JEE MAIN_{S1}_180321]**

28. The diameter of a spherical bob is measured using a vernier callipers. 9 divisions of the main scale, in the vernier callipers, are equal to 10 divisions of vernier scale. One main scale division is 1 mm. The main scale reading is 10 mm and 8th division of vernier scale was found to coincide exactly with one of the main scale division. If the given vernier callipers has positive zero error of 0.04 cm, then the radius of the bob is_____ × 10^{-2} cm. **[JEE MAIN_{S1}_310821]**

29. For $Z = a^2x^3y^{\frac{1}{2}}$, where 'a' is a constant. If percentage error in measurement of 'x' and 'y' are 4% and 12%, respectively, then the percentage error for 'z' will be %. **[JEE MAIN_{S2}_250622]**

30. In an experiment to find acceleration due to gravity (g) using simple pendulum, time period of 0.5 s is measured from time of 100 oscillation with a watch of 1 s resolution. If measured value of length is 10 cm known to 1 mm accuracy. The accuracy in the determination of g is found to be x%. The value of x is **[JEE MAIN_{S2}_280722]**

ANSWER KEY

1.	(1)	2.	(2)	3.	(2)	4.	(1)	5.	(2)	6.	(3)	7.	(2)
8.	(3)	9.	(3)	10.	(1)	11.	(2)	12.	(1)	13.	(4)	14.	(3)
15.	(3)	16.	(2)	17.	(4)	18.	(4)	19.	(1)	20.	(1)	21.	(1)
22.	(4)	23.	(4)	24.	(1)	25.	60.00	26.	1050.00			27.	34
28.	52	29.	18	30.	5								

MATHEMATICAL TOOLS & RECTILINEAR MOTION SOLUTION

1. $t_A = t_B - t$

$v_A = a_1(t_B - t) = a_2t_B + v$ .....(i)

$S = \frac{1}{2}a_1(t_B - t)^2 = \frac{1}{2}a_2t_B^2$

$\Rightarrow t_B\left[1 - \sqrt{\frac{a_2}{a_1}}\right] = t$ .....(ii)

Solving (i) and (ii) $v = \sqrt{a_1a_2}\,t$

2. $x = at + bt^2 - ct^3 \quad \Rightarrow \quad \dot{x} = a + 2bt - 3ct^2$

$\ddot{x} = 2b - 6ct$

For $\ddot{x} = 0 \quad t = +\frac{b}{3c}$

$\therefore \quad v = x = a + 2b\left(\frac{+b}{3c}\right) - 3c\left(\frac{b^2}{3c \times 3c}\right)$

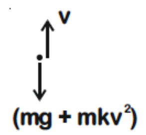
$\Rightarrow \quad v = \frac{2b^2}{3c} - \frac{b^2}{3c} + a = a + \frac{b^2}{3c}$

3. $v = \frac{dx}{dt} = b\sqrt{x}$ ...(i)

$\Rightarrow \quad \int_0^x \frac{dx}{\sqrt{x}} = \int_0^\tau b\,dt$

$\Rightarrow \quad 2\sqrt{x} = b\tau$ ...(ii)

$\Rightarrow \quad v = b \cdot \frac{b\tau}{2} = \frac{b^2\tau}{2}$



4. $|a| = g + kv^2$

$\Rightarrow \quad -\frac{vdv}{dh} = g + kv^2$

$\Rightarrow \quad \int_u^0 \frac{vdv}{g + kv^2} = \int_0^{H_{max}} -dh$

On solving

$H_{max} = \frac{1}{2k}\ln\left(1 + \frac{ku^2}{g}\right)$

5. $F = -ax^2$

$ma = -ax^2$

$a = \frac{-\alpha x^2}{m}$

$\frac{vdv}{dx} = \frac{\alpha}{m}x^2$

$\int_{v_0}^{0} v\,dv = \int_0^x -\frac{\alpha}{m}x^2dx$

$\left(\frac{v^2}{2}\right)_{v_0}^{0} = -\frac{\alpha}{m}\left(\frac{x^3}{3}\right)_0^x$

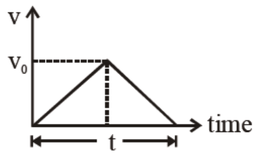
$\frac{-v_0^2}{2} = -\frac{\alpha}{m}\frac{x^3}{3}$

$\boxed{x = \left(\frac{3mv_0^2}{2\alpha}\right)^{\frac{1}{3}}}$

6. $v_0 = \alpha t_2$ and $0 = v_0 - \beta t_2 \Rightarrow v_0 = \beta t_2$

$t_1 + t_2 = t$

$v_0\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) = t$



$\Rightarrow \quad v_0 = \frac{\alpha\beta t}{\alpha + \beta}$

Distance = area of v–t graph

$= \frac{1}{2} \times t \times v_0 = \frac{1}{2} \times t \times \frac{\alpha\beta t}{\alpha + \beta} = \frac{\alpha\beta t^2}{2(\alpha + \beta)}$

7. $V = \alpha t + \beta t^2$

$\frac{ds}{dt} = \alpha t + \beta t^2$

$\int_{S_1}^{S_2} ds = \int_1^2 (\alpha t + \beta t^2)dt$

$S_2 - S_2 = \left[\frac{\alpha t^2}{2} + \frac{\beta t^3}{3}\right]_1^2$

As particle is not changing direction

so distance = displacement.

Distance = $\left[\frac{\alpha[4-1]}{2} + \frac{\beta[8-1]}{3}\right] = \frac{3\alpha}{2} + \frac{7\beta}{3}$

8. $u = \sqrt{2gh}$

Now,

$S = \frac{h}{3}$ $\qquad a = -g$

$S = ut + \frac{1}{2}at^2$

$\frac{h}{3} = \sqrt{2gh}t + \frac{1}{2}(-g)t^2$

$t^2\left(\frac{g}{2}\right) - \sqrt{2gh}t + \frac{h}{3} = 0$

From quadratic equation

$$t_1, t_2 = \frac{\sqrt{2gh} \pm \sqrt{2gh - \frac{4g}{2}\frac{h}{3}}}{g}$$

$$\frac{t_1}{t_2} = \frac{\sqrt{2gh} - \sqrt{\frac{4gh}{3}}}{\sqrt{2gh} + \sqrt{\frac{4gh}{3}}} = \frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}+\sqrt{2}}$$

9. $X_P(t) = \alpha t + \beta t^2$ $\qquad X_Q = ft - t^2$

$V_P(t) = \alpha + 2\beta t^2$ $\qquad X_Q = f - 2t$

$V_P = V_Q$

$\alpha + 2\beta t = f - 2t$

$t = \frac{f-\alpha}{2\beta + 2}$

10. $V = -100 - 10\,t$

11. $\vec{r} = 3t\hat{i} + 5t^3\hat{j} + 7k$

$\frac{d^2\vec{r}}{dt^2} = 30t\,\hat{j}$

At $t = 1 \Rightarrow \frac{d^2\vec{r}}{dt^2} = 30\,\hat{j}$

12. P.V. of G = $\frac{a}{2}(\hat{i} + \hat{k})$

P.V. of H = $\frac{a}{2}(\hat{j} + \hat{k})$

$\vec{G}H = \frac{a}{2}(\hat{j} - \hat{i})$

13. Clearly, $|\vec{A} + \vec{B}|^2 = A^2 + B^2 + 2AB\cos\theta$

and $|\vec{A} - \vec{B}|^2 = A^2 + B^2 - 2AB\cos\theta$

As, $|\vec{A} + \vec{B}|^2 = n^2|\vec{A} - \vec{B}|^2$

$\therefore$ $A^2 + B^2 + 2AB\cos\theta = n^2(A^2 + B^2 - 2AB\cos\theta)$

$\therefore$ $A^2 + B^2 + 2AB\cos\theta = n^2A^2 + n^2B^2 - 2n^2AB\cos\theta$

$\therefore$ $\cos\theta \times 2AB(1 + n^2) = A^2(n^2 - 1) + B^2(n^2 - 1)$

$\Rightarrow \cos\theta = \frac{(n^2-1)(A^2+B^2)}{2AB(1+n^2)}$

$\Rightarrow \cos\theta = \frac{n^2-1}{n^2+1}$

$\Rightarrow \theta = \cos^{-1}\left(\frac{n^2-1}{n^2+1}\right)$

14. We know,

$\because$ $\overrightarrow{OA} + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD} + \overrightarrow{OE} + \overrightarrow{OF} + \overrightarrow{OG} + \overrightarrow{OH} = \vec{0}$

By triangle law of vector addition, we can write

$\overrightarrow{AB} = \overrightarrow{AO} + \overrightarrow{OB}$; $\overrightarrow{AC} = \overrightarrow{AO} + \overrightarrow{OC}$

$\overrightarrow{AD} = \overrightarrow{AO} + \overrightarrow{OD}$; $\overrightarrow{AE} = \overrightarrow{AO} + \overrightarrow{OE}$

$\overrightarrow{AF} = \overrightarrow{AO} + \overrightarrow{OF}$; $\overrightarrow{AG} = \overrightarrow{AO} + \overrightarrow{OG}$

$\overrightarrow{AH} = \overrightarrow{AO} + \overrightarrow{OH}$

Now

$\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} + \overrightarrow{AE} + \overrightarrow{AF} + \overrightarrow{AG} + \overrightarrow{AH}$

$= (7\overrightarrow{AO}) + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD} + \overrightarrow{OE} + \overrightarrow{OF} + \overrightarrow{OG} + \overrightarrow{OH}$

$= (7\overrightarrow{AO}) + \vec{0} - \overrightarrow{OA}$

$= (7\overrightarrow{AO}) + \overrightarrow{AO}$

$= 8\overrightarrow{AO} = 8(2\hat{i} + 3\hat{j} - 4\hat{k})$

$= 16\hat{i} + 24\hat{j} - 32\hat{k}$

15. $|\vec{P}| = |\vec{Q}| = x$ $\qquad$ ...(1)

$|\vec{P} + \vec{Q}| = n\,|\vec{P} - \vec{Q}|$

$P^2 + Q^2 + 2PQ\cos\theta = n^2(P^2 + Q^2 - 2PQ\cos\theta)$

Using (1) in above equation

$\cos\theta = \frac{n^2-1}{1+n^2}$, $\theta = \cos^{-1}\left(\frac{n^2-1}{n^2+1}\right)$

16. (a) $\vec{C} = \vec{A} + \vec{B}$ option (iv)

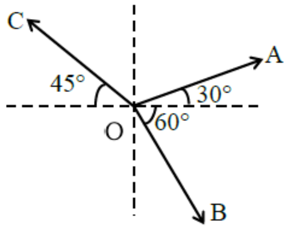
(b) $\vec{A} = \vec{B} + \vec{C} = \vec{C} + \vec{B}$ - option (iii)

(c) $\vec{B} = \vec{A} + \vec{C}$ - option (i)

(d) $\vec{A} + \vec{B} + \vec{C} = 0$ option (ii)

17. Polygon law is applicable in both but the equation given in the reason is not useful in explaining the assertion.

18.



Let magnitude be equal to λ.

$$\overrightarrow{OA} = \lambda[\cos 30°\hat{i} + \sin 30\hat{j}] = \lambda\left[\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right]$$

$$\overrightarrow{OB} = \lambda[\cos 60°\hat{i} - \sin 60\,\hat{j}] = \lambda\left[\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right]$$

$$\overrightarrow{OC} = \lambda[\cos 45°(-\hat{i}) + \sin 45\,\hat{j}] = \lambda\left[-\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right]$$

$\therefore \overrightarrow{OA} + \overrightarrow{OB} - \overrightarrow{OC}$

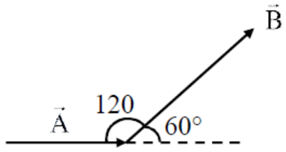
$$= \lambda\left[\left(\frac{\sqrt{3}+1}{2} + \frac{1}{\sqrt{2}}\right)\hat{i} + \left(\frac{1}{2} - \frac{\sqrt{3}}{2} - \frac{1}{\sqrt{2}}\right)\hat{j}\right]$$

$\therefore$ angle with x-axis

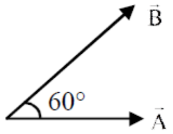
$$\tan^{-1}\left[\frac{\frac{1}{2} - \frac{\sqrt{3}}{2} - \frac{1}{\sqrt{2}}}{\frac{\sqrt{3}}{2} + \frac{1}{2} + \frac{1}{\sqrt{2}}}\right] = \tan^{-1}\left[\frac{\sqrt{2} - \sqrt{6} - 2}{\sqrt{6} + \sqrt{2} + 2}\right]$$

$$= \tan^{-1}\left[\frac{1 - \sqrt{3} - \sqrt{2}}{\sqrt{3} + 1 + \sqrt{2}}\right]$$

Hence option (1)



19.



Angle between $\vec{A}$ and $\vec{B}$, $\theta = 60°$

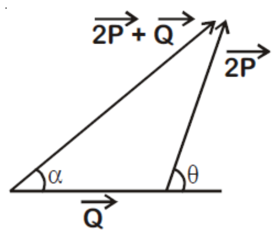
Angle between $\vec{A}$ and $\vec{A} - \vec{B}$

$$\tan\alpha = \frac{B\sin\theta}{A - B\cos\theta}$$

$$= \frac{B\sqrt{\frac{3}{2}}}{A - B\times\frac{1}{2}2}$$

$$\tan\alpha = \frac{\sqrt{3}B}{2A - B}$$

20.



$P^2 = P^2 + Q^2 + 2PQ.\cos\theta$

$\Rightarrow \quad \cos\theta = \frac{Q}{2P}$ ....(i)

$\tan\alpha = \frac{2P\sin\theta}{Q + 2P\cos\theta} = \infty$

$\Rightarrow \quad \alpha = 90°$

21. $-PQ \sin\theta$

$= PQ \sin\theta$

$\Rightarrow q = 180°$

22. Direction of P $\hat{v}_1 = \pm\frac{\vec{A}\times\vec{B}}{|\vec{A}\times\vec{B}|} = \pm\frac{\hat{i} - \hat{j} + \hat{k}}{\sqrt{3}}$

Direction of Q $\hat{v}_2 = \pm\frac{\vec{A}\times\vec{C}}{|\vec{A}\times\vec{C}|} = \pm\frac{2\hat{k}}{2} = \pm\hat{k}$

Angle between $\hat{v}_1$ and $\hat{v}_2$

$$\frac{\hat{v}_1.\hat{v}_2}{|\hat{v}_1||\hat{v}_2|} = \frac{\pm 1/\sqrt{3}}{(1)(1)} = \pm\frac{1}{\sqrt{3}}$$

x = 3

23. $$\vec{P}\times\vec{Q} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & \sqrt{3} & 2 \\ 4 & \sqrt{3} & 2.5 \end{vmatrix} = \sqrt{3}\frac{\hat{i}}{2} + \frac{\hat{j}}{2} - \sqrt{3}\hat{k}$$

$$\Rightarrow \frac{\vec{P}\times\vec{Q}}{|\vec{P}\times\vec{Q}|} \frac{1}{2}\left(\sqrt{3}\frac{\hat{i}}{2} + \frac{\hat{j}}{2} - \sqrt{3}\hat{k}\right)$$

$$= \frac{1}{4}(\sqrt{3}\,\hat{i} + \hat{j} - 2\sqrt{3}\,\hat{k}) \quad x = 4$$

24. For particle 'A' — For particle 'B'

$X_A = -3t^2 + 8t + 10$ — $Y_B = 5 - 8t^3$

$\vec{V}_A = (8 - 6t)\hat{i}$ — $\vec{V}_B = -24t^2\hat{j}$

$\vec{a}_A = -6\hat{i}$ — $\vec{a}_B = -48t\,\hat{j}$

at t = 1 sec

$\vec{v}_A = 2\hat{i},\ \vec{v}_B - 24\hat{j}$

$\therefore \quad \vec{v}_{B/A} = -\vec{v}_A + \vec{v}_B = -2\hat{i} - 24\hat{j}$

Speed of B w.r.t. A,

$|\vec{v}_{B/A}| = \sqrt{4 + 576} = \sqrt{580}$

$\therefore \quad v = 580\ (m/s)^2$

25. $h = \frac{1}{2}gt^2$

$\Rightarrow \quad 200 = gt^2 \qquad ...(i)$

$\Rightarrow \quad t = \sqrt{\frac{200}{g}}$

Also $\frac{1}{2}g\left(t - \frac{1}{2}\right)^2 = 81$

$\therefore \quad g\left(t - \frac{1}{2}\right)^2 = 81\times 2 \qquad ...(ii)$

$\left(t - \frac{1}{2}\right) = \sqrt{\frac{81\times 2}{g}}$

$\therefore$

$\frac{1}{2} = \frac{1}{\sqrt{g}}\left(\sqrt{200} - \sqrt{81\times 2}\right) \Rightarrow \sqrt{g} = 2\left(10\sqrt{2} - 9\sqrt{2}\right)$

$\Rightarrow \quad \sqrt{g} = 2\sqrt{2}$

$\therefore \quad g = 8\ m/s^2$

26. $2x\frac{dx}{dt} = 2at + 2b$

$x\frac{dx}{dt} = at + b \Rightarrow \frac{dx}{dt} = \frac{(at+b)}{x}$

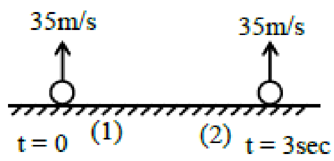
$\Rightarrow \quad x\frac{d^2x}{dt^2} + \left(\frac{dx}{dt}\right)^2 = a$

$\Rightarrow \quad \frac{d^2x}{dt^2} = \frac{a - \left(\frac{dx}{dt}\right)^2}{x} = \frac{a - \left(\frac{at+b}{x}\right)^2}{x}$

$\frac{ax^2 - (at+b)^2}{x^3} = \frac{ac - b^2}{x^3}$

$\Rightarrow \quad a \propto x^{-3}$

27.



When both balls will collied

$y_1 = y_2$

$35t - \frac{1}{2}\times 10\times t^2 = 35(t-3) - \frac{1}{2}\times 10\times (t-3)^2$

$35t - \frac{1}{2}\times 10\times t^2 = 35t - 105 - \frac{1}{2}\times 10\times t^2$

$-\frac{1}{2}\times 10\times 3^2 + \frac{1}{2}\times 10\times 6t$

0 = 150 – 30 t

t = 5 sec

$\therefore$ Height at which both balls will collied

$h = 35t - \frac{1}{2}\times 10\times t^2$

$= 35\times 5 - \frac{1}{2}\times 10\times 5^2$

h = 50 m

Ans. **50.00**

28. $<\vec{v}> = \frac{\text{Displacement}}{\text{time}}$

(Let displacement be l)

$$= \frac{\ell}{\left(\frac{\ell}{V_3}+\frac{\ell}{V_2}+\frac{\ell}{V_1}\right)\frac{1}{3}}$$

$$= \frac{3}{\frac{1}{V_1}+\frac{1}{V_2}+\frac{1}{V_3}} = \frac{3}{\frac{1}{11}+\frac{1}{22}+\frac{1}{33}}$$

$= 18$ m/s

29. $v_i = \sqrt{2gh_i}$

$= \sqrt{2 \times 10 \times 9.8} \downarrow$

$= 14\,\text{m/s} \downarrow$

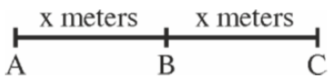
$v_f = \sqrt{2gh_f}$

$= \sqrt{2 \times 10 \times 5} \uparrow$

$= 10\,\text{m/s} \uparrow$

$$|\vec{a}_{avg}| = \left|\frac{\Delta\vec{v}}{\Delta t}\right| = \frac{24}{0.2} = 120\,\text{m/s}^2$$

30.



$$t_{AB} = \frac{x}{5\,\text{m/s}}$$

In motion BC

where d_1 & d_2 we the distance travelled with 10 m/s and 15 m/s respectively in equal time intervals $\frac{'t'}{2}$ each

$$d_1 = \frac{10t}{2}, d_2 = \frac{15t}{2}$$

$$d_1 + d_2 = x = \frac{t}{2}(10+15) = \frac{25t}{2}$$

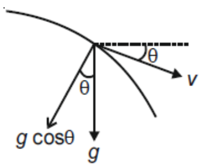
$$< v > = \frac{2x}{\frac{x}{5}+\frac{2x}{25}} = \frac{2 \times 25}{5+2} = \frac{50}{7}\,\text{m/s}$$

Ans. : 50

PROJECTILE MOTION & RELATIVE MOTION SOLUTION

1. $\dfrac{A_1}{A_2}=\dfrac{\pi R^2_{1.max}}{\pi R^2_{2.max}}=\left(\dfrac{u_1^2}{u_2^2}\right)=\left(\dfrac{1}{4}\right)^2=\dfrac{1}{16}$

2. $T=\dfrac{2u\sin\theta}{g}$



$=\dfrac{2\times 10}{10}\times\dfrac{\sqrt{3}}{2} \quad \Rightarrow \quad T=\sqrt{3}\,s$

$V_y=5\sqrt{3}-10=-1.34\ ms^{-1}$

$V_x=10\times\dfrac{1}{2}=5\ ms^{-1}$

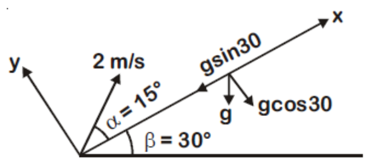
$|\tan\theta|=\left|\left(-\dfrac{1.34}{5}\right)\right|$

θ = 15°

$R=\dfrac{V^2}{g\cos\theta}=\dfrac{26.79}{10\times 0.97}=2.77m\ ;\ 2.8m$

3. Time of flight (T) = $\dfrac{2u\sin\alpha}{g\cos\beta}$

$T=\dfrac{(2)(2\sin 15)}{g\cos 30}=\dfrac{4\sin 15}{10\cos 30}$



Range (R) = (2 cos 15) $T-\dfrac{1}{2}g\sin 30(T)^2$

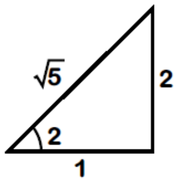
=

$(2\cos 15)\dfrac{4}{10}\dfrac{\sin 15}{\cos 30}-\left(\dfrac{1}{3}\times 10\sin 30\right)\dfrac{16}{100}\dfrac{\sin^2 15}{\cos^2 30}$

$=\dfrac{16\sqrt{3}-16}{60}\ ;\ 0.1952m=20cm$

4. y = 2x – 9x²

Comparing it with equation of trajectory



$y=x\tan\theta-\dfrac{gx^2}{\cos^2\theta\, 2v^2}$

$\therefore\quad \tan\theta=2$

And $9=\dfrac{10\times 5}{2v_0^2} \quad \Rightarrow$

$v_0=\dfrac{5}{3}m/s$

5. At complementary angles, ranges are equal.

$\therefore\quad h_1=\dfrac{u^2\sin^2\theta}{2g}, h_2=\dfrac{u^2\cos^2\theta}{2g}$

$\therefore\quad h_1\times h_2=\left(\dfrac{2u^2\sin\theta\cos\theta}{g}\right)^2\times\left(\dfrac{1}{16}\right)$

$\Rightarrow\quad 16h_1h_2=R^2$

6. $y=\alpha x-\beta x^2$

comparing with trajectory equation

$y=x\tan\theta-\dfrac{1}{2}\dfrac{gx^2}{u^2\cos^2\theta}$

$\tan\theta=\alpha\Rightarrow\theta=\tan^{-1}\alpha$

$\beta=\dfrac{1}{2}\dfrac{g}{u^2\cos^2\theta}$

$u^2=\dfrac{g}{2\beta\cos^2\theta}$

Maximum height : H

$H=\dfrac{u^2\sin^2\theta}{2g}=\dfrac{g}{2\beta\cos^2\theta}u^2=\dfrac{\sin^2\theta}{2g}$

$H=\dfrac{\tan^2\theta}{4\beta}=\dfrac{\alpha^2}{4\beta}$

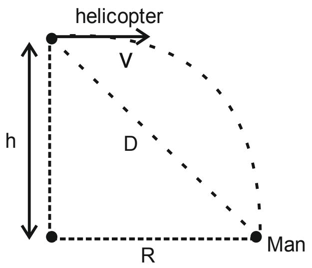
7. $H=\dfrac{U^2\sin^2\theta}{2g}=\dfrac{(25)^2.(\sin 45)^2}{2\times 10}=15.625m$

$$T = \frac{U\sin\theta}{g} = \frac{25\times\sin 45^\circ}{10}$$

$= 2.5 \times 0.7$

$= 1.77$ s

8.



$$R = \sqrt{\frac{2h}{g}}.v$$

$$D = \sqrt{R^2 + h^2}$$

$$= \sqrt{\left(\sqrt{\frac{2h}{g}}.v\right)^2 + h^2}$$

$$D = \sqrt{\frac{2hv^2}{g} + h^2}$$

Option (3) is correct

9. $$R = \frac{V^2(2\sin\theta\cos\theta)}{g}$$

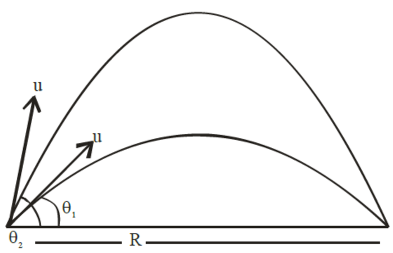
$$t = \frac{V\sin\theta}{g} \Rightarrow V = \frac{gt}{\sin\theta}$$

$$\Rightarrow R = \frac{g^2t^2}{\sin^2\theta}.\frac{2\sin\theta\cos\theta}{g}$$

$$\tan\theta = \frac{2gt^2}{R} = \frac{20t^2}{R}$$

$$\cot\theta = \frac{R}{20t^2}$$

10. For same range $\theta_1 + \theta_2 = 90^\circ$



$$h_1 = \frac{u^2\sin^2\theta_1}{2g} \qquad h_2 = \frac{u^2\sin^2\theta_2}{2g}$$

$$h_1h_2 = \frac{u^2\sin^2\theta_1}{2g} \times \frac{u^2\sin^2\theta_2}{2g}$$

$Q_2 = 90 - \theta_1$

$$h_1h_2 = \frac{u^2\sin^2\theta_1}{2g}.\frac{u^2\cos^2\theta_1}{2g}$$

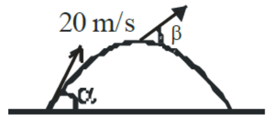
$$= \left[\frac{u^2\sin\theta_1\cos\theta_1}{2g}\right]^2$$

$$= \left[\frac{u^2\sin\theta_1\cos\theta_1}{2g} \times \frac{2}{2}\right]^2 = \frac{R^2}{16}$$

$$R = 4\sqrt{h_1h_2}$$

So R is correct explanation of A

11.



$v_x = u_x = 20 \cos \alpha$

$v_y = 20 \sin \alpha - 10 \times 10$

$$\tan\beta = \frac{v_y}{v_x} = \frac{20\sin\alpha - 100}{20\cos\alpha}$$

$= \tan\alpha - 5\sec\alpha$

12. Let they meet at time t.

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 80}{10}}$$

$= 4$ sec

Time taken by ball B to meet A = 2 sec

using $S = ut + \frac{1}{2}at^2$

$$-80 = -u \times 2 + \frac{1}{2}(-10)(2)^2$$

$u = 30$

13. $$y = x - \frac{10x^2}{2u^2\left(\frac{1}{2}\right)} \Rightarrow 10 = 20 - \frac{(10)(100)}{u^2}$$

$u = 20$

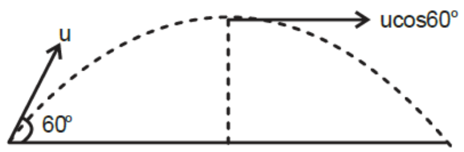
$$T = \frac{(2)(20)}{\sqrt{2}(10)} = 2\sqrt{2}$$

$$\vec{v} = 10\sqrt{2}\,\hat{i} + (10\sqrt{2} - 10(2))\hat{j}$$

Momentum

$$\vec{p} = M\vec{v} - = 100\sqrt{2}\,\hat{i} + (100\sqrt{2} - 200)\hat{j}$$

14.



$$E = \frac{1}{2}mu^2$$

At Highest point, Velocity

$$V = u\cos 60° = \frac{u}{2}$$

$$\therefore \text{ K.E at topmost point } = \frac{1}{2}m\left(\frac{u}{2}\right)^2 = \frac{E}{4}$$

15. $H_{max} = \dfrac{v^2}{2g} = 136\,m$

$$R_{max} = \frac{v^2}{g} = 2H_{max} = 2(136) = 272\,m$$

16. Range = $\dfrac{u^2 \sin 2\theta}{g}$

Range for projection angle "α"

$$R_1 = \frac{u^2 \sin 2\alpha}{g}$$

Range for projection angle "β"

$$R_2 = \frac{u^2 \sin 2\beta}{g}$$

$\alpha + \beta = 90°$ (Given)

$\Rightarrow \boxed{\beta = 90° - \alpha}$

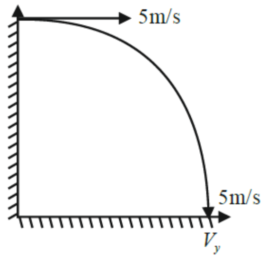
$$R_2 = \frac{u^2 \sin 2(90° - \alpha)}{g}$$

$$R_2 = \frac{u^2 \sin(180° - 2\alpha)}{g}$$

$$R_2 = \frac{u^2 \sin 2\alpha}{g}$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{\left(\dfrac{u^2 \sin 2\alpha}{g}\right)}{\left(\dfrac{u^2 \sin 2\alpha}{g}\right)} = \frac{1}{1}$$

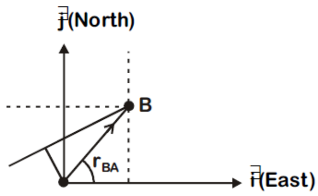
17.



$$v_y = \sqrt{2gh} = \sqrt{200}$$

$$\upsilon_{net} = \sqrt{25 + 200} = 15\,m/s$$

18.



$$\vec{v}_A = 30i + 50j \text{ km/hr}$$

$$\vec{r}_{BA} = (80i + 150j) \text{ km/hr}$$

$$\vec{v}_B = (-10i) \text{ km/hr}$$

$$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A = -10\hat{i} - 30\hat{i} - 50\hat{i} = -40\hat{i} - 50\hat{j}$$

Projection of

$$\left(\vec{r}_{BA}\right) \text{on } \vec{v}_{BA} = \frac{\left(\vec{r}_{BA}\right)\cdot\left(\vec{v}_{BA}\right)}{\left|\vec{v}_{BA}\right|}$$

$$= \frac{\left(80\hat{i} + 150\hat{j}\right)\left(-40\hat{i} - 50\hat{j}\right)}{10\sqrt{41}} = \frac{\sqrt{mk}}{qB}$$

$$\therefore \quad t = \frac{10 \times 107}{\sqrt{41} \times 10\sqrt{41}} = \frac{107}{41} = 2.6 \text{ Hrs.}$$

19. $v^2 = u^2 - 2aS$

$$v^2 = (1)^2 - (2)\left[\frac{2.5 \times 10^{-2}}{20 \times 10^{-3}}\right]\frac{20}{100}$$

$$v^2 = 1 - \frac{1}{2}$$

$$\Rightarrow v = \frac{1}{\sqrt{2}} m/s = 0.7 m/s$$

20. $V_P = (10 - 0.5)$

$= 9.5$ m/s

A 10 m/s → ← **B** 20 m/s

$V_{PB} = 29.5$ m/s

21. Given :

$$\vec{v} - = 0.5t^2\hat{i} + 3t\hat{j} + 9\hat{k}$$

$$\vec{v}_{\text{at } t=2} = 2\hat{i} + 6\hat{j} + 9\hat{k}$$

∴ Angle made by direction of motion of mosquito will be,

$$\cos^{-1}\frac{2}{11}(\text{from } x-\text{axis}) = \tan^{-1}\frac{\sqrt{117}}{2}$$

$$\cos^{-1}\frac{6}{11}(\text{from } y-\text{axis}) = \tan^{-1}\frac{\sqrt{85}}{6}$$

$$\cos^{-1}\frac{9}{11}(\text{from } z-\text{axis}) = \tan^{-1}\frac{\sqrt{40}}{9}$$

22. L = Length of escalator

$$V_{b/esc} = \frac{L}{t_1}$$

When only escalator is moving

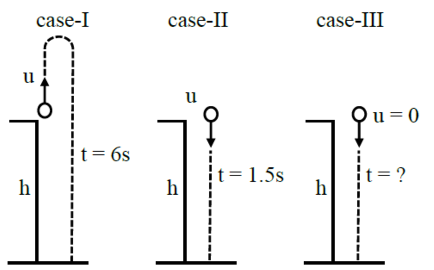
$$V_{esc} = \frac{L}{t_2}$$

When both are moving

$$V_{b/g} = V_{b/esc} + V_{esc}$$

$$V_{b/g} = \frac{L}{t_1} + \frac{L}{t_2} \Rightarrow \left[t = \frac{L}{V_{b/g}} = \frac{t_1 t_2}{t_1 + t_2}\right]$$

23. Let height of tower be h and speed of projection in first two cases be u.



For case-I : 2nd equation $s = ut + \frac{1}{3}at^2$

$$h = -u(6) + \frac{1}{2}g(6)^2$$

H = – 6u + 18 g …….(i)

For case-II : $h = u(1.5) + \frac{1}{2}g(1.5)^2$

$$h = 1.5u + \frac{2.25g}{2} \quad .....(ii)$$

Multiplying equation (ii) by 4 we get

4h = 6u + 4.5 g …. (iii)

equation (i) + equation

(iii) we get 5h = 22.5g

h = 4.5g … (iv)

For case-III :

$$h = 0 + \frac{1}{2}gt^2 \quad ... (v)$$

Using equation (4) & equation (5)

$$4.5g = \frac{1}{2}gt^2$$

$t^2 = 9 \Rightarrow t = 3s$

24. Let they meet at t = t

So first ball gets t sec.

& 2nd gets (t – 2) sec. & they will meet at same height

$$h_1 = 50t - \frac{1}{2}gt^2$$

$$h_2 = 50(t-2) - \frac{1}{2}g(t-2)^2$$

$h_1 = h_2$

$$50t - \frac{1}{2}gt^2 = 50(t-2) - \frac{1}{2}g(t-2)^2$$

$$100 = \frac{1}{2}g[t^2 - (t-2)^2]$$

$$100 = \frac{10}{2}[4t - 4]$$

$5 = t - 1$

$t = 6$ sec.

25. $u_x = 1$

$y = 5x\,(1-x)$

$$\frac{dy}{dt} = 5\frac{dx}{dt} - 10x\frac{dx}{dt}$$

For initial y-component of velocity

$$u_y = \left(\frac{dy}{dt}\right)_{x=0} \Rightarrow 5(1) = 5$$

$$\vec{u}_y = 5\hat{j}$$

26. $$R_{max} = \frac{u^2 \sin 2(45^o)}{g} = \frac{u^2}{g}$$

$$\frac{R}{2} = \frac{u^2}{2g} = \frac{u^2 \sin 2\theta}{g}$$

$$\sin 2\theta = \frac{1}{2}$$

$2\theta = 30^o, 150^o$

$\theta = 15^o, 75^o$

Ans. 15,75

27. II^{nd} body will be projected at 30º from the ground (complementary angle)

height attain by body 1(h_1) $= \dfrac{(40\sin 60^o)^2}{2g}$

= 60 m

height attain by body 2 (h_2)= $\dfrac{(40\sin 30^o)^2}{2g}$

= 20 m

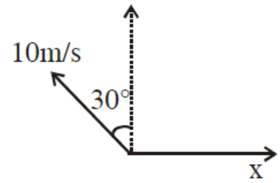
the sum of the maximum height $= h_1 + h_2$

= 80 m

28. $12\sin\theta = v_r \Rightarrow \sin\theta = \dfrac{1}{2}$

$\theta = 30^o \quad \Rightarrow \therefore \alpha = 120^o$

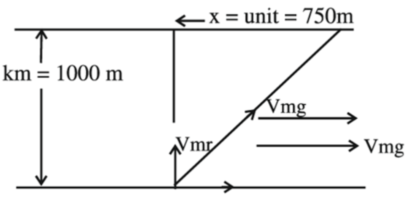
29.



10 sin 30º = x

x = 5 m/s

30.



time to cross the River width ω = 1000 m

is = $\dfrac{1\text{km}}{4\text{km/h}}$

Drift x = Vm/g × t

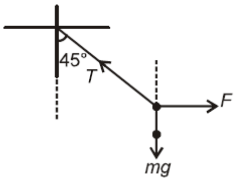
Where Vm/g is velocity of River w.r. to ground.

$x = Vm = g \times \dfrac{1}{4} = 750\text{m} = \dfrac{3}{4}\text{km}$

Vm / g = 3km / hr

Ans is 3 km/hr.

NEWTON'S LAWS OF MOTION SOLUTION

1. 

$T\cos 45° = mg$

$T\sin 45° = F$

$\Rightarrow F = mg$

$= 10 \times 10 = 100$ N

2. $F = kt$

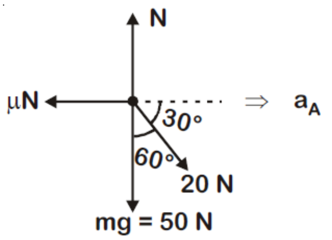
$$\frac{dp}{dt} = kt \qquad \Rightarrow \qquad \int_p^{3p} dp = k\int_0^t t\,dt$$

$$2p = \frac{kt^2}{2} \qquad \Rightarrow \qquad t = 2\sqrt{\frac{p}{k}}$$

3. N = 60 N

F = 0.2 × 60 = 12 N

$$a_A = \frac{\left(\frac{20\sqrt{3}}{2} - 12\right)}{5} = \frac{5.3}{5} = 1.06\ m/s^2$$



For B N = 40 N

$$F = 8N \Rightarrow \frac{20\sqrt{3}}{2} - 8 = 5a_B$$

$$a_B = \frac{17.3 - 8}{5} = \frac{9.3}{5} = 1.86\,m/s^2$$

$a_B - a_A = 0.8\ m/s^2$

4. $F_{total} = Mg$ + friction

= 2000 × 10 + 4000

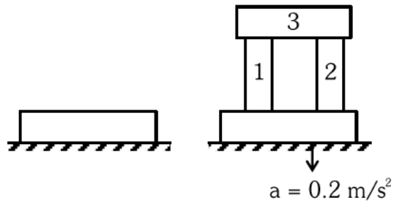
= 20,000 + 4000 = 24000 N

P = F × v

60 × 746 = 24000 × v

$\Rightarrow v = 1.86$ m/s ≈ 1.9 m/s

5. Writing force equation in vertical direction



$Mg - N = Ma$

$\Rightarrow 70g - N = 70 \times 0.2$

$\Rightarrow N = 70\,[g - 0.2] = 70 \times 9.8$

$\therefore$ N = 686 Newton

Note : Since there is no compressive normal from the sides, hence friction will not act.

Hence option 2.

6. $$\frac{d\vec{v}}{dt} = \vec{a} = \frac{\vec{F}}{m} = (8\,\hat{i} + 2\,\hat{j})m/s^2$$

$$\frac{d\vec{r}}{dt} = \vec{v} = (8t\,\hat{i} + 2t\,\hat{j})m/s$$

$$\vec{r} = (8\,\hat{i} + 2\,\hat{j})\frac{t^2}{2}m$$

At t = 10 sec

$$\vec{r} = \left[(8\,\hat{i} + 2\,\hat{j})50\right]m$$

$$\vec{r} = (400\,\hat{i} + 100\,\hat{j})m$$

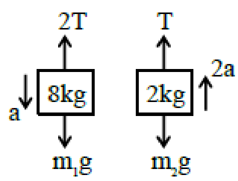
7. t = 0, u = 0

$$a = \frac{F_0}{M} - \frac{F_0}{MT^2}(t-T)^2 = \frac{dv}{dt}$$

$$\int_0^v dv = \int_{t=0}^{2T}\left(\frac{F_0}{M} - \frac{F_0}{MT^2}(t-T)^2\right)dt$$

$$V = \left[\frac{F_0}{M}t\right]_0^{2T} - \frac{F_0}{MT^2}\left[\frac{t^3}{3} - t^2T + T^2t\right]_0^{2T}$$

$$V = \frac{4F_0T}{3M}$$

8. 

$(m_1g - 2T) = m_1a$ – (1)

$T - m_2g = m_2\,(2a)$

$2T - 2m_2g = 4m_2a - (2)$

$m_1g - 2m_2g = (m_1 + 4m_2)\,a$

$$a = \frac{(8-4)g}{(8+8)} = \frac{4}{16}g = \frac{g}{4}$$

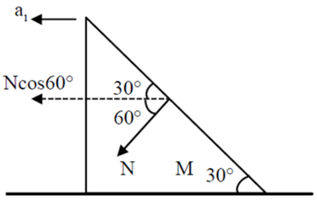
$$a = \frac{10}{4}\,m/s^2$$

$$S = \frac{1}{2}at^2$$

$$\frac{0.2 \times 2 \times 4}{10} = t^2$$

t = 0.4 sec

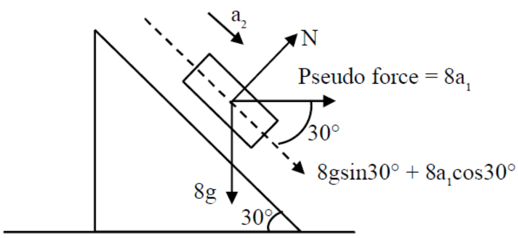
9. Let acceleration of wedge is a_1 and acceleration of block w.r.t. wedge is a_2



$N\cos 60 = Ma_1 = 16a_1$

$\Rightarrow N = 32a_1$

F.B.D. of block w.r.t wedge



$\perp$ to incline

$N = 8g \cos 30° - 8a_1 \sin 30° \Rightarrow 32a_1 = 4\sqrt{3}g - 4a_1$

$$\Rightarrow a_1 = \frac{\sqrt{3}}{9}g$$

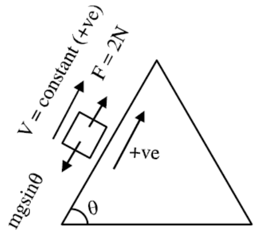
Along incline

$8g\sin 30° + 8a_1\cos 30° = ma_2 = 8a_2$

$$a_2 = g \times \frac{1}{2} + \frac{\sqrt{3}}{9}g.\frac{\sqrt{3}}{2} = \frac{2g}{3}$$

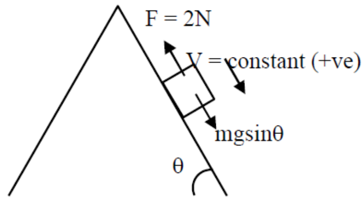
Option (4)

10. During upward motion



F = 2N = (+ve) constant

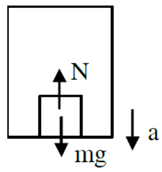
During downward motion



$\Rightarrow$ F = 2N = (–ve) constant

$\Rightarrow$ Best possible answer is option (2)

11.

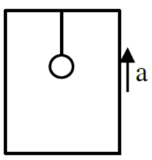


$mg - N = ma$

$\Rightarrow N = m(g - a)$

$\therefore$ Person experiences weightloss, when acceleration of lift is downward.

12. $T = 2\pi\sqrt{\dfrac{\ell}{g_{eff}}}$

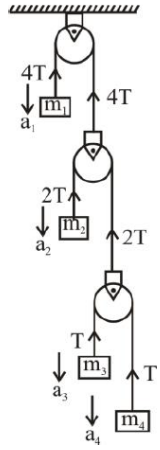


(a) when $a = 0,\ T = 2\pi\sqrt{\dfrac{\ell}{g}}$

(b) when $a = \dfrac{g}{6},\ T' = 2\pi\sqrt{\dfrac{\ell}{g + \dfrac{g}{6}}}$

$$\therefore T' = \sqrt{\frac{6}{7}}T$$

13.



Using constraint

$\sum \vec{T}.\vec{a} = 0$

$-4Ta_1 - 2Ta_2 - Ta_3 - Ta_4 = 0$

$4a_1 + 2a_2 + a_3 + a_4 = 0$

14. $F = \frac{dp}{dt} = u\frac{dm}{dt}$

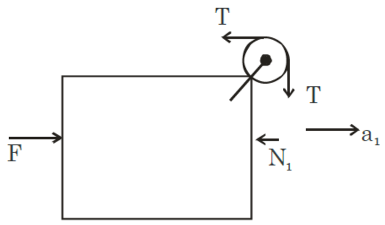
$\Rightarrow Ma = 10 \times 1$

$\Rightarrow 2a = 10$

$a = 5 m/sec^2$

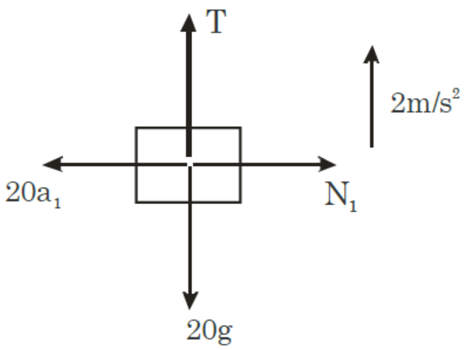
15. Let acceleration of 100 kg block = a_1

FBD of 100 kg block w.r.t ground



$F–T–N_1 = 100\ a_1$ ……..(i)

FBD of 20 block wrt 100kg

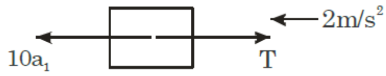


$T - 20g = 20(2)$

$T = 240$ ….. (ii)

$N_1 = 20a_1$ ….. (iii)

FBD of 10 kg block wrt 100 kg



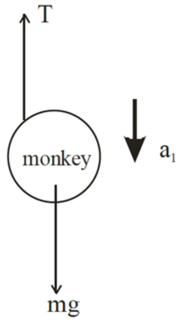
$10a_1 - 240 = 10(2)$

$a_1 = 26 m/s^2$

$F - 240 - 20(26) = 100 \times 26$

$\Rightarrow F = 3360$ N

16. F.B.D of monkey while moving downward

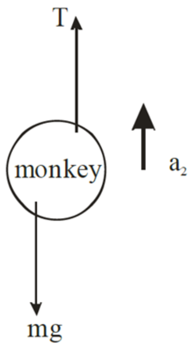


Using Newton's second law

$mg - T = ma_1$

$\therefore 500 - T = 50 \times 4 \Rightarrow T = 300$ N

F.B.D of monkey while moving up



Using Newton's second law of motion

$T - mg = ma_2$

$\Rightarrow T - 500 = 50 \times 5$

$\Rightarrow T = 750$ N

Breaking strength of string = 350 N

$\therefore$ String will break while monkey is moving upward

17. $a = \dfrac{m_2g - m_1g}{m_1 + m_2}$

Case-1 $M_2 = 2m_1$

$a_1 = \dfrac{2m_1g - m_1g}{3m_1}$

$a_1 = g/3$

Case-2

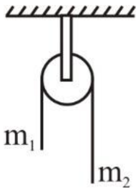
$M_2 = 3m_1$

$a_2 = \dfrac{3m_1g - m_1g}{4m_1}$

$a_2 = \dfrac{g}{2}$

$\dfrac{a_1}{a_2} = \dfrac{\frac{g}{3}}{\frac{g}{2}} = \dfrac{2}{3}$

18.



$a = \dfrac{(m_2 - m_1)}{(m_2 + m_1)} g$

$\dfrac{g}{2} = \dfrac{(\lambda(L-\ell) - \lambda\ell)g}{\lambda L} \Rightarrow L = \dfrac{L}{4} = \dfrac{L}{x}$

$x = 4$

19. Using $mv = \sqrt{2mk}$

$u = \dfrac{1}{0.2}\sqrt{2 \times 0.2 \times 90} = 30 m/s$

$u = \dfrac{1}{0.2}\sqrt{2 \times 0.2 \times 40} = 20 m/s$

$a = \dfrac{20 - 30}{1} = -10 m/s^2$

$s = \dfrac{-u^2}{2a} = 45 m$

20. For equilibrium $m_2g = m_1g \sin\theta$

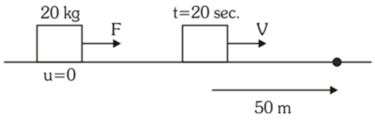
$\sin\theta = \dfrac{m_2}{m_1} = \dfrac{3}{5}$

$\sin\theta = \dfrac{4}{5}$

Normal force on $m_1 = 5g \cos\theta$

$= 5 \times 10 \times \dfrac{4}{5} = 40N$

21.



$50 = V \times 10$

$V = 5 m/s$

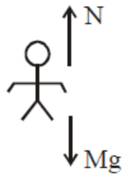
$V = 0 + a \times 20$

$5 = a \times 20$

$a = \dfrac{1}{4} m/s^2$

$F = ma = 20 \times \dfrac{1}{4} = 4N$

22.



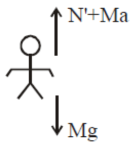
When lift is at rest

$N = mg$

$\Rightarrow 60 \times 10 = 600$ N

When lift moves with downward acceleration.

In frame of lift pseudo force will be in upward direction.

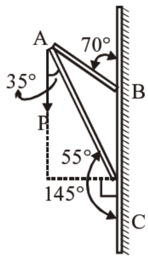


$N' = M(g - a)$

$\Rightarrow 60(10 - 1.8)$

$N' \Rightarrow 492$ N

23.



Component along AC

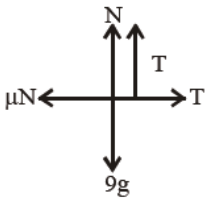
$= 100 \cos 35°$N

$= 100 \times 0.819$ N

= 81.9 N

≈ 82 N

24.



N + T = 90

T = μ N = 0.5 (90 – T)

1.5 T = 45

T = 30

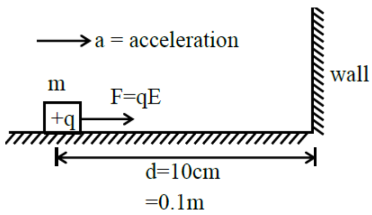
25. $v^2 = u^2 + 2as$

$$0 = (10)^2 + 2(-a)\left(\frac{1}{2}\right)$$

a = 100 m/s²

F = ma = (0.1) (100) = 10 N

26.



F = ma , qE = ma

$$a = \frac{qE}{m}$$

Now $d = \frac{1}{2}at^2$,

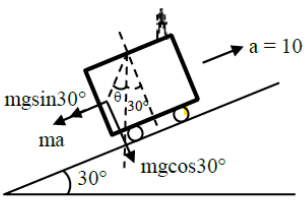
$$t = \sqrt{\frac{2d}{\left(\frac{qE}{m}\right)}}$$

$$t = \sqrt{\frac{2 \times 0.1}{\left(\frac{8 \times 10^{-6}}{10^{-3}}\right) \times 100}} = \frac{1}{2}$$

∴ Time period = 2t = 1 sec

Ans. = 1.00

27.



$$\tan(30+\theta) = \frac{mg\sin 30° + ma}{mg\cos 30°}$$

$$\tan(30+\theta) = \frac{5+10}{5\sqrt{3}} = \frac{1+2}{\sqrt{3}}$$

$$\frac{\tan\theta + \frac{1}{\sqrt{3}}}{1 - \frac{1}{\sqrt{3}}\tan\theta} = \sqrt{3}$$

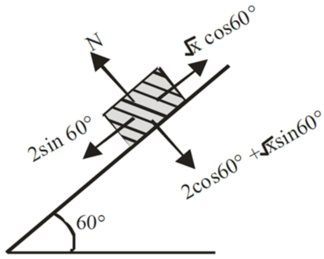
$$\sqrt{3}\tan\theta + 1 = 3 - \sqrt{3}\tan\theta$$

$$2\sqrt{3}\tan\theta = 2$$

$$\tan\theta = \frac{1}{\sqrt{3}}$$

$\theta = 30°$

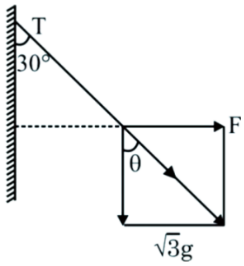
28. mg = 2N



$$\sqrt{x}\,\frac{1}{2} = \frac{2\sqrt{3}}{2}$$

x = 12

29.



θ = 30°

$$\cos\theta = \frac{\sqrt{3}g}{T}$$

$$\Rightarrow \quad \frac{\sqrt{3}}{2} = \frac{\sqrt{3}g}{T}$$

⇒ T = 20 N

30. 2Mg – T = 4Ma

Using $\vec{F}_{net} = \mu\vec{a}$, T – Mg = Ma

$$\Rightarrow a = \frac{g}{5}$$

$$T = Mg + Ma = Mg + \frac{Mg}{5} = \frac{6}{5}Mg$$

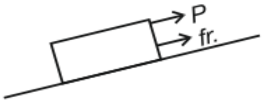
FRICTION & CIRCULAR MOTION SOLUTION

1. $\mu(m + m_2) = m_1$

$$m + m_2 = \frac{m_1}{\mu} \Rightarrow m = \frac{m_1}{\mu} - m_2$$

$$m = \frac{5}{0.15} - 10 = 23.33\text{kg}$$

2



Friction force should be acting upward along the plane. So for state of impending motion.

$$3 + 10 \times 10\frac{1}{\sqrt{2}} = P + 10 \times 10\frac{1}{\sqrt{2}} \times \frac{6}{10}$$

$\Rightarrow 73.71 - 42.42 = P$

$\Rightarrow P = 31.28 \approx 32$ N

3 $$a_c = \left(\frac{F - f}{M + m}\right)$$

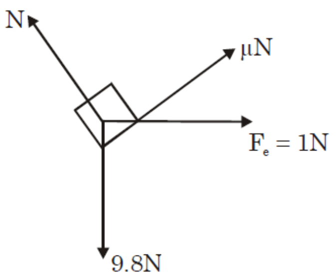
$$a = \frac{F - (0.2)4 \times 10}{4} = \left(\frac{F - 8}{4}\right)$$

We have $\frac{F - 8}{4} \leq (0.2)10$

$\Rightarrow \quad F - 8 \leq 8$

$\Rightarrow \quad F \leq 16$

4. FBD



here N = 9.8 cos 30 + 1 sin 30

$\approx$ 9N

so a = $\dfrac{9.8\sin 30 - 1\cos 30 - \mu N}{1}$

a = 2.233 m/s^2

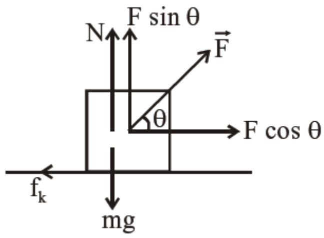
By S = $ut + \frac{1}{2}at^2$

$= \frac{1}{2}(2.233)t^2$

sin 30º

t $\approx$ 1.3 sec.

5.



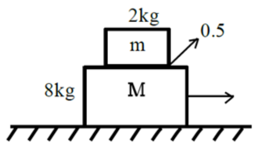
N = mg – f sin θ

F cos θ – μ_k N = ma

F cos θ – μ_k (mg – F sin θ) = ma

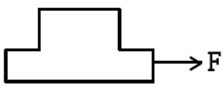
$$a = \frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$$

6.



$(\alpha_A)_{max}$ = 0.5g = 4.9 m/s^2

For moving together



$F_{max} = m_T\alpha_A$

= 10 × 4.9

= 49 N

7. Net Acc. a = $\frac{20}{5}$ m/sec^2 = 4 m/sec^2

Net force F = m × a

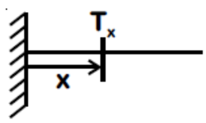
Net force is provided by friction force = μ × N

μ × N = m × a

μ × m × g = m × a

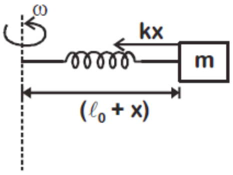
μ = $\frac{a}{g}$ = 0.4

8.



$$T_x = \frac{M}{L}(L-x)\left\{x + \frac{L-x}{2}\right\}\omega^2 = \frac{M\omega^2}{2L}(L^2 - x^2)$$

9.



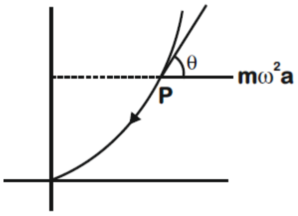
At elongated position (x),

$F_{radial} = mr\omega^2$

$\therefore \quad kx = m(\ell + x)\omega^2$

$\therefore \quad x = \dfrac{m\ell\omega^2}{k - m\omega^2}$

10.



$y = 4Cx^2$

$\Rightarrow \quad \dfrac{dy}{dx} = \tan\theta = 8Cx$

At P, $\tan\theta = 8Ca$

For steady circular motion

$mg\sin\theta = m\omega^2 a\cos\theta$

$\Rightarrow \quad \tan\theta = \dfrac{\omega^2 a}{g} \quad \Rightarrow \quad 8Ca \times g = \omega^2 \times a$

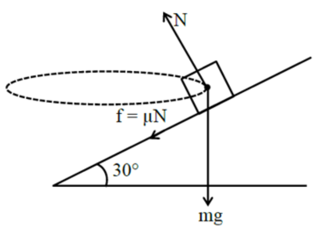
$\Rightarrow \quad \omega = \sqrt{8gC} \quad \Rightarrow \quad \omega = 2\sqrt{2gC}$

11. $\mu_s N = \dfrac{mv^2}{R}$

$N = \dfrac{mv^2}{\mu_s R} = mg + F_L$

$F_L = \dfrac{mv^2}{\mu_s R} - mg$

12. At V_{max}, f will be limiting in nature.



$\therefore$ Balancing force in vertical direction,

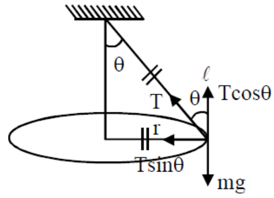
N cos30° – mg - μNcos 60° = 0

$\Rightarrow$ N [cos30° - μcos 60° = 0] = mg

$\therefore \quad N = \dfrac{800 \times 10}{(0.87 - 0.1)} \approx 10.2 \times 10^3 \text{kgm/s}^2$

Hence option 1.

13. Conical pendulum



$r = \dfrac{\ell}{\sqrt{2}}$

$\sin\theta = \dfrac{1}{\ell} = \dfrac{1}{\sqrt{2}}$

$\theta = 45°$

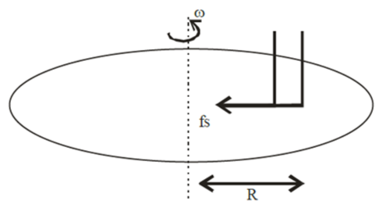
$T\sin\theta = \dfrac{mv^2}{r}$

$T\cos\theta = mg$

$\tan\theta = \dfrac{v^2}{rg} \Rightarrow v = \sqrt{rg}$

14. Theory

15. For beaker to move with disc



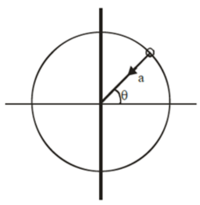
$f_s = m\omega^2 R$

We know that $f_S \le f_{smax}$

$m\omega^2 R \le \mu mg$

$R \le \dfrac{\mu g}{\omega^2}$

16. $a = |\vec{a}| = \dfrac{V^2}{R}$

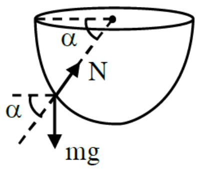


$\vec{a} = -a\cos\theta\hat{i} - a\sin\theta\hat{j}$

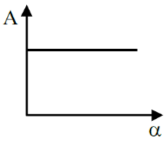
$= -\frac{V^2}{R}\cos\theta\hat{i} - \frac{V^2}{R}\sin\theta\hat{j}$

17. $V = \sqrt{2gR\sin\alpha}$

$N - mg\sin\alpha = \frac{mv^2}{R} = 2mg\sin\alpha$

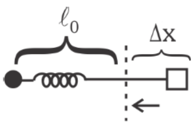


$\frac{N}{2mg\sin\alpha} = \frac{1}{2} + 1 = \frac{3}{2}$



$\Rightarrow$ A = constant

18.



$k\,\Delta x = m(\ell_0 + \underline{\underline{\Delta}}x)\omega^2$

$k\,\Delta x = m\,\ell_0\,\omega^2 + m\omega^2\,\Delta x$

$\Delta x = \frac{m\,\ell_0\omega^2}{k - m\omega^2}$

19. $v = \sqrt{u^2 - 2gL}$

$\Delta v = \sqrt{u^2 + v^2}$

$\Delta v = \sqrt{u^2 + v^2 - 2gL}$

$\Delta v = \sqrt{2u^2 - 2gL}$

$\Delta v = \sqrt{2(u^2 - gL)}\; x = 2$

20. $\frac{d\omega}{dt} = 6t^2 - 2t$

$\int_{10}^{\omega} d\omega = 2t^3 - t^2$

$\omega = 10 + 2t^3 - t^2$

$\frac{d\theta}{dt} = 10 + 2t^3 - t^2$

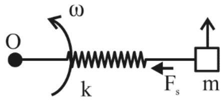
$\int_4^{\theta} d\theta = 10 + 2t^3 - t^2$

$\int_4^{\theta} d\theta = 10t + \frac{t^4}{2} - \frac{t^3}{3}$

$\theta = 4 + 10t + \frac{t^4}{2} - \frac{t^3}{3}$

21. Natural length = L_0

Extension = x



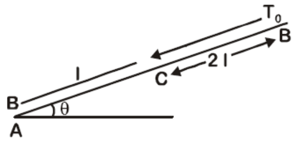
$kx = m(L_0 + x)\omega^2$

$\Rightarrow$ $12.5x = \frac{1}{5}(L_0 + x)25$

$\Rightarrow$ $1.5x = L_0$

$\Rightarrow$ $\frac{x}{L_0} = \frac{2}{3}$

22.



Work done by all the force/s is equal to zero.

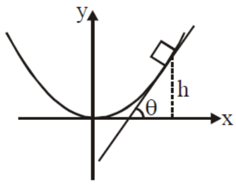
$\therefore$ $0 = mg3l\sin\theta - \mu mgl\cos\theta = 0$

$3\sin\theta = \mu\cos\theta$

$\Rightarrow$ $\mu = 3\tan\theta$

$\therefore$ k = 3

23.



At maximum ht. block will experience maximum friction force. Therefore if at this height slope of the tangent is tan θ, then θ = Angle of repose.

$\therefore \tan\theta = \frac{dy}{dx} = \frac{2x}{4} = \frac{x}{2} = 0.5$

$\Rightarrow$ x = 1 and therefore

$y = \frac{x^2}{4} = 0.25$ m

= 25 cm

$\therefore$ Answer is 25 cm

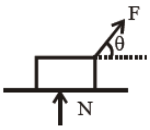
(Assuming that x & y in the equation are given in meter)

24. $a_{max} = \mu g = \frac{3}{7} \times 9.8$

$F = (M + m)a_{max} = 5\ a_{max}$

= 21 Newton

25.



F cos θ = m N

F sin θ + N = mg

$\Rightarrow F = \frac{\mu mg}{\cos\theta + \mu \sin\theta}$

$F_{min} = \frac{\mu mg}{\sqrt{1+\mu^2}} = \frac{\frac{1}{\sqrt{3}} \times 10}{\frac{2}{\sqrt{3}}} = 5$

26. $t_a = \frac{1}{2} t_d\ ,\ \sqrt{\frac{2s}{a_a}} = \frac{1}{2}\sqrt{\frac{2s}{a_d}}$ ...(i)

$a_a = g \sin\theta + \mu g \cos\theta$

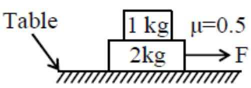
$= \frac{g}{2} + \frac{\sqrt{3}}{2}\mu g$

$a_d = g \sin\theta - \mu g \cos\theta$

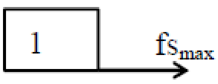
$= \frac{g}{2} - \frac{\sqrt{3}}{2}\mu g$

Using the above values of a_a and a_d and putting in equation (i) we will gate $\mu = \frac{\sqrt{3}}{5}$

27.



F = 3a (For system) ....(i)



fS_{max} = 1a (for 1 kg block) ......(ii)

$\mu \times 1 \times g = a$

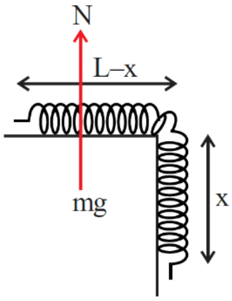
$\Rightarrow 5 = a$

F = 15 N

28. Mass per unit length = l

N = mg = λ(L - x)g

$fs_{max} = \mu_s N$



fs_{max} = (0.5)(λ)(L - x)g

And also $fs_{max} = m_x g$

0.5λ(L - x)g = λxg

$\frac{L-x}{2} = x$

$\frac{L}{2} = \frac{3x}{2} \Rightarrow x = \frac{L}{3} = \frac{6}{3} = 2m$

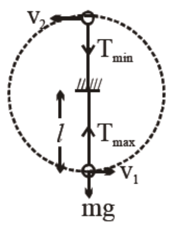
29. Let the speed of bob at lowest position be v_1 and at the highest position be v_2.

Maximum tension is at lowest position and minimum tension is at the highest position.

Now, using, conservation of mechanical energy,

$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2 + mg2l$

$\Rightarrow v_1^2 = v_2^2 + 4gl$ ...(1)



Now $T_{max} - mg = \frac{mv_1^2}{l}$

$\Rightarrow T_{max} = mg + \frac{mv_1^2}{l}$

& $T_{min} + mg = \frac{mv_2^2}{l}$

$\Rightarrow T_{min} = \frac{mv_2^2}{l} - mg$

$$\frac{T_{max}}{T_{min}} = \frac{5}{1}$$

$$\Rightarrow \frac{mg + \frac{mv_1^2}{l}}{\frac{mv_1^2}{l} - mg} = \frac{5}{1}$$

$$\Rightarrow mg + \frac{mv_1^2}{l} = \left[\frac{mv_2^2}{l} - mg\right]5$$

$$\Rightarrow mg + \frac{m}{l}[v_2^2 + 4gl] = \frac{5mv_2^2}{l} - 5mg$$

$$\Rightarrow mg + \frac{mv_2^2}{l} + 4mg = \frac{5mv_2^2}{l} - 5mg$$

$$\Rightarrow 10mg = \frac{4mv_2^2}{l}$$

$$v_2^2 = \frac{10 \times 10 \times 1}{4}$$

$$\Rightarrow v_2^2 = 25 \Rightarrow v_2 = 5 m/s$$

30. $$f_{smax} = \frac{mv^2}{R}$$

$$\mu mg = \frac{mv^2}{R}$$

$$v = \sqrt{\mu Rg}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{R_2}{R_1}}$$

$$\frac{v_2}{30} = \sqrt{\frac{48}{75}}$$

v_2 = 24 m/s

WORK, POWER & ENERGY SOLUTION

1. $U = -\dfrac{k}{2r^2}$

$F = -\dfrac{du}{dr} = -\left(-\dfrac{K}{2}\left(-\dfrac{2}{r^3}\right)\right) = -\dfrac{K}{r^3}$

$\dfrac{K}{r^3} = \dfrac{mv^2}{r} \Rightarrow mv^2 = \dfrac{K}{r^2}$

$K.E. = \dfrac{1}{2}mv^2 = \dfrac{K}{2r^2}$

E = P.E. + K.E. = 0

2 $N - mg = \dfrac{mg}{2}$

$N = \dfrac{3mg}{2} \quad \Rightarrow \quad S = \dfrac{1}{2}\left(\dfrac{g}{2}\right)t^2$

$w = \dfrac{3mg}{2} \times \dfrac{g}{4}t^2 \quad \Rightarrow \quad w = \dfrac{3mg^2}{8}t^2$

3 Initial compression = $\dfrac{3 \times 10}{k}$, since spring constant

is high. So initial compression is low.

Let v_1 be velocity after collision.

$4v_1 = v_0$

$V_0 = \sqrt{2g \times 100}$

$\dfrac{1}{2} \times 4 \times v_1^2 = \dfrac{1}{2}kx^2$

x = 2 cm

4 Area under F–x graph

$\Delta K.E = W = \dfrac{1}{2} \times (3+2) \times (3-2) + 2 \times 2$

= 2.5 + 4

= 6.5 J

5.

$m_1 = \dfrac{M}{n}$

$U_i = \dfrac{-M}{n} \times g\dfrac{L}{2n} \quad \Rightarrow \quad W = \dfrac{MgL}{2n^2}$

6. $l_1 = nl_2$

$\because\ k \propto \dfrac{1}{l}$

$\therefore\ \dfrac{k_1}{k_2} = \dfrac{l_2}{l_1} = \dfrac{1}{n}$

7. $W = \int dW = \int (-x\hat{i} + y\hat{j}) \cdot (dx\hat{i} + dy\hat{j})$

$W = \int_1^0 xdx + \int_0^1 ydy$

$= \dfrac{1}{2} + \dfrac{1}{2} = 1J$

8. $\Delta K + \Delta U = 0$

$\dfrac{1}{2}m_1v^2 + \dfrac{1}{2}m_2v^2 + \dfrac{1}{2}I\dfrac{v^2}{r^2} = (m_1 - m_2)gh$

$v = \sqrt{\dfrac{2(m_1 - m_2)gh}{m_1 + m_2 + \dfrac{I}{r^2}}}$

$w = \dfrac{V}{r}$

9. $F = \dfrac{du}{dr}$

$= -\left[\dfrac{6A}{r^7} - \dfrac{12B}{r^{13}}\right]$

F = 0

$\Rightarrow \quad r = \left(\dfrac{2B}{A}\right)^{1/6}$

$U\left(\text{at } r = \left(\dfrac{2B}{A}\right)^{1/6}\right) = \dfrac{A^2}{48} - \dfrac{A^2}{4B}$

10. C comes to rest

V_{cm} of A & B = $\dfrac{v}{2}$

$\Rightarrow \dfrac{1}{2}\text{is } v_{ret}^2 = \dfrac{1}{2}kx^2$

$x = \sqrt{\dfrac{\mu \times v^2}{k}} = \sqrt{\dfrac{m}{2k}}v$

11. $K_2 = 4K_1$

$\dfrac{1}{2}mv_2^2 = 4\dfrac{1}{2}mv_1^2$

$v_2 = 2v_1$

$P = mv$

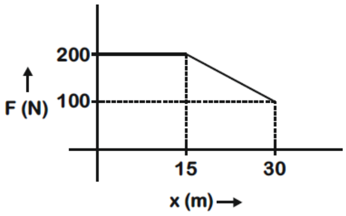
$P_2 = mv_2 = 2mv_1$

$P_1 = mv_1$

% change

$$= \frac{\Delta P}{P_1} \times 100 = \frac{2mv_1 - mv_1}{mv_1} \times 100 = 100\%$$

12.



Work = Area of F–x curve

$$= 200 \times 15 + \frac{1}{2}(200 + 100) \times 15$$

= 5250 J

13. $E_{mech.}$ = 8J

(A) at $x > x_4$, U = constant = 6J

K = $E_{mech.}$ – U = 2J = constant

(B) at $x < x_1$, U = constant = 8J

K = $E_{mech.}$ – U = 8 – 8 = 0 J

Particle is at rest.

(C) At $x = x_2$, U = 0 $\Rightarrow$ $E_{mech.}$ = K = 8 J

KE is greatest, and particle is moving at fastest speed.

(D) At $x = x_3$, U = 4 J

U + K = 8 J

K = 4 J

14. P = const.

$$P = Fv = \frac{mv^2 dv}{dx}$$

$$\int_0^x \frac{P}{m} dx = \int_0^v v^2 dv$$

$$\frac{Px}{m} = \frac{v^3}{3}$$

$$\left(\frac{3Px}{m}\right)^{1/3} = v = \frac{dx}{dt}$$

$$\left(\frac{3P}{m}\right)^{1/3} \int_0^t dt = \int_0^x x^{-1/3} dx$$

$$x = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$$

15. $\vec{F} = 4x\hat{i} + 3y^2\hat{j}$

WD = ΔKE

$$W = \int \vec{F} - (dx\hat{i} + dy\hat{j})$$

$$= \int_1^2 4x dx + \int_2^3 3y^2 dx$$

$$= (2x^2)_1^2 + (y^3)_2^3$$

= (8 – 2) + (27 – 8)

= 6 + 19 = 25 J

16. Work done = area under F – x curve. Area below x –axis is negative & area above x-axis is positive.

so

$W_3 > W_2 > W_1 > W_4$

17. Work done by gravity = $K_B - K_A$

$mgy_0 = K_B - 0$

$K_B = mgy_0$

18. $P' = P + \frac{20}{100}P = 1.2P$

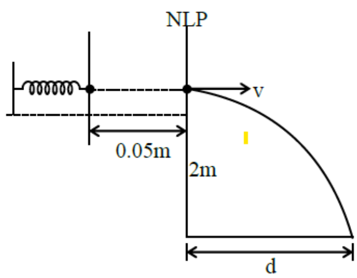
$$\% \text{ change in KE} = \frac{K' - K}{K} \times 100$$

$$= \left(\frac{\frac{P'^2}{2m} - \frac{P^2}{2m}}{\frac{P^2}{2m}}\right) \times 100$$

= [(1.2)² – 1] × 100

= 44 %

19.



$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2 \text{ , } Kx^2 = mv^2 s$$

$$v = x\sqrt{\frac{k}{m}} = 0.05\sqrt{\frac{100}{0.1}} = 0.05 \times 10\sqrt{10}$$

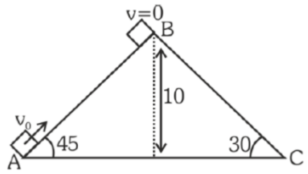
$v = 0.5\sqrt{10}$

From $h = \frac{1}{2}gt^2$

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 2}{10}} = \frac{2}{\sqrt{10}}$

$\therefore\ d = vt = 0.5\sqrt{10} \times \frac{2}{\sqrt{10}} = 1m$

20.



From E.C. $= \frac{1}{2}mv_0^2 = mgh$

$V_0 = 10\sqrt{2}$

For $A \to B$

at B, v = 0

$a = -g\sin 45° = \frac{-10}{\sqrt{2}}$

$v = u + at_1 \Rightarrow 0 = 10\sqrt{2} - \frac{10}{\sqrt{2}}t_1 \Rightarrow t_1 = 2\sec$

For $B \to C$

$s = ut_2 + \frac{1}{2}at_2^2$

$\frac{10}{\sin 30°} = \frac{1}{2}(10\sin 30°)t_2^2$

$t_2 = 2\sqrt{2}$

so total time

$T = t_1 + t_2$

$= 2\sqrt{2} + 2 \quad \Rightarrow \quad 2(\sqrt{2}+1)\sec$

21. Using work – energy theorem

$W_{net} = (K_f - K_i)$

$\Rightarrow -\frac{1}{2}Kx^2 = \frac{1}{2}m\left(\frac{v}{2}\right)^2 - \frac{1}{2}mv^2 = \frac{E}{4} - E$

$\Rightarrow \frac{1}{2}Kx^2 = \frac{3E}{4} \Rightarrow K = \frac{3E}{2x^2} \quad \Rightarrow$

$K = \frac{3E}{2\times\left(\frac{1}{4}\right)^2} = 24E$

22. KE = mgΔh

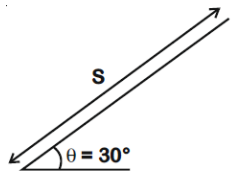
= 1 × 10 × 1 = 10 J

23. $\Delta PE = \Delta KE$

$\Rightarrow \quad (mg)\frac{1}{2}\sin 30° = \frac{1}{2}\left(\frac{ml^2}{3}\right)\omega^2$

$\Rightarrow \quad \omega = \sqrt{15}\ rad/s$

24. For upward motion



$\frac{1}{2}mv_0^2 = \left(mg\frac{S}{2} + \mu mg\frac{\sqrt{3}}{2}S\right) \quad$ ....(i)

$\frac{1}{2}\frac{mv_0^2}{4} = \left(mg\frac{S}{2} - \mu mg\frac{\sqrt{3}}{2}\cdot S\right) \quad$ ....(ii)

for downward

$4 = \frac{(1+\mu\sqrt{3})}{(1-\mu\sqrt{3})}$

$\Rightarrow \quad 4 - 4\mu\sqrt{3} = 1 + \mu\sqrt{3}$

$\Rightarrow \quad 3 = 5\mu\sqrt{3}$

$\therefore \quad \mu = \frac{\sqrt{3}}{5} \approx \frac{346.41}{1000}$

l = 346

25. $pt = \frac{1}{2}mv^2$

$\Rightarrow \quad v = \sqrt{\frac{2pt}{m}}$

$\Rightarrow \quad \frac{ds}{dt} = \sqrt{\frac{2pt}{m}}$

$\Rightarrow \quad \int_0^s ds = \int_0^t \sqrt{\frac{2pt}{m}}dt$

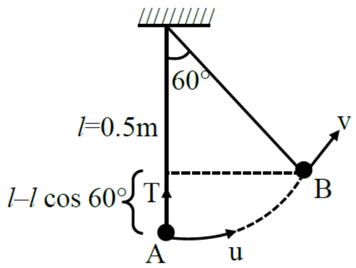
$\Rightarrow \quad s = \left(\sqrt{\frac{2p}{m}}\right)\left(\frac{2t^{\frac{3}{2}}}{3}\right) = (1)\times(2)\times\frac{27}{3} = 18$

26. Using work energy theorem.

$W_g = \Delta K.E.$

$(10)\,(g)\,(5) = \frac{1}{2}(10)v^2 - 0$

v = 10 m/s

27. 

Applying work energy theorem :

$w_g + w_T = \Delta K$

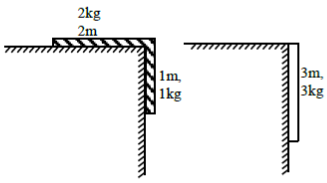
$$-mgl(1-\cos 60^\circ) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$v^2 = u^2 - 2gl(1-\cos60°)$

$$v^2 = 9 - 2 \times 10 \times 0.5\left(\frac{1}{2}\right)$$

$v^2 = 4$

$v = 2$ m/s

28. 

From energy conservation

$K_i + U_i = K_f + U_f$

$$0+\left(-1\times10\times\frac{1}{2}\right) = k_f + \left(-3\times10\times\frac{3}{2}\right)$$

$-5 = k_f - 45$

$k_f = 40$ J

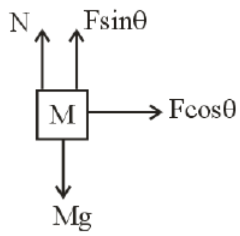
29. By energy conservation

PE = KE

$$mg\left(H+\frac{H}{2}\right) = \frac{1}{2}kx^2\left(x=\frac{H}{2}\right)$$

$$0.100\times10\times\frac{3}{2}(0.10) = \frac{1}{2}k(0.05\times0.05)$$

$$k = \frac{3\times0.10}{0.05\times0.05} = \frac{3\times1000}{25} = 120\text{N}/\text{m}$$

30. 

F cos θ = ma

$$2\cos(kx) = \frac{mvdv}{dx}$$

$$\int_0^v vdv = 2\int_0^x \cos(kx)dx$$

$$\frac{mv^2}{2} = \frac{2}{k}\sin kx$$

$$\text{K.E.} = \frac{2}{k}\sin\theta$$

n = 2

CENTRE OF MASS SOLUTION

1. Case-I

JBC 

JAC 

$2V_2 - V_1 = V$

$V_2 + V_1 = V$

$3V_2 = 2V$

$V_2 = \frac{2V}{3}$

$V_1 = \frac{V}{3}$

$$p_d = \frac{\frac{1}{2}mV^2 - \frac{1}{2}mV_1^2}{\frac{1}{2}mV^2} = \frac{1-\frac{1}{9}}{1} = \frac{8}{9} = 0.89$$

Case-II

JBC 

JAC 

$12V_2 - V_1 = V$

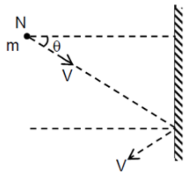
$V_2 + V_1 = V$

$13V_2 = 2V$

$V_2 = \frac{2V}{13}$

$V_1 = V - \frac{2V}{13} = \frac{11V}{13}$

$$P_c = \frac{\frac{1}{2}mv^2 - \frac{1}{2}mv_1^2}{\frac{1}{2}mv^2} = \frac{1-\frac{121}{169}}{1} = \frac{48}{169} = 0.28$$

2. 

$F_{ovg} = 2NmV\cos\theta$

Pressure = $\frac{2NmV\cos\theta}{A}$

$$= \frac{2(10^{23})(3.32\times10^{-27})\frac{1}{\sqrt{2}}\times10^3}{2\times10^{-4}}$$

$= 2.35 \times 10^3$ N/m^2

3. $K_i = \frac{1}{2}mv_0^2$

Linear momentum conservation

$mv_0 = (2m+M)v_F$

$v_F = \frac{mv_0}{2m+M}$

$\Rightarrow$ According to questions

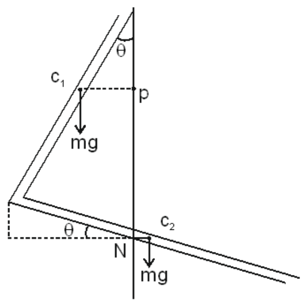
$K_F = \frac{K_i}{6} = \frac{K_i}{K_F} = 6$

$$\frac{\frac{1}{2}mv^2}{\frac{1}{2}(2m+M)\left(\frac{mv}{2m+M}\right)^2}$$

$= \frac{2m+M}{m} = 6$

$= \frac{M}{m} = 4$

4.



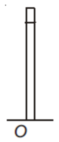
The system is in equilibrium

Torque net about hinge = 0

$mg\, c_1\, p = mg\, c_2\, N$

$$mg\frac{L}{2}\sin\theta = mg\left(\frac{L}{2}\cos\theta - L\sin\theta\right)$$

$$\tan\theta = \frac{1}{3}$$

5. 

time taken for the particle to collide

$$t = \frac{d}{v_{rel}} = \frac{100}{100} = 1\text{sec}$$

V_{wood} = just before collision

= gt = 10 m/s

V_{bullet} just before collision

= v – gt = 100 – 10 = 90 m/s

conservation of momentum

= $m_1u_1 + m_2u_2 = m_{total} \times v_c$

$$(0.03)(-10) + (0.02) \times 90 = (0.05)v_c$$

v_c = 30 m/s

$$h_{max} = \frac{v^2}{2g} = \frac{30 \times 30}{2 \times 10} = 45$$

$$s = ut + \frac{1}{2}gt^2$$

s = 5

$$h_{net} = 45 - 5 = 40\text{m}$$

6. Let assume linear mass dinsity is λ

then, $m_1 = 2L\lambda$, and $r_{1cm} \equiv (L, L)$

$m_2 = L\lambda$, and $r_{2cm} \equiv \left(2L, \frac{L}{2}\right)$

$m_3 = L\lambda$, and $r_{3cm} \equiv \left(\frac{5L}{2}, 0\right)$

$$\therefore \quad X_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$

$$\Rightarrow \quad X_{cm} = \frac{13}{8}L$$

and, $Y_{cm} = \dfrac{m_1y_1 + m_2y_2 + m_3y_3}{m_1 + m_2 + m_3} = \dfrac{5}{8}L$

7. X- coordinate of CM of remaining sheet

$$X_{cm} = \frac{MX - mx}{M - m}$$

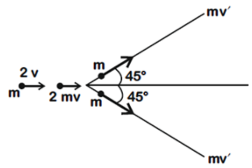
$$= \frac{(4m) \times \left(\frac{a}{2}\right) - m\left(\frac{3a}{4}\right)}{4m - m} = \frac{5a}{12}$$

Similarly $y_{cm} = \dfrac{5b}{12}$

$$\therefore \quad CM\left(\frac{5a}{12}, \frac{5b}{12}\right)$$

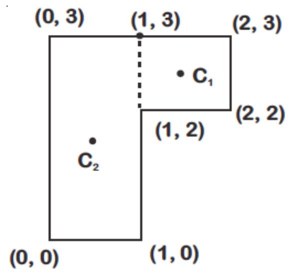
8. Initial momentum · P_i = 2mv + 2mv = 4 mv

Let v′ be the speed of I particle



$$\therefore \quad 2\frac{mv'}{\sqrt{2}} = 4mv$$

$$\Rightarrow \quad v' = 2\sqrt{2}v$$

9. 

For given Lamina

$m_1 = 1$, $C_1 = (1.5, 2.5)$

$m_2 = 3$, $C_2 = (0.5, 1.5)$

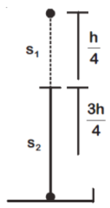
$$\therefore \quad X_{cm} = \frac{1.5 + 1.5}{4} = 0.75$$

$$\therefore \quad Y_{cm} = \frac{2.5 + 4.5}{4} = 1.75$$

∴ Coordinate of centre of mass

(0.75, 1.75)

10. Time of collision



$$t_0 = \frac{h}{\sqrt{2gh}} = \sqrt{\frac{h}{2g}}$$

$$\therefore \quad s_1 = \frac{1}{2}gt_0^2 = \frac{1}{2}g \cdot \frac{h}{2g} = \frac{h}{4}$$

$\therefore \qquad s_2 = \dfrac{3h}{4}$

Speed of (A) just before collision $v_1 \downarrow$

$= gt_0 = \sqrt{\dfrac{gh}{2}}$

And speed of (B) just before collision $v_2 \uparrow$

$= \sqrt{2gh} - \sqrt{\dfrac{gh}{2}}$

After collision velocity of centres of mass

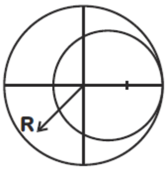
$$V_{cm} = \frac{m\left(\sqrt{2gh} - \sqrt{\dfrac{gh}{2}}\right) - m\sqrt{\dfrac{gh}{2}}}{2m} = 0$$

So from there, time of fall 't'

$\Rightarrow \qquad \dfrac{3h}{4} = \dfrac{1}{2}gt^2$

$\Rightarrow \qquad t = \sqrt{\dfrac{3}{2}\dfrac{h}{g}}$

11.



$M_0 = \dfrac{4}{3}\pi R^3 \rho$

$M_{cavity} = \dfrac{4}{3}\pi (1)^3 \rho$

$M_{(Remaining)} = \dfrac{4}{3}\pi (1)^3 \rho$

$\therefore$

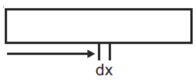
$$\left(\frac{4}{3}\pi R^3 \rho - \frac{4}{3}\pi(1)^3\rho\right) \times 2 + \frac{4}{3}\pi(1)^3\rho = \frac{4}{3}\pi R^3 \rho \cdot R$$

$\Rightarrow \qquad R^4 - 2R^3 + 1 = 0 \qquad \because \; R \neq 1$

$\therefore \qquad R^3 - R^2 - R - 1 = 0$

$\Rightarrow \qquad (R^2 + R + 1)(2 - R) = 1$

12. $X_{cm} = \dfrac{\int_0^L X\, dM}{M}$



$M = aL + \dfrac{bL}{3}$

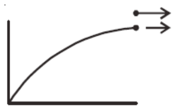
$$\int_0^L X dm = \int_0^L \left(aX + \frac{bX^3}{l^2}\right)dx = \left(\frac{aL^2}{2} + \frac{bL^2}{4}\right)$$

$$X_{cm} = \frac{3L}{4}\left(\frac{2a+b}{3a+b}\right)$$

13.

$2mv_x = mu + mu \cos 60°$

$v_x = \dfrac{3u}{4}$



Horizontal range after collision

$= \dfrac{3u}{4} \times \sqrt{\dfrac{2H}{g}}$

$= \dfrac{3\sqrt{3}u^2}{8g}$

14. $\vec{P}_i = \vec{P}_f$

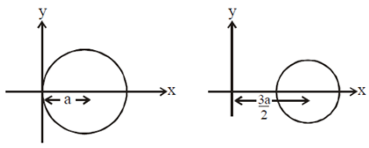
$\Rightarrow \qquad mv = (16\,m)v_0 \qquad \Rightarrow \qquad v_0 = \dfrac{v}{16}$

$$(\Delta KE)_{Loss} = \frac{1}{2}mv^2 - \frac{1}{2}(16\,m)\left(\frac{v}{16}\right)^2$$

$$\Rightarrow \qquad \% \text{ Loss} = \frac{(\Delta KE)_{Loss}}{\frac{1}{2}mv^2} \times 100 = \left(1 - \frac{1}{16}\right) \times 100$$

; 94%

15.



Let σ be the uniform mass density of disc then

$$x_{COM} = \frac{(\sigma\pi a^2)a - \sigma\pi\left(\dfrac{a^2}{4}\right) \times \dfrac{3a}{2}}{\sigma\pi a^2 - \dfrac{\sigma\pi a^2}{4}}$$

$$= \frac{a - \dfrac{3a}{8}}{1 - \dfrac{1}{4}} = \frac{5a}{6}$$

16. $a_{cm} = \dfrac{m_1 a_1 + m_2 a_2}{m_1 + m_2}$

$$\frac{F}{2M} = \frac{Ma + Ma_B}{2M}$$

$$a_B = \frac{F - Ma}{M}$$

17. From energy conservation,

$$\left[\begin{array}{l}\text{after bullet gets embedded till the} \\ \text{system comes momentarily at rest}\end{array}\right]$$

$$(M+m)g\ h = \frac{1}{2}(M+m)v_1^2$$

[v_1 is velocity after collisision]

$$\therefore\ V_1 = \sqrt{2gh}$$

Applying momentum conservation, (just before and just after collision)

$mv = (M + m)\ v_1$

$$v = \left(\frac{M+m}{m}\right)v_1 = \frac{6}{10\times10^{-3}} \times \sqrt{2\times9.8\times9.8\times10^{-2}}$$

$$\approx 831.55\ m/s$$

18. $v_0 = \sqrt{2gh}$

$v = e\sqrt{2gh} = \sqrt{2gh}$

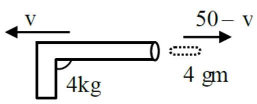
$\Rightarrow$ e = 0.9

$S = h + 2e^2h + 2e^4\ h + ...$

$$t = \sqrt{\frac{2h}{g}} + 2e\sqrt{\frac{2h}{g}} + 2e^2\sqrt{\frac{2h}{g}} + ...$$

$$v_{av} = \frac{s}{t} = 2.5\ m/s$$

19.



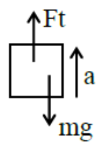
By momentum conservation

$4 \times 10^{-3}\ (50 - v) - 4v = 0$

$$v = \frac{4\times10^{-3}\times50}{4 + 4\times10^{-3}} \approx 0.05 ms^{-1}$$

Impulse $J = mv = 4 \times 0.05 = 0.2\ kg\ ms^{-1}$

20.



$$F_{thrust} = \left(\frac{dm}{dt}.V_{rel}\right)$$

$$\left(\frac{dm}{dt}V_{rel} - mg\right) = ma$$

$$\Rightarrow \left(\frac{dm}{dt}\right)\times500 - 10^3\times10 = 10^3\times20$$

$$\frac{dm}{dt} = (60\,kg/s)$$

21. $$\Delta x_G = \frac{m_1\Delta x_1 + m_2\Delta x_2}{m_1 + m_2}$$

$$0 = \frac{10\times6 + 30(\Delta x_2)}{40}$$

$\Delta x_2 = -2$ cm

Block of mass 30 kg will to move towards 10 kg.

22. Velocity after collision

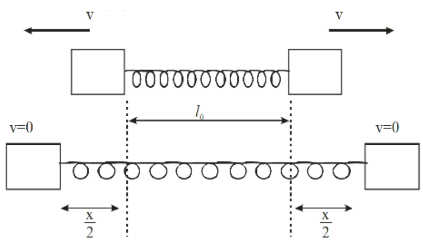
$$V_2 = \frac{(m_2 - m_1)u_2 + 2m_1u_1}{m_1 + m_2}$$

$$V_2 = \frac{(m_2 - m_1)0 + 2m.u_0}{m_1 + 5m_2} = \frac{u_0}{3}$$

$$\%\Delta KE = \frac{\frac{1}{2}5m\left(\frac{u_0}{3}\right)^2 - 0}{\frac{1}{2}mu_0^2}\times100$$

$$= \frac{5u_0^2}{9u_0^2}\times100 = \frac{500}{9} = 55.6\%$$

23.



using energy conservation

$$\frac{1}{2}mv^2\times2 = \frac{1}{2}kx^2$$

$$\Rightarrow \frac{1}{2}\times\frac{1}{4}\times V^2\times2 = \frac{1}{2}\times2\times x^2$$

$$\therefore\ x = \frac{v}{2}$$

24. $$20\times10^{-3}\times\frac{180}{60}\times100 = 10V$$

$\Rightarrow v = 0.6$ m/s

25. By conservation of momentum

$\vec{u}_A + \vec{u}_B = \vec{v}_A + \vec{v}_B$ (Masses are equal)

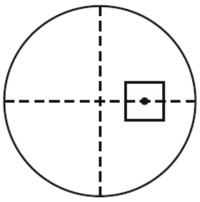
$\therefore \quad (3\hat{i} + 5\hat{j}) = \vec{v}_B + (4\hat{i} + 4\hat{j}) = \hat{j} - \hat{i}$

$\therefore \quad KE_B = \frac{1}{2}mv_B^2 = \frac{1}{2} \times 0.1 \times \left(\sqrt{2}\right)^2$

$= \frac{1}{10}J = \frac{x}{10}J$

$\therefore \quad x = 1$

26.



Let the density is σ

Then original mass $m_0 = \pi a^2 \sigma$

Remaining mass

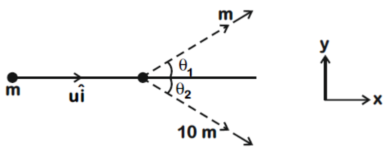
$$m' = \left(\pi a^2 - \frac{a^2}{4}\right)\sigma = a^2\left(\frac{4\pi - 1}{4}\right)\sigma$$

Removed mass $m = \frac{a^2}{4} \cdot \sigma$

$\therefore \quad \pi a^2 \sigma(0) = \frac{a^2}{4} \cdot \sigma \times \frac{a}{2} + \frac{\sigma a^2}{4}(4\pi - 1)r$

$\Rightarrow \quad r = \frac{-a}{2(4\pi - 1)} = \frac{-a}{23.13} \approx \frac{-a}{23}$

27.



Since energy of m reduced by half

$\therefore \; u_1 = \frac{u}{\sqrt{2}}$

and $\frac{1}{2} \times 10m \cdot v_1^2 = \frac{1}{2}m\frac{u^2}{2} \Rightarrow \quad v_1 = \frac{u}{\sqrt{20}}$

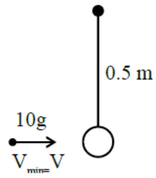
Now, momentum in y direction will remain conserved

$\therefore \quad mu_1\sin\theta_1 = 10mv_1\sin\theta_2$

$\Rightarrow \quad \frac{u}{\sqrt{2}}\sin\theta_1 = 10\frac{u}{\sqrt{20}}\sin\theta_2$

$\Rightarrow \quad \sin\theta_1 = \sqrt{10}\sin\theta_2$

28.



$V' = \sqrt{5gR} = \sqrt{5 \times 10 \times 0.5}$

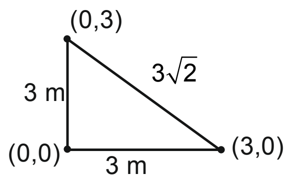
$V' = 5$ m/s

$m_1V = m_2 \times 5 - m_1 \times 100$

$\frac{10}{1000} \times V = 5 - \frac{10}{1000} \times 100$

$V = 400$ m/s

29.



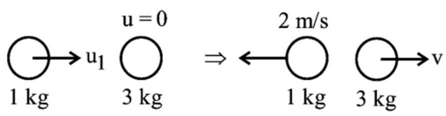
$\vec{r}_{com} = \frac{M(0\hat{i} + 0\hat{j}) + M(3\hat{i}) + M(3\hat{j})}{3M}$

$\vec{r}_{com} = \hat{i} + \hat{j}$

$|\vec{r}_{com}| = \sqrt{2} = \sqrt{x}$

$x = 2$

30.



$1 \times u_1 = -2 + 3v \Rightarrow u_1 = -2 + 3v$ ... (1)

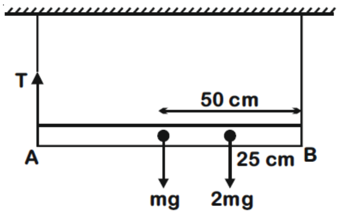
$1 = \frac{v + 2}{u_1} \quad \Rightarrow v + 2 = u_1$ ... (2)

Solving (1) and (2)

$u_1 = 4$ m/s

RIGID BODY DYNAMIC (ROTATIONAL DYNAMICS) SOLUTION

1.



Net torque about B = 0

$\Rightarrow T \times 100 = mg \times 50 + 2mg \times 25$

$\Rightarrow T = mg$

2. $mvl = \left(\frac{Ml^2}{3} + ml^2\right)\omega$

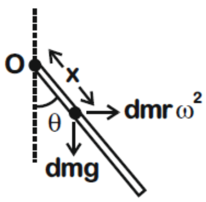
$$\frac{1}{2}\left(\frac{Ml^2}{3} + ml^2\right)\omega^2 = \left[Mg\frac{l}{2} + mgl\right](1-\cos\theta)$$

$\omega = \frac{18}{5}\text{rad/s}$

$1-\cos\theta = \frac{18}{5}\times\frac{3}{20}$

$\theta = 63°$

3.

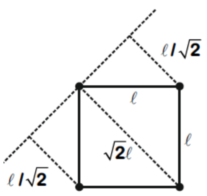


From a rotating frame rod will appear in equilibrium. Net torque about suspension point must be zero.

$$\int_0^L \left(\frac{M}{L}dx\right)(x\sin\theta)\omega^2 x\cos\theta = Mg\frac{L}{2}\sin\theta$$

$\Rightarrow \qquad \cos\theta = \frac{3g}{2l\omega^2}$

4.



$$I = m\left(\frac{\ell^2}{2}\right)\times 2 + m\times\left(\sqrt{2}\ell\right)^2 = 3m\ell^2$$

$\therefore L = Iw = 3m\ell^2\omega$

5. $M = \int_0^L \lambda dx = \int_0^L \lambda_0\left(1+\frac{x}{L}\right)dx$

$= \frac{3}{2}\lambda_0 L$

$= I = \int_0^L (\lambda dx)x^2 = \frac{7}{12}\lambda_0 L^3$

$= I = \frac{7}{18}ML^2$

6. Ring $I_1 = \frac{MR^2}{2}$ about diameter

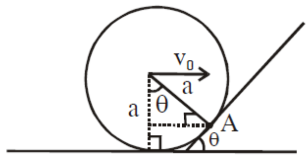
Disc $I_2 = \frac{MR^2}{2}$

Solid cylinder $I_3 = \frac{MR^2}{2}$

Solid sphere $I_4 = \frac{2}{5}MR^2$

$I_1 = I_2 = I_3 > I_4$

7.



Angular momentum conservation about A

$mv_0 a\cos\theta + \frac{2}{5}ma^2\omega$

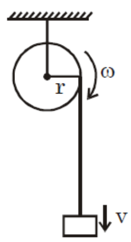
$= mva + \frac{2}{5}ma^2\omega^1$

$mv_0 \times a\left[\frac{2}{5}+\cos\theta\right] = \frac{7}{5}mva$

$v\times\frac{5}{7} = v_0\left[\frac{2}{5}+\cos\theta\right]$

$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{7}{10}mv^2 = mgh$

8. mgh = $\frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$



$v = \omega r$

mgh = $\frac{1}{2}I\omega^2 + \frac{1}{2}m\omega^2 r^2$

$$\frac{2mgh}{(I+mr^2)} = \omega^2$$

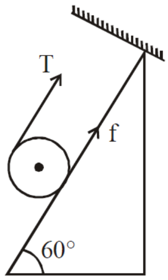
9 We know $\vec{L} = m(\vec{r} \times \vec{v})$

Now with respect to A, we always get direction of $\vec{L}$ along +ve z-axis and also constant magnitude as mvr. But with respect to B, we get constant magnitude but continuously changing direction.

10. $\pi r = L \Rightarrow r = \frac{L}{\pi}$

$$I = Mr^2 = \frac{ML^2}{\pi^2}$$

11.



Let's take solid cylinder is in equilibrium

T + f = mg sin 60 ...(i)

TR – fR = 0 ...(ii)

$$T = f_{req} = \frac{mg\sin\theta}{2}$$

But limiting friction < required friction

$$\mu mg \cos 60^\circ < \frac{mg\sin 60}{2}$$

$\therefore$ Hence cylinder will not remain in equilibrium

Hence f = static

$= \mu_s N$

$= \mu_s mg \cos 60^\circ$

$= \frac{mg}{5}$

12. From conservation of angular momentum we get

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$$\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

$$k_i = \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2$$

$$k_f = \frac{1}{2}(I_1 + I_2)\omega^2$$

$$k_i - k_f = \frac{1}{2}\left[I_1\omega_1^2 + I_2\omega_2^2 - \frac{(I_1\omega_1 + I_2\omega_2)^2}{I_1 + I_2}\right]$$

Solving above we get

$$k_i - k_f = \frac{1}{2}\left(\frac{I_1 I_2}{I_1 + I_2}\right)(\omega_1 - \omega_2)^2$$

13. $K_{total} = K_{rotational} + K_{Translational}$

$$K_{total} = \frac{1}{2}I_{cm}\omega^2 + \frac{1}{2}mV_{cm}^2$$

$v_{cm} = R\omega$ for pure rolling

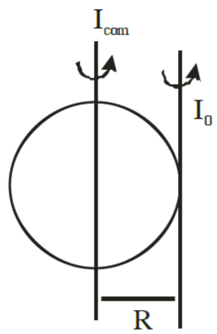
$$I_{cm} = \frac{2}{5}mR^2$$

$$K_{Rot} = \frac{1}{2}I_{cm}\omega^2 = \frac{1}{2} \times \frac{2}{5}mR^2 \times \frac{v_{cm}^2}{R^2} = \frac{1}{5}mv_{cm}^2$$

$$K_{Total} = \frac{1}{5}mv_{cm}^2 + \frac{1}{2}mv_{cm}^2 = \frac{7}{10}mv_{cm}^2$$

$$\frac{K_{Rot}}{K_{Total}} \frac{\frac{1}{2}mv_{cm}^2}{\frac{7}{10}mv_{cm}^2} = \frac{2}{7}$$

14. Solid sphere

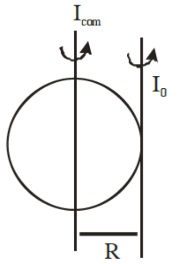


$I_0 = I_{com} + MR^2$ (Parallel Axis theorem)

$$I_0 = \frac{2}{5}MR^2 + MR^2$$

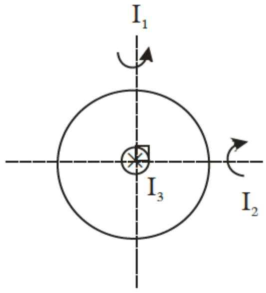
$$I_0 = \frac{7}{5}MR^2$$

Hollow sphere



$I_0 = I_{com} + MR^2$

$$= \frac{2}{3}MR^2 + MR^2 = \frac{5}{3}MR^2$$



$I_1 + I_2 + I_3$ (Perpendicular axis theorem)

By symmetry MOI

About 1" and 2" Axis are same i.e.

$I_1 = I_2$

$\therefore 2I_1 - I_3 = MR^2$ ($I_{com} = MR^2$)

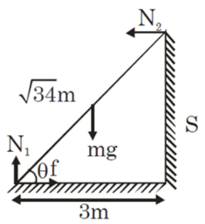
$$I_1 = \frac{MR^2}{2}$$

Similarly in disc

$$2I_1 = \frac{MR^2}{2} \left\{ I_{com} = \frac{MR^2}{2} \right\}$$

$$I_1 = \frac{MR^2}{4}$$

15.



$f = N_2$

$N_1 = mg$

$$N_2 \times \ell \sin\theta = mg\frac{\ell}{2}\cos\theta$$

$$N_2 = \frac{mg}{2}\cot\theta$$

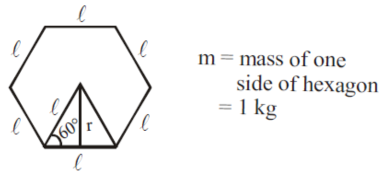
$$\frac{F_W}{F_f} = \frac{\frac{mg}{2}\cot\theta}{\sqrt{(mg)^2 + \left(\frac{mg}{2}\cot\theta\right)^2}} = \frac{1}{\sqrt{1 + \frac{4}{\cot^2\theta}}} = \frac{3}{\sqrt{109}}$$

16. $$V = \sqrt{\frac{2gH}{1 + k^2/R^2}}$$

$$\frac{V_{cylinder}}{V_{sphere}} = \sqrt{\frac{(1 + k^2/R^2)_{sphere}}{(1 + k^2/R^2)_{cylinder}}}$$

$$= \frac{V_{cylindere}}{V_{sphere}} = \sqrt{\frac{7}{5} \times \frac{2}{3}} = \sqrt{\frac{14}{15}}$$

17.



$6\ell = 2.4$ $\quad\quad \ell = 0.4$m

$$\sin 60^\circ = \frac{r}{\ell}$$

$$r = \ell \sin 60^\circ = \frac{\ell\sqrt{3}}{2}$$

M.o.i, $\quad I = \left[\frac{m\ell^2}{12} + mr^2\right]6$

$$= \left[\frac{m\ell^2}{12} + m\left(\frac{\ell\sqrt{3}}{2}\right)^2\right]6$$

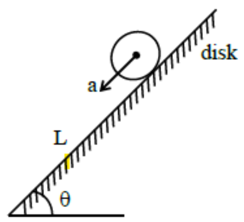
$= 5\ ml^2$

$= 5 \times 1 \times 0.16$

$= 0.8$

$I = 8 \times 10^{-1}$ kg m^2

18. If disk slips on inclined plane, then it's acceleration



$a_1 = g \sin\theta$

$$L = \frac{1}{2}a_1 t_1^2 \Rightarrow t_1 = \sqrt{\frac{2L}{a_1}} \quad ...(i)$$

If disk rolls on inclined plane, its acceleration,

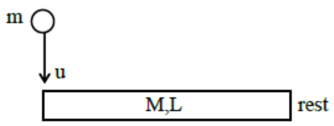
$$a=\frac{g\sin\theta}{1+\frac{k^2}{R^2}}=\frac{g\sin\theta}{1+\frac{1}{2}}=\frac{2}{3}g\sin\theta$$

Now $L=\frac{1}{2}a_2.t_2^2$

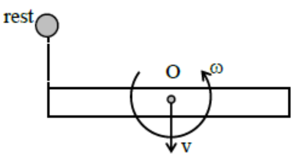
$$\Rightarrow t_2=\sqrt{\frac{2L}{a_2}} \quad ...(ii)$$

Now $\frac{t_2}{t_1}=\sqrt{\frac{a_1}{a_2}}=\sqrt{\frac{3}{2}}\Rightarrow x=2$

19.



Just before collision



Just after collision

From momentum conservation, $P_i^0=P_f$

mu = Mv ....(i)

From angular momentum conservation about O,

$$mu.\frac{L}{2}=\frac{ML^2}{12}\omega \ ,\Rightarrow \omega=\frac{6mu}{ML} \quad ...(ii)$$

From $e=\frac{R.V.S}{R.V.A}$

$$1=\frac{V+\frac{\omega L}{2}}{u}\ ,\ v+\frac{\omega L}{2}=u\ ,\ v+\frac{3mu}{M}=u$$

$$\frac{mu}{M}+\frac{3mu}{M}=u\ ,\ \frac{4mu}{M}=u$$

$$\frac{m}{M}=\frac{1}{4}\ ,\ X=4$$

20. I in both cases is about point of contact

Ring

$$mgh=\frac{1}{2}I\omega^2$$

$$mgh=\frac{1}{2}(2mR^2)\frac{v_R^2}{R^2}$$

$$v_R=\sqrt{gh}$$

Solid cylinder

$$mgh=\frac{1}{2}I\omega^2$$

$$mgh=\frac{1}{2}\left(\frac{3}{2}mR^2\right)\frac{v_C^2}{R^2}$$

$$V_C=\sqrt{\frac{4gh}{3}}\ ,\ \frac{V_R}{V_C}=\frac{\sqrt{3}}{2}$$

21. $\vec{r}=10\alpha t^2\hat{i}+5\beta(t-5)\hat{j}$

$$\vec{v}=20\alpha t\hat{i}+5\beta\ \hat{j}$$

$$\vec{L}=m(\vec{r}\times\vec{v})$$

$$=m[10\alpha t^2\hat{i}+5\beta(t-5)\hat{j}]\times[20\alpha\ t\hat{i}+5\beta\ \hat{j}]$$

$$\vec{L}=m[50\alpha\beta\ t^2\ \hat{k}-100\alpha\beta(t^2-5\ t)\hat{k}]$$

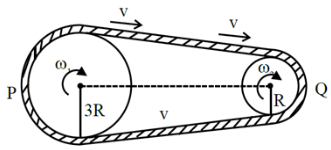
At t = 0, $\vec{L}=\vec{0}$

$$50\alpha\beta\ t^2-100\alpha\beta(t^2-5\ t)=0$$

t – 2 (t – 5) = 0

t = 10 sec

22.

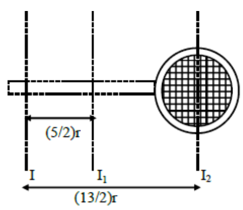


$$\frac{1}{2}I_1(\omega_1)^2=\frac{1}{2}I_2(\omega_2)^2$$

$$I_1\left(\frac{v}{3R}\right)^2=I_2\left(\frac{v}{R}\right)^2$$

$$\frac{I_1}{I_2}=\frac{9}{1}$$

23.



$$I = \left[I_1 + M\left(\frac{5}{2}r\right)^2\right] + \left[I_2 + M\left(\frac{13r}{2}\right)^2\right]$$

$$= \left[\frac{M(36r^2)}{12} + \frac{M(25r^2)}{4}\right] + \left[\frac{Mr^2}{2} + \frac{169Mr^2}{4}\right]$$

$= 52\ Mr^2$

24. $\tau = I\alpha \Rightarrow (12t - 3t^2)\ 1.5 = 4.5\ \alpha$

$\Rightarrow \alpha = 4t - t^2$

$$\Rightarrow \frac{d\omega}{dt} = 4t - t^2 \Rightarrow \omega = \int_0^t (4t - t^2)dt$$

$\Rightarrow \omega = 2t^2 - t^3/3$

For $\omega = 0 = 2t^2 - \frac{t^3}{3} \Rightarrow t^2\left(2 - \frac{t}{3}\right) = 0$

$\Rightarrow t = 0, 6$

$$\frac{d\theta}{dt} = 2t^2 - \frac{t^3}{3} \Rightarrow \theta = \int_0^6 (2t^2 - \frac{t^3}{3})dt$$

$$= \left[\frac{2t^3}{3} - \frac{t^4}{12}\right]_0^6$$

$$= 6^3\left(\frac{2}{3} - \frac{6}{12}\right) = 6^3\left(\frac{8-6}{12}\right) = \frac{6^3}{6} = 36$$

No. of revolutions $= \frac{36}{2\pi} = \frac{18}{\pi}$

$\therefore$ K = 18

25. From energy conservation

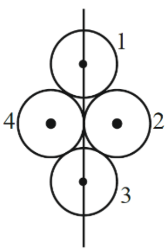
$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}\frac{mR^2}{2}\omega^2$$

$$10h = \frac{16}{2} + \frac{16}{4} \Rightarrow h = 1.2m = 120\ cm$$

26. $I_1 = I_3 = \frac{MR^2}{4}$

$$I_2 = \frac{MR^2}{4} + MR^2 = \frac{5}{4}MR^2 = I_4$$



so $I = I_1 + I_2 + I_3 + I_4$

$$= \frac{MR^2}{4} + \frac{5}{4}MR^2$$

$= 3\ MR^2$, Putting $R = \frac{a}{2}$

$I = \frac{3Ma^2}{4}$, So x = 3

27. $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = 7 \times 10^{-3}$

$$\frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}MR^2\right)\left(\frac{V}{R}\right)^2 = 7 \times 10^{-3}$$

$$\frac{1}{2}MV^2\left[1 + \frac{2}{5}\right] = 7 \times 10^{-3}$$

$$\frac{1}{2}(1)(V^2)\left(\frac{7}{5}\right) = 7 \times 10^{-3}$$

$V^2 = 10^{-2}$

$V = 10^{-1} = 0.1$ m/s = 10 cm/s

28. $\frac{R_1 + R_2}{10} = \frac{60}{40} = \frac{3}{2} \Rightarrow R_1 + R_2 = 15$

Now $\frac{R_1R_2}{(R_1 + R_2) \times 3} = \frac{40}{60} = \frac{2}{3} \Rightarrow R_1R_2 = 30$

29. $a = -\mu kg = -3$

$V = 18 - 3 \times 2$

$V = 12$ m/s

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}\frac{mr^2}{2}\frac{v^2}{r^2}$$

$$KE = \frac{3}{4}mv^2$$

KE = 3 × 18 = 54 J

30. $(KE)_{Rotational} = \frac{1}{2}I\omega^2 = E$

$$E = \frac{1}{2}\frac{m\ell}{12}\omega^2$$

$$E = \frac{1}{2}\frac{dA\ell}{12}\omega^2$$

$$E = \frac{dA(2)^3}{24}\omega^2$$

$$\sqrt{\frac{3E}{dA}} = \omega$$

$\alpha = 3$ Ans.

SIMPLE HARMONIC MOTION SOLUTION

1. $T = 2\pi\sqrt{\frac{m}{k}}$ $\quad \omega = \sqrt{\frac{m}{k}}$

$v_{max} = A.\omega \quad \because F = kA,\ A = \frac{F}{k}$

$V_{max} = \frac{F}{k}.\sqrt{\frac{k}{m}} \Rightarrow V_{max} = \frac{F}{\sqrt{mK}}$

2. $I_1 = \frac{M(2L)^2}{12} = \frac{ML^2}{3}$

$I_2 = I_1 + 2\frac{mL^2}{4} = \frac{ML^2}{3} + \frac{mL^2}{2}$

$\omega \propto \frac{1}{\sqrt{I}}$

$\frac{\omega_1}{\omega_2} = \frac{1}{0.8} = \sqrt{\frac{\frac{M}{3}+\frac{m}{2}}{\frac{M}{3}}} \Rightarrow \frac{m}{M} = 0.375$

3. $a = \omega^2 x = -\omega^2 \times 4$

$V = \omega\sqrt{A^2 - x^2} = \omega \times \sqrt{5^2 - 4^2}$

$\therefore \quad \omega^2 \times 4 = \omega \times 3$

$\Rightarrow \quad \omega = \frac{3}{4} \quad \Rightarrow T = \frac{2\pi}{3/4} = \frac{8\pi}{3}$

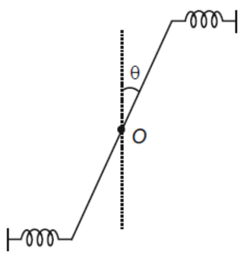
4. $\frac{KE}{PE} = \frac{\frac{1}{2}kA^2 - \frac{1}{2}kA^2\sin^2\frac{\pi t}{90}}{\frac{1}{2}kA^2\sin^2\frac{\pi t}{90}} = \frac{1}{3}$

5. $T = 2\pi\sqrt{\frac{l}{g_{eff}}} \Rightarrow \omega = \sqrt{\frac{g_{eff}}{l}}$

$\frac{\Delta\omega}{\omega} = \frac{1}{2}\frac{\Delta g_{eff}}{g_{eff}} = \frac{1}{2}\frac{(2\omega^2 A)}{g}$

$\frac{\Delta\omega}{\omega} = 10^{-3}\,\text{rad/s}$

6.



$\tau = I\,\alpha$

$\frac{Ml^2}{12}\alpha = 2k\left(\frac{l}{2}\right)\left(\frac{l}{2}\right)\theta$

$\frac{Ml^2}{12}\alpha = \frac{-kl^2}{2}\theta$

$\Rightarrow \omega = \sqrt{\frac{6k}{m}}$

$\Rightarrow \nu = \frac{1}{2\pi}\sqrt{\frac{6K}{m}}$

7. $u = \omega\theta_0$

$v = \omega\theta_1$

$\Rightarrow \quad \frac{u}{v} = \frac{\theta_0}{\theta_1}$

Now, $v = \frac{M-m}{M+m} \times u$

$\Rightarrow \quad \frac{M+m}{M-m} = \frac{u}{v} = \frac{\theta_0}{\theta_1}$

$\Rightarrow \quad \frac{M}{m} = \frac{\theta_0 + \theta_1}{\theta_0 - \theta_1}$

$\Rightarrow \quad M = m\left(\frac{\theta_0 + \theta_1}{\theta_0 - \theta_1}\right)$

8. Time for 10 oscillations = $\frac{10}{5} = 2$ s

$A = A_0\, e^{-kt}$

$\frac{1}{2} = e^{-2k} \Rightarrow \ln 2 = 2k$

$10^{-3} = e^{-kt} \Rightarrow 3\ln 10 = kt$

$t = \frac{3\ln 10}{k} \times \frac{3\ln 10}{\ln 2} \times 2$

$= 6 \times \frac{2.3}{0.69} \approx 20\text{s}$

9. $l = 25.0$ cm

Time of 40 oscillation is 50 sec

$\therefore \quad g = \frac{4\pi^2 l}{T^2} \Rightarrow \frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$

$\Rightarrow \quad \frac{\Delta g}{g} = \left(\frac{0.1}{25.0}\right) + 2\left(\frac{1}{50}\right)$

$\Rightarrow \quad \left(\frac{\Delta g}{g} \times 100\right) = 4.4\%$

10. AT $t = \frac{3T}{4}$, particle is at mean position

$\Rightarrow$ Force = 0

At t = T, particle is at extreme position

$\Rightarrow$ Acceleration is maximum

At $t = \frac{T}{4}$, particle is at mean position

$\Rightarrow$ Speed is maximum

11. $T = 2\pi\sqrt{\frac{I}{Mgd}}$

$\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}}$

$I_1 = 2MR^2, I_2 = \frac{MR^2}{2} + MR^2 = \frac{3}{2}MR^2$

$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{4}{3}} = \frac{2}{\sqrt{3}}$

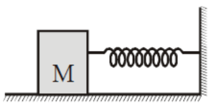
12. $y(t) = \frac{y_0}{2}(1 - \cos 2\omega t)$

$\frac{Mg}{K} = \frac{y_0}{2}$[Amplitude]

$2\omega = \sqrt{\frac{K}{m}}$

$\omega = \frac{1}{2}\sqrt{\frac{K}{m}} = \frac{1}{2}\sqrt{\frac{2g}{y_0}} = \sqrt{\frac{g}{2y_0}}$

13.



Momentum of system remains conserved.

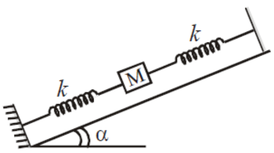
$p_i = p_f$

$MA\omega = (m + M) A'\omega'$

$MA\sqrt{\frac{k}{M}} = (m + M)\, A'\sqrt{\frac{k}{m + M}}$

$A' = A\sqrt{\frac{M}{M + m}}$

14.

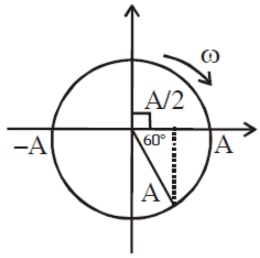


$K_{eq} = K_1 + K_2 = K + K = 2K$

$T = 2\pi\sqrt{\frac{m}{K_{eq}}} = 2\pi\sqrt{\frac{m}{2K}}$

$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{2K}{m}}$

15.



initial phase $\frac{\pi}{2} + \frac{\pi}{3} = \frac{5\pi}{6}$

16. $v^2 = \omega^2(A^2 - x^2)$

$\frac{v^2}{\omega^2} + x^2 = A^2$

$\frac{v^2}{(\omega A)^2} + \frac{x^2}{A^2} = 1$

This is an equation of an ellipse.

17. KE = PE

$\frac{1}{2}m\omega^2(A^2 - x^2) = \frac{1}{2}m\omega^2 x^2$

$A^2 - x^2 = x^2$

$2x^2 = A^2$

$x = \pm\frac{A}{\sqrt{2}}$

18. $g = \frac{4\pi^2 l}{T^2}$

$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T} = \frac{0.1}{10} + 2\left(\frac{\frac{1}{200}}{0.5}\right)$

$\frac{\Delta g}{g} = \frac{1}{100} + \frac{1}{50}$

$\frac{\Delta g}{g} \times 100 = 3\%$

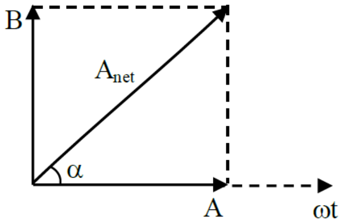
19. x = A sin ωt + B cos ωt

$v = \frac{dx}{dt} = A\omega\cos\omega t - B\omega\sin\omega t$

At t = 0, x (0) = B

v (0) = Aω

x = A sin ωt + B sin (ωt + 90°)



$A_{net} = \sqrt{A^2 + B^2}$

$\tan\alpha = \frac{B}{A} \Rightarrow \cot\alpha = \frac{A}{B}$

$\Rightarrow x = \sqrt{A^2 + B^2}\sin(\omega t + \alpha)$

$\Rightarrow x = \sqrt{A^2 + B^2}\cos(\omega t - (90 - \alpha))$

x = C cos ($\omega t - \phi$)

$\Rightarrow C = \sqrt{A^2 + B^2}$

$C = \sqrt{\frac{[v(0)]^2}{\omega^2} + [x(0)]^2}$

$\phi = 90 - \alpha$

$\tan\alpha = \cos\alpha = \frac{A}{B}$

$\Rightarrow \tan\phi = \frac{v(0)}{x(0).\omega}$

$\phi = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

20. $T = 2\pi\sqrt{\frac{m}{k}}$

$0.2 = 2\pi\sqrt{\frac{0.5}{k}}$

k = 50 π^2

= 500

x = A sin ($\omega t + \phi$)

$= 5\text{cm}\sin\left(\frac{\omega T}{4} + 0\right)$

$= 5\text{cm}\sin\left(\frac{\pi}{2}\right)$

= 5 cm

$PE = \frac{1}{2}kx^2$

$= \frac{1}{2}(500)\left(\frac{5}{100}\right)^2$

= 0.6255

21. Potential energy is maximum at maximum distance from mean.

22. From potential energy curve

$U_{max} = \frac{1}{2}kA^2 \Rightarrow 10 = \frac{1}{2}k(2)^2$

$\Rightarrow$ k = 5

Now $T_{spring} = T_{pendulum}$

$2\pi\sqrt{\frac{5}{5}} = 2\pi\sqrt{\frac{4}{g}}$

$\Rightarrow i = \sqrt{\frac{4}{g}} \Rightarrow$ g = 4 on planet

Option (3)

23. $T \propto \frac{1}{\sqrt{g}}$

24. $T_a = 2\pi\sqrt{\frac{M}{K}}$

$T_b = 2\pi\sqrt{\frac{M}{K/2}}$

$\frac{T_b}{T_a} = \sqrt{2} = \sqrt{x}$

$\Rightarrow$ x = 2

25. $\omega = \sqrt{\frac{k_{eq}}{\mu}}$

μ = reduced mass

springs are in series connection

$k_{eq} = \frac{k_1k_2}{k_1 + k_2}$

$k_{eq} = \frac{k \times 4k}{5k} = \frac{4k}{5}$

$k_{eq} = \frac{4 \times 20}{5}N/m = 16N/m$

$\mu = \frac{m_1m_2}{m_1 + m_2} = \frac{0.2 \times 0.8}{0.2 + 0.8} = 0.16kg$

$\mu = \sqrt{\frac{16}{0.16}} = \sqrt{100} = 10$

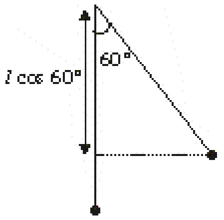
26. $T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow \ell = \frac{T^2g}{4\pi^2}$

$E = mg\ell\frac{\theta^2}{2} = mg^2\frac{T^2\theta^2}{8\pi^2}$

$\frac{dE}{E} = 2\left(\frac{dg}{g} + \frac{dT}{T}\right)$

= (4 + 3) = 14%

27. $V_{max} = \sqrt{2gh}$



The speed will be highest at the lowest position.

$$h = (\ell - \ell\cos 60°) = \frac{\ell}{2}$$

$$V_{max} = \sqrt{2 \times g \times \frac{\ell}{2}} = \sqrt{10 \times 2.5} = 5\, m/s$$

28.

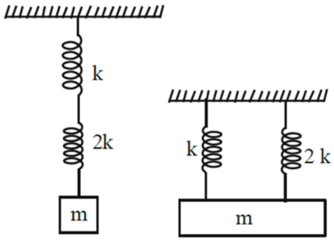


figure (a) figure (b)

For figure (a) :

$$K_{eq} = \frac{K \times 2K}{K + 2K} = \frac{2K}{3}$$

$$T = 2\pi\sqrt{\frac{m}{K_{eq}}} = 2\pi\sqrt{\frac{m}{2K/3}} = 2\pi\sqrt{\frac{3m}{2K}}$$

For figure (b) :

$$K_{eq} = 3K, T' = 2\pi\sqrt{\frac{m}{3K}}$$

$$\frac{T}{T} = \sqrt{\frac{m \times 2K}{3K \times 3m}} = \frac{\sqrt{2}}{3}$$

$$T' = \sqrt{2}$$

x = 2

29. $\frac{1}{2}kA^2 = \frac{p^2}{2m}$

$$\Rightarrow \left(\frac{A_1}{A_2}\right)^2 = \frac{m_2}{m_1} = \frac{1024}{900}$$

$$\Rightarrow \frac{A_1}{A_2} = \frac{32}{30} = \frac{16}{15} = \frac{16}{16-1}$$

$\therefore \alpha = 16$

30. $T = 2\pi\sqrt{\frac{m}{k}} = 1$

$$T' = 2\pi\sqrt{\frac{m+3}{k}} = 2$$

$$\frac{T}{T'} = \sqrt{\frac{m}{m+3}} = \frac{1}{2}$$

$$\Rightarrow \frac{m}{m+3} = \frac{1}{4}$$

m = 1

WAVE ON A STRING SOLUTION

1. By equation

$f = \dfrac{1}{0.04}$ and $\lambda = 0.5$

$\Rightarrow \quad V = \dfrac{1}{0.04} \times 0.5 = \dfrac{25}{2}$

by $V = \sqrt{\dfrac{T}{\mu}} \Rightarrow \left(\dfrac{25}{2}\right)^2 = \dfrac{T}{0.04}$

$\Rightarrow T = \dfrac{625}{4} \times 0.04$

$T = 6.25$ N

2. $y(x,t) = e^{-[\sqrt{a}x+\sqrt{b}t]^2}$

It is transverse type $y(x,t) = e^{-(ax+bt)^2}$

Speed $v = \dfrac{\sqrt{b}}{\sqrt{a}}$

and wave is moving along –x direction.

$y(x,t) = e^{-[\sqrt{a}x+\sqrt{b}t]^2}$

3. $Y = A\sin(\omega t - kx) + A\sin(\omega t + kx)$

$Y = 2A\sin\omega t\cos kx$ standing wave

For nodes $\cos kx = 0$

$\dfrac{2\pi}{\lambda}.x = (2n+1)\dfrac{\pi}{2}$

$\therefore \quad x = \dfrac{(2n+1)\lambda}{4}$, n = 0,1,2,3,........

4. Since, $I \propto A^2\omega^2$

$I_1 \propto (2a)^2\,\omega^2$

$I_2 \propto a^2\,(2\omega)^2$

$I_1 = I_2$

Intensity depends on frequency also.

5. $v = \sqrt{\dfrac{T}{\mu}} = \sqrt{\dfrac{mg}{\mu}} \qquad v' = \sqrt{\dfrac{m\sqrt{g^2+a^2}}{\mu}}$

$\Rightarrow \dfrac{v'}{v} = \sqrt{\dfrac{\sqrt{g^2+a^2}}{g}} \qquad \Rightarrow a = 1.83$

$\Rightarrow a = \dfrac{g}{5}$

6. $v = \sqrt{\dfrac{T}{\mu}} = \sqrt{\dfrac{8\times 1}{5\times 10^{-3}}} = 40\,m/s$

$\lambda = \dfrac{v}{f} = \dfrac{40}{100} = 0.4m$

Separation between successive nodes = $\dfrac{\lambda}{2}$

$= 0.2m\ ;\ 20cm$

7. $Y = A\sin\omega\left(t - \dfrac{x}{v}\right)$

V = 50 m/s by comparison.

$50 = \sqrt{\dfrac{T}{\mu}}$

$T = 2500 \times 5 \times 10^{-3}$

T = 12.5 N

8. $y(x, t) = 10^{-3}\sin(50t + 2x) \Rightarrow$

$v = \dfrac{\omega}{k} = \dfrac{50}{2} = 25\ ms^{-1}$

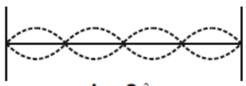
And wave is travelling in –ve x-direction.

9. $\dfrac{V_A}{V_B} = \sqrt{\dfrac{\mu_B}{\mu_A}} = \dfrac{r_B}{r_A}2 = \dfrac{\lambda_A}{\lambda_B}$

$\Rightarrow \lambda_A = 2\lambda_B \Rightarrow \dfrac{p}{q} = \dfrac{1}{2}$

10. $k = 0.157 = \dfrac{3.14}{20} = \dfrac{\pi}{20}$

In 4th harmonic



$L = 2\lambda$

$\therefore k = \dfrac{2\pi}{\lambda} = \dfrac{\pi}{20} \qquad \lambda = 40m$

$\therefore L = \dfrac{4\lambda}{2} = 80m$

11. $\dfrac{\lambda}{2} = \dfrac{2}{3}$

$\Rightarrow \lambda = \dfrac{4}{3}m$

$\therefore v = \dfrac{4}{3} \times 240 = 320\,m/s$

3rd harmonic

$f_n = nf_0$

$f_0 = \frac{240}{3} = 80\,\text{Hz}$

12. Beat frequency = $|f_1 - f_2|$ = 11 – 9 = 2 Hz

13. y = A sin (ωt – kx + φ)

At t = 0 and x = 0 particle is at mean position and will proceed in positive y direction

14. l = 60 cm, m = 6 g, A = 1 mm², v = 90 m/s

$$v = \sqrt{\frac{T}{m}\times l} \Rightarrow T = \frac{mv^2}{l}$$

$$\therefore \Delta L = \frac{Tl}{YA} = \frac{mv^2 \times l}{l(YA)}$$

$$= \frac{6\times10^{-3}\times90^2}{16\times10^{11}\times10^{-6}} = 3\times10^{-4}\,\text{m}$$

= 0.03 mm

15. $v = \sqrt{\frac{T}{\mu}}$

$$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{v}{v}\times 2 = \sqrt{\frac{2.06\times10^4}{T_2}}$$

$$\Rightarrow T_2 = \frac{2.06\times10^4}{4} = 0.515\times10^4\,\text{N}$$

$\Rightarrow T_2 = 5.15 \times 10^3$N

16. $f = \frac{v}{\lambda}$

$$\frac{V_1}{\lambda_1} = \frac{V_2}{\lambda_2}$$

$$\Rightarrow \lambda_2 = \lambda_1\frac{V_2}{V_1}$$

$$= \lambda_1\sqrt{\frac{T_2}{T_1}} = \lambda_1\sqrt{\frac{8g}{2g}}$$

$\Rightarrow \lambda_2 = 12$

17. y = F(x, t)

For travelling wave y should be linear function of x and t and they must exist as (x ± vt) y = Asin (15x – 2t) → linear function in x and t

18. $A_1 = 5 \quad A_2 = 3$

$\Delta\theta = 2\pi(1.5) = 3\pi$

$$A_{net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(3\pi)}$$

$= |A_1 - A_2|$

= 2 cm

19. y = 2 sin (ωt – kx)

Maximum particle velocity = A ω

Wave velocity $= \frac{\omega}{k}$

$$\frac{\omega}{k} = A\omega \qquad k = \frac{1}{A} = \frac{2\pi}{\lambda}$$

$\lambda = 2\pi A$

= 4 π cm

20. $y = 0.5\sin\left(\frac{2\pi}{\lambda}400t - \frac{2\pi}{\lambda}x\right)$

$$\omega = \frac{2\pi}{\lambda}400$$

$$K = \frac{2\pi}{\lambda}$$

$$v = \frac{\omega}{k}\ [v = 400\,\text{m/s}]$$

21. V_P max = $4V_{wave}$

$$\omega A = 4\left(\frac{\omega}{k}\right) \Rightarrow A = \frac{4\lambda}{2\pi}$$

$$\lambda = \frac{2\pi A}{4} \Rightarrow \frac{20\pi}{4} \Rightarrow 5\pi$$

22. From the given equation k = 8 m⁻¹ and ω = 4 rad/s

Velocity of wave = $\frac{\omega}{k}$

v = $\frac{4}{8}$ = 0.5m/s

23. $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{70}{70\times10^{-3}}} = 100\,\text{m/s}$

24. $v = \sqrt{\frac{T}{\mu}}$

$$\frac{\Delta V}{V} = \frac{1}{2}\frac{\Delta T}{T}$$

25. μ = 0.135 gm / cm = 0.0135 kg/m

y = –0.21 sin (x + 30t)

(x in meter & t in sec)

$$v = \frac{\omega}{k} = \frac{30}{1} = 30\,m/s$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow T = v^2\mu = (30)^2(0.0135)$$

= 12.15

= x × 10^{-2} N

⇒ x = 1215

26. At t = 0 , $y = \frac{1}{1+x^2}$

At time t = t, $y = \frac{1}{1+(x-vt)^2}$

At t = 1, $y = \frac{1}{1+(x-v)}$ ...(i)

At t = 1, $y = \frac{1}{1+(x-2)^2}$ ...(ii)

Comparing (i) & (ii) , v = 2m/s

27.

$$\mu = 9.0 \times 10^{-4}\,\frac{kg}{m}$$

$$T = 900N$$

$$V = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{900}{9\times10^{-4}}} = 1000m/s$$

$$f_1 = 500Hz$$

$$f = 550$$

$$\frac{nV}{2\ell} = 500 \quad ...\ (i)$$

$$\frac{(n+1)V}{2\ell} = 550\ ...(ii)$$

$$(ii)(i)\frac{V}{2\ell} = 50$$

$$\ell = \frac{1000}{2\times50} = 10$$

28. $10\cos\left(\frac{4\pi}{3}\right)$

29. $V_w = \sqrt{\frac{T}{\mu}}$

$$60 = \sqrt{\frac{T}{10\times10^{-3}}\times0.5}$$

$$T = \frac{(60)^2\times10^{-2}}{0.5} = 72N$$

$$\Delta\ell = \frac{F\ell}{AY} = \frac{72\times0.5}{2\times10^{-6}\times1.2\times10^{11}}$$

$$= \frac{72\times5}{24}\times10^{-5} = 15\times10^{-5}$$

= 15

30. $y_1 = 10\sin\left(\omega t + \frac{\pi}{3}\right)cm$

$y_2 = 5\left[\sin(\omega t) + \sqrt{3}\cos\omega t\right]cm =$

$10\sin\left(\omega t + \frac{\pi}{3}\right)cm$

$$Y_{res} = Y_1 + Y_2$$

$$Y_{res} = 10\sin(\omega t + \frac{\pi}{3}) + 10\sin(\omega t + \frac{\pi}{3})$$

$$= 20\sin(\omega t + \frac{\pi}{3})$$

amplitude for the result wave = 20.

SOUND WAVE SOLUTION

1. $f_0 = \frac{1}{2\ell}\sqrt{\frac{Y}{\rho}} = \frac{1}{2(0.6)}\sqrt{\frac{9.27\times10^{10}}{2.7\times10^{3}}} = 4.9\times10^{3}\,Hz;\ 5kHz$

2. $l = 0.50$

$\lambda = \frac{1}{2}m$

$\nu = 330 \times 2 = 660$ Hz

3. $f_1 = f_0\left(\frac{340}{340-34}\right)$

$f_2 = f_0\left(\frac{340}{340-17}\right)$

$\frac{f_1}{f_2} = \frac{340-17}{340-34} = \frac{19}{18}$

4. $f_o = \frac{v}{4L}$

Also, $f_n = (2n + 1) f_o$

So (2n + 1) would take value of

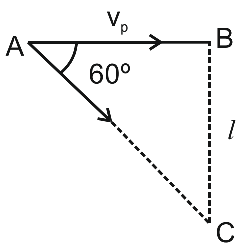
$\frac{20000}{1500} = 13.33$

$\Rightarrow$ 1, 3, 5, 7, 9, 11, 13

So overtones are 3, 5, 7, 9, 11, 13

Total 6 No. of overtones would be heard

5.



$AB = v_p \cdot t$

$AC = v \cdot t$

$\cos 60° = \frac{AB}{AC} = \frac{v_p t}{v \cdot t}$

$v = \frac{v_p}{2}$

6. $V_1 = \frac{1000}{3} m/s$

$V \propto \sqrt{T}$

$\frac{dV}{V} = \frac{1}{2}\frac{dT}{T}$

$[\because\ dv = 336 - \frac{1000}{3} = \frac{1008-1000}{3} = \frac{8}{3}\ ]$

$\frac{8\times3}{3\times1000} = \frac{1}{2}\times\frac{dT}{273}$

$dT = \frac{273\times2\times8}{1000} = 4.36°C$

7. Frequency of sound source (f_0) = 500 Hz

When observer is moving away from the source

Apparent frequency $f_1 = 480 = f_0\left(\frac{\nu-\nu'_0}{\nu}\right)$ ....(i)

And when observer is moving towards the Source $f_2 = 530 = f_0\left(\frac{\nu+\nu''_0}{\nu}\right)$ ....(ii)

From equation (i)

$480 = 500\left(\frac{300-\nu'_0}{300}\right)$

$\nu'_0 = 12\ m/s$

From equation (ii)

$530 = 500\left(1+\frac{\nu''_0}{\nu}\right)$

$\therefore\ \nu''_0 = 18$ m/s

8. $f_{app} = f_{act}\left(\frac{V \pm V_0}{V \mp V_s}\right)$

$1000 = f_{act}\left(\frac{350-0}{350+(-50)}\right)$ and $f' = f_{act}\left(\frac{350}{350+50}\right)$

$\frac{1000}{f'} = \frac{400}{300}$

$\Rightarrow\ f'_{act} = \frac{1000\times300}{400};\quad f'_{act} = 750$ Hz

9. $120 = 10\log_{10}\frac{I}{10^{-12}}$

$\Rightarrow \quad \dfrac{I}{10^{-12}} = 10^{12} \qquad \Rightarrow I = 1\ W/m^2$

$I = \dfrac{2}{4\pi r^2} = 1$

$\Rightarrow r = \sqrt{\dfrac{2}{4\pi}} m = 0.399m$

= 40 cm

10. l_1 = 30 cm, l_2 = 70 cm

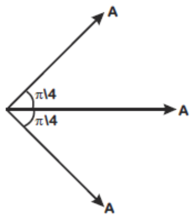
$\therefore \quad \dfrac{\lambda}{2} = (l_2 - l_1) = 40\,cm$

$\Rightarrow \quad \lambda$ = 80 cm

$\therefore \quad v = f\lambda$ = 480 × (0.8) m/s

= 384 m/s

11. $I_0 = CA^2$



$A_R = A + A\sqrt{2} = A(1+\sqrt{2})$

$I_R = CA_R^2$

$= CA^2\left(1+\sqrt{2}\right)^2$

$I_R = I_0\left(1+\sqrt{2}\right)^2 = 5.8279 I_0$

12. $\left(\dfrac{\lambda}{2}\right) \times n = 1.5$, n is odd integer

$\lambda \times m = 5$, m is integer

$\Rightarrow \quad \lambda$ can be $\dfrac{1}{1}, \dfrac{1}{3}, \dfrac{1}{5}$

as $\lambda = \dfrac{3}{n}$ and, $\lambda = \dfrac{5}{m}$

13. $\because \quad \Delta P_0 = B\dfrac{\omega}{v} \times S_0$

$\Rightarrow \quad S = \dfrac{\Delta P \times v}{B\omega} = \dfrac{\Delta P \times v}{\rho v^2 \times 2\pi f}$

$\Rightarrow \quad S \propto \dfrac{\Delta P}{\rho v f}$

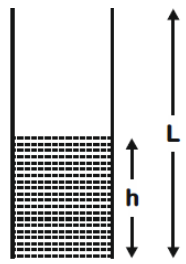
$\Rightarrow \quad S = \dfrac{\Delta P}{\rho v f}$

$= \dfrac{10}{1 \times 300 \times 1000}$

$= \dfrac{1}{30} mm$

$\approx \dfrac{3}{100} mm$

14.



$L - h_1 = n\dfrac{\lambda}{2} + \dfrac{\lambda}{4}$

$L - h_2 = (n-1)\dfrac{\lambda}{2} + \dfrac{\lambda}{4}$

$\Rightarrow \quad \dfrac{\lambda}{2} = h_2 - h_1 = 24.5 - 17.0 = 7.5\,cm$

$\Rightarrow \quad \lambda$ = 15 cm

$u = f\lambda$

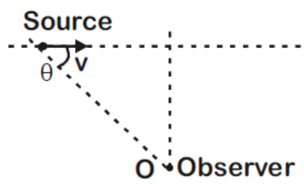
f = 2200 Hz

15. $f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$

$k = \dfrac{YA}{L}$

$f = \left(\dfrac{1}{2\pi}\right)\sqrt{\dfrac{YA}{mL}}$

16.



While approaching

$\nu = \nu_0\left(\dfrac{c}{c - v\cos\theta}\right)$

While receding

$$\nu = \nu_0\left(\frac{c}{c + v\cos\theta}\right)$$

17. Initially beat frequency = 5 Hz

so, $\rho_A = 340 \pm 5 = 345\text{Hz}$, or 335 Hz

after filing frequency increases slightly

so, new value of frequency of A > ρ_A

Now, beat frequency = 2Hz

$\Rightarrow \rho_A = 340 \pm 2 = 342\text{Hz}$, or 338 Hz

hence, original frequency of A is ρ_A = 335 Hz

18. $f_b = f_1 - f_2$

$$\frac{v}{4.08} - \frac{v}{4.16} = \frac{40}{12}$$

$\Rightarrow$ v = 707.2

19. vair = 300 m/s

$$v_{gas} = \sqrt{\frac{B}{2\rho_{air}}} = \frac{300}{\sqrt{2}} = 150\sqrt{2}\,m/s$$

$$f_{n^{th}harmonics} = \frac{nv}{2L} \text{(open organ pipe)}$$

$$\therefore \quad f_1 - f_0 = \frac{v_{gas}}{2L} = \frac{150\sqrt{2}}{2\times 1} = 75\sqrt{2}\,\text{Hz.}$$

20. Sound level decreases by 5dB every km so sound level decreased in 20 km = 100 dB

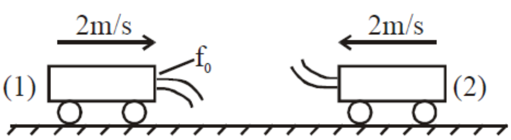
$$\beta_2 - \beta_1 = 10\log_{10}\frac{I_2}{I_1}$$

$$-100 = 10\log_{10}\frac{I_2}{I_1} \Rightarrow \frac{I_1}{I_2} = 10^{10}$$

$I_2 = 10^{-10}\, I_1 \Rightarrow P_2 = 10^{-10}\, P_1 = 10^{-8}$ W

x = 8

21.



Frequency of sound heard by car-1, which comes by reflection from car-2

$$f_1 = f_0\left(\frac{340+2}{340-2}\right)\left(\frac{340+2}{340-2}\right)$$

$$= f_0\left(\frac{342}{338}\right)^2$$

Frequency of sound coming directly from car-2

$$f_2 = f_0\left(\frac{340+2}{340-2}\right)$$

$$\therefore \quad f_1 - f_2 = f_0\left(\frac{342}{338}\right)\left(\frac{342}{338} - 1\right) = 8.09\ ;\ 8$$

22. $f_c = f_0$

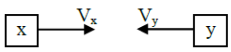
$$\frac{3V_C}{4L} = \frac{2V_0}{2L'}$$

$$L' = \frac{4L}{3}\frac{V_0}{V_C} = \frac{4L}{3}\sqrt{\frac{B.\rho_1}{\rho_2.B}} \quad \text{(B is bulk modulus)}$$

$$= \frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$$

X = 4

23.



V_x = 36 km/hr = 10 m/s

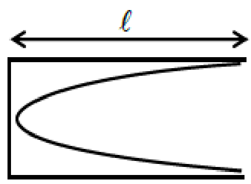
V_y = 72 km/hr = 20 m/s

By doppler's effect

$$f' = f_0\frac{V \pm V_0}{V \pm V_s}$$

$$1320 = f_0\left(\frac{340+20}{340-10}\right) \Rightarrow f_0 = 1210\text{Hz}$$

24.



$$\frac{\lambda}{4} = \ell \Rightarrow \lambda = 4\ell$$

$$f = \frac{V}{\lambda} = \frac{V}{4\ell}$$

$$250 = \frac{340}{4\ell} \Rightarrow \ell = \frac{34}{4\times 25} = 0.34\text{m}$$

ℓ = 34 cm

25. $f_1 = f$

$f_2 = f + 4$

$f_3 = f + 2 \times 4$

$f_4 = f + 3 \times 4$

$f_{20} = f + 19 \times 4$

$f + (19 \times 4) = 2 \times f$

$f = 76$ Hz.

Frequency of last tuning forks = 2f

= 152 Hz

26. Assumption : Ignore word "fundamental mode" in question.

$$\lambda = \frac{V}{f} = \frac{340}{340} = 1\text{m}$$

First resonating length $= \frac{\lambda}{4} = 25\,\text{cm}$

Second resonating length $= \frac{3\lambda}{4} = 75\,\text{cm}$

Third resonating length $= \frac{5\lambda}{4} = 125\,\text{cm}$

Height of water required = 125 – 75 = 50 cm

27. For first resonance

$$\ell_1 + e = \frac{\lambda}{4}$$

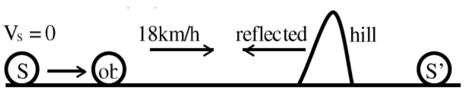
$$\lambda = \frac{336}{400} \times 100\,\text{cm} = 84\,\text{cm} \Rightarrow \frac{\lambda}{4} = 21\,\text{cm}$$

e = 21 – 20 = 1 cm

For third resonance

$$\ell_3 + e = \frac{5\lambda}{4} = 105\,\text{cm} \Rightarrow \ell_3 = 104\,\text{cm}$$

28.



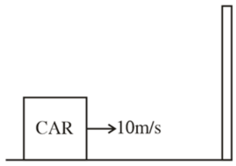
$V_S = 0$, $V_{ob} = 5$m/ s

$$f_{direct} = \left(\frac{320 - 5}{320}\right) 640 = 630\,\text{Hz}$$

$$f_{reflected} = \left(\frac{320 + 5}{320}\right) 640 = 650\,\text{Hz}$$

$f_{beat} = 650 – 630 = 20$Hz

29. The hill will be a secondary source.



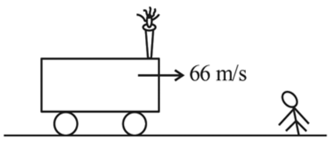
f_1 = frequency of the car w.r.t. the hill

$$f_1 = \left(\frac{v}{v - v_s}\right) f = \left(\frac{330}{320}\right) \times 320 = 330\,\text{Hz}$$

f_2 = Frequency of the sound reflected by hill w.r.t. the car (echo)

$$f_2 = \left(\frac{v + v_0}{v}\right) f_1 = \frac{(330 + 10)}{330} \times 330 = 340\,\text{Hz}$$

30.



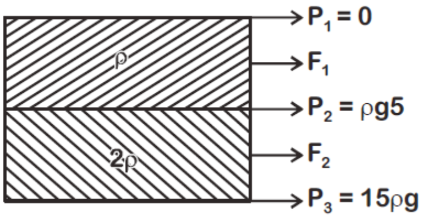
$$f_{app} = f\left(\frac{v}{v - v_s}\right)$$

$$= 320\left(\frac{330}{330 - 66}\right)$$

= 440 Hz

FLUID MECHANICS SOLUTION

1.



$$F_1 = \frac{(P_1 + P_2)}{2}A$$

$$F_2 = \frac{(P_2 + P_3)}{2}A$$

$$\therefore \qquad \frac{F_1}{F_2} = \frac{5\rho g}{20\rho g} = \frac{5}{20} = \frac{1}{4}$$

2. $(P_A - P_B) = \frac{1}{2}\rho\left(V_B^2 - V_A^2\right)$

$$\Rightarrow \qquad \Delta P = \frac{1}{2}\rho\left(V_B^2 - \frac{V_B^2}{4}\right)$$

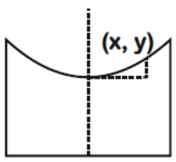
$$\Rightarrow \qquad \Delta P = \frac{3}{8}\rho V_B^2$$

$$V_B = \sqrt{\frac{(\Delta P)8}{3\rho}} = \sqrt{\frac{(\Delta P)4}{1500}} = \sqrt{\frac{700 \times 4}{1500}}\,m/s$$

$$Q = A_B V_B = (20)\left(\sqrt{\frac{28}{15}}\right) \times 100\,\frac{cm^3}{s}$$

$$Q \approx 2720\,cm^3/s$$

3.



$$y = \frac{\omega^2 x^2}{2g}$$

$$x = R \qquad \Rightarrow y = \frac{25\omega^2}{2g}$$

4. $\frac{4}{3}\pi r^3 \rho_w g - mg = ma$

$$\Rightarrow \qquad m = \frac{\frac{4}{3}\pi r^3 \rho_w g}{g + a}$$

= 4.15 gm

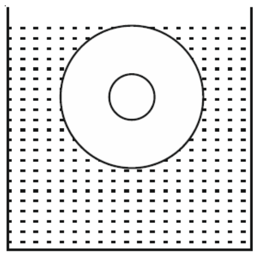
5. |Change in energy| = $U_i - U_f$

$$= (dsx_1)g\frac{x_1}{2} + (dsx_2)g\frac{x_2}{2}$$

$$-2 \times \left\{ds\left(\frac{x_1 + x_2}{2}\right)\right\} g\left(\frac{x_1 + x_2}{4}\right)$$

$$\frac{1}{4}gds(x_2 - x_1)^2$$

6. $\frac{4}{3}\pi R^3 \times \rho_w \times g = \frac{4}{3}\pi\left(R^3 - r^3\right)\rho_m \times g$



$$\Rightarrow \qquad R^3 = \left(R^3 - r^3\right) \times \frac{27}{8}$$

$$\Rightarrow \qquad r = \left(\frac{19}{27}\right)^{\frac{1}{3}} R \approx \frac{8}{9}R$$

7. $P + \frac{1}{2}\rho v^2 = \frac{P}{2} + \frac{1}{2}\rho V^2$

$$\Rightarrow \qquad V = \sqrt{\frac{P}{\rho} + v^2}$$

8. $P_1 = \rho gd + P_0 = 3 \times 10^5$ Pa

$\therefore$ $\rho gd = 2 \times 10^5$ Pa

$P_2 = 2\,\rho gd + P_0$

$= 4 \times 10^5 + 10^5 = 5 \times 10^5$ Pa

$$\%\text{ increase} = \frac{P_2 - P_1}{P_1} \times 100$$

$$= \frac{5 \times 10^5 - 3 \times 10^5}{3 \times 10^5} \times 100 = \frac{200}{3}\%$$

9. For no sliding

$f \geq \rho a v^2$

$\mu mg \geq \rho a v^2$

$\mu \rho A h g \geq \rho a 2gh$

$\mu \geq \frac{2a}{A}$

Option (3)

10. At terminal speed

a = 0

$F_{net} = 0$

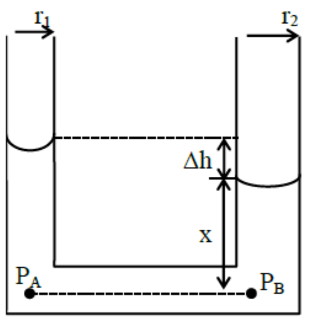
$mg = F_v = 6\pi \eta R v$

$v = \frac{mg}{6\pi\eta R}$

$v = \frac{\rho_w \frac{4\pi}{3} R^3 g}{6\pi\eta R} = \frac{2\rho_w R^2 g}{9\eta} = \frac{400}{81} m/s$

= 4.94 m/s

11.



We have $P_A = P_B$. [Points A and B at same horizontal level]

$\therefore P_{atm} - \frac{2T}{r_1} + \rho g(x + \Delta h) = P_{atm} - \frac{2T}{r_2} + \rho g x$

$\therefore \rho g \Delta h = 2T\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

$= 2 \times 7.3 \times 10^{-2}\left[\frac{1}{2.5 \times 10^{-3}} - \frac{1}{4 \times 10^{-3}}\right]$

$\therefore \Delta h = \frac{2 \times 7.3 \times 10^{-2} \times 10^3}{10^3 \times 10}\left[\frac{1}{2.5} - \frac{1}{4}\right]$

= 2.19 × 10^{-3} m = 2.19 mm

Hence option (2)

12. $v_t = \frac{2}{9}\frac{gr^2(\rho_p - \rho_1)}{\eta}; v_t \propto r^2$

13. Reynold's number is given by $\frac{\rho v d}{\eta}$

14. Let R = radius of combined drop

r = radius of smaller drop

Volume will remain same

$\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$

R = 4r

Q = 64q

q : charge of smaller drop

Q : Charge of combined drop

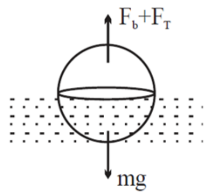
$\frac{\sigma_{bigger}}{\sigma_{smaller}} = \frac{\frac{Q}{4\pi R^2}}{\frac{q}{4\pi r^2}} = \frac{Q}{q}\frac{r^2}{R^2} = 64\frac{r^2}{16r^2} = 4$

$\frac{\sigma_{bigger}}{\sigma_{smaller}} = \frac{4}{1}$

15. $F_V = mg - F_B$

$= mg - \left(\frac{m}{d_1} \times d_2\right)g \quad = mg\left(1 - \frac{d_2}{d_1}\right)$

16.



Boyant force + surface tension = mg

$\sigma \frac{V}{2} g + 2\pi RT = \rho V g$

$2\pi RT = \frac{(2\rho - \sigma)}{2}\frac{4}{3}\pi R^3 g; \left[V = \frac{4}{3}\pi R^3\right]$

$R^2 = \frac{3T}{(2\rho - \sigma)g} \Rightarrow R = \sqrt{\frac{3 \times 7.5 \times 10^{-2} N - m^{-1}}{(2\rho - \sigma) \times 10}}$

$R = \frac{3}{20\sqrt{(2\rho - \sigma)}} m = \frac{15}{\sqrt{2\rho - \sigma}} cm$

17. $F = \rho a v^2 = 10^3 \times 10 \times 10^{-4} \times 20 \times 20$

F = 400

18. Apply Bernoulli's theorem between Piston and hole $P_A + \rho g h = P_0 + \frac{1}{2}\rho v_e^2$

Assuming there is no atmospheric pressure on piston

$$\frac{5\times10^5}{\pi} + 10^3 \times 10 \times 10 = 1.01\times10^5 + \frac{1}{2}\times10^3 \times v_e^2$$

v_e = 17.8 m/s

19. $P_2A - P_1A = 5.4 \times 10^5 \times g$

$P_2 - P_1 = \frac{5.4\times10^6}{500} = 5.4 \times 2 \times 10^2 \times 10 = 10.8 \times 10^3$

$P_2 + 0 + \frac{1}{2}\rho V_2^2 = P_1 + 0 + \frac{1}{2}\rho V_1^2$

$P_2 - P_1 = \frac{1}{2}\rho(V_1^2 - V_2^2) = \frac{1}{2} = \rho(V_1 - V_2)(V_1 + V_2)$

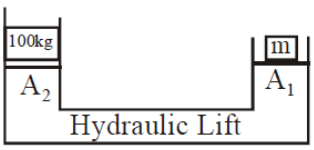
$10.8 \times 10^3 = \frac{1}{2} \times 1.2(V_1 - V_2) \times 2 \times 3 \times 10^2$

$10.8 \times 10 = 3.6(V_1 - V_2)$

$V_1 - V_2 = 30$

$$\left(\frac{V_1 - V_2}{V}\right)\times100 = \frac{30}{300}\times100 = 10\%$$

20. Using Pascals law



$$\frac{100\times g}{A_2} = \frac{mg}{A_1} \qquad ...(i)$$

Let m mass can lift M_0 in second case then

$$\frac{M_0 g}{16A_2} = \frac{mg}{A_1/16} \qquad ...(ii)$$

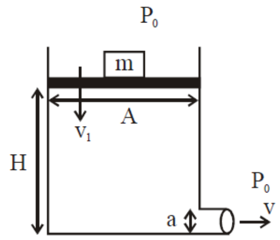
$$\left\{\text{Since } A = \frac{\pi d^2}{4}\right\}$$

From equation (1) and (2) we get

$$\frac{M_0}{16\times100} = 16$$

$= M_0 = 25600$ kg

21.



m = 24 kg

A = 0.4 m^2

a = 1 cm^2

H = 40 cm

Using Bernoulli's equation

$$\Rightarrow \left(P_0 + \frac{mg}{A}\right) + \rho g H + \cancelto{0}{\frac{1}{2}\rho v_1^2}$$

$$= p_0 + 0 + \frac{1}{2}\rho v^2 \qquad ...(1)$$

$\Rightarrow$ Neglecting v_1

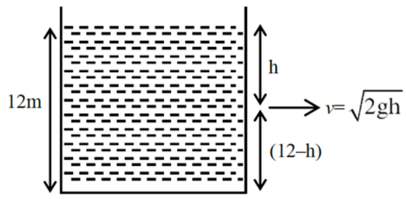
$$\Rightarrow v = \sqrt{2gH + \frac{2mg}{A\times\rho}}$$

$\Rightarrow v = \sqrt{8 + 1.2}$

$\Rightarrow$ v = 3.033 m/s

$\Rightarrow v\ ;\ 3m/s$

22.



$$R = \sqrt{2gh} \times \sqrt{\frac{(12-h)\times2}{g}}$$

$\sqrt{4h(12-h)} = R$

For maximum R

$\frac{dR}{dh} = 0 \Rightarrow h = 6$ m

23. From continuity equation

$av_1 = \frac{a}{2}v_2$

$v_2 = 2v_1$

From Bernoulli's theorem,

$$P_1+\rho gh_1+\frac{1}{2}\rho v_1^2=P_2+\rho gh_2+\frac{1}{2}\rho v_2^2$$

$$P_1+P_2=\rho\left[\left(\frac{v_2^2-v_1^2}{2}\right)+g(h_2-h_1)\right]$$

$$4100=800\left[\left(\frac{4v_1^2-v_1^2}{2}\right)+10\times(0-1)\right]$$

$$\frac{41}{8}+10=\frac{3v_1^2}{2}$$

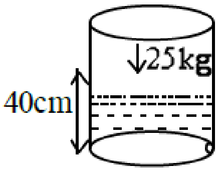
$$\frac{121}{8}\times\frac{2}{3}=v_1^2$$

$$v_1=\sqrt{\frac{121}{4\times 3}\times\frac{3}{3}}$$

$$v_1=\frac{\sqrt{363}}{6}\,m/s$$

X = 363

24.



$$P_0+\frac{250}{0.5}+\rho g(40\times 10^{-2})=P_0+\frac{1}{2}\rho v^2$$

$$500+\frac{1000\times 10\times 40}{100}=\frac{1}{2}\times 1000\times v^2$$

V = 3 m/s

V = 300 cm/s

25. Speed after falling through height h
Should be equal to terminal velocity

$$\sqrt{2gh}=\frac{2}{9}\frac{r^2(d-\rho)g}{\eta}$$

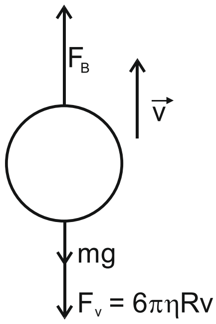
$$\sqrt{2gh}=\frac{2\times 10^{-8}}{9}\frac{(10000-1000)\times 10}{10^{-5}}$$

$$=\frac{2}{9}\times 10^{-8}\frac{9\times 10^4}{10^{-5}}=20$$

2 × 10 × h = 400

h = 20 m

26. As the bubble is rising steadily the net force acting on it will be zero



(Because of density of air the value of mg can be neglected)

$$\text{so } F_v=F_B=\frac{4\pi}{3}R^3\rho g=6\pi\eta Rv$$

Putting R = 1 mm = 10^{-3} m

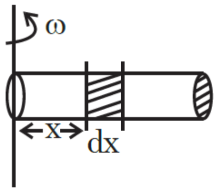
$\rho = 1.75 \times 10^3$ kg/m^3

g = 10 m/s^2

v = 0.35×10^{-2} m/s

$$\eta=\frac{10}{9}$$ = 1.11 SI unit = 11 poise (CGS)

27.



$$F=\int(dm)\omega^2x$$

$$=\int_0^L\left(\frac{m}{L}dx\right)\omega^2x$$

$$=\frac{m}{L}\omega^2\frac{L^2}{2}=\frac{m\omega^2L}{2}$$

$$\omega=\sqrt{\frac{2}{mL}}\sqrt{F}$$

$$=\sqrt{\frac{2}{0.25\times 0.5}}\sqrt{F}$$

$$=\sqrt{16}\sqrt{F}$$

$$=4\sqrt{F}$$

28. $F_V + F_B = mg$ (v = constant)

$F_V = mg - F_B$

$= \rho_B Vg - \rho_L Vg$

$= (\rho_B - \rho_L) Vg$

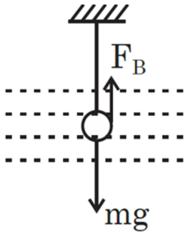
$$= (8-1.3)\times 10^{+3}\times\frac{0.3\times 10^{-3}}{8\times 10^{3}}\times 10$$

$$= \frac{6.7\times 0.3}{8}\times 10^{-2}\ (g=10)$$

$$= \frac{67\times 3}{8}\times 10^{-4} = 25.125\times 10^{-4}$$

= 25.125

29. mg' = mg – F_B



$$g' = \frac{mg - F_B}{m} = \frac{\rho_B Vg - \rho_w Vg}{\rho_B V} = \left(\frac{\rho_B - \rho_w}{\rho_B}\right)g$$

$$= \frac{5-1}{5}\times g = \frac{4}{5}g$$

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

$$\frac{T'}{T} = \sqrt{\frac{g}{g'}} = \sqrt{\frac{g}{\frac{4}{5}g}} = \sqrt{\frac{5}{4}}$$

$$T' = T\sqrt{\frac{5}{4}} = \frac{10}{2}\sqrt{5}$$

$$T' = 5\sqrt{5}$$

30. $A_1V_1 = A_2V_2$

$750 \times 10^{-4} V_1 = 500 \times 10^{-6} \times 0.3$

$$V_1 = \frac{500\times 3\times 10^{-3}}{750} m/s = 2\times 10^{-3}\ m/s$$

$$\frac{dh}{dt} = -2\times 10^{-3} m/s$$

ELASTICITY AND VISCOSITY (PROPERTIES OF SOLID) & SURFACE TENSION SOLUTION

1. $\Delta P = \frac{mg}{a}$

$K = -\frac{\frac{mg}{a}}{\frac{4\pi r^2 dr}{\frac{4}{3}\pi r^3}}$

$\frac{dr}{r} = \frac{mg}{2ka}$

2. $\rho = \frac{128kg}{m^3} = \frac{128}{\left(\frac{100}{25}\right)^3}\frac{1000}{50} = \frac{128}{4^3}\times 20 = 40$

3. Area of wire A = πr^2

$\frac{Mg}{\pi r^2} = \frac{\Delta\ell}{\ell_0}Y$

$\Rightarrow \quad \frac{Mg}{\pi r^2} = \frac{4\times 10^{-3}}{2}Y$ .....(i)

$8v_0\rho_0 = M$

Now when load is immersed in liquid then

$\frac{8v_0\rho_0 g - 2v_0\rho_0 g}{\pi r^2} = \frac{\Delta\ell}{\ell_0}Y$ ....(ii)

$\Rightarrow \quad \frac{6v_0\rho_0 g}{\pi r^2} = \frac{\Delta\ell'}{\ell_0}Y$

$\frac{\Delta\ell'}{4\times 10^{-3}} = \frac{6v_0\rho_0 g}{8v_0\rho_0 g}$

$\Rightarrow \quad \Delta\ell' = \frac{6}{8}\times 4\times 10^{-3} m$

$\Rightarrow \quad \Delta\ell' = 3\times 10^{-3} m = 3mm$

4. $\frac{1}{2}\cdot\left(\frac{YA}{L}\right)(\Delta l)^2 = \frac{1}{2}mv^2$

$\Rightarrow Y = \frac{mv^2 L}{A(\Delta l)^2}$

$= \frac{0.02\times 400\times 0.42\times 4}{\pi\times 36\times 10^{-6}\times 0.04}$

$= 2.3 \times 10^6$ N/m^2

So, order is 10^6.

5. $\Delta L = \frac{FL}{YA}$

$\Rightarrow \frac{L_A}{Y_A r_A^2} = \frac{L_B}{Y_B r_B^2}$

$\Rightarrow r_A = \sqrt{\frac{L_A}{L_B}\cdot\frac{L_B}{L_A}}\cdot r_B$

$= \sqrt{\frac{2\times 2\times 4}{3\times 7}}\times 2mm$

$= \frac{4}{4.58}\times 2 = 1.7mm$

6. Ratio of surface tension

$\frac{S_{Hg}}{S_{Water}} = 7.5$

$\frac{\rho_{Hg}}{\rho_w} = 13.6$ & $\frac{\cos\theta_{Hg}}{\cos\theta_w} = \frac{\cos 135^\circ}{\cos 0^\circ} = \frac{1}{\sqrt{2}}$

$\frac{R_{Hg}}{R_{Water}} = \left(\frac{S_{Hg}}{S_W}\right)\left(\frac{\rho_w}{\rho_{Hg}}\right)\left(\frac{\cos\theta_{Hg}}{\cos\theta_W}\right)$

=

$7.5\times\frac{1}{13.6}\times\frac{1}{\sqrt{2}} = 0.4 = \frac{2}{5}$

7. Stress = $\frac{400}{\pi r^2} \le 379\times 10^6 N/m^2$

$\Rightarrow r^2 \ge \frac{400}{379\times 10^6\pi}$; $\quad 2r \ge 1.15$ mm

8. Y- Younge modulus, K- Bulk modulus,

η- modulus of rigidity

We know that

$y = 3k\,(1 - 2\sigma)$

$\sigma = \frac{1}{2}\left(1 - \frac{y}{3k}\right)$ ....(i)

$y = 2\eta\,(1 + \sigma)$

$\sigma = \frac{y}{2\eta} - 1$ ....(ii)

From Eq.(i) and Eq. (ii)

$$\frac{1}{2}\left(1-\frac{Y}{3k}\right)=\frac{y}{2\eta}-1$$

$$1-\frac{y}{3k}=\frac{y}{\eta}-2$$

$$\frac{y}{3k}=3-\frac{y}{\eta}$$

$$\frac{y}{3k}=\frac{3\eta-y}{\eta}$$

$$\frac{\eta y}{3k}=3\eta-y$$

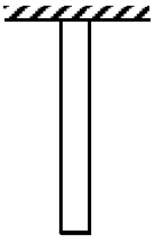
$$k=\frac{\eta y}{9\eta-3y}$$

9. Viscous force = Weight

$$=\rho\times\left(\frac{4}{3}\pi r^3\right)g$$

$= 3.9 \times 10^{-10}$

10.



We know

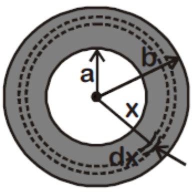
$$\Delta\ell=\frac{WL}{2AY},$$

$$\Delta\ell=\frac{10\times1}{2\times5\times100\times10^{-4}\times2\times10^{11}}$$

$$\Delta\ell=\frac{1}{2}\times10^{-9}=5\times10^{-10}\,m$$

Option (4)

11.



$$dR=\frac{(\rho)(dx)}{4\pi x^2}$$

$$R=\int dR$$

$$=\left(\frac{\rho}{4\pi}\right)\times\int_a^b\frac{dx}{x^2}$$

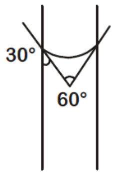
$$=\left(\frac{\rho}{4\pi}\right)\cdot\left(\frac{1}{a}-\frac{1}{b}\right)$$

12. $$T.2\pi r+\frac{2}{3}\pi r^3\rho g=\frac{4}{3}\pi r^3 dg$$

$$T=\frac{r^2}{3}(2d-\rho)g$$

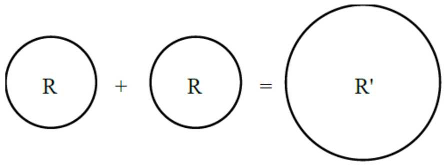
$$r=\sqrt{\frac{3T}{(2d-\rho)g}}$$

13. Angle of contact = 30°



$$h=\frac{2T\cos\theta}{r\rho g}=\frac{2\times0.05\times\left(\frac{\sqrt{3}}{2}\right)}{0.15\times10^{-3}\times667\times10}=0.087\,m$$

14.



$$\frac{4}{3}\pi R^3+\frac{4}{3}\pi R^3=\frac{4}{3}\pi R'^3$$

$$R'=2^{\frac{1}{3}}R \qquad ...(i)$$

$$A_i=2[4\pi R^2]$$

$$A_f=4\pi R'^2$$

$$\frac{U_i}{U_f}=\frac{A_i}{A_f}=\frac{2R^2}{2^{2/3}R^2}=2^{1/3}$$

15. In series combination $\Delta l = \ell_1 + \ell_2$

$$Y=\frac{F/A}{\Delta\ell/\ell}\Rightarrow\Delta\ell=\frac{F\ell}{AY}\Rightarrow\Delta\ell\propto\frac{\ell}{Y}$$

Equivalent length of rod after joing is = 2ℓ

As, lengths are same and force is also same in series

$\Delta\ell = \Delta\ell_1 + \Delta\ell_2$

$$\frac{\ell_{eq}}{Y_{eq}}=\frac{\ell}{Y_1}+\frac{\ell}{Y_2}\Rightarrow\frac{2\ell}{Y}=\frac{\ell}{Y_1}+\frac{\ell}{Y_2}$$

$\therefore Y = \dfrac{2Y_1Y_2}{Y_1+Y_2}$

16. d = 2cm; r = 1 cm; T = 0.075

$\Delta SE = T\Delta A$

$= 0.075\ A\ (A_f - A_1)$

$A_i = 4\pi r^2$

$A_f = 4\pi r_0^2 \mid \times 64$

By volume conservation

$\dfrac{4}{3}\pi r^3 = 64.\dfrac{4}{3}\pi r_0^3$

$r_0 = \dfrac{r}{4}$

$A_f = 4\pi\left(\dfrac{r}{4}\right)^2 .64 = 16\pi r^2$

$\Delta SE = 0.075\ (16\ \pi r^2 - 4\pi r^2)$

$= 0.075\ (12\pi\ (0.01)^2) = 2.8 \times 10^{-4}$ J

17. Initial surface energy = TA

Where T is surface tension and A is surface area

$U_i = \left(\dfrac{75\times10^{-5}}{10^{-2}}\dfrac{N}{m}\right)\times\left[4\pi(1\times10^{-2})^2\right]$

$= 75 \times 10^{-3} \times 4\pi \times 10^{-4} = 942 \times 10^{-7}$ J

To get final radius of drops by volume conservation

$\dfrac{4}{3}\pi R^3 = 729\left(\dfrac{4}{3}\pi r^3\right)$

R = Initial radius

r = final radius

$r = \dfrac{R}{(729)^{1/3}} = \dfrac{R}{9} = \dfrac{1}{9}$cm

Final surface energy

$U_f = 729\ (TA)$

$= 729\left[\dfrac{75\times10^{-5}}{10^{-2}}\dfrac{N}{m}\right]\times\left[4\pi\left(\dfrac{1}{9}\times10^{-2}\right)^2\right]$

$= 729\left[75\times10^{-3}\times\dfrac{4\pi\times10^{-4}}{81}\right]$

$= 9\ [942 \times 10^{-7}$ J]

Gain in surface energy

$\Delta U = 9 \times 942 \times 10^{-7} - 942 \times 10^{-7}$

$= 8 \times 942 \times 10^{-7} = 7536 \times 10^{-7}$ J

$= 7.5 \times 10^{-4}$ J

18. Surface area of soap bubble = $2 \times 4\pi R^2$

Work done = change in surface energy × T_s

$= T_s \times 8\pi \times \left(R_2^2 - R_1^2\right)$

$= 2 \times 10^{-2} \times 8 \times \dfrac{22}{7} \times 49 \times \dfrac{3}{4} \times 10^{-4}$

$= 18.48 \times 10^{-4}$ J

19. $Y = \dfrac{E/A}{\dfrac{\Delta\ell}{\ell}}$

$\Rightarrow F = \dfrac{YA}{\ell}\Delta\ell$

$\left(\dfrac{A\Delta\ell}{\ell}\right)_1 = \left(\dfrac{A\Delta\ell}{\ell}\right)_2$

$\Rightarrow \dfrac{\Delta\ell_2}{\Delta\ell_1} = \dfrac{A_1}{A_2}\times\dfrac{\ell_2}{\ell_1}$

$\Rightarrow \dfrac{\Delta\ell_2}{0.2} = \dfrac{1}{2.4\times2.4}\times\dfrac{2}{1}$

$\Rightarrow \Delta\ell_2 = 6.9\times10^{-2}$ mm

20. First case $P_1 = \dfrac{V^2}{R} = \dfrac{(240)^2}{36}$

Second case Resistance of each half = 18 Ω

$P_2 = \dfrac{(240)^2}{18} + \dfrac{(240)^2}{18} = \dfrac{(240)^2}{9}$

$\dfrac{P_1}{P_2} = \dfrac{1}{4}$

x = 4.00

21. L = 1m

$\Delta L = 0.4 \times 10^{-3}$ m

m = 1kg

$d = 0.4 \times 10^{-3}$ m

$\dfrac{F}{A} = Y\times\dfrac{\Delta L}{L}$

$Y = \dfrac{FL}{A\Delta L} = \dfrac{(mg).(1)}{\left(\dfrac{\pi d^2}{4}\right)0.4\times10^{-3}}$

$$\Rightarrow \frac{10\times 4}{\pi(0.4\times 10^{-3})^2\times 0.4\times 10^{-3}}$$

$$Y = \frac{40}{\pi(0.4\times 10^{-3})^3}$$

$$Y = \frac{40\times 7}{22\times 64\times 10^{-3}\times 10^{-9}}$$

$Y = 0.199 \times 10^{+12}$ N/m^2

$$\frac{\Delta Y}{Y} = \frac{\Delta F}{F} + \frac{\Delta L}{L} + \frac{\Delta A}{A} + \frac{\Delta(\Delta L)}{(\Delta L)}$$

$$= \frac{0.02}{0.4} + 2\frac{\Delta d}{d} = \frac{0.2}{4} + 2\times\frac{0.01}{0.4} = \frac{0.1}{2} + \frac{0.1}{2} = 0.1$$

$\Rightarrow \Delta Y = 0.1 \times Y$

$= 0.199 \times 10^{11} = 1.99 \times 10^{10}$

22. $\frac{F}{A} = \eta\frac{x}{\ell} \Rightarrow \frac{F\ell}{A\eta} = x$

$\Rightarrow$

$$x = \frac{18\times 10^4\times 60\times 10^{-2}}{60\times 10^{-2}\times 15\times 10^{-2}\times 25\times 10^9} = 48\times 10^{-6}\text{m} = 48\mu\text{m}$$

23. $T = \frac{mv^2}{\ell} = \frac{10\times v^2}{0.5} = 20v^2$

T_{max} = Breaking stress × Area

$= 5 \times 10^8 \times 10^{-4} = 5 \times 10^4$

$20\,V^2 = 5 \times 10^4$

$$V = \sqrt{\frac{1}{4}10^4} = 50\,\text{m/s}$$

24. $h = \frac{2T\cos\theta}{\rho g r}$

$$\Rightarrow \quad T = \frac{\rho g r \times h}{2\cos\theta} = \frac{900\times 10\times 15\times 15}{100\times 1000\times 100\times 2}$$

$\Rightarrow$ T = 0.10125 Nm^{-1}

$\Rightarrow$ T = 101.25 $\approx$ 101 milli Newton m^{-1}

25. $4t_T = 100\times\frac{4}{3}\pi r^3$

$$= 100\times\frac{4\pi}{3}\times\frac{3}{40\pi}\times 10^{-9} = 10^{-8}\text{ cm}^3$$

$t_T = 25 \times 10^{-10}$ cm

$= 25 \times 10^{-12}$ m

$t_0 = 0.01\, t_T = 25 \times 10^{-14}$ m

= 25

26. For A = $\frac{E}{\pi r^2} = y\frac{2mm}{a}$ .....(1)

For B = $\frac{E}{\pi.16r^2} = y\frac{4mm}{b}$ .....(2)

$\therefore$ (1)/ (2)

$$16 = \frac{2b}{4a}$$

$\frac{a}{b} = \frac{1}{32}$ $\therefore$ **Answer = 32**

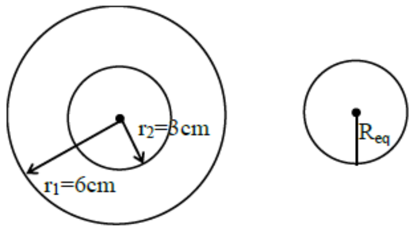
27. By energy conservation

$$\frac{1}{2}.\frac{YA}{L}.x^2 = \frac{1}{2}mv^2$$

$$\frac{0.5\times 10^9\times 10^{-6}\times(0.04)^2}{0.1} = \frac{20}{1000}v^2$$

$\therefore v^2 = 400$

v = 20 m/s



28.

Excess pressure inside the smaller soap bubble

$$\Delta P = \frac{4S}{r_1} + \frac{4S}{r_2} \quad \text{.... (i)}$$

The excess pressure inside the equivalent soap bubble

$$\Delta P = \frac{4S}{R_{eq}} \quad \text{... (ii)}$$

From (i) & (ii)

$$\frac{4S}{R_{eq}} = \frac{4S}{r_1} + \frac{4S}{r_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{6} + \frac{1}{3}$$

R_{eq} = 2 cm

Ans. 2.00

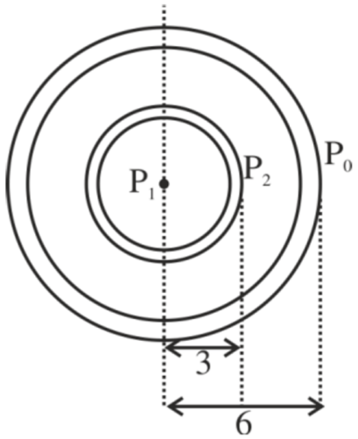
29. $F = \eta A \dfrac{\Delta v_x}{\Delta y}$

$$\frac{F}{A} = \eta \frac{\Delta v_x}{\Delta y}$$

$$\Rightarrow 10^{-3} = 10^{-2} \times \frac{36 \times 1000}{h \times 3600}$$

$$\Rightarrow h = 10^{-2} \times \frac{36 \times 1000}{10^{-3} \times 3600} = 100\,m$$

30.

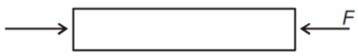


$$P_2 - P_0 = \frac{4T}{6} \;\&\; P_1 - P_2 = \frac{4T}{3}$$

$$\Rightarrow P_1 - P_0 = \frac{4T}{2} = 2$$

CALORIMETRY AND THERMAL EXPANSION SOLUTION

1. $\Delta L_{Themal} = L_0\, \alpha\, \Delta T$ (+ve)



$$\Delta L_{Mechanical} = \frac{FL_0}{AY}(-ve)$$

$$\Delta L_{eff} = 0 \Rightarrow L_0 \alpha \Delta T = \frac{FL_0}{AY}$$

$$\Rightarrow Y = \frac{F}{A\alpha\Delta T} = \frac{F}{A\alpha\Delta T}$$

2. $192 \times s(100 - 21.5) = 128 \times 0.394 \times (21.5 - 8.4) + 240 \times 4.18 \times (21.5 - 8.4)$

$$\Rightarrow s = \frac{660.65 + 13142}{15072}$$

$$\Rightarrow s ;\ 916\ J\,kg^{-1}\,K^{-1}$$

3. $$\frac{2x_0}{3} = 100^\circ C$$

$$\Rightarrow \frac{x_0}{2} = \frac{x_3}{3} + \frac{x_0}{6}$$

$$= 0^\circ + \frac{1}{6} \times \frac{3 \times 100}{2} = 25^\circ C$$

4. $$\frac{1}{2}k\Delta x^2 = E(\text{dissipated})$$

$$\therefore \quad \frac{1}{2} \times 800 \times \left(\frac{2 \times 2}{100 \times 100}\right) = \frac{16}{100} J$$

$$\frac{16}{100} = \frac{1}{2} \times 400 \times \Delta T + 1 \times 4184 \times \Delta T$$

$$\Rightarrow \quad \frac{16}{100} = (200 + 4184)\Delta T = 4384\Delta T$$

$$\therefore \quad \Delta T = \frac{16}{4384 \times 100} = 3.6 \times 10^{-5} K$$

5. $M_1 \times 5 + M_1 L = M_2\ 50$

$$L = \frac{50M_2}{M_1} - 5$$

6. $\Delta Q = 1 \times 4200 \times 80 + 2260 \times 10^3$ J

$= (336 + 2260) \times 10^3$ J $= 2596 \times 10^3$ J

$$\Delta Q = I_{rms} V_{rms} t = 200 \times \frac{200}{20} t = 2000t$$

$$\Rightarrow t = \frac{2596}{2} s \approx 21.6 \text{minutes} \approx 22 \text{minutes}$$

7. $m[540 + (100 - 31)] = 200 \times [31 - 25]$

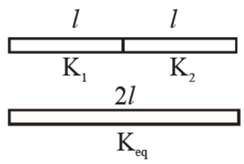
$$M = \frac{1200}{609}$$

$; \ 2gm$

8. $(L_1 + L_2)\alpha_{eq} \times \Delta T = L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$

$$\alpha_{eq} = \frac{L_1\alpha_1 + L_2\alpha_2}{(L_1 + L_2)}$$

9.



$$R_{eff} = \frac{l}{K_1 A} + \frac{l}{K_2 A} = \frac{2l}{K_{eq} A}$$

$$K_{eff} = \frac{2K_1K_2}{K_1 + K_2}$$

10.

$$Y = \frac{FL}{A\Delta L} \Rightarrow Y = \frac{T_1 \ell_0}{A(\ell_1 - \ell_0)} = \frac{T_2 \ell_0}{A(\ell_2 - \ell_0)}$$

$$1 = \frac{T_1(\ell_2 - \ell_0)}{T_2(\ell_1 - \ell_0)}$$

$$T_2\ell_1 - T_2\ell_0 = T_1\ell_2 - T_1\ell_0$$

$$(T_1 - T_2)\ell_0 = T_1\ell_2 - T_2\ell_1$$

$$\ell_0 = \left(\frac{T_1\ell_2 - T_2\ell_1}{T_1 - T_2}\right)$$

11. $$\left(\frac{\Delta Q}{\Delta t}\right)_A = \left(\frac{\Delta Q}{\Delta t}\right)_B$$

$$mS_A\left(\frac{\Delta T}{\Delta t}\right)_A = mS_B\left(\frac{\Delta T}{\Delta t}\right)_B$$

$$\frac{S_A}{S_B} = \frac{\left(\frac{\Delta T}{\Delta t}\right)_B}{\left(\frac{\Delta T}{\Delta t}\right)_A} = \frac{90/6}{120/3} = \frac{15}{40} = \frac{3}{8}$$

12.

X	Y	Z
$m_1 = m$	$m_2 = m$	$m_3 = m$
$T_1 = 10°C$	$T_2 = 20°C$	$T_3 = 30°C$
s_1	s_2	s_3

when x & y are mixed, $T_{f_1} = 16°C$

$m_1s_1T + m_2s_2T_2 = (m_1s_1 + m_2s_2)Tf_1$

$s_1 \times 10 + s_2 \times 20 = (s_1 + s_2) \times 16$

$s_1 = \frac{2}{3}s_2$ ....(i)

when y & z are mixex, $T_{f_2} = 26°C$

$m_2s_2T + m_3s_3T_3 = (m_3s_3 + m_3s_3)Tf_2$

$s_2 \times 20 + s_3 \times 30 = (s_2 + s_3) \times 26$

$s_3 = \frac{3}{2}s_2$ .....(ii)

when x & z are mixex

$m_1s_1T_1 + m_3s_3T_3 = (m_1s_1 + m_3s_3)Tf$

$$\frac{2}{3}s_2 \times 10 + \frac{3}{2}s_2 \times 20 = \left(\frac{2}{3}s_2 + \frac{3}{2}s_2\right)T_f$$

$T_f = 23.84°C$

Ans (3)

13. $R = \frac{\ell}{\theta}$

$$\text{Time} = \frac{4 \times 2\pi R}{v} = \frac{4 \times 2\pi}{v}\left(\frac{\ell}{\theta}\right)$$

put $\ell = 4.4 \times 9.46 \times 10^{15}$

$v = 8 \times 1.5 \times 10^{15}$

$$\theta = \frac{4}{3600} \times \frac{\pi}{180}\text{rad}$$

We get time = 4.5×10^{10} sec

14. Change in P.E. = Heat energy

$mgh = mS\Delta T$

$$\Delta T = \frac{gh}{S} = \frac{10 \times 63}{4200J/kgC}$$

$= 0.147°$ C

15. $\Delta T \;\alpha\; R \;\alpha\; \frac{\ell}{k}$

$$\frac{\Delta T_1}{\Delta T_2} = \frac{\ell_1}{k_1} \times \frac{k_2}{\ell_2} = \frac{16}{k_1} \times \frac{k}{8}$$

$$\frac{20}{80} = \frac{16}{k_1} \times \frac{k}{8} \rightarrow k_1 = 8k$$

16. $$\frac{1}{2} \times 1.5 \times 60^2 \times \frac{1}{4} = 0.1 \times 420 \times \Delta T$$

17. Increase in volume $\Delta V = \gamma V_0 \Delta T$

$\gamma = 3\alpha$

So $\Delta V = (3\alpha) V_0 \Delta T$

Total surface area = $6a^2$, where a is side length

$24 = 6a^2$ $\quad$ $a = 2m$

Volume $V_0 = (2)^3 = 8m^3$

$\Delta V = (3 \times 5 \times 10^{-4})$ (8) $\times$ 10

$= 1.2 \times 10^5$ cm^3

18. Heat given by block to get 0ºC temperature

$\Delta Q_1 = 5 \times (0.39 \times 10^3) \times (500 – 0)$

$= 975 \times 10^3$ J

Heat absorbed by ice to melt m mass

$\Delta Q_2 = m \times (335 \times 10^3)$J

$\Delta Q_1 = \Delta Q_2$

$m \times (335 \times 10^3) = 975 \times 10^3$

$$m = \frac{975}{335} = 2.910\text{kg}$$

19. $R = R_0 (1 + \alpha\Delta T)$

$3 = R_0 (1 + \alpha (30 – 0))$

$2 = R_0 (1 + \alpha (10 – 0))$

$$\frac{3}{2} = \frac{1 + 30\alpha}{1 + 10\alpha}$$

$$\alpha = \frac{1}{30} = 0.033$$

20. $\Delta \ell = 6.241 – 6.230 = 0.011$ cm

$\Delta \ell = \ell \alpha \Delta \theta$

$0.011 = 6.230 \times 1.4 \times 10^{-5} (\theta – 27)$

$$\theta - 27 = \frac{0.011 \times 10^5}{6.230 \times 1.4}$$

θ = 153.11 nearest is 152.7°C.

21. $\Delta Q = 184 \times 10^3$

m = 0.600 kg at –12°C

S = 222.3 J/kg/°C

L = 336 × 10^3 J/kg

Q_1 = 0.600 × 2222.3 × 12 = 16000.56 J

Remaining heat ΔQ_1 = 184000 – 16000.56

= 167999.44 J

For meeting at 0°C

ΔQ_2 = 0.600 × 336000 = 201600 J needed

∴ 100% ice is not melted

Amount of ice melted 167999.44

= m × 336000 = 0.4999 kg

∴ mass of water = 0.4999 kg

Mass of ice = 0.1001

$\therefore$ Ratio = $\frac{0.1001}{0.4999} \approx 1:5$

Correct Ans. (1) : A and D only

22. $\frac{\text{reading on scale Lower fixed point}}{\text{upper fixed point lower fixed point}}$

= constant

$$\frac{t_P - 30}{180 - 30} = \frac{t_Q - 0}{100 - 0}$$

$$\frac{t_P - 30}{150} = \frac{t_Q}{100}$$

23. Let C_1 is at θ_1 ; C_2 is at θ_2 and C_3 is at θ_3 then

ms (θ_1 – 60) = 2ms (60 – θ_2)

$\Rightarrow \theta_1 - 60 = 120 - 2\theta_2$

$\Rightarrow \theta_1 = 180 - 2\theta_2$ ...(i)

and ms(θ_2 – 30) = 2ms(30 – θ_3)

$\Rightarrow \theta_2 = 90 - 2\theta_3$ ...(ii)

and 2ms (θ_1 – 60) = ms (60 – θ_3)

$\Rightarrow 2\theta_1 - 120 = 60 - \theta_3$

$\Rightarrow 2\theta_1 + \theta_3 = 180$ ...(iii)

Adding them together $3(\theta_1 + \theta_2 + \theta_3) = 9\theta$

$\Rightarrow \theta$ = 50°C

24. V_0 = 500 cc

$V_b = V_0 + V_0\,\gamma_{beaker}\,\Delta T$

And for Mercury

$V'_B = V_m + V_m\,\gamma_m\,\Delta T$

Unfilled volume ($V_0 - V_m$) = $\left(V_b - V'_m\right)$

$\Rightarrow V_0\,\gamma_{beaker} = V_m\,\gamma_M$

$\therefore V_m = \frac{500 \times 6 \times 10^{-6}}{1.5 \times 10^{-4}}$ $\Rightarrow V_m$ = 20 cc

25. Thermal force F = Ay $\propto \Delta T$

F = (10 × 10^{-4}) (2 × 10^{11}) (10^{-4})(400)

F = 8 × 10^5 N $\Rightarrow$ x = 8

26. Heat rejected = $mL_f + mS\Delta T$

= (50 × 540) + 50 (1) (100 – 20)

= 31000 Cal $\Rightarrow$ 31 × 10^3 Cal

27. m = 2000 gm/min

Heat required by water/min = $mS\Delta T$

= (2000) × 4.2 × 40 J/min

= 336000 J/min

The rate of combustion = $\left(\frac{dm}{dt}L\right)$ = 336000 J/min

$$\frac{dm}{dt} = \frac{336000}{8 \times 10^3}\,g/min = 42 \text{ gm/min}$$

28. $\ell_B (1 + \alpha_B \Delta T) - \ell_i (1 + \alpha_i \Delta T) = \ell_B - \ell_i$

$\alpha_B \ell_B = \ell_i \alpha_i$

1.8 × 10^{-5} × 40 = ℓ_i × 1.2 × 10^{-5}

$$\ell_i = \frac{1.8 \times 10^{-5} \times 40}{1.2 \times 10^{-5}} = \frac{3 \times 40}{2} = 60$$

ℓ_i = 60cm

29. Energy released by water

= 0.3 × 25 × 4200 = 31500 J

let m kg ice melts

m × 3.5 × 10^5 = 31500

$$m = \frac{31500 \times 10^{-5}}{3.5} = 9000 \times 10^{-5}$$

m = 0.09 kg = 90 gm

x = 90

30. $\frac{41° - 5°}{95° - 5°} = \frac{C - 0°}{100° - 0°}$

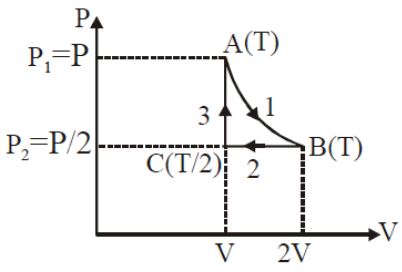
$\Rightarrow$ $C = \frac{36}{90} \times 100 = 40°C = 313K$

KTG & THERMODYNAMICS SOLUTION

1. $W_{Isothermal} = nRT\ln\left(\frac{V_2}{V_1}\right)$

$W_{Isobaric} = P\Delta V = nR\Delta T$

$W_{Isochoric} = 0$



$$W_1 = nRT\ \ln\left(\frac{2V}{V}\right) = nRT\ \ln 2$$

$$W_2 = nR\left(\frac{T}{2} - T\right) = -nR\frac{T}{2}$$

$W_3 = 0$

$\Rightarrow W_{net} = W_1 + W_2 + W_3$

$$W_{net} = nRT\left(\ln 2 - \frac{1}{2}\right)$$

2. (a) Isothermal $\Rightarrow$ Temperature constant

(a) $\rightarrow$ (ii)

(b) Isochoric Þ Volume constant

(a) $\rightarrow$ (iii)

(c) Adiabatic $\Rightarrow \Delta Q = 0$

$\Rightarrow$ Heat content is constant

(c) $\rightarrow$ (iv)

(d) Isobaric $\Rightarrow$ Pressure constant

(d) $\rightarrow$ (i)

3. A – B = isothermal process

$$W_{AB} = P_1V_1\ \ln\left[\frac{2V_1}{V_1}\right] = P_1V_1\ln(2)$$

B – C $\rightarrow$ Isochoric process

$W_{BC} = 0$

C – A $\rightarrow$ Adiabatic process

$$W_{CA} = \frac{P_1V_1 - \frac{P_1}{4}\times 2V_1}{1-\gamma} = \frac{P_1V_1\left[1-\frac{1}{2}\right]}{1-\gamma} = \frac{P_1V_1}{2(1-\gamma)}$$

$W_{net} = W_{AB} + W_{BC} + W_{CA}$ $\{P_1V_1 = RT\}$

$$= P_1V_1\ln(2) + 0 + \frac{P_1V_1}{2(1-\gamma)}$$

$$W_{net} = RT\left[\ln(2) - \frac{1}{2(\gamma-1)}\right]$$

4. Let the final temperature of the mixture be T.

Since, there is no loss in energy.

$\Delta U = 0$

$$\Rightarrow \frac{F_1}{2}n_1R\ \Delta T + \frac{F_2}{2}n_2R\Delta T = 0$$

$$\Rightarrow \frac{F_1}{2}n_1R(T_1 - T) + \frac{F_2}{2}n_2R(T_2 - T) = 0$$

$\Rightarrow$

$$T = \frac{F_1n_1RT_1 + F_2n_2RT_2}{F_1n_1R + F_2n_2R} \Rightarrow \frac{F_1n_1T_1 + F_2n_2T_2}{F_1n_1 + F_2n_2}$$

5. Adiabatic process is from C to D

$$WD = \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

$$= \frac{P_DV_D - P_CV_C}{1-\gamma}$$

$$= \frac{200(3) - (100)(4)}{1-1.4}$$

$= -500$ J Ans (1)

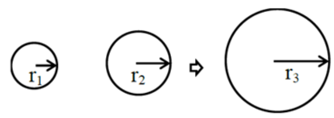
6. PV^{γ} = constant

Differentiating

$$\frac{dP}{dV} = \frac{-\gamma P}{V}$$

$$\frac{dP}{P} = \frac{-\gamma dV}{V}$$

7.



no. of moles is conserved

$n_1 + n_2 = n_3$

$P_1V_1 + P_2V_2 = P_3V$

$$\frac{4S}{r_1}\left(\frac{4}{3}\pi r_1^3\right)+\frac{4S}{r_2}\left(\frac{4}{3}\pi r_2^2\right)=\frac{4S}{r_3}\left(\frac{4}{3}\pi r_3^3\right)$$

$$r_1^2+r_2^2=r_3^2$$

$$r_3=\sqrt{r_1^2+r_2^2}$$

8. Work done in adiabatic process =

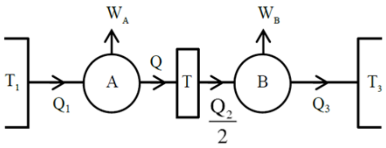
$$\frac{-nR}{\gamma-1}(T_f-T_i)$$

$$\therefore W_{AD}=\frac{-nR}{\gamma-1}(T_2-T_1)$$

and $W_{BC}=\dfrac{-nR}{\gamma-1}(T_2-T_1)$

$\therefore W_{AD} = W_{BC}$

9.



$$W_A=1-\frac{Q_2}{Q_1}=1-\frac{T}{T_1}\Rightarrow\frac{Q_2}{Q_1}=\frac{T}{T_1}$$

$$W_B=1-\frac{Q_3}{(Q_2/2)}=1-\frac{T_3}{T}\Rightarrow\frac{2Q_3}{Q_2}=\frac{T_3}{T}$$

Now, $W_A = W_B$

$$Q_1-Q_2=\frac{Q_2}{2}-Q_3$$

$$\frac{2Q_1}{Q_2}+\frac{2Q_3}{Q_2}=3$$

$$\frac{2T_1}{T}+\frac{T_3}{T}=3$$

$$\frac{2T_1}{3}+\frac{T_3}{3}=T$$

10. $V_{RMS}=\sqrt{\dfrac{3RT}{M_W}}$

At the same temperature $V_{RMS}\propto\dfrac{1}{\sqrt{M_W}}$

$\Rightarrow V_H > V_0 > V_C$

11. $P_m = \rho RT$

$$\therefore \frac{P_1}{P_2}=\frac{\rho_1T_1}{\rho_2T_2}$$

$$\frac{\rho_1}{\rho_2}\Rightarrow\frac{P_1T_2}{P_2T_1}=\left(\frac{76}{45}\right)\times\frac{266}{300}$$

$$\frac{\rho_1}{\rho_2}\Rightarrow\frac{M_1}{M_2}=\frac{76\times266}{45\times300}$$

$$\therefore M_2\Rightarrow\frac{45\times300\times185}{76\times266}=123.54\,\text{kg}$$

12.

$$\int_{p_0}^{p}\frac{dp}{p}=-a\int_0^v dv$$

$$\ell n\left(\frac{p}{p_0}\right)=-av$$

$$p=p_0e^{-av}$$

For temperature maximum p-v product should be maximum

$$T=\frac{pv}{nR}=\frac{p_0ve^{-av}}{R}$$

$$\frac{dT}{dv}=0\Rightarrow\frac{p_0}{R}\left\{e^{-av}+ve^{-av}(-a)\right\}$$

$$\frac{p_0e^{-av}}{R}\{1-av\}=0$$

$$v=\frac{1}{a},\infty$$

$$T=\frac{p_0 1}{Rae}=\frac{p_0}{Rae}$$

at $v=\infty$

$T = 0$, Option

13. PV = nRT

$$400\times10^3\times500\times10^{-6}=n\left(\frac{25}{3}\right)(300)$$

$$n=\frac{2}{25}$$

$n = n_1 + n_2$

$$\frac{2}{25}=\frac{M_1}{2}+\frac{M_2}{32}$$

Also $M_1 + M_2 = 0.76$ gm

$$\frac{M_2}{M_1} = \frac{16}{3}$$

14. PV = nRT

$$\frac{V}{T} = \frac{nR}{P}$$

$$\frac{nR}{P_1} < \frac{nR}{P_2}$$

$P_2 < P_1$

15. $W_{adiabatic} = \frac{NR(T_f - T_i)}{1-\gamma} \rightarrow \text{statment1}$

Q = W + ΔU

0 = W + ΔU

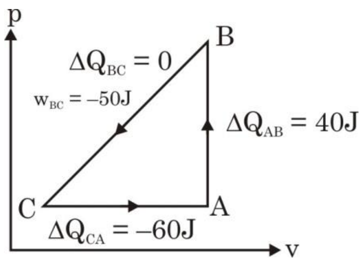
ΔU = – W

If work is done on the gas, i.e. work is negative

∴ ΔU is positive.

∴ Temperature will increase.

16.



$\Delta Q_{cycle} = 40 - 60 = \Delta W$

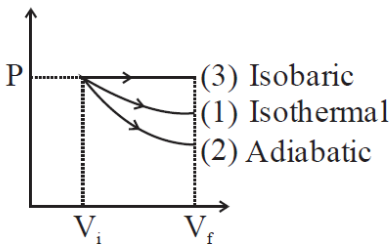
$\Rightarrow \Delta W = -20J = W_{BC} + W_{CA}$

$\Rightarrow W_{CA} = -20J - W_{BC}$

= –20 – (–50)

= 30 J

17.



Area under curve is work

$W_2 < W_1 < W_3$

18. No of moles of H_2 = 8 moles

No of moles of O_2 = 4 moles

Total moles = 12 moles

At STP 1 mole occupy = 22.4ℓ = 22.4 × 10^3 cm^3

12 moles will occupy = 12 × 22.4 × 10^3 cm^3

≈ 26.8 × 10^4 cm^3

19. Constant entropy means process is adiabatic

PV^γ = constant

$$V_2 = \frac{V_1}{8}$$

$$P_1V_1^\gamma = P_2V_2^\gamma$$

$$P_1V_1^\gamma = P_2\left(\frac{V_1}{8}\right)^{5/3}$$

$$P_1V_1^{5/3} = \frac{P_2V_1^{5/3}}{32}$$

$P_2 = 32P_1$

20. $\eta = 1 - \frac{T_L}{T_H}$

$$\frac{1}{2} = 1 - \frac{T_L}{T_H} \qquad ...(i)$$

$$1 - \left(\frac{T_L - 40}{T_H}\right) = 0.65 \qquad ...(ii)$$

for (i) and (ii)

$$\frac{800}{3}K$$

T_H = 266.7 K

21. $W_{DE} = \frac{1}{2}(600+300)3\,J$

= 1350 J

W_{EF} = – 300 × 3 = – 900 J

W_{DEF} = 450 J

22. $\sqrt{\frac{3RT}{M}} = \sqrt{\frac{\alpha+5}{\alpha}} \times \sqrt{\frac{8}{\pi}\frac{RT}{M}}$

$$3 = \frac{\alpha+5}{\alpha}\frac{8}{\pi}$$

α = 28

23. Taking volume constant : $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\Rightarrow P_2 = \frac{P_1}{T_1} \times T_2 = \frac{270 \times (309)}{300}$ = 278 kPa

24. $P = kV^3$

$T_i = 100°C$ & $T_f = 300°C$

$\Delta T = 300 - 100$

$\Delta T = 200°C$

$P = kV^3$

now PV = nRT

$\therefore kV^4 = nRT$

now $4kV^3\,dV = nRdT$

$\therefore PdV = nRdT/4$

$\therefore$ Work $= \int PdV = \int \frac{nRdT}{4} = \frac{nR}{4}\Delta T$

$= \frac{200}{4} \times nR = 50nR$

25. For equilibrium

$\frac{dU}{dr} = 0$

$\frac{-10\alpha}{r^{11}} + \frac{5\beta}{r^6} = 0$

$\frac{5\beta}{r^6} = \frac{10\alpha}{r^{11}}$

$r^5 = \frac{2\alpha}{\beta}$

$r = \left(\frac{2\alpha}{\beta}\right)^{\frac{1}{5}}$

a = 1

26. We know that work done is

$W = \int PdV$ ...(1)

$\Rightarrow P = \frac{nRT}{V}$ ...(2)

$\Rightarrow W = \int \frac{nRT}{V} dv$ ...(3)

and $V = KT^{2/3}$ ...(4)

$\Rightarrow W = \int \frac{nRT}{KT^{2/3}}.dv$ ...(5)

$\Rightarrow$ from (4) : $dv = \frac{2}{3}KT^{-1/3}dT$

$\Rightarrow W = \int_{T_1}^{T_2} \frac{nRT}{KT^{2/3}} \frac{2}{3} K \frac{1}{T^{1/3}} dT$

$\Rightarrow W = \frac{2}{3} nR \times (T_2 - T_1)$ ...(6)

$\Rightarrow T_2 - T_1 = 90K$ ...(7)

$\Rightarrow W = \frac{2}{3} nR \times 90$

$\Rightarrow$ W = 60 nR

Assuming 1 mole of gas

n = 1, So W = 60 R

27. $\Delta Q = \Delta E + WD \Rightarrow Q = \Delta E + \frac{Q}{4}$

$\Rightarrow n\frac{3R}{2}\Delta T = \Delta E = \frac{3Q}{4}$

$\therefore n\Delta T = \frac{Q}{2R}$

$\therefore C = 2R$

28. $W = nR\Delta T = 150$ J

$Q = \left(\frac{f}{2}+1\right) nR\Delta T = \left(\frac{8}{2}+1\right)150 = 750J$

29. PV^γ = const $\quad d = \frac{m}{v} \quad p\left(\frac{m}{d}\right)^\gamma$ = const

$\frac{p}{d^\gamma}$ = const $\quad \frac{d_2}{d_1} = 32$

$\frac{p_1}{p_2} = \left(\frac{d_1}{d_2}\right)^\gamma = \left(\frac{1}{32}\right)^{7/5} = \frac{1}{128}$

$\frac{T_1}{T_2} = \frac{P_1V_1}{P_2V_2} = \frac{1}{128}32 = \frac{1}{4}$

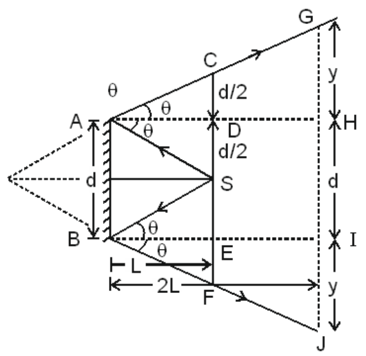
30. $C_v / \text{mix} = \frac{n_1Cv_1 + n_2Cv_2}{n_1 + n_2}$

$= \frac{1.\frac{3R}{2} + 3.\frac{5R}{2}}{1+3} = \frac{9R}{4} = \frac{\alpha^2}{4}R$

$\alpha = 3$

GEOMETRICAL OPTICS SOLUTION

1.



AB = HI = d

DS = CD = d/2

since , AH = 2AD

$\Rightarrow$ GH = 2CD = $2\times\frac{d}{2}=d$

similarly

IJ = d

GJ = GH + HI + IJ

= d + d + d = 3 d

Hence, the distance over which the imgage can be seen is d + d + d = 3d.

2. For lens A

$$\frac{1}{v}-\frac{1}{(-20)}=\frac{1}{5}$$

$$\Rightarrow v=\frac{20}{3}\text{cm}$$

For lens B

$$u=\frac{20}{3}-2$$

$$u=\frac{14}{3}\text{cm}$$

$$\therefore \frac{1}{v}=\frac{1}{\frac{14}{3}}=-\frac{1}{5}$$

$\Rightarrow$ v = 70 cm

Image is real and right of B.

3. f_L = 18 cm

$$\frac{1}{f_1}=0.5\times\frac{2}{18}\Rightarrow f_1=18\text{cm}$$

$$\frac{1}{f_2}=(\mu-1)\left(-\frac{1}{18}\right)$$

$$\frac{1}{27}=\frac{1}{18}-\frac{(\mu_1-1)}{18}=\frac{1-\mu_1+1}{18}$$

$\Rightarrow$ 2 = 3 (2 – μ_1) = 6 – 3 μ_1

$$\Rightarrow \mu_1=\frac{4}{3}$$

4. Focal length of plano-convex lens-

$$f_1=\frac{R}{(\mu_1-1)}$$

Focal length of plano concave lens-

$$f_2=\frac{R}{(\mu_2-1)}$$

For the combination of two lens-

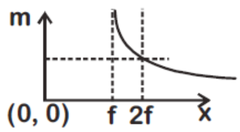
$$\frac{1}{f_{eq}}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{\mu_1-1}{R}-\frac{\mu_2-1}{R}$$

$$=\frac{\mu_1-\mu_2}{R}$$

$$\therefore f_{eq}=\frac{R}{\mu_1-\mu_2}$$

5. At focus magnification is ∞

And at x = 2f, magnification is 1.



6.

$$\mu=\frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\mu=\frac{\sin\left(\frac{A+A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\mu=\frac{\sin A}{\sin\frac{A}{2}}=2\cos\frac{A}{2}$$

$$A=2\cos^{-1}\left(\frac{\mu}{2}\right)$$

7. 

Mirror used is convex mirror (rear-view mirror)

$\therefore V_{I/m} = -m^2 V_{O/m}$

Given

$V_{O/m} = 40$ m/s

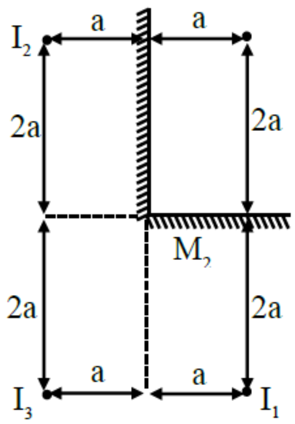
$$m = \frac{f}{f-u} = \frac{10}{10+190} = \frac{10}{200}$$

$$\therefore V_{I/m} = -\frac{1}{400} \times 40 = -0.1\, m/s$$

$\therefore$ Car will appear to move with speed 0.1 m/s.

Hence option (4)

8. Shortest distance is 2a between I_1 & I_3

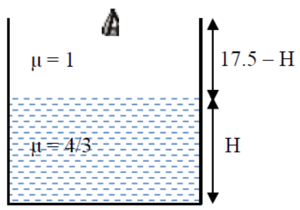


But answer given is for I_1 & I_2

$\sqrt{(4a)^2 + (2a)^2}$

$a\sqrt{20}$

4.47 a Option (2)

9. 

Height of water observed by observer

$$= \frac{H}{\mu_w} = \frac{H}{(4/3)} = \frac{3H}{4}$$

Height of air observed by observer = 17.5 – H

According to question, both height observed by observer is same.

$$\frac{3H}{4} = 17.5 - H \quad \Rightarrow \quad H = 10 \text{ cm}$$

Option (2)

10. Speed of wave $= \frac{2 \times 10^{10}}{200} = 10^8\, m/s$

Refractive index $= \frac{3 \times 10^8}{10^8} = 3$

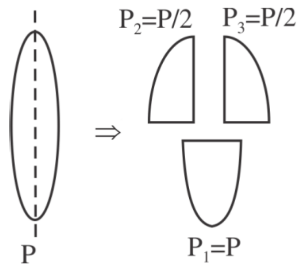
Now refractive index $= \sqrt{\varepsilon_r \mu_r}$

$3 = \sqrt{\varepsilon_r (1)}$

$\Rightarrow \varepsilon_r = 9$

Option (1)

11.



12. In primary rainbow, red colour is at top and violet is at bottom.

Intensity of secondary rainbow is less in comparison to primary rainbow.

13. $\frac{\mu_2}{\mu_{air}} = \frac{C}{v_2}$

$$\therefore \frac{\sqrt{\mu_2 \varepsilon_{r_2}}}{(1)} = \frac{C}{v_2}$$

$$\therefore \sqrt{(1)(9)} = \frac{C}{v_2}$$

$$\therefore v_2 = \frac{C}{3}$$

14. $f_0 + f_e = 30$

$$m = \frac{f_0}{f_e}$$

$$2 = \frac{f_0}{f_e} \Rightarrow f_0 = 2f_e$$

so $f_0 + \frac{f_0}{2} = 30$

f_0 = 20 cm

15. $P = \frac{\mu_2}{f} = (\mu_1 - \mu_2)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ (For this formula refer to NCERT Part-2, Chapter-9, Page No. 328, solving example 8)

(μ_1 is refractive index of lens and μ_2 is of surrounding medium)

$$1.25 = (1.5 - \mu_2)\left(\frac{1}{0.2} + \frac{1}{0.4}\right)$$

$$\frac{1.25 \times 0.08}{0.6} = (1.5 - \mu_2)$$

$$\Rightarrow \mu_2 = \frac{4}{3}$$

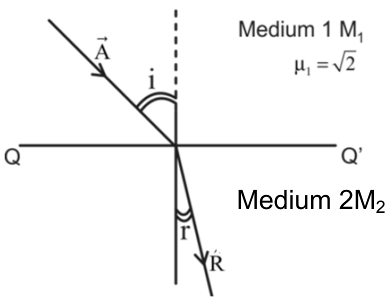
16. xy = f^2 (by Newton's formula)

$v' \mu' = 225$

$f^2 = 225$

f = 15 cm

17. $\vec{A} = 4\sqrt{3}\hat{i} - 3\sqrt{3}\hat{j} - 5\hat{k}$



$\mu_1 \sin i = \mu_2 \sin r$

As incident vector A makes i angle with normal z-axis & refracted vector R makes r angle with normal z-axis with help of direction cosine

$$i = \cos^{-1}\frac{A_z}{A} = \cos^{-1}\frac{5}{\sqrt{(4\sqrt{3})^2 + (3\sqrt{3})^2 + 5}}$$

$$i = \cos^{-1}\frac{5}{10} \Rightarrow i = 60^\circ$$

$$\sqrt{2}\sin 60 = \sqrt{3} \times \sin r$$

r = 45°

Difference between I & r = 60 – 45 = 15

18. $\frac{1}{f_1} = (1.75 - 1)\left(-\frac{1}{30}\right)$

$\Rightarrow f_1$ = –40 cm

$$\frac{1}{f_2} = (1.75 - 1)\left(\frac{1}{30}\right)$$

$\Rightarrow f_2$ = 40

Image from L_1 will be virtual and on the left of L_1 at focal length 40 cm. So the object for L_2 will be 80 cm from L_2 which is 2f. Final image is formed at 80 cm from L_2 on the right.

So x = 120

19. $u = \frac{h}{h'} = \frac{5.25}{5.00}$

Least count = $\frac{1}{20}\text{cm} - \frac{49}{50}\cdot\frac{1}{20}\text{cm}$

$$= \frac{1}{50} \times \frac{1}{20}\text{cm} = 0.01\,\text{mm}$$

In u = In h – In h'

$$\frac{du}{u} = \frac{dh}{h} - \frac{dh'}{h'}$$

$$du = \left[\frac{0.01}{5.25} + \frac{0.01}{5.00}\right]\frac{5.25}{5.00}$$

$$= \frac{41}{10} \times 10^{-3}$$

Ans. = 41

20. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{-1}{120} - \frac{1}{40} = \frac{1}{f},\ f = -30\,\text{cm}$$

Now,

$$\frac{-1}{v^2}dv - \frac{1}{u^2}du = -\frac{1}{f^2}df$$

Also $dv = du = \frac{1}{20}\text{cm}$

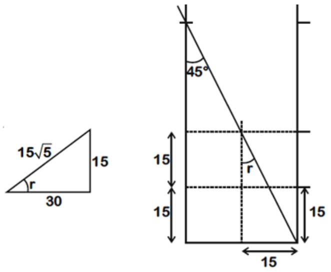
$$\therefore\ \frac{\frac{1}{20}}{(120)^2} + \frac{\frac{1}{20}}{(40)^2} = \frac{df}{(30)^2}$$

On solving df = $\frac{1}{32}$cm

$\therefore$ k = 32

21. See the figure

For r

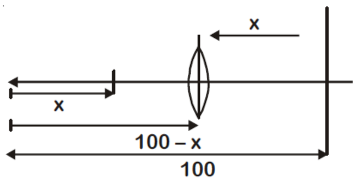


$\mu_1 \sin 45^\circ = \mu_2 \sin r$

$$\Rightarrow \frac{1}{\sqrt{2}} = \frac{\mu}{\sqrt{5}}$$

$$\Rightarrow \mu = \sqrt{\frac{5}{2}}\ ;\ 1.58 \approx \frac{158}{100}$$

22.



Clearly 100 – x – x = 40

$\Rightarrow$ 60 = 2x

$\therefore$ x = 30, And 100 – x = 70

$$\frac{1}{70} + \frac{1}{30} = \frac{1}{f}$$

$$\Rightarrow \frac{100}{21 \times 100} = \frac{1}{f} = \frac{1}{21}$$

$$\therefore\ f = \left(\frac{21}{100}\right)$$

$$\therefore\ \text{Power} = \frac{1}{f} = \left(\frac{100}{21}\right) \approx 4.76$$

$$\frac{N}{100} = 4.76$$

$\therefore$ N = 476

23. $m = \dfrac{f}{u+f}$

$$+m = \frac{f}{-10+f} \qquad ...(1)$$

$$-m = \frac{f}{-20+f} \qquad ...(2)$$

(1)/(2)

$$-1 = \frac{f}{f-10}$$

10 – f = f – 20

30 = 2 f

f = 15 cm

24. $\lambda_m = \dfrac{\lambda_a}{\mu} \Rightarrow \mu = \dfrac{3}{2}$

$$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$$

$$\frac{3}{2 \times 10} + \frac{1}{15} = \frac{\frac{3}{2} - 1}{R}$$

$$R = \frac{30}{13} = 30$$

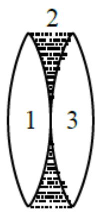
25. For simple microscope,

$$m = 1 + \frac{D}{f_0},\quad 6 = 1 + \frac{D}{f_0},\quad 5 = \frac{25}{f_0}, f_0 = 5\,\text{cm}$$

For compound microscope,

$$m = \frac{\ell \cdot D}{f_0 \cdot f_e},\quad 12 = \frac{60 \times 25}{5 \cdot f_e}\quad f_e = 25\,\text{cm}$$

26.



$$\frac{1}{f_1} = \frac{1}{15} = \left(\frac{3}{2} - 1\right)\left[\frac{2}{R}\right]$$

$$\frac{1}{R} = \frac{1}{15}$$

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

$$= \frac{1}{15} + \left(\frac{5}{4} - 1\right)\left[\frac{-2}{R}\right] + \frac{1}{15}$$

$$= \frac{1}{15} - \frac{1}{30} + \frac{1}{15} = \frac{2-1+2}{30}$$

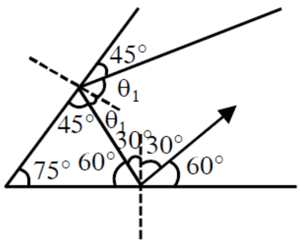
$$= \frac{3}{30} = \frac{1}{10} = 10$$

27. $\ell = t\sin i\left[1-\dfrac{\cos i}{\sqrt{\mu^2-\sin^2 i}}\right]$

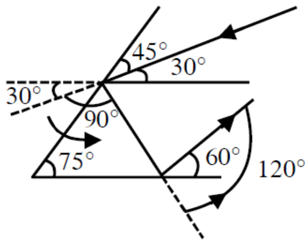
$\Rightarrow\ 4\sqrt{3} = t\sin 60^\circ\left[1-\dfrac{\cos 60^\circ}{\sqrt{3-\frac{3}{4}}}\right]$

28. $\delta_{total} = 360^\circ - 2\theta$

$= 360^\circ - 2\times 75^\circ$

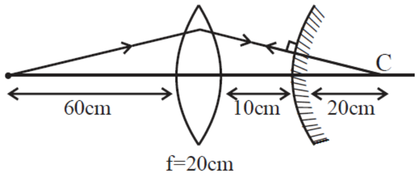


$\theta_1 = 45^\circ$



$\delta = 120^\circ + 90^\circ = 210^\circ$

29.



For lens

$\dfrac{1}{v}-\dfrac{1}{u}=\dfrac{1}{f}$

$\Rightarrow \dfrac{1}{v}-\dfrac{1}{(-60)}=\dfrac{1}{20} \Rightarrow \dfrac{1}{v}+\dfrac{1}{60}=\dfrac{1}{20}$

v = 30 cm

For final image to be formed on the object itself, after refraction from lens the ray should meet the mirror perpendicularly and the image by lens should be on the centre of curvature of mirror

R = 30 – 10 = 20 cm

Focal length of mirror = R/2 = 10 cm

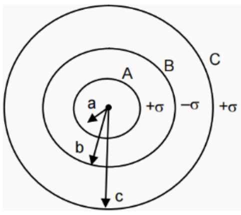
30. $\delta = A(\mu_y - 1) - A'(\mu'_y - 1)$

$= 6(1.5-1) - 5(1.55-1)$

$= \dfrac{1}{4}$

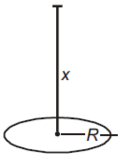
ELECTROSTATICS SOLUTION

1.



$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{4\pi a^2\sigma}{b} - \frac{1}{4\pi\varepsilon_0}\frac{4\pi b^2\sigma}{b} + \frac{1}{4\pi\varepsilon_0}\frac{4\pi c^2\sigma}{C} = \frac{\sigma}{\varepsilon_0}\left(\frac{a^2-b^2}{b}+c\right)$$

2.



$$E(x) = \frac{Q.x}{4\pi\in_0 (R^2+x^2)^{\frac{3}{2}}}$$

$$\because \frac{dE}{dx} = 0 \text{ for maximum}$$

$\Rightarrow$

$$\frac{Q}{4\pi\in_0}\left[\frac{(R^2+x^2)^{\frac{3}{2}} - x.\frac{3}{2}(R^2+x^2)^{\frac{1}{2}}.2x}{(R^2+x^2)^3}\right] = 0$$

$$\Rightarrow \frac{(R^2+x^2)^{\frac{1}{2}}Q}{4\pi\in_0 .(R^2+x^2)^3}(x^2+R^2-3x^2) = 0$$

$$\Rightarrow x = \frac{R}{\sqrt{2}} \qquad \Rightarrow h = \frac{R}{\sqrt{2}}$$

3. $$Q = \int_0^R 4\pi r^2.\frac{A}{r^2}e^{-2r/a}dr$$

$$= \frac{4\pi Aa}{-2}e^{-2r/a}\Big|_0^R = 2\pi aA\left[1-e^{\frac{-2R}{a}}\right]$$

$$= e^{-2R/a} = 1-\frac{Q}{2\pi aA}$$

$$\Rightarrow e^{\frac{2R}{a}} = \frac{1}{\left(1-\frac{Q}{2\pi aA}\right)}$$

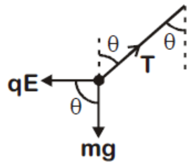
$$\Rightarrow R = \frac{a}{2}\ln = \frac{1}{\left(1-\frac{Q}{2\pi aA}\right)}$$

4. $$\frac{Q^2}{4\pi\in_0 R_0} = \frac{Q^2}{4\pi\in_0 R} + \frac{1}{2}mv^2$$

$$\Rightarrow v = \sqrt{\frac{Q^2}{4\pi\in_0}\times\frac{2}{m}\left[\frac{1}{R_0}-\frac{1}{R}\right]}$$

So v increases and attains a finite value after large time.

5.



$T\cos\theta = mg$

$T\sin\theta = qE$

$$\tan\theta = \frac{qE}{mg}$$

$$\tan\theta = \frac{5\times10^{-6}\times2000}{2\times10^{-3}\times10} = \frac{1}{2}$$

$$\Rightarrow \tan^{-1}\left(\frac{1}{2}\right)$$

6. $$dV = -\vec{E}\cdot\vec{dr} = -(Ax+B)dx$$

$$\int_{V_2}^{V_1} dV = \int_{-5}^{1} -(Ax+B)dx$$

$$\Rightarrow V_1 - V_2 = \left(-A\frac{x^2}{2}-Bx\right)_{-5}^{1}$$

$$= \left(-\frac{A}{2}-B\right)+\left(\frac{A}{2}25+B(-5)\right)$$

= 12A – 6B = 240 – 60 = 180V

7. $$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\int_{V_G}^{V_P} dV = \int_{r}^{r_0} -\frac{\lambda}{2\pi\varepsilon_0 r}dr$$

$$\Rightarrow V_P - V_G = \frac{\lambda}{2\pi\varepsilon_0}\ln\frac{r}{r_0}$$

$$\frac{1}{2}mv^2 = q(V_P - V_G)$$

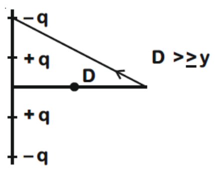
$$\Rightarrow \quad v \propto \left[\ln\left(\frac{r}{r_0}\right)\right]^{\frac{1}{2}}$$

8. $$U = \frac{Kq^2}{d} + QV$$

$$V = \frac{KP}{D^2} = \frac{Kqd}{D^2}$$

$$U = \frac{Kq^2}{d} = \frac{KQqd}{D^2}$$

9.



$$\vec{E} = \frac{2qD}{4\pi\varepsilon_0(D^2+4y^2)^{\frac{3}{2}}} - \frac{2qD}{4\pi\varepsilon_0(D^2+y^2)^{\frac{3}{2}}}(-\text{ve } \vec{x})$$

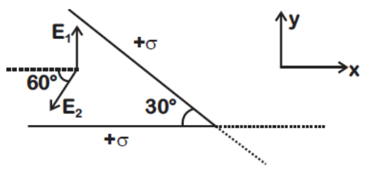
$$|\vec{E}| = \frac{2qD}{4\pi\varepsilon_0 D^3}\left[\frac{1}{\left(1+\left(\frac{2y}{D}\right)^2\right)^{\frac{3}{2}}} - \frac{1}{\left(1+\left(\frac{y}{D}\right)^2\right)^{\frac{3}{2}}}\right]$$

$\Rightarrow$

$$|\vec{E}| = \frac{2q}{4\pi\varepsilon_0 D^2}\left(1-\frac{3}{2}\cdot\frac{4y^2}{D^2}-1+\frac{3}{2}\frac{y^2}{D^2}\right) = \frac{9qy^2}{4\pi\varepsilon_0 D^4}$$

10. Since dipole is having zero net charge. So inside surface shall have non-zero non-uniform charge distribution. And net field outside the region would be same as that would have been for point charge at surface.

11.



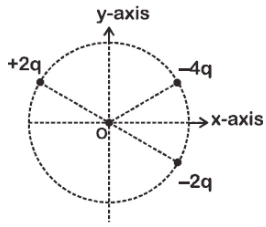
$$\vec{E}_1 = \frac{\sigma}{2\varepsilon_0}\hat{y}$$

$$\vec{E}_2 = \frac{\sigma}{2\varepsilon_0}(-\cos 60°\hat{x} - \sin 60°\hat{y})$$

$$= \frac{\sigma}{2\varepsilon_0}\left(-\frac{1}{2}\hat{x} - \frac{\sqrt{3}}{2}\hat{y}\right)$$

$$\therefore \quad \vec{E}_P = \vec{E}_1 + \vec{E}_2 = \frac{\sigma}{2\varepsilon_0}\left[-\frac{1}{2}\hat{x} + \left(1-\frac{\sqrt{3}}{2}\right)\hat{y}\right]$$

12.



Electric field due to charge +2q at centre O –

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{2q}{d^2}\left[\frac{+\sqrt{3}\hat{i}-\hat{j}}{2}\right]$$

Due to –2q

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\frac{2q}{d^2}\left[\frac{\sqrt{3}\hat{i}-\hat{j}}{2}\right]$$

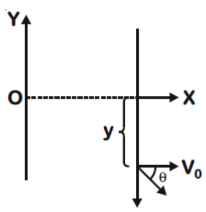
Due to –4q

$$\vec{E}_3 = \frac{1}{4\pi\varepsilon_0}\frac{4q}{d^2}\left[\frac{\sqrt{3}\hat{i}-\hat{j}}{2}\right]$$

Net electric field at point O

$$\vec{E}_0 = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 = \frac{\sqrt{3}q}{\pi\varepsilon_0 d^2}\hat{i}$$

13.



$$\frac{qE}{m}\frac{d}{V_0}$$

$$y = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{d}{V_0}\right)^2$$

$$y = \frac{qEd}{mV_0^2}x + C$$

$$\text{At } x = d,\ y = -\frac{qEd^2}{2mV_0^2}$$

$$\Rightarrow \quad C = \frac{qEd^2}{2mV_0^2}$$

$$y = -\frac{qEd}{mV_0^2}x + \frac{qEd^2}{2mV_0^2}$$

$$y = \frac{qEd}{mV_0^2}\left(\frac{d}{2} - x\right)$$

14. Let charges on shells be q_1 and q_2

$q_1 + q_2 = Q$ .....(i)

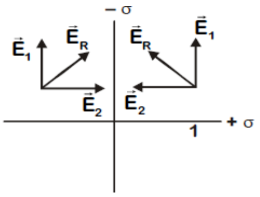
$$\frac{q_1}{4\pi r^2} = \frac{q_2}{4\pi R^2} \quad ....(ii)$$

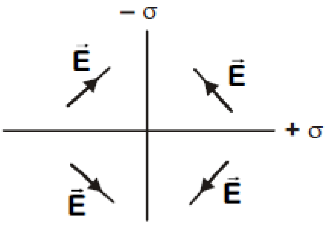
We get $q_1 = \frac{r^2}{r^2+R^2}Q$, $q_2 = \frac{R^2}{r^2+R^2}Q$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r} + \frac{q_2}{R}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$$

15.





16. $E = E_0(1 - ax^2)$

$$\frac{vdv}{dx} = \frac{qE_0}{m}(1 - ax^2)$$

$$\Rightarrow \frac{v^2}{2} = \frac{qE_0}{m}\left[x - \frac{ax^3}{3}\right] = 0$$

$$\Rightarrow x = \sqrt{\frac{3}{a}}$$

17. $E = \frac{k\lambda}{a}(\sin\theta_1 + \sin\theta_2)$

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{L} \times \frac{1}{\left(\frac{\sqrt{3}L}{2}\right)} \times (2\sin\theta)$$

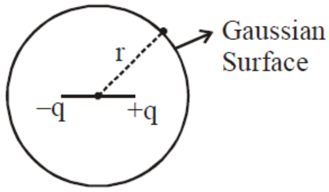
$$\tan\theta = \frac{L/2}{\frac{\sqrt{3}L}{2}} = \frac{1}{\sqrt{3}}$$

$$\sin\theta = \frac{1}{2}$$

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{2Q}{\sqrt{3}L^2} \times \left(2 \times \frac{1}{2}\right)$$

$$E = \frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$$

18.



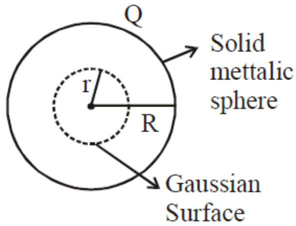
$$\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0} = 0 = \phi$$

Flux of $\vec{E}$ through sphere is zero.

But $\oint \vec{E}.\vec{ds} = 0 \Rightarrow \{\vec{E}\cdot\vec{ds} \neq 0\}$

for small section ds only

Statement - 2

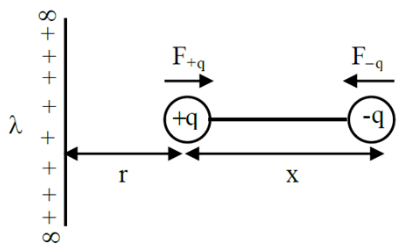


As charge encloses within gaussian surface is equal to zero.

$$\phi = \oint \vec{E}\vec{ds} = 0$$

Option (2) statement-1 correct statement-2 false.

19.



r = 10 mm, x = 2,

$$|\vec{F}_q| = \frac{2k\lambda}{r}.q$$

$$|\vec{F}_{-q}| = \frac{2k\lambda}{r+x}.q$$

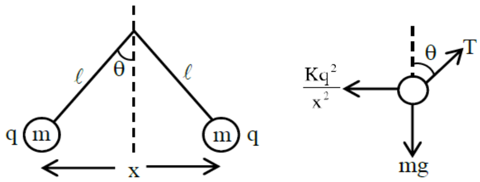
$$|\vec{F}_{net}| = \frac{2k\lambda q}{r} - \frac{2k\lambda q}{r+x}$$

$$|\vec{F}_{net}| = \frac{2k\lambda q.x}{r(r+x)}$$

$$4 = \frac{2\times 9\times 10^{9}\times 3\times 10^{-6}\times q\times 2mm}{10mm.12mm}$$

$q = 4.44\ \mu C$

20.



$T\cos\theta = mg$

$$T\sin\theta = \frac{kq^2}{x^2}$$

$$\tan\theta = \frac{kq^2}{x^2 mg}$$

as $\tan\theta \approx \sin\theta \approx \dfrac{x}{2L}$

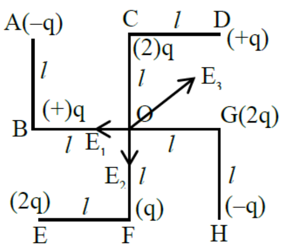
$$\frac{x}{2L} = \frac{Kq^2}{x^2 mg}$$

$$x = \left(\frac{q^2 L}{2\pi\varepsilon_0 mg}\right)^{1/3}$$

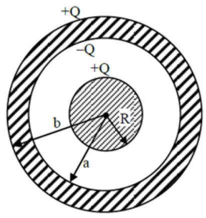
21. $E_1 = \dfrac{kq}{\ell^2} = E_2$

$$E_3 = \frac{kq}{(\sqrt{2}\ell)^2} = \frac{kq}{2\ell^2}$$

$$E = \frac{\sqrt{2}kq}{\ell^2} - \frac{kq}{2\ell^2} = \frac{kq}{2\ell^2}(2\sqrt{2}-1)$$



22. outer spherical shell is conducting

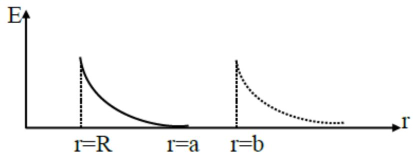


$r < R,\ E = 0$

$R \le r < a \qquad E = \dfrac{kQ}{r^2}$

$a \le r < b, \qquad E = 0$

$r \ge b \qquad E = \dfrac{kQ}{r^2}$



23. As electric field is in y-direction so electric flux is only due to top and bottom surface

Bottom surface y = 0

$\Rightarrow E = 0 \Rightarrow \phi = 0$

Top surface y = 0.5 m

$\Rightarrow E = 150\,(.5)^2 = \dfrac{150}{4}$

Now flux $\phi = EA = \dfrac{150}{4}(0.5)^2 = \dfrac{150}{16}$

By Gauss's law $\phi = \dfrac{Q_{in}}{\epsilon_0}$

$$\frac{150}{16} = \frac{Q_{in}}{\epsilon_0}$$

$$Q_{in} = \frac{150}{16}\times 8.85\times 10^{-12} = 8.3\times 10^{-11}C$$

24. Mg = qE

$(0.1 \times 10^{-3})\,(9.8) = 4.9 \times 10^{5}\,q$

$$\frac{2\times 10^{-4}}{10^5} = q$$

$q = 2 \times 10^{-9}$ C

25. $F = \dfrac{1}{(4\pi\varepsilon_0)}\dfrac{q_1q_2}{kd^2}$ (in medium)

$$F_{Air} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{d'^2}$$

$F = F_{Air}$

$$\frac{q_1q_2}{4\pi\varepsilon_0 kd^2}=\frac{q_1q_2}{4\pi\varepsilon_0 d'^2}$$

$$d'=d\sqrt{k}$$

26. Potential at centre

$$V=\frac{(\lambda\cdot\pi R_2)}{4\pi\varepsilon_0 R_2}+\frac{(\lambda\cdot\pi R_1)}{4\pi\varepsilon_0 R_1}=\frac{\lambda}{2\varepsilon_0}$$

27. From symmetry $\phi=\frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$

$$=\frac{12\times10^{-6}}{6\times8.85\times10^{-12}}$$

$$=225.98\times10^{3}\frac{Nm^2}{s}$$

$$;\ 226\times10^{3}\frac{Nm^2}{C}$$

28. $(27)\left(\frac{4}{3}\pi r^3\right)=\frac{4}{3}\pi R^3$

R = 3r

Potential energy of smaller drop :

$$U_1=\frac{3}{5}\frac{kq^2}{r}$$

Potential energy of bigger drop:

$$U=\frac{3}{5}\frac{kQ^2}{R}$$

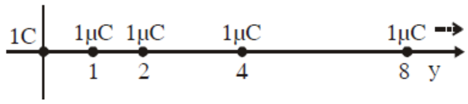
$$U=\frac{3}{5}\frac{k(27q)^2}{R}$$

$$U=\frac{3}{5}k\frac{(27)(27)q^2}{3r}$$

$$U=\frac{(27)(27)}{3}\left(\frac{3}{5}\frac{kq^2}{r}\right)$$

$U = 243\ U_1$

29.



$$F=k(1C)(1\mu C)\left[1+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+....\right]$$

$$=9\times10^{3}\left[\frac{1}{1-\frac{1}{4}}\right]=12\times10^{3}\ N$$

30. Electric field density

$$(\vec{D})=\frac{\text{charge}}{\text{Area}}\times\hat{r}=\frac{Q}{4\pi r^2}\hat{r}=\epsilon_0\left(\frac{Q}{4\pi\epsilon_0 r^2}\hat{r}\right)$$

$$E=\frac{\vec{D}}{\epsilon_0}=\frac{e^{-x}\sin\hat{i}-e^{-x}\cos y\hat{j}+2z\hat{k}}{\epsilon_0}$$

Also by Gauss's law

$$\frac{\rho}{\epsilon_0}=\left(\frac{\partial}{\partial x}\hat{i}+\frac{\partial}{\partial y}\hat{j}+\frac{\partial}{\partial z}\hat{k}\right).\vec{E}=\left(\frac{\partial}{\partial x}\hat{i}+\frac{\partial}{\partial y}\hat{j}+\frac{\partial}{\partial z}\hat{k}\right).\frac{\vec{D}}{\epsilon_0}$$

$$\rho=\frac{\partial}{\partial x}(e^{-x}\text{siny})+\frac{\partial}{\partial y}(-e^{-x}\text{cosy})+\frac{\partial}{\partial z}(2z)$$

$\rho = -e^{-x}\sin y + e^{-x}\sin y + 2$

At origin $\rho = -e^{-0}\sin 0 + e^{-0}\sin 0 + 2$

$\rho = 2C/m^3$

Charge = ρ × volume = 2 × 2 × 10^{-9} = 4 × 10^{-9} = 4 nC

GRAVITATION SOLUTION

1. $$E_1 - \frac{GMm}{R} = -\frac{GMm}{(R+h)}$$

$$E_1 = \frac{GMm}{R} - \frac{GMm}{(R+h)}$$

$$E_1 = \frac{GMmh}{R(R+h)}$$

$$\frac{mv^2}{R+h} = \frac{G\,Mm}{(R+h)^2}$$

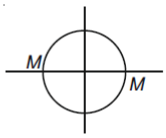
$$E_2 = \frac{1}{2}\frac{GMm}{(R+h)^2}$$

Given $E_1 = E_2$

$$\frac{h}{R} = \frac{1}{2}, h = \frac{R}{2}$$

2. $2R = d = 2 \times 10^{11}$ m

$\Rightarrow R = 10^{11}$ m



$\therefore$ V(at centre) = $\frac{GM}{R} \times 2$

$\therefore$ Let v_0 be the minimum speed of meteorite

then $\frac{1}{2}mv_0^2 - \frac{2GMm}{R} = 0$

$$v_0 = \sqrt{\frac{4GM}{R}} = \sqrt{\frac{4 \times 6.67 \times 10^{-11} \times 3 \times 10^{31}}{10^{11}}}$$

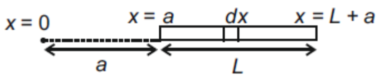
$\Rightarrow v_0 = 2.83 \times 10^5$ m/s $= 2.8 \times 10^5$ m/s

3. $$v_0 = \sqrt{gR}$$

$$v_e = \sqrt{2gR}$$

$$\Delta v = \sqrt{gR}\left(\sqrt{2} - 1\right)$$

4.



$$dF = -Gm \int_a^{L+a} \frac{(A + Bx^2)dx}{x^2}$$

$$F = -Gm\left[-A\left[\frac{1}{L+a} - \frac{1}{a}\right] + BL\right]$$

$$= -Gm\left[A\left[\frac{1}{a} - \frac{1}{a+L}\right] + BL\right]$$

5. $$r = \frac{a}{\sqrt{2}}, F = \frac{GM^2}{a^2}\left(\sqrt{2}\right) + \frac{GM^2}{2a^2}$$

$$\therefore \quad \frac{Mv^2}{\left(\frac{a}{\sqrt{2}}\right)} = \frac{GM^2}{a^2}\left(\sqrt{2} + \frac{1}{2}\right)$$

$$\Rightarrow \quad v^2 = \frac{GM}{a}\left(1 + \frac{1}{2\sqrt{2}}\right)$$

$$\Rightarrow \quad v = \sqrt{\frac{GM}{a}\left(1 + \frac{1}{2\sqrt{2}}\right)} = 1.16\sqrt{\frac{GM}{a}}$$

6. $$E = \frac{GM_E m}{R_E}$$

$$E' = \frac{GM_M m}{R_M}$$

$$\rho R_E^3 = 64 \rho R_M^3$$

$\Rightarrow \quad R_E = 4\,R_M$

$$\frac{E'}{E} = \frac{M_M}{M_E} \cdot \frac{R_E}{R_M} = \frac{1}{64} \cdot 4 = \frac{1}{16}$$

$$\Rightarrow \quad E' = \frac{E}{16}$$

7. $$M_{(in)} = \int_0^R 4\pi r^2 dr.\frac{k}{r^2}$$

$M_{(in)} = 4\pi KR$

$$\therefore \quad G \cdot \frac{4\pi KR}{R^2} = \frac{V^2}{R} \Rightarrow v = \sqrt{4\pi GK}$$

$$\therefore \quad T = \frac{2\pi R}{v} = \frac{2\pi \cdot R}{\sqrt{4\pi GK}}$$

$\therefore \quad \frac{T}{R}$ = constant

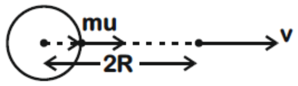
8. $W_{man} = Mg_{eff}\,l$

due to motion of swing the g_{eff} at lowest point will be

$$g_{eff} = g(1 + \theta_0^2)$$

$$W_{man} = Mgl(1 + \theta_0^2)$$

9.



$$\frac{1}{2}mu^2 + \frac{-GMm}{R} = \frac{1}{2}mv^2 + \frac{-GMm}{2R}$$

$$\Rightarrow \quad \frac{1}{2}m\left(v^2 - u^2\right) = \frac{-GMm}{2R}$$

$$\Rightarrow \quad v = \sqrt{u^2 - \frac{GM}{R}} \quad ....(i)$$

$$v_0 = \sqrt{\frac{GM}{2R}} \qquad \therefore \; v_{rad} = \frac{m \times v}{\left(\frac{m}{10}\right)} = 10\,v$$

$$\therefore \; \frac{9m}{10} \times \sqrt{\frac{GM}{2R}} = \frac{m}{10} \times v_\tau \Rightarrow v_\tau^2 = 81\frac{GM}{2R}$$

$$\therefore \; KE_{rocket} = \frac{1}{2} \times \frac{m}{10} \times \left(\left(u^2 - \frac{GM}{R}\right)100 + 81\frac{GM}{2R}\right)$$

$$= \frac{m}{20} \times 100\left(u^2 - \frac{GM}{R} + \frac{81}{200}\frac{GM}{R}\right)$$

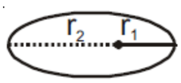
$$= 5m\left(u^2 - \frac{119}{200}\frac{GM}{R}\right)$$

10. Total energy $E = \frac{-GMm}{2a}$

$$\therefore \quad \frac{1}{2}m \times \left(\frac{2}{3}\frac{GM}{R}\right) - \frac{GMm}{R} = \frac{-GMm}{2a}$$

$\Rightarrow \quad a = 2R$

Major axis = 4R



$r_1 = R \Rightarrow r_2 = 3R$

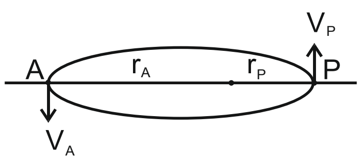
11. $g_{equator} = g - \omega^2 R$

$$g_h = g\left(1 - \frac{2h}{R}\right)$$

$$g\left(\frac{2h}{R}\right) = \omega^2 R$$

$$h = \frac{\omega^2 R^2}{2g}$$

12.

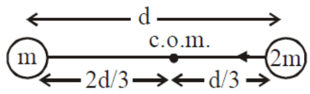


$$\frac{V_P}{V_A} = \frac{6}{1}$$

$$mV_p \cdot r_P = mV_A r_A$$

$$\frac{r_P}{r_A} = \frac{V_A}{V_P} = \frac{1}{6}$$

13.



$$F = \frac{G(2m)m}{d^2} = (2m)\omega^2 \; (d/3)$$

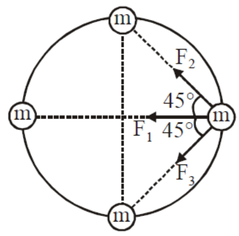
$$\frac{Gm}{d^2} = \omega^2 \frac{d}{3}$$

$$\Rightarrow \; \omega^2 = \frac{3Gm}{d^3}$$

$$\Rightarrow \; \omega = \sqrt{\frac{3Gm}{d^3}}$$

$$\Rightarrow \; T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{d^3}{3Gm}}$$

14.



m = 1 kg
R = 1 m

$$F_1 = \frac{Gmm}{(2R)^2} = \frac{Gm^2}{4R^2}$$

$$F_2 = \frac{Gmm}{\left(\sqrt{2}R\right)^2} = \frac{Gm^2}{2R^2}$$

$$F_3 = \frac{Gmm}{\left(\sqrt{2}R\right)^2} = \frac{Gm^2}{2R^2}$$

$\Rightarrow \quad F_{net} = F_1 + F_2 \cos 45° + F_3 \cos 45°$

$$= \frac{Gm^2}{4R^2} + \frac{Gm^2}{2R^2}\frac{1}{\sqrt{2}} + \frac{Gm^2}{2R^2}\frac{1}{\sqrt{2}}$$

$$= \frac{Gm^2}{R^2}\left(\frac{1}{4} + \frac{1}{2\sqrt{2}} + \frac{1}{2\sqrt{2}}\right)$$

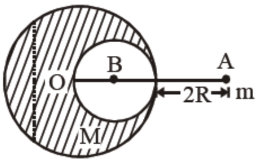
$$= \frac{Gm^2}{R^2}\left(\frac{1}{4} + \frac{1}{\sqrt{2}}\right) = \frac{Gm^2}{4R^2}\left(1 + 2\sqrt{2}\right)$$

$$= F_{net} = \frac{Gm^2}{4R^2}\left(1+2\sqrt{2}\right) = \frac{mv^2}{R}$$

$$v = \frac{\sqrt{G\left(1+2\sqrt{2}\right)}}{2}$$

15. Let initial mass of sphere is m'. Hence mass of removed portion will be m'/8

$$F_1 = m.E. = \frac{m.Gm'}{9R^2}$$



$$F_2 = m\left[\frac{G.m'}{(3R)^2} - \frac{G.m'/8}{(5R/2)^2}\right]$$

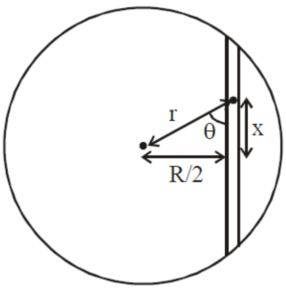
$$= \left(\frac{G.m'}{9R^2} - \frac{G.m'\times 4}{(8\times 25)R^2}\right)m$$

$$= \left(\frac{1}{9} - \frac{1}{50}\right)\frac{Gm'}{R^2} \times m$$

$$F_2 = \frac{41}{50\times 9}.\frac{Gm'}{R^2} \times m$$

$$\frac{F_1}{F_2} = \frac{1}{9} \times \frac{50\times 9}{41} = \frac{50}{41}$$

16.



Force along the tunnel

$$F = -\left(\frac{GMmr}{R^3}\right)\cos\theta$$

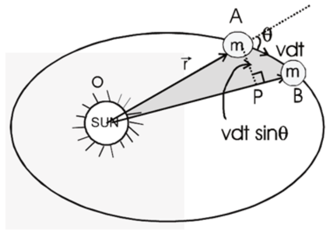
$$F = -\frac{gm}{R}x$$

$$\because \left(\frac{GM}{R^2} = g, r\cos\theta = x\right)$$

$$a = -\frac{g}{R}x$$

$$\omega^2 = \frac{g}{R} \qquad T = 2\pi\sqrt{\frac{R}{g}}$$

17.



dA = 1/2 (Base) (Perpendicular height)

dA = 1/2 (r) (vdtsinθ)

so rate of area swept = $\frac{dA}{dt} = \frac{1}{2}vr\sin\theta$

we can write $\frac{dA}{dt} = \frac{1}{2}\frac{mvr\sin\theta}{m}$

where mvr sinθ = angular momentum of the planet about the sun, which remains conserved (constant)

$$\Rightarrow \frac{dA}{dt} = \frac{L_{planet/sun}}{2m} = constant$$

18.

$$U = -\frac{C}{r}$$

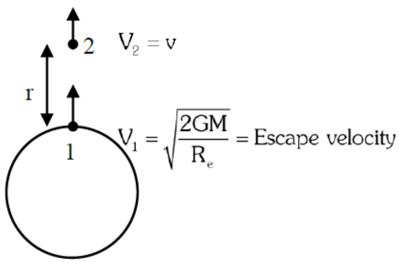
$$F = -\frac{dU}{dr} = -\frac{C}{r^2}$$

$$|F| = \frac{mv^2}{r}$$

$$\frac{C}{r^2} = \frac{mv^2}{r}$$

$$v^2 \propto \frac{1}{r}$$

19.



Applying energy conservation from (1) to (2)

$$\frac{1}{2}m.\left(\frac{2GM}{R_e}\right) - \frac{GMm}{R_e} = \frac{1}{2}mv^2 - \frac{GMm}{R_e+r}$$

$$\frac{1}{2}mv^2 = \frac{GMm}{R_e+r}$$

$$v = \sqrt{\frac{2GM}{R_e + r}} = \frac{dr}{dt}$$

$$\sqrt{2GM}\int_0^t dt = \int_0^h (\sqrt{R_e + r})dr$$

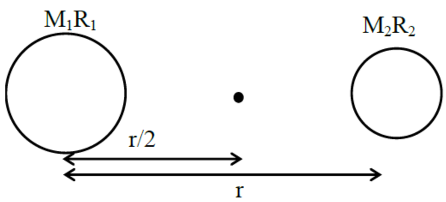
$$\sqrt{2GM}.t = \frac{2}{3}\left[(R_e + r)^{3/2}\right]_0^h$$

$$t = \frac{2}{3}\sqrt{\frac{R_e^3}{2GM}}\left[\left(1+\frac{h}{R_e}\right)^{3/2} - 1\right]$$

$$\frac{GM}{R_e^2} = g$$

$$t = \frac{1}{3}\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2} - 1\right]$$

20.



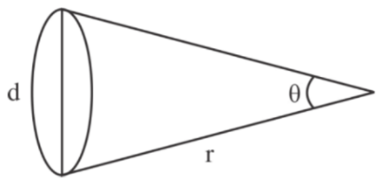
$$\frac{1}{2}mV^2 - \frac{GM_1m}{r/2} - \frac{GM_2m}{r/2} = 0 \ ,$$

$$\frac{1}{2}mV^2 = \frac{2Gm}{r}(M_1 + M_2) \ ,$$

$$V = \sqrt{\frac{4G(M_1 + M_2)}{r}}$$

Option (2)

21.



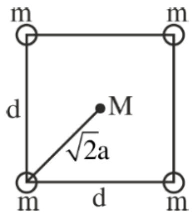
$$\theta = \frac{d}{r}$$

$$\frac{2000}{60\times 60}\times\frac{\pi}{180} = \frac{d}{1.5\times 10^{11}}$$

$$d = \frac{2000}{60\times 60}\times\frac{\pi}{180}\times 1.5\times 10^{11}$$

$$= \frac{\pi\times 1.5}{3\times 6\times 18}\times 10^{11} = 1.45\times 10^{9}$$

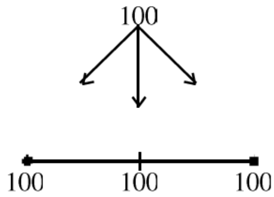
22.



$$-\frac{Gm}{d}\times 4 - \frac{Gm^2}{\sqrt{2}d}\times 2 - \frac{GMm}{d}\times 4\sqrt{2}$$

$$-\frac{Gm}{d}\left[(4+\sqrt{2})m + 4\sqrt{2}M\right]$$

23.



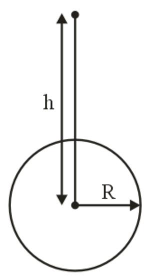
$$F = \frac{GMM}{r^2} + \sqrt{2}\frac{GMM}{(\sqrt{2}\,r)^2}$$

$$= \frac{GMM}{r^2}\left(1+\frac{1}{\sqrt{2}}\right)$$

$$= \frac{G\times 10^4}{13^2}\left(1+\frac{1}{\sqrt{2}}\right)$$

F = 100G

24.



$$-\frac{GMm}{R} + \frac{1}{2}m\lambda^2 V_e^2 = -\frac{GMm}{h}$$

$$-\frac{GMm}{R} + \frac{1}{2}\lambda^2\frac{2GMm}{R} = -\frac{GMm}{h}$$

$$\frac{\lambda^2}{R} - \frac{1}{R} = \frac{-1}{h}$$

$$\frac{1}{h} = \frac{1-\lambda^2}{R}$$

$$h = \frac{R}{1-\lambda^2}$$

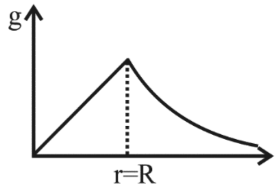
25. $T^2 \propto R^3 \Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3$

$$\Rightarrow \quad \left(\frac{1}{2.83}\right)^2 = \left(\frac{1.5\times10^6}{R_2}\right)^3$$

$$\Rightarrow \quad R_2 = \left[(2.83)^2 \times (1.5\times10^6)^3\right]^{1/3} = =$$

$8^{1/3} \times 1.5 \times 10^6 \times 3 \times 10^6$ km

26. $g' = \dfrac{g}{\left(1+\dfrac{h}{R}\right)^2}$ $\qquad g' = g\left\{1-\dfrac{d}{R}\right\}$



Statement I is correct and Statement II is incorrect

27. Acceleration due to gravity at height h

$$g' = \frac{g}{\left[1+\frac{h}{R}\right]^2}$$

So weight at given height

$$mg' = \frac{mg}{\left[1+\frac{h}{R}\right]^2} = \frac{18}{\left[1+\frac{1}{2}\right]^2} = 8N$$

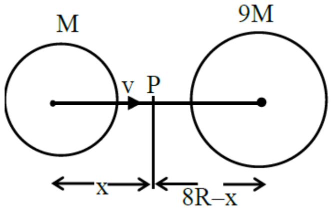
28. $-\dfrac{GM_Em}{10R} + \dfrac{1}{2}mV_0^2 = -\dfrac{GM_Em}{R} + \dfrac{1}{2}mV^2$

$$\Rightarrow \quad \frac{GM_E}{R}\left(1-\frac{1}{10}\right) + \frac{V_0^2}{2} = \frac{V^2}{2}$$

$$V^2 = V_0^2 + \frac{9}{5}gR$$

$$\Rightarrow \quad V = \sqrt{V_0^2 + \frac{9}{5}gR} \approx 16\,km/s$$

29. Acceleration due to gravity will be zero at P therefore,



$$\frac{GM}{x^2} = \frac{G9M}{(8R-x)^2}$$

$8R - x = 3x$

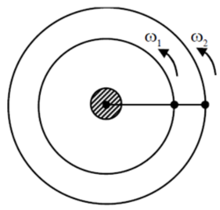
$x = 2R$

Apply conservation of energy and consider velocity at P is zero.

$$\frac{1}{2}mv^2 - \frac{GMm}{R} - \frac{G9Mm}{7R} = 0 - \frac{GMm}{2R} - \frac{G9Mm}{6R}$$

$$\therefore V = \sqrt{\frac{4}{7}\frac{GM}{R}}$$

30.



T_1 = 1 hour

$\Rightarrow \omega_1 = 2\pi$ rad/hour

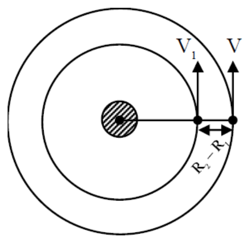
T_2 = 8 hours

$$\Rightarrow \omega_2 = \frac{\pi}{4}\text{rad / hour}$$

$R_1 = 2 \times 10^3$ km

As $T^2 \propto R^3$

$$\Rightarrow \frac{R_2}{R_1} = \left(\frac{8}{1}\right)^{2/3} = 4 \Rightarrow R_2 = 8\times10^3\text{km}$$



$V_1 = \omega_1 R_1 = 4\pi \times 10^3$ km / h

$V_2 = \omega_2 R_2 = 2\pi \times 10^3$ km / h

Relative $\omega = \dfrac{V_1 - V_2}{R_2 - R_1} = \dfrac{2\pi\times10^3}{6\times10^3}$

$$= \frac{\pi}{3}\text{rad / hour}$$

X = 3

CURRENT ELECTRICITY SOLUTION

1. $\frac{R}{X} = \frac{l}{100-l}$

Using the above expression

$x = \frac{R(100-l)}{l}$

for case (a) $x = \frac{100 \times 40}{60} = \frac{2000}{3}\Omega$

for case (b) $x = \frac{100 \times 87}{13} = \frac{8700}{13}\Omega$

for case (c) $x = \frac{10 \times 98.5}{1.5} = \frac{1970}{3}\Omega$

for case (d) $x = \frac{1 \times 99}{1} = 99\Omega$

Clearly we can see that the value of x calculate in case (d) is inconsistent than other cases.

2. For R_1

$\because$ $I_g = 10^{-3}$ A

$\therefore$ $10^{-3}(R_1 + 100) = 2 \text{ V} \Rightarrow R_1 = 1900\ \Omega$

For R_2

$10^{-3}(R_1 + R_2 + 100) = 10$ V

$\Rightarrow$ $R_1 + R_2 + 100 = 10000$

$\Rightarrow$ $R_2 = 8000\ \Omega$

For R_3

$10^{-3}(R_1 + R_2 + R_3 + 100) = 20$ V

$\Rightarrow$ $R_1 + R_2 + R_3 + 100 = 20 \times 1000$

$\Rightarrow$ $R_3 = 10000\ \Omega$

3. $V = \frac{ER}{R+r}$

for $R = \infty$, $V = E = 1.5$ V

for $R = 0$, $I = E/r = 1$

$r = 1.5\ \Omega$

4. $V = I_g(R_v + G) = GI_0$ ...(1)

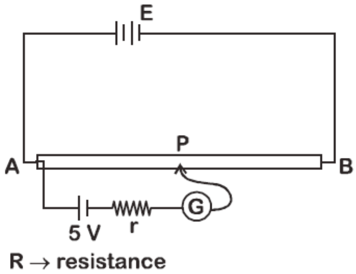
$(I_0 - I_g)R_A = I_gG$ ...(2)

From (1), $R_V = \frac{G(I_0 - I_g)}{I_g}$

From (2), $R_A = \frac{I_gG}{I_0 - I_g}$ $\Rightarrow$ $R_AR_V = G^2$

$\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

5.



Potential gradient for the potentiometer wire

'AB' is $-\frac{dV}{d\ell} = \left[\frac{60 \times R}{\ell_{AB}}\right] mv/m$

$\therefore$ $V_{AP} = \left(-\frac{dV}{d\ell}\right)\ell_{AP} = \frac{60 \times R}{1200} \times 1000$ mV

$\therefore$ $V_{AP} = 50$ R mV

Also, $V_{AP} = 5$ V (for balance point at P)

$\therefore$ $R = \frac{5}{50 \times 10^{-3}} = 100\Omega$

6. $\rho_M = 98 \times 10^{-8}$

$\rho_A = 2.80 \times 10^{-8}$

$\rho_C = 1.72 \times 10^{-8}$

$\rho_T = 5.65 \times 10^{-8}$

$\rho_M > \rho_T > \rho_A > \rho_C$

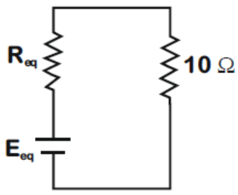
7. Power in external $R = \left(\frac{\varepsilon}{r+R}\right)^2 R$

This power is maximum, when R = r

$r = \int_a^b \rho \frac{dx}{2\pi xl}$

$r = \frac{\rho}{2\pi l} \ln \frac{b}{a}$

8.



$$\frac{1}{R_{eq}}=\frac{1}{4}+\frac{1}{7}\Rightarrow R_{eq}=\frac{28}{11}\Omega$$

Circuit can be reduced to

$$\frac{11E_{eq}}{28}=\frac{20}{7}+\frac{10}{4}$$

$$E_{eq}=\frac{150}{11}V$$

$$I=\frac{\frac{150}{11}}{\frac{28}{11}+10}=\frac{150}{138}A$$

$$\frac{1500}{138}=10+4\,I$$

$$I=\frac{30}{138}A$$

9. $i = 20t + 8t^2$

$$i=\frac{dq}{dt}\Rightarrow\int dq=\int idt$$

$$\Rightarrow\ q=\int_0^{15}(20t+8t^2)\,dt$$

$$q=\left(\frac{20t^2}{2}+\frac{8t^3}{3}\right)_0^{15}$$

$$q=10\times(15)^2+\frac{8(15)^3}{3}$$

$q = 2250 + 9000$

$q = 11250$ C

10. At t = 0, current through inductor is zero,

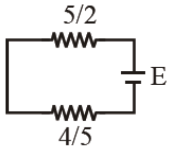
hence $R_{eq} = (5 + 1) \,||\, (5 + 4) = \frac{18}{5}$

$i_1 = \frac{E}{18/5}=\frac{5E}{18}$

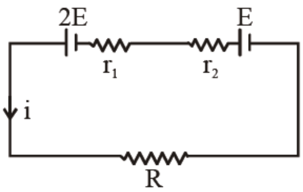
At t = ∞, inductor becomes a simple wire and now the circuit will be as shown in figure

hence $R_{eq} = (5 \,||\, 5) + (4 \,||1) = \frac{33}{10}$; (|| $\Rightarrow$ parallel)

$i_2 = \frac{E}{33/10}=\frac{10E}{33}$



11.



$$i=\frac{3E}{R+r_1+r_2}$$

TPD = $2E - ir_1 = 0$

$2E = ir_1$

$$2E=\frac{3E\times r_1}{R+r_1+r_2}$$

$$2R+2r_1+2r_2=3r_1$$

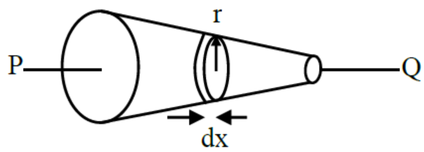
$$R=\frac{r_1}{2}-r_2$$

12. Max voltage that can be measured by this potentiometer will be equal to potential drop across AB

$R_{AB} = 10 \times 0.1 \times 100 = 100$ ohm.

$$\therefore\ V_{AB}=\frac{6}{20+100}\times100=6\times\frac{100}{120}=5V$$

13.



Current is constant in conductor

i = constant

Resistance of element $dR=\frac{\rho dx}{\pi r^2}$

$dV = idR = \frac{i\rho dx}{\pi r^2}$

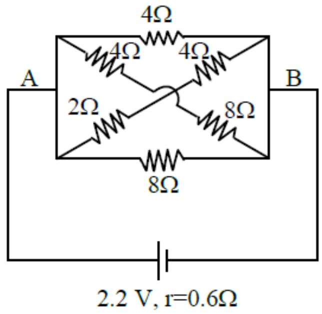
$$E=\frac{dV}{dx}=\frac{i\rho}{\pi r^2}\ \&\ V_d=\frac{eE\tau}{m}$$

$\therefore\ V_d \propto E$

$$E\propto\frac{1}{r^2}$$

if r decreases , E will increase $\therefore$ V_d will increase

14.



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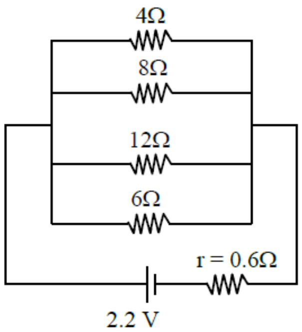
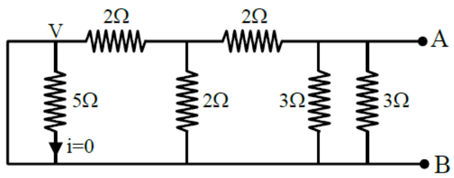


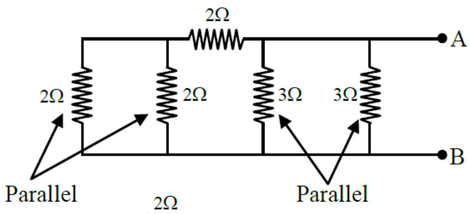
$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{6} = \frac{6+3+2+4}{24} = \frac{15}{24}$$

$$R_{eq} = \frac{24}{15} = 1.6 \Rightarrow R_T = 1.6 + 0.6 = 2.2\Omega$$

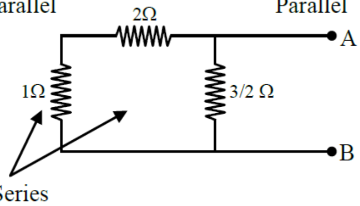
$$P = \frac{V^2}{R_T} = \frac{(2.2)^2}{2.2} = 2.2W$$

15.





⇒



$$R_{eq} = \frac{3 \times 3/2}{3 + 3/2} = \frac{9/2}{9/2} = 1\Omega$$

16. Velocity gradient $= \frac{dV}{dx} = \frac{1}{S}$

$$\lambda = \frac{1}{S}$$

17.

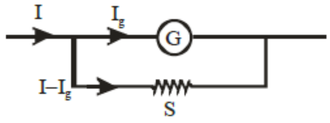


Figure of merit $\frac{I_g}{\theta} = K$

$I_g = Kn$

$$I = \frac{I_g}{s}(G + S)$$

$$I = \frac{nK}{S}(G + S)$$

18. Electric displacement

$\vec{D} = \epsilon_0 \vec{E}$ -

$$[D] = [\epsilon_0 E] = \left[\epsilon_0 \frac{\sigma}{\epsilon_0}\right]$$

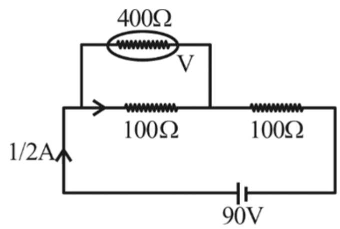
$[D] = [\sigma]$

$\rightarrow$ Surface change density = σ.

19. $R_{eq} = \frac{400 \times 100}{500} + 100 = 180\Omega$

$$i = \frac{90}{180} = \frac{1}{2}A$$

Reading = $\frac{1}{2} \times \frac{400}{500} \times 100 = 40$ volt



20. Length of AB = 10 m

For battery E_1, balancing length is l_1

l_1 = 380 cm [from end A]

For battery E2, balancing length is l_2

l_2 = 760 cm [from end A]

Now, we know that $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

$$\Rightarrow \frac{E_1}{E_2} = \frac{380}{760} = \frac{1}{2} = \frac{a}{b}$$

$\therefore$ a = 1 & b = 2

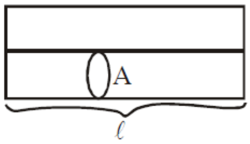
a = 1

21. For parallel combination current divides in the inverse ratio of resistance.

$$i_{PQ} = \frac{2}{6} \times 6 \text{ A}$$

22. $\because$ in parallel

$$R_{net} = \frac{R_1R_2}{R_1 + R_2}$$

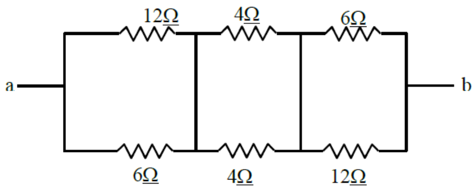


$$\frac{\rho l}{2A} = \frac{\rho_1 \frac{l}{A} \times \rho_2 \frac{l}{A}}{\rho_1 \frac{l}{A} + \rho_2 \frac{l}{A}}$$

$$\frac{\rho}{2} = \frac{6 \times 3}{6 + 3} = 2$$

$\rho = 4$

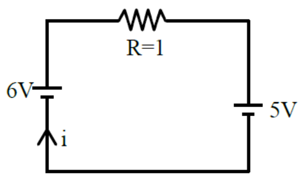
23. When switch S_1 and S_2 are closed



$$\frac{12 \times 6}{12 + 6} + 2 + \frac{6 \times 12}{6 + 12}$$

$$\frac{72}{18} + 2 + \frac{72}{18} = 4 + 2 + 4 = 10\Omega$$

24. From graph voltage at t = 3.2 sec is 6 volt



$$i = \frac{6 - 5}{1}$$

i = 1 A

25. In series

R_{eq} = nR = 10 n

$$i_s = \frac{20}{10 + 10n} = \frac{2}{1 + n}$$

In parallel

$$R_{eq} = \frac{10}{n}$$

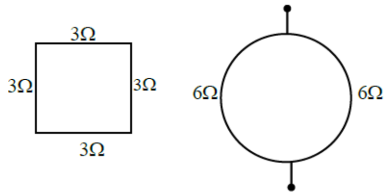
$$i_p = \frac{20}{\frac{10}{n} + 10} = \frac{2n}{1 + n}$$

$$\frac{i_p}{i_s} = 20$$

$$\frac{\left(\frac{2n}{1+n}\right)}{\left(\frac{1}{1+n}\right)} = 20$$

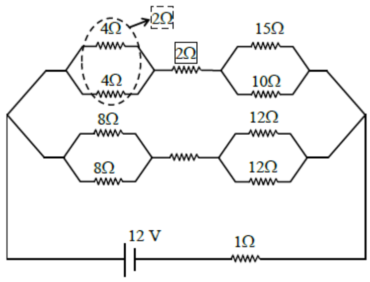
n = 20

26.

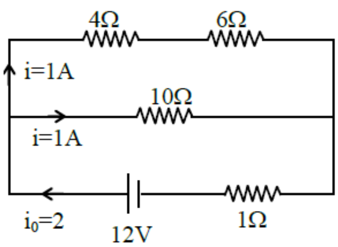


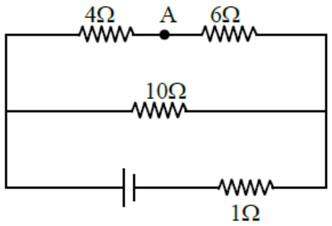
Req = 3Ω

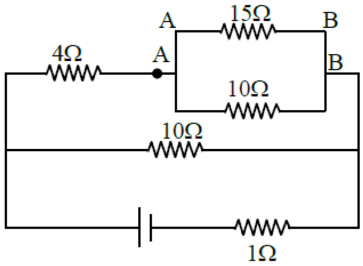
27.



$\Rightarrow$ effective circuit diagram will be

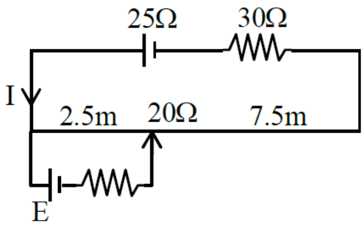




$\Rightarrow$ 

Point drop across 6Ω = 1 × 6 = 6 = VAB

$\Rightarrow$ Hence point drop across 15Ω = 6 volt = VAB

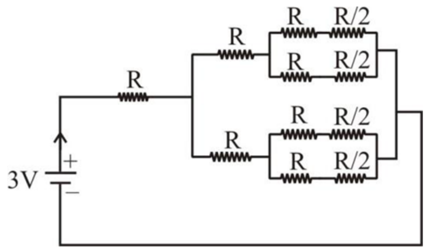
28. 

$$I = \frac{25}{50} = \frac{1}{2} A$$

$\therefore \Delta V = 10$ V

10 m $\to$ 10V

2.5m $\to$ 2.5V

29. 

$$R_{eq} = \frac{15R}{8} = \frac{15}{8}\Omega$$

$$I = \frac{3}{\frac{15}{8}} = \frac{8}{5} A \quad \therefore a = 8$$

30. As volume is constant,

So resistance $\propto$ (length)^2

$\Rightarrow$ % change in resistance = 20 + 20 + $\frac{400}{100}$ = 44%

HEAT TRANSFER SOLUTION

1. $\dfrac{dQ}{dt} = -kA\dfrac{d\theta}{dx}$

at steady state $\dfrac{dQ}{dt}$ = constant.

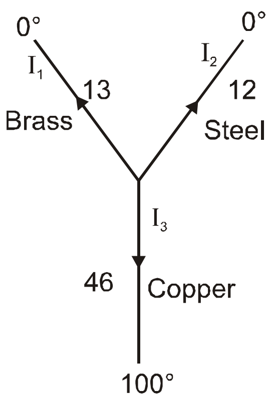
$d\theta \ \alpha - dx$

$$\int_{\theta_0}^{\theta} d\theta = -k\int_0^x dx$$

$\theta = \theta_0 - kx$

2. According to Newtons cooling law option **(3)** is correct Answer.

3.



$I_1 + I_2 + I_3 = 0$

$$\frac{K_1(T-0)}{\ell_1} + \frac{K_2(T-0)}{\ell_2} + \frac{K_3(T-100)}{\ell_3} = 0$$

$$\frac{0.12}{12}T + \frac{0.26}{13}T + \frac{0.92}{46}(T-100) = 0$$

T = 40°C

$\dfrac{dQ}{dt}$ through copper $= \dfrac{0.92\times 4}{46}$ (100 – 40)

= 4.8 cal/sec.

4. $C = C_V + \dfrac{R}{1-n}$

$C - C_V = \dfrac{C_P - C_V}{1-n}$; $1 - n = \dfrac{C_P - C_V}{C - C_V}$

$n = 1 - \dfrac{C_P - C_V}{C - C_V} = \dfrac{C - C_P}{C - C_V}$

5. $\dfrac{2(T_A - T_P)}{L} = \left(\dfrac{T_P - T_Q}{L}\right) + \dfrac{2}{3}\left(\dfrac{T_P - T_Q}{L}\right)$

$2(T_A - T_P) = \dfrac{5}{3}(T_P - T_Q)$ ....(1)

$2(T_Q - T_B) = \dfrac{5}{3}(T_P - T_Q)$ ....(2)

From (1) and (2)

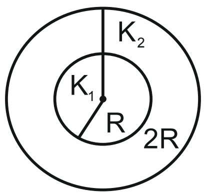
$2(T_A - T_B) = 2(T_P - T_Q)\dfrac{10}{3}(T_P - T_Q)$

$\Rightarrow 2\times 120 = \dfrac{16}{3}(T_P - T_Q)$

$\Rightarrow T_P - T_Q = \dfrac{2\times 120\times 3}{16} 45°C$

6. $\dfrac{Q}{A} = \dfrac{K[T_1 - T_2]}{L} = \dfrac{0.1\times 900}{1} = 90\ w/m^2$

7.



$\therefore \ K_{eq} = \dfrac{K_1A_1 + K_2A_2}{A_1 + A_2}$

$\Rightarrow K_{eq} = \dfrac{K_1\pi R^2 + K_2 3\pi R^2}{4\pi R^2}$

$= \dfrac{K_1 + 3K_2}{4}$

8. $mS\left(-\dfrac{dT}{dt}\right) = e\sigma AT^4$

$-\dfrac{dT}{dt} = \dfrac{e\sigma\times A\times T^4}{\rho\times Vol.\times S}$ $\Rightarrow$

$$\frac{\left(-\frac{dT}{dt}\right)_A}{\left(-\frac{dT}{dt}\right)_B} = \frac{\rho_B}{\rho_A}\times(2) > 1$$

So, A cools down at faster rate.

9. $K_1\,(100 - 70) = K_2\,(50)$

$K_3\,(20) = K_2\,(50)$

10. $\frac{\Delta T}{\Delta t} = -b\left(T_{av} - T_s\right)$

$\therefore \quad \frac{50-40}{5} = -b[45-20]$

and, $\frac{40 - T_3}{5} = -b\left[\frac{40+T_3}{2} - 20\right]$

$\Rightarrow \quad T_3 = \frac{200}{6} \approx 33°C$

11. A and R are true but R is not the correct explanation of A.

12. $n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\therefore \quad n^{1/3} r = R$

$\therefore$ Total change in surface energy

$= (n(4\pi r^2) - 4\pi R^2)T$

$\Rightarrow 4\pi T(nr^2 - R^2)$

$\therefore$ Heat energy

$= \frac{4\pi T(nr^2 - R^2)}{J \times \frac{4}{3}\pi R^3} = \frac{3T}{J}\left(\frac{nr^2}{R^3} - \frac{1}{R}\right)$

Put $nr^3 = R^3$

$\therefore \quad \frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$

13. Energy associated with each degree of freedom per molecule = $\frac{1}{2}k_a T$.

14. $\frac{\Delta T}{\Delta t} = K(T_t - T_s)$ $\quad T_t$ = average temp.

T_S = surrounding temp.

$\frac{61-59}{4} = K\left(\frac{61+59}{2} - 30\right)$ ....(1)

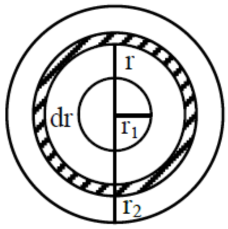
$\frac{51-49}{t} = K\left(\frac{51+49}{2} - 30\right)$ ....(2)

Divide (1) & (2)

$\frac{t}{4} = \frac{60-30}{50-30} = \frac{30}{20}$

so, t = 6 minutes

15. Thermal resistance of spherical sheet of thickness dr and radius r is



$R = \frac{dr}{K\left(4\pi r^2\right)}$, $R = \int_{r_1}^{r_2} \frac{dr}{K\left(4\pi r^2\right)}$

$R = \frac{1}{4\pi K}\left(\frac{1}{r_1} - \frac{r}{r_2}\right) = \frac{1}{4\pi K}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$

Thermal current (i) = $\frac{\theta_2 - \theta_1}{R}$

$i = \frac{4\pi K r_1 r_2}{r_2 - r_1}\left(\theta_2 - \theta_1\right)$

16. $P = \frac{\alpha}{\beta}\log_e\left(\frac{kt}{\beta x}\right)$

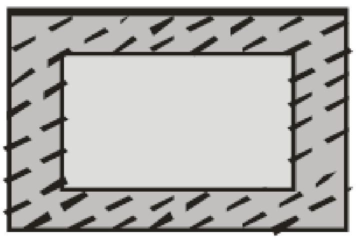
$\frac{kt}{\beta x} = 1 \Rightarrow \beta = \frac{kt}{x} = \frac{ML^2T^{-2}}{L}$

$\left(\because E = \frac{1}{2}kt\right)$

As P is dimensionless

$\Rightarrow [\alpha] = [\beta] = [MLT^{-2}]$

17.



$\frac{dQ}{dt} = \frac{KA\Delta T}{\ell}$

A = 2 (0.6 × 0.5 + 0.5 × 0.2 + 0.2 × 0.6)

= 2(0.3 + 0.1 + 0.12)

= 2(0.4 + 0.12)

= 2(0.52)

= 1.04 m^2

$$R_{th} = \frac{\ell}{KA} \Rightarrow \frac{1\times10^{-2}}{0.05\times1.04} \Rightarrow \frac{10^{-2}}{0.052}$$

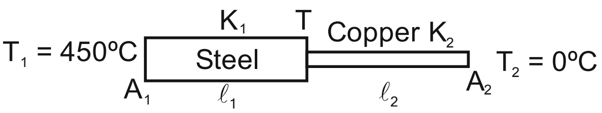
$$\frac{dQ}{dt} = \frac{\Delta T}{R_{th}} \Rightarrow \frac{40\times0.052}{10^{-2}} \Rightarrow 2.08\times10^{2}\,J/s$$

$2.08 \times 10^2 = m \times 3.4 \times 10^5$

$$m = \frac{2.08}{3.4\times10^{3}} \Rightarrow 0.61\times10^{-3}\,kg/s$$

$= 61 \times 10^{-5}$ Kg/s

18.



$$\frac{dQ}{dt} = \frac{K_1A}{\ell_1}(T_1 - T) = \frac{K_2A_2}{\ell_2}(T - T_2)$$

$$\frac{450 - T}{T - 0} = \frac{K_2A_2\ell_1}{K_1A_1\ell_2} = 9\times\frac{1}{2}\times2$$

$450 - T = 9T \Rightarrow T = 45ºC$

19. Heat Transfer

A. by Newton's low of colling $\frac{d\theta}{dt} = \propto \Delta T$

B. $H = \frac{d\theta}{dt} = \sigma eAT^4 \Rightarrow \frac{H_P}{H_Q} = \left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{283}{293}\right)^4$

$H_P : H_Q = 1 : (1.03)^4 = 1 : (1.03)^4 = 1 : 1.15$

$\Rightarrow$ B is correct

C. $\eta = 1 - \frac{100}{400} = \frac{3}{4} = 75\%$

D. is wrong as $\frac{d\theta}{dt} \propto \Delta T$

20.

Let length of wire by 'ℓ'

Area of wire as 'A'

For equivalent wire length = 2ℓ & area will be A

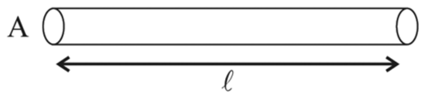
Thermal resistance

$R_{eq} = R_1 + R_2$

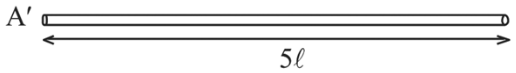
$$\frac{2\ell}{\sigma_{eq}A} = \frac{\ell}{\sigma_1A} + \frac{\ell}{\sigma_1A}$$

$$\frac{2\ell}{\sigma_{eq}} = \frac{\ell}{\sigma_1} + \frac{\ell}{\sigma_2} \Rightarrow \sigma_{eq} = \frac{2\sigma_1\sigma_2}{\sigma_1 + \sigma_2}$$

21.



$$R_{initial} = \frac{\rho\ell}{A} = 5\Omega$$



$\because$ Volume of wire is constant in stretching

$V_i = V_f$

$A_i\ell_i = A_f\ell_f$

$A\ell = A'(5\ell)$

$$A' = \frac{A}{5}$$

$$R_f = \frac{\rho\ell_f}{A_f} = \frac{\rho(5\ell)}{\left(\frac{A}{5}\right)}$$

$= 25\left(\frac{\rho\ell}{A}\right)$ = 25 × 5 = 125 Ω

22. Basic theory

Translational K.E on average of a molecule is $\frac{3}{2}$ KT which is independent of nature, pressure and volume.

23. $H = \frac{V^2}{R}\times t$

$$\frac{H_1}{H_2} = \frac{\frac{V^2t}{R}}{\frac{V^2t}{3R}} = 3:1$$

24. $c\in E^2 = \frac{100}{4\pi\times3^2}$

$$c\in\left(\sqrt{\frac{x}{5}}E\right)^2 = \frac{60}{4\pi\times3^2}$$

$$\Rightarrow \frac{x}{5} = \frac{3}{5}$$

$\Rightarrow x = 3$

25. By newton's law of cooling (with approximation)

$$\frac{\Delta T}{\Delta t} = -C(T_{avg} - T_s)$$

$$1^{st}\ \frac{-10^\circ C}{5\min} = -C(70^\circ C - 25^\circ C)$$

$$C = \frac{2}{45}\min^{-1}$$

$$2^{nd}\ \frac{T-65}{5\min} = -C\left(\frac{T+65}{2} - 25\right) = -\left(\frac{2}{45}\right)\left(\frac{T+15}{2}\right)$$

$9(T - 65) = -(T + 15)$

$10T = 570$

$T = 57^\circ C$

Alternate solution :

Newton's law of cooling (without approximation)

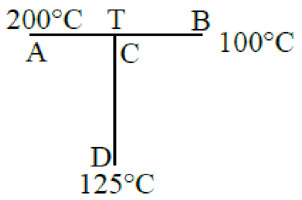
$T_P - T_S = (T_i - T_S)\, e^{-Ct}$

$1^{st}\ 65 - 25 = (75 - 25)\, e^{-5C} \Rightarrow e^{-5C} = \frac{4}{5}$

$2^{nd}\ T - 25 = (65 - 25)\, e^{-5C} = 40 \times \frac{4}{5} = 32$

$T = 57^\circ C$

26.



Rods are identical so

$R_{AB} = R_{CD} = 10\ Kw^{-1}$

C is mid-point of AB, so

$R_{AC} = R_{CB} = 5\ Kw^{-1}$

At point C

$$\frac{200-T}{5} = \frac{T-125}{10} + \frac{T-100}{5}$$

$2(200 - T) = T - 125 + 2(T - 100)$

$400 - 2T = T - 125 + 2T - 200$

$$T = \frac{725}{5} = 145^\circ C$$

$$I_h = \frac{145-125}{10} w = \frac{20}{10} w$$

$I_h = 2w$

27. $T - T_0 = (T_i - T_0)\ e^{-\lambda t}$

$6\lambda = \ln 1.5$

$40 = 60e^{-\lambda(6)} \Rightarrow 6\lambda = \ln 1.5$

$20 = 60e^{-\lambda t_2} \Rightarrow t_2\,\lambda = \ln 3$

$$\frac{t_2}{6} = \frac{\ln 3}{\ln 1.5}$$

$\therefore t_2 = 16.25$ min

So ≈ 16

28. $\frac{dQ}{dt} = i^2R = \frac{V^2}{R}$ (we know)

$\Rightarrow$ In 't' time , $\Delta Q = \left(\frac{V^2}{R}\right)t$

Given that, (for same source, v = same)

$$Q_0 = \frac{v^2}{R_1} \times 20 = \frac{V^2}{R_2} \times 60 \qquad \text{....(1)}$$

$\Rightarrow R_2 = 3R_1$

If they are connected in parallel then

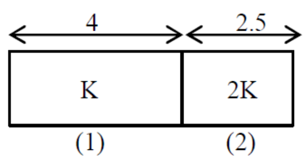
$$Req = \frac{R_2R_1}{R_1 + R_2} = \frac{3R_1.R_1}{3R_1 + R_1} = \left(\frac{3R_1}{4}\right)$$

To produce same heat, using equation ....(1)

$$Q_0 = \frac{V^2}{R_1} \times 20 = \frac{v^2}{\left(\frac{3R_1}{4}\right)} \times t$$

$$t = \frac{3 \times 20}{4} = 15 \text{ min}$$

29.



$$\frac{\Delta Q}{\Delta t} = \left(\frac{1}{R}\right)\Delta T$$

R : Thermal resistivity

$$\therefore R_1 = \frac{L_1}{K_1A} = \frac{L_1}{K(120)}$$

$L_1 = 4$ cm

$A = 120$ cm^2

$$R_2 = \frac{2.5}{(2K)(120)}$$

Now, R_{eq} of this series combination

$R_{eq} = R_1 + R_2$

where $L_{eq} = 4 + 2.5 = 6.5$

$$\frac{L_{eq}}{K_{eq}(A)} = \frac{4}{K(120)} + \frac{5}{\frac{2}{2K(120)}}$$

$$\frac{6.5}{K_{eq}(120)} = \frac{4}{K(120)} + \frac{5}{4K(120)}$$

$$\frac{6.5}{K_{eq}} = \frac{21}{4K}$$

$$K_{eq} = \frac{26}{21}K = \left(1 + \frac{5}{21}\right)K$$

$\therefore$ a = 21

30. P' = 10 % of 110 W

$$= \frac{10}{100} \times 110\text{W}$$

= 11 W

$$I_1 - I_2 = \frac{P'}{4\pi r_1^2} - \frac{P'}{4\pi r_2^2}$$

$$= \frac{11}{4\pi}\left[\frac{1}{1} - \frac{1}{25}\right] = \frac{11}{4\pi} \times \frac{24}{25}$$

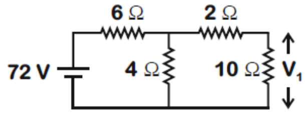
$$= \frac{264}{\pi} \times 10^{-2} = 84 \times 10^{-2}\,\text{W}/\text{m}^2$$

CAPACITANCE SOLUTION

1. At steady state current through capacitor is zero.

$V_C = V_1$

$$V_1 = \frac{5}{6} \times V_0 \times \frac{3}{9}$$



$$V_1 = \frac{5 \times 72 \times 3}{6 \times 9} = 20\,V$$

$Q_1 = CV_1$; $= 200\ \mu C$

2. Equivalent capacitance for series combination

$$C' = \frac{C_1C_2}{C_1 + C_2}$$

For parallel combination $C'' = C_1 + C_2$

Also $C'' > C'$

$$C_1 + C_2 = \frac{500}{10} = 50\,\mu F$$

and $\dfrac{C_1C_2}{C_1 + C_2} = \dfrac{80}{10} = 8\,\mu F$

$\therefore$ $C_1C_2 = 400\ \mu F$

Solving $C_1 = 40\ \mu F$ $C_2 = 10\ \mu F$

3. $$\frac{1}{C_1} = \frac{d}{3A\varepsilon_0}\left(\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3}\right)$$

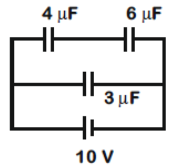
$$C_1 = \frac{3A\varepsilon_0(K_1K_2K_3)}{d(K_1K_2 + K_2K_3 + K_3K_1)}$$

$$C_2 = \frac{A\varepsilon_0}{3d}(K_1 + K_2 + K_3)$$

$$\frac{E_1}{E_2} = \frac{C_1}{C_2} = \frac{3K_1K_2K_3}{(K_1K_2 + K_2K_3 + K_3K_1)} \times \frac{3}{(K_1 + K_2 + K_3)}$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{9K_1K_2K_3}{(K_1 + K_2 + K_3)(K_1K_2 + K_2K_3 + K_3K_1)}$$

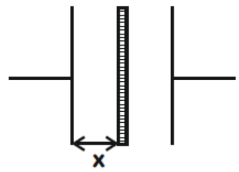
4.



$$Q_{(4\mu F)} = \left(\frac{4 \times 6}{4 + 6}\right) \times 10\,\mu C$$

$= 24\ \mu C$

5.



$k = K\,(1 + \alpha x)$

$$C_{el} = \frac{\varepsilon_0 K(1 + \alpha x)A}{dx}$$

$$\therefore \int d\left(\frac{1}{C}\right) = \frac{1}{C_{el}} = \int_0^d \left(\frac{dx}{\varepsilon_0 KA(1 + \alpha x)}\right)$$

$$\Rightarrow \frac{1}{C} = \frac{1}{\varepsilon_0 KA\alpha}[\ln(1 + \alpha x)]_0^d$$

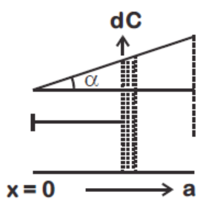
$$\Rightarrow \frac{1}{C} = \frac{1}{\varepsilon_0 KA\alpha}\ln(1 + \alpha d)$$

$$= \frac{1}{\varepsilon_0 KA\alpha}\left[\alpha d - \frac{\alpha^2 d^2}{2}\right]$$

$$= \frac{d}{\varepsilon_0 KA}\left[1 - \frac{\alpha d}{2}\right]$$

$$\therefore\ C = \frac{\varepsilon_0 KA}{d\left(1 - \frac{\alpha d}{2}\right)} \Rightarrow C = \frac{\varepsilon_0 KA}{d}\left(1 + \frac{\alpha d}{2}\right)$$

6.



$y = \tan \alpha x$

$\therefore\ dC = \dfrac{\varepsilon_0\, adx}{d + x\tan\alpha}$

$\therefore\ C_{eq} = \int dc = a\varepsilon_0 \displaystyle\int_{x=0}^{x=a} \dfrac{dx}{x\tan\alpha + d}$

[By Binomial expansion]

$\therefore\ C_{eq} = \dfrac{a\varepsilon_0}{d}\displaystyle\int_0^a \left(1 - \dfrac{x\tan\alpha}{d}\right)dx = \dfrac{a\varepsilon_0}{d}\left(x - \dfrac{x^2\tan\alpha}{d2}\right)_0^a$

$\therefore\ C_{eq} = \dfrac{a^2\varepsilon_0}{d}\left(1 - \dfrac{a\tan\alpha}{2d}\right) = \dfrac{\varepsilon_0 a^2}{d}\left(1 - \dfrac{x^2\tan\alpha}{d2}\right)_0^a$

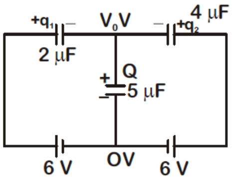
7. $U = \dfrac{1}{2}CV^2$

$\dfrac{U_1}{U_2} = 2 \ \Rightarrow \dfrac{C_1}{C} = 2$

$\dfrac{kx + (\ell - x)}{\ell} = 2$

$x = \dfrac{\ell}{3}$

8.



$Q = q_1 + q_2$

$5V_0 = 2(6 - V_0) + 4(6 - V_0)$

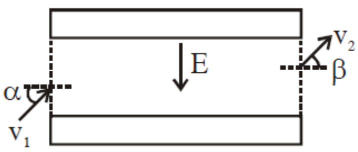
$V_0 = \dfrac{36}{11}V$

$Q = 5V_0 = \dfrac{180}{11}\mu C$

9. $\tau = RC = 10\ \mu s$

For $0 < t < 5\ \mu s$, it will get charged. For $5 < t < 10\ \mu s$ potential is constant and again gets charged after that.

10.



velocity along the plate will not change.

$\therefore\quad v_1 \cos\alpha = v_2 \cos\beta$

$\dfrac{K_1}{K_2} \Rightarrow \dfrac{v_1^2}{v_2^2} = \dfrac{\cos^2\beta}{\cos^2\alpha}$

11. When connected in parallel

$C_{eq} = C_1 + C_2$

When in series

$C'_{eq} = \dfrac{C_1C_2}{C_1 + C_2}$

$C_1 + C_2 = \dfrac{15}{4}\left(\dfrac{C_1C_2}{C_1 + C_2}\right)$

$4(C_1 + C_2)^2 = 15C_1C_2$

$4C_1^2 + 4C_2^2 - 7C_1C_2 = 0$

dividing by C_1^2

$4\left(\dfrac{C_2}{C_1}\right)^2 - \dfrac{7C_2}{C_1} + 4 = 0$

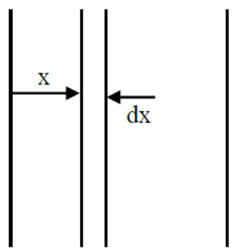
Let $\dfrac{C_2}{C_1} = x$

$4x^2 - 7x + 4 = 0$

$b^2 - 4ac = 49 - 64 < 0$

No Solution exits

12.



Taking an element of width dx at a distance x (x < d/2) from left plate

$dc = \dfrac{(\varepsilon_0 + kx)A}{dx}$

Capacitance of half of the capacitor

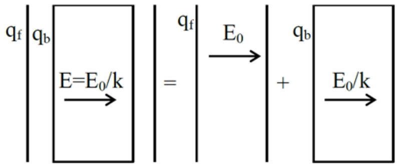
$\dfrac{1}{C} = \displaystyle\int_0^{d/2} \dfrac{1}{dc} = \dfrac{1}{A}\int_0^{d/2} \dfrac{dx}{\varepsilon_0 + kx}$

$\dfrac{1}{C} = \dfrac{1}{kA}\ln\left(\dfrac{\varepsilon_0 + kd/2}{\varepsilon_0}\right)$

Capacitance of second half will be same

$$C_{eq}=\frac{C}{2}=\frac{kA}{2\ln\left(\frac{2\varepsilon_0+kd}{2\varepsilon_0}\right)}$$

13.



When a dielectric is inserted in a capacitor

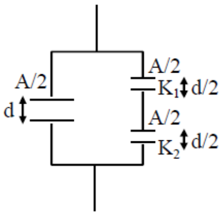
Due to free charge $\vec{E}=\vec{E}_0$ only

After dielectric $E'=\frac{E_0}{k}$

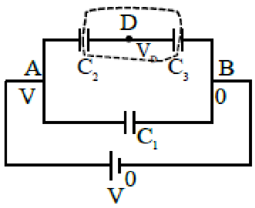
$$q_B=q_r\left(1-\frac{1}{k}\right)$$

14. $$C_{eq}=\frac{\frac{A}{2}\varepsilon_0}{d}+\frac{A\varepsilon_0}{d}\frac{K_1K_2}{K_1+K_2}$$

$$=\frac{A\varepsilon_0}{d}\left(\frac{1}{2}+\frac{K_1K_2}{K_1+K_2}\right)$$



15.



$(V_D - V)\ C_2 + (V_D - 0\ )\ C_3 = 0$

$(V_D - V)\ 6 + (V_D - 0\ )\ 12 = 0$

$V_D - V + 2V_D = 0$

$$V_D=\frac{V}{3}$$

$$q_2=(V-V_D)C_2=\left(V-\frac{V}{3}\right)(6\mu F)$$

$q_2 = (4V)\ \mu F$

$$q_3=(V_D-0)C_3=\frac{V}{3}\times 12\mu F=4V\mu F$$

$q_1 = (V - 0)\ C_1 = V\ (2\mu F)$

$q_1 : q_2 : q_3 = 2 : 4 : 4$

$q_1 : q_2 : q_3 = 1 : 2 : 2$

16. $V = V_0\ (1-e^{-t/RC})$

$2 = 20\ (1-e^{-t/RC})$

$$\frac{1}{10}=1-e^{-t/RC}$$

$$e^{-t/RC}=\frac{10}{9}$$

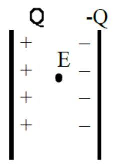
$$e^{t/RC}=\frac{10}{9}$$

$$\frac{t}{RC}=\ell n\left(\frac{10}{9}\right)\Rightarrow C=\frac{t}{R\ell n\left(\frac{10}{9}\right)}$$

$$C=\frac{10^{-6}}{10\times 0.105}=0.95\mu F$$

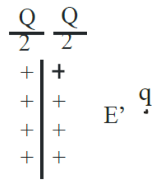
Option (2)

17.



$$F=qE=q\left(\frac{Q}{A\in_0}\right)=\frac{qQ}{A\in_0}=10N$$

Now, when one plate is removed.



$$E'=\frac{Q}{2A\in_0}$$

$$F=qE'=\frac{Qq}{2A\in_0}=5N$$

18. In t_1 time energy becomes half so charge will

become $\frac{1}{\sqrt{2}}$ time

$$q = Q_0 e^{\frac{t_1}{RC}} = \frac{Q_0}{\sqrt{2}}$$

and $$q = Q_0 e^{\frac{t_1}{RC}} = \frac{Q_0}{8} = \left(\frac{Q_0}{\sqrt{2}}\right)^6$$

$t_2 = 6t_1$

$$\frac{t_1}{t_2} = \frac{1}{6}$$

19. Q = CV

$$V = \frac{1}{C}Q$$

Straight line with slope = $\frac{1}{C}$

Slope $= \frac{1}{C} = \frac{1}{2 \times 10^{-6}} = 5 \times 10^5$

20. Capacitance of isolated Conducting sphere

$= 4\pi\varepsilon_0 R_1$

By enclosing inside another sphere of radius

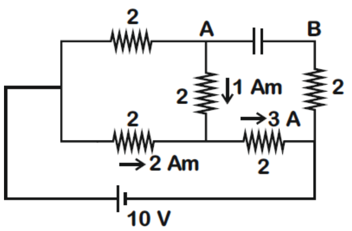
R_2, new capacitance $= \frac{4\pi\varepsilon_0 R_1 R_2}{(R_2 - R_1)}$

Given: $\frac{4\pi\varepsilon_0 R_1 R_2}{(R_2 - R_1)} = n \times 4\pi\varepsilon_0 R_1$

$$\Rightarrow \frac{R_2}{(R_2 - R_1)} = n \Rightarrow \frac{\frac{R_2}{R_1}}{\left(\frac{R_2}{R_1} - 1\right)} = n$$

$$\Rightarrow \frac{R_2}{R_1} = n\frac{R_2}{R_1} - n \Rightarrow \frac{R_2}{R_1} = \frac{n}{(n-1)}$$

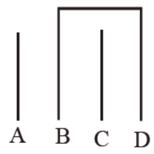
21.

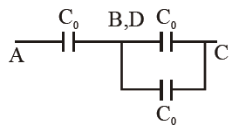


After solving the circuit we got the final current distribution as shown in the above diagram. So potential difference between A and B is

0 + (2 × 3) + (2 × 1) = 8 volt

22.





$$C_{eq} = \frac{2C_0}{3} = \frac{2}{3}\frac{\epsilon_0 A}{d}$$

$$C_{eq} = \frac{2\epsilon_0}{3d} \times \left(2 \times \frac{3}{2}\right) = 2 \quad (\because A = lb = 2 \times \frac{3}{2})$$

23. $U_i = \frac{1}{2} \times 14 \times 12 \times 12\,pJ \quad (\because U = \frac{1}{2}CV^2)$

= 1008 pJ

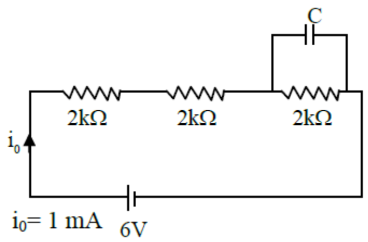
$U_f = \frac{1008}{7}pJ = 144\,pJ \quad (\because C_m = kC_0)$

Mechanical energy = ΔU

= 1008 – 144

= 864 pJ

24.



Pot. Diff. across each resistor = 2V

Q = CV

$= 50 \times 10^{-6} \times 2 = 100 \times 10^{-6} = 100\ \mu C$

25. $$\Delta U = \frac{1}{2}(\Delta C)V^2$$

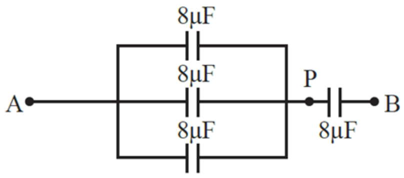
$$\Delta U = \frac{1}{2}(KC - C)V^2$$

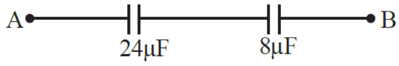
$$\Delta U = \frac{1}{2}(2-1)CV^2$$

$$\Delta U = \frac{1}{2} \times 200 \times 10^{-6} \times 200 \times 200$$

ΔU = 4 J

26. Two capacitors are short circuited





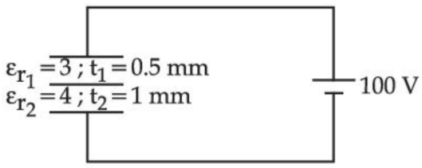
Finally equivalent capacitance

$$= \frac{24 \times 8}{24 + 8} = \frac{24 \times 8}{32} = 6\mu F$$

27. Parallel combination

$$c_{eq} = \varepsilon_0 A\left[\frac{1}{5b} + \frac{1}{3b} + \frac{1}{b}\right] = \frac{23}{15}\frac{\varepsilon_0 A}{b}$$

28.



Capacitance of each capacitor

$$C_1 = \frac{A3 \in_0}{\frac{1}{2}} = 6A \in_0$$

$C_2 = A4 \in_0 = 4A \in_0$

Equivalent capacitance

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} \Rightarrow \frac{24}{10} A \in_0$$

$q_{net} = C_{eq}\ (\Delta V) \Rightarrow 240\ A \in_0$

$$\Delta V_2 = \frac{240 A \in_0}{4A \in_0} = 60V$$

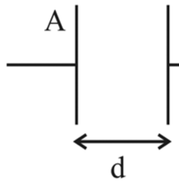
(ΔV_2 = Potential drop across C_2)

V_{foil} V = 60V

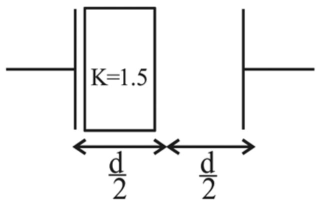
29. $C_0 = \frac{\in_0 A}{d} = 15pF$

$$C = \frac{K \in_0 A}{2d} = \frac{3.5}{2} \times 15pF = \frac{105}{4} pF$$

30.



$\frac{\in_0 A}{d} = 5\mu F$



$$\frac{\in_0 A}{d} = 5\mu F$$

$$C_{new} = \frac{\in_0 A}{\frac{\left(\frac{d}{2}\right)}{1.5} + \frac{\left(\frac{d}{2}\right)}{1}}$$

$$= \frac{\in_0 A}{\left(\frac{d}{3} + \frac{d}{2}\right)} = \frac{6 \in_0 A}{5d}$$

$$= \frac{6}{5} \times 5\mu F = 6\mu F$$

EMF SOLUTION

1. Soft ferromagnetic materials are materials which can be easily magnetised and demagnetised by external magnetic field. When external field is applied, the domains experiences a net torque hence change its orientation.

2. $F = q(\vec{v}\times\vec{B}) = \frac{q}{m}(\vec{p}\times\vec{B})$

$\Rightarrow\ F \propto \frac{q}{m}$

thus $F_1 : F_2 : = \frac{q_1}{m_1} : \frac{q_2}{m_2} : \frac{q_2}{m_3}$

$= \frac{e}{m_p} : \frac{e}{2m_p} : \frac{2e}{4m_p}$

$= \frac{1}{1} : \frac{1}{2} : \frac{2}{4}$

= 2 : 1 : 1

Now for speed calculation

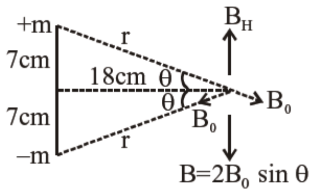
P = constant $\Rightarrow v \propto \frac{1}{m}$

thus $v_1 : v_2 : v_3 = \frac{1}{m_p} : \frac{1}{2m_p} : \frac{1}{4m_p}$

$= \frac{1}{1} : \frac{1}{2} : \frac{1}{4}$

= 4 : 2 : 1

3.



i.e. $\frac{2\mu_0}{4\pi}\frac{m}{r^2}\times\frac{7}{r} = 0.4\times10^{-4}$

$\Rightarrow\ 2\times10^{-7}\times\frac{m\times7}{(7^2+18^2)^{3/2}}\times10^4$

$= 0.4 \times 10^{-4}$

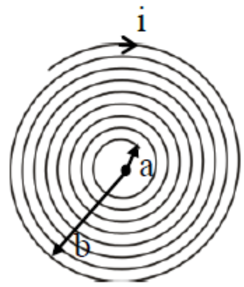
$m = \frac{4\times10^{-2}\times(373)^{3/2}}{14}$

m = m × 14 cm = m × $\frac{14}{100}$

$= \frac{0.04\times(373)^{3/2}}{14}\times\frac{14}{100}$

$= 4 \times 10^{-4} \times 7203.82 = 2.88$ J/T

4.

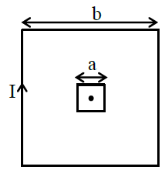


No. of turns in dx width $= \frac{N}{b-a}dx$.

$\int dB = \int_a^b \left(\frac{N}{b-a}\right)dx\,\frac{\mu_0 i}{2x}$, $B = \frac{N\mu_0 i}{2(b-a)}\ell n\left(\frac{b}{a}\right)$

Option (1)

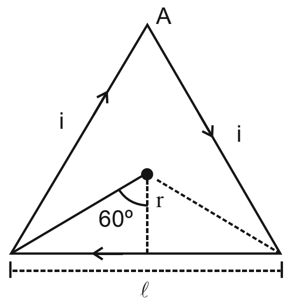
5.



$B = \left[\frac{\mu_0}{4\pi}\frac{I}{b/2}\times2\sin45\right]\times4$, $\phi = 2\sqrt{2}\,\frac{\mu_0}{\pi}\frac{I}{b}\times a^2$

$\therefore\ M = \frac{\phi}{I} = \frac{2\sqrt{2}\mu_0 a^2}{\pi b} = \frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$

6.



$$B = 3\left[\frac{\mu_0 i}{4\pi r}\left(\sin 60^\circ + \sin 60^\circ\right)\right]$$

$$\tan 60^\circ = \frac{\ell/2}{r}$$

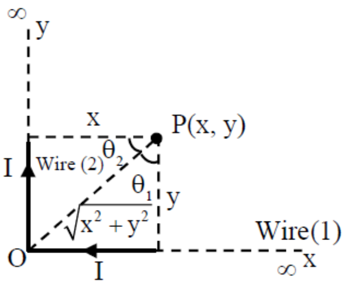
$$\text{Where} = r = \frac{9\times10^{-2}}{2\sqrt{3}} m$$

$$\therefore B = 3\times10^{-5} T$$

Current is flowing in clockwise direction so, $\vec{B}$ is inside plane of triangle by right hand rule.

7. Conceptual question

Option (1)



8.

$$B_{\text{due to wire (1)}} = \frac{\mu_0 I}{4\pi y}[\sin 90 + \sin\theta_1]$$

$$= \frac{\mu_0}{4\pi}\frac{I}{y}\left(1 + \frac{x}{\sqrt{x^2+y^2}}\right) \quad \text{.........(i)}$$

$$B_{\text{due to wire (2)}} = \frac{\mu_0}{4\pi}\frac{I}{x}[\sin 90^\circ + \sin\theta_2]$$

$$= \frac{\mu_0}{4\pi}\frac{I}{x}\left(1 + \frac{y}{\sqrt{x^2+y^2}}\right) \quad \text{........(ii)}$$

Total magnetic field

$B = B_1 + B_2$

$$B = \frac{\mu_0 I}{4\pi}\left[\frac{1}{y} + \frac{x}{y\times\sqrt{x^2+y^2}} + \frac{1}{x} + \frac{y}{x\sqrt{x^2+y^2}}\right]$$

$$B = \frac{\mu_0 I}{4\pi}\left[\frac{x+y}{xy} + \frac{x^2+y^2}{xy\sqrt{x^2+y^2}}\right]$$

$$B = \frac{\mu_0 I}{4\pi}\left[\frac{x+y}{xy} + \frac{\sqrt{x^2+y^2}}{xy}\right]$$

$$B = \frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2} + (x+y)\right]$$

Option (1)

9. $B_C = \frac{\mu_0 I}{2r}, B_a = \frac{\mu_0 I r^2}{2(x^2+r^2)^{3/2}}$

At $x = \frac{r}{2}$

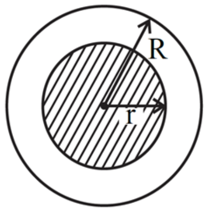
$$B_a = \frac{\mu_0 I r^2}{2\left(\frac{r^2}{4}+r^2\right)^{3/2}}$$

$$= \frac{\mu_0 I r^2}{2\left(\frac{5}{4}r^2\right)^{3/2}} = \frac{\mu_0 I}{2r}\left(\frac{4}{5}\right)^{3/2} = \frac{\mu_0 I}{2r}\left(\frac{2}{\sqrt{5}}\right)^3$$

10. As the sheet is very large $\vec{E}$ is independent of distance from it.

Thus $E_1 = E_2 = \frac{\sigma}{2\varepsilon_0}$

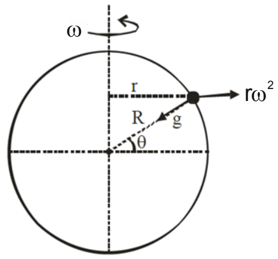
11. Use Ampere's law



$$B.2\pi r = \mu_0 \frac{I}{\pi R^2}.\pi r^2$$

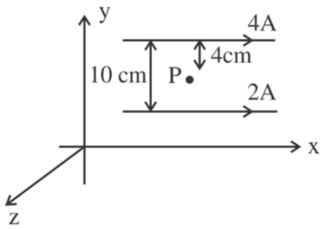
Thus $B \propto r$

12. Effective acceleration due to gravity is the resultant of g & $r\omega^2$ whose direction & magnitude depends upon θ. Hence assertion is false.



When θ = 0° (at equator), effective acceleration is radially inward.

13.



$$B_{net} = B_1 - B_2 = \frac{\mu_0 \times 4}{2\pi[.04]} - \frac{\mu_0 \times 2}{2\pi[.06]}$$

$$\vec{B}_{net} = \frac{\mu_0}{2\pi}\left[\frac{200}{3}\right](-\hat{k})$$

$$\vec{F} = q[\vec{v} \times \vec{B}]$$

$$= [3\pi]\left[(2\hat{i} + 3\hat{j}) \times \left(\frac{\mu_0}{2\pi}\right)\left(\frac{200}{3}\right) - \hat{k}\right]$$

$$= 3\pi \times \frac{\mu_0}{2\pi}\left(\frac{200}{3}\right)\left[2 \times \hat{j} - 3(\hat{i})\right]$$

$$= (4\pi \times 10^{-7})(100)(-3\hat{i} + 2\hat{j})$$

$$= 4\pi \times 10^{-5} \times [-3\hat{i} + 2\hat{j}]$$

14. $x = 4\sin\left(\frac{\pi}{2} - \omega t\right) \Rightarrow x = 4\cos(\omega t)$

$x = 4\cos(\omega t)$ $\quad y = 4\sin(\omega t)$

Eliminate 't' to find relation between x and y

$x^2 + y^2 = y^2\cos^2\omega t + y^2\sin^2\omega t = 4^2$

$x^2 + y^2 = 4^2$

15. $\chi = 1.2 \times 10^{-5}$

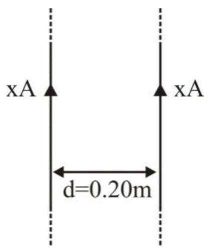
$\mu_r = 1 + \chi = 1 + 1.2 \times 10^{-5}$

Fractional Change

$$= \frac{\Delta B}{B} = \frac{\mu_0\mu_r ni - \mu_0 ni}{\mu_0 ni} = (\mu_r - 1)$$

$= 1.2 \times 10^{-5}$

16.



Force per unit length $= \frac{\mu_0 i_1 i_2}{2\pi d}$

$$= \frac{\mu_0 . x^2}{2\pi \times 0.2}$$

$$F = 2 \times 10^{-6} = \frac{4\pi \times 10^{-7} \times x^2}{2\pi \times 0.2}$$

$$10^{-6} = 10^{-7}\frac{x^2}{0.2}$$

$x^2 = 10 \times 0.2 = 2$

$x = \sqrt{2} \approx 1.4$ Amp

17. $f = \frac{1}{T} = \frac{eB}{2\pi m}$

$$= \frac{1.6 \times 10^{-19} \times 10^{-4}}{2\pi \times 9 \times 10^{-31}} = 2.8 \times 10^6 \text{Hz}$$

18. As $\vec{F} = q(\vec{v} \times \vec{B})$ -

$$\vec{a} = \frac{q}{m}(\vec{v} \times \vec{B})$$

so, $\vec{a}$ and $\vec{B}$ are $\perp$ to each other

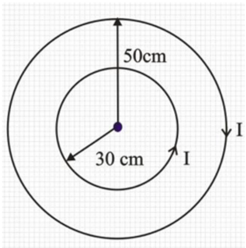
Hence, $\vec{a}.\vec{B} = 0$

$(\alpha\hat{i} - 4\hat{j}).(2\hat{i} + 3\hat{j}) = 0$

α (2) + (–4) (3) = 0

$\alpha = \frac{12}{2} \Rightarrow \alpha = 6$

19.



Magnetic moment

$$\vec{M} = -i\pi(0.5)^2\hat{k} + i\pi(0.3)^2\hat{k}$$

$$\vec{M} = -7 \times \frac{22}{7}\left(\frac{25}{100} - \frac{9}{100}\right)\hat{k}$$

$$= -22\left(\frac{16}{100}\right)\hat{k}$$

$$\vec{M} = 3.52\hat{k}\,\text{Am}^2$$

$$= -\frac{7}{2}\hat{k}\,\text{Am}^2$$

20. $\vec{E} = E\hat{k}$ $\qquad$ B = 12 mT

$\vec{B} = B\hat{j}$ $\qquad$ Energy = 728 eV

Energy $= \frac{1}{2}mv^2$

$$728\,\text{eV} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$$

$v = 16 \times 10^6$ m/s

E = vB

$E = 16 \times 10^6 \times 12 \times 10^{-3}$

$E = 192 \times 10^3$ V/m

21. $T = 2\pi\sqrt{\frac{I}{MB_H}}$

$$\frac{T_1}{T_2} = \frac{2\pi\sqrt{\frac{I_1}{M_1 B_H}}}{2\pi\sqrt{\frac{I_2}{M_2 B_H}}} = \frac{3}{4}$$

$$\sqrt{\frac{I_1}{I_2} \times \frac{M_2}{M_1}} = \frac{3}{4}$$

$$\sqrt{\frac{I_1}{I_2}} \times \sqrt{\frac{M_2}{M_1}} = \frac{3}{4}$$

$$\sqrt{\frac{3}{2}} \times \sqrt{\frac{M_2}{M_1}} = \frac{3}{4}$$

$$\frac{3}{2} \times \frac{M_2}{M_1} = \frac{9}{16}$$

$$\frac{M_1}{M_2} = \frac{8}{3}$$

22. $\tan\theta' = \dfrac{\tan\theta}{\cos\alpha}$

$\theta' = 60^\circ$

$\alpha = 45^\circ$

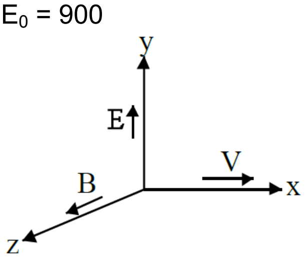
$$\sqrt{3} = \frac{\tan\theta}{\frac{1}{\sqrt{2}}}$$

$$\tan\theta = \sqrt{\frac{3}{2}}$$

$$\theta = \tan^{-1}\sqrt{\frac{3}{2}}$$

23. $E_y = 900\sin\left(\omega t - \dfrac{\omega x}{c}\right)$

$E_0 = 900$



$F_E = qE_0$

$F_B = qvB_0$

$$\frac{F_E}{F_B} = \frac{E_0}{vB_0} = \frac{c}{v} = \frac{3\times10^8}{3\times10^7} = 10:1$$

24. $T = 2\pi\sqrt{\dfrac{I}{B_H M}}$

$$T_1 = 3\sec = 2\pi\sqrt{\frac{I}{(B_P\cos30^\circ)M}}$$

$$T_2 = 6\sec = 2\pi\sqrt{\frac{I}{(B_Q\cos60^\circ)M}}$$

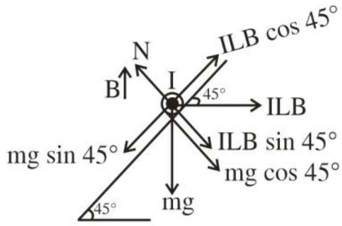
$$\frac{3}{6} = \sqrt{\frac{1}{\left(B_P\frac{\sqrt{3}}{2}\right)} \times (B_Q/2)}$$

$$\frac{3}{6} = \sqrt{\left(\frac{B_Q}{\sqrt{3}B_P}\right)}$$

$$\frac{\sqrt{3}}{4} = \frac{B_Q}{B_P}$$

$B_Q : B_P = \sqrt{3} : 4$

25.



mg sin 45° = ILB cos 45°

$$\therefore I = \left(\frac{m}{L}\right)\frac{g}{B} = \frac{(0.45)(10)}{0.15} = 30A$$

26. $B = \dfrac{\mu_0 i}{2R} \times 4$

$B' = \dfrac{\mu_0 i}{2R'}$

$R' = 4R$

$B' = \dfrac{\mu_0 i}{8R}$

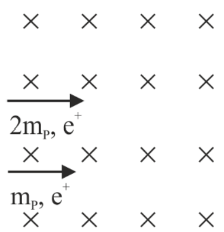
$\dfrac{B'}{B} = \dfrac{1}{16}$

$B' = 2T$

27. $\dfrac{\Delta M}{M} = \dfrac{\Delta\mu}{\mu} = \dfrac{250}{500} = \dfrac{1}{2}$

$\dfrac{1}{2} = \dfrac{x}{499} \Rightarrow x\ ;\ 250$

28.



$R = \dfrac{mv}{q\times B}$

$$R_D = \frac{(2m_P)v_D}{eB}$$

$$R_P = \frac{(m_P)V_P}{eB}$$

$$\frac{R_D}{R_P} = \frac{2v_D}{v_P} = \frac{2v_D}{\sqrt{2}v_D} = \frac{\sqrt{2}}{1}$$

$$\frac{1}{2}(2m_p)v_D^2 = \frac{1}{2}m_p \cdot v_p^2$$

$$\sqrt{2}v_D = v_P$$

x = 2

29. $R = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

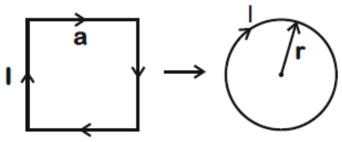
30. $B_{centre} = \frac{N\mu_0 I}{2R}$

$$37.68 \times 10^{-4} = \frac{100 \times 4\pi \times 10^{-7} \times I}{2 \times 5 \times 10^{-2}}$$

I = 3A

EMI SOLUTION

1.

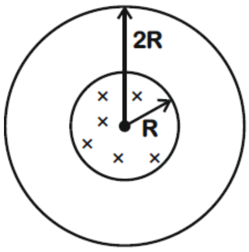


$2\pi r = 4a \quad \Rightarrow \quad r = \left(\frac{2a}{\pi}\right)$

$m = (I)\,a^2$; $\quad m_1 = (I)\,\pi r^2$

$m_1 = (I)(\pi)\left(\frac{4a^2}{\pi^2}\right)$; $\quad m_1 = \frac{4Ia^2}{\pi}$; $\quad m_1 = \frac{4m}{\pi}$

2.



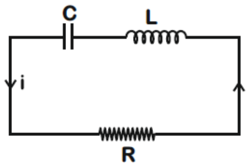
$I = I_0 t - I_0 t^2$

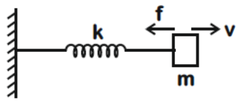
$\phi = (\mu_0 nI) \times (\pi R^2)$

$\therefore \quad \varepsilon = \frac{-d\phi}{dt}$

$\varepsilon = \mu_0 n \pi R^2 (I_0 - 2I_0 t)$

$\Rightarrow \qquad \varepsilon = 0 \text{ at } t = \frac{1}{2}\text{s}$





3.

In damped oscillation,

$$\frac{md^2x}{dt^2} = -kx - bv$$

$$\Rightarrow \quad \frac{md^2x}{dt^2} + b\frac{dx}{dt} + kx = 0 \qquad ....(i)$$

In LCR circuit, $\frac{-q}{C} - iR - \frac{Ldi}{dt} = 0$

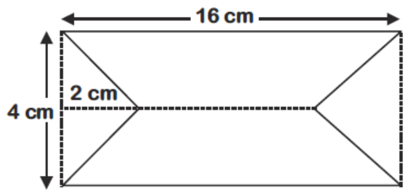
$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = 0$$

$\therefore \quad m \equiv L,\ b \equiv R,\ k \equiv \frac{1}{C}$

4. Using faraday law

Induced EMF $= \left|-\frac{d\phi}{dt}\right| = \left|A\frac{dB}{dt}\right|$

$\therefore \quad \frac{dB}{dt} = \frac{1000-500}{5} \times 10^{-4} = 10^{-2}\ \text{T/sec}$



Area = (16 × 4 – 2 × Area of triangle) cm²

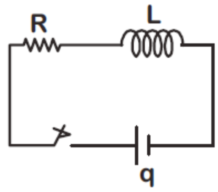
$= \left(64 - 2 \times \frac{1}{2} \times 2 \times 4\right)\text{cm}^2$

= 56 × 10–4 m2

$\therefore \quad \varepsilon_{induced} = 56 \times 10^{-6}\ \text{V} = 56\ \mu\text{V}$

5.

$i = \frac{E}{R}(1 - e^{-t/t_c})$



$\because \quad t_C = \frac{L}{R}$

$\Rightarrow \quad \int dq = \int \frac{E}{R}(1 - e^{-t/t_C})dt$

$\Rightarrow \quad q = \frac{E}{R}\left[t + t_C e^{-t/t_C}\right]_0^{t_C}$

$\Rightarrow \quad q = \frac{E}{R}\left[t_C + \frac{t_C}{e} - t_C\right]$

$\Rightarrow \quad q = \frac{E}{R}\frac{L}{Re}$

$\therefore \quad q = \frac{EL}{R^2 e}$

6. $\vec{M} = \vec{M}_1 + \vec{M}_2$

$\vec{M}_1 = abl\,\hat{j}$

$\vec{M}_2 = abl\,\hat{k}$

$\vec{M} = \sqrt{2}abl\left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$

7. Area of loop = $\frac{\ell^2}{16}$

$\varepsilon = -\frac{d\phi}{dt} = \left(\frac{dB}{dt}\right)\frac{\ell^2}{16}$

$I = \frac{\left(\frac{dB}{dt}\right)\frac{\ell^2}{16} \times \frac{\pi d^2}{4}}{\rho\ell}$

I = 0.61 A

8. Current direction reverses when magnet exits from solenoid and when magnet is completely inside, current is zero.

9. $|U_f - U_i| = \frac{1}{2}I\omega^2$

$20 \times 4 \times \frac{\sqrt{3}}{2} - 0 = \frac{1}{2} \times (0.8)\omega^2$

$\Rightarrow \quad \omega$ = 13.16 rad/s

10. $\frac{1}{2}Li^2 = \frac{1}{n}\frac{1}{2}Li_0^2$

$\Rightarrow \quad i = \frac{i_0}{\sqrt{n}}$

During growth of current,

$i = i_0(1 - e^{-t/\tau}) \quad \left(\tau = \frac{L}{R}\right)$

$e^{t/\tau} = \frac{\sqrt{n}}{\sqrt{n} - 1}$

$t = \frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n} - 1}\right)$

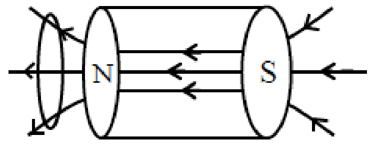
11. $U = \frac{1}{2}Li^2 = 64 \Rightarrow L = 2$

i^2R = 640

$R = \frac{640}{(8)^2} = 10$

$\tau = \frac{L}{R} = \frac{1}{5} = 0.2$

12.



$\rightarrow$ When magnet passes through centre region of solenoid , no current / Emf is induced in loop.

$\rightarrow$ While entering flux increases so negative induced emf

$\rightarrow$ While leaving flux decreases so positive induced emf.

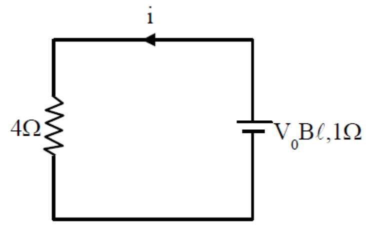
13. emf = BLV

= 1 (2R).1

= 2 V

14. $\vec{B}$ must not be parallel to the plane of coil for non zero flux and according to lenz law if B is outward it should be decreasing for anticlockwise induced current.-

15. Equivalent circuit

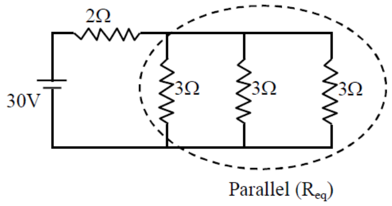


$i = \frac{V_0B\ell}{4+1} \Rightarrow V_0 = \frac{5(2mA)}{5 \times .2} = 10^{-2}$ m/s = 1 cm/s

Option (2)

16. In steady state, inductor behaves as a conducting wire.

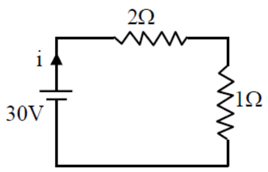
So, equivalent circuit becomes



$$\frac{1}{R_{eq}} = \frac{1}{3}+\frac{1}{3}+\frac{1}{3} = 1$$

$\Rightarrow R_{eq} = 1\Omega$

$\Rightarrow$ Circuit becomes



$$\Rightarrow i = \frac{30}{3} = 10A$$

17. e_2 : induced emf in secondary coil

i_1 : Current in primary coil

M : Mutual inductance

$$e_2 = -M\frac{di_1}{dt}$$

$$M = -\frac{e_2}{\frac{di_1}{dt}}$$

$$[M] = \frac{[e_2]}{\left[\frac{di_1}{dt}\right]} = \frac{\left[\frac{W}{q}\right]}{\left[\frac{di_1}{dt}\right]} = \frac{[ML^2T^{-2}]}{\left[\frac{AT}{AT^{-1}}\right]}$$

$= [ML^2T^{-2}A^{-2}]$

18. Current on both the inductor is in opposite direction.

Hence:

$L_{eq} = L_1 + L_2 - 2M$

19. emf induced between the two ends

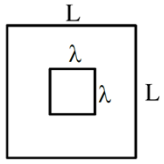
$$= \frac{B_H \omega t^2}{2}$$

$$\frac{0.2\times10^{-4}\times5\times1}{2} = 0.5 \times 10^{-4} = 50 \times 10^{-6}\ V$$

$= 50\ \mu V$

20. Assuming current I in outer loop magnetic field at

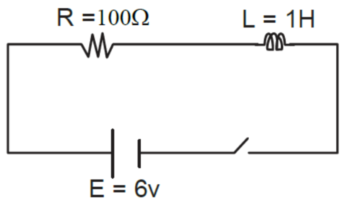
$$\text{centre} = 4\times\frac{\mu_0 i}{4\pi\times\frac{L}{2}}\times(2\sin45^\circ) = \frac{2\sqrt{2}\mu_0 i}{\pi L}$$



$$M = \frac{\text{Flux through inner loop}}{i}$$

$$M = \frac{2\sqrt{2}\mu_0\ell^2}{\pi L}$$

21. Given circuit is R – L growth circuit



$$i = \frac{E}{R}(1-e^{-t/\tau})$$

$$i = \frac{E}{2R} = \frac{E}{R}(1-e^{-t/\tau})$$

Solving $t = \tau \ln 2$

$$t = \frac{1}{R}\ln 2 = \frac{1}{100}0.693 = 0.00693 = 7\,ms$$

$$i(15\,ms) = \frac{E}{R}(1-e^{-\frac{15}{10}})$$

$$i = \frac{6}{100}(1-\frac{1}{4}) = \frac{3}{4}\times\frac{6}{100}$$

$$U = \frac{1}{2}LI^2$$

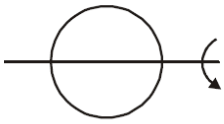
by solving we get U = 1 mJ

22. $B = \mu_0 nI = 4\pi \times 10^{-7} \times 70 \times 10^2 \times 2$

$= 56\pi \times 10^{-4}$ T

$= 176\pi \times 10^{-4}$ T

23.



$$\omega = \frac{\pi \times 10}{2} = 5\pi \text{ rad/s}$$

$\phi = \pi r^2.B\cos\omega t$

$$\therefore \quad |\epsilon| = \left(\frac{d\phi}{dt}\right) = \pi r^2 B\omega \sin\omega t$$

$$\therefore \quad |\epsilon|_{max} = \pi r^2 B\omega$$

$$= \frac{\pi \times 1}{100} \times 3 \times 10^{-5} \times 5 \times \pi$$

Taking $\pi^2 \approx 10$ we get (ϵ_{max}) = 15 × 10^{-6} volt

24. $\phi = \vec{B}.\vec{S}$ -

$$\phi = \frac{4}{\pi} \times 10^{-3}\left(1 - \frac{t}{100}\right).\pi R^2$$

$$\phi = 4 \times 10^{-3} \times (1)^2\left(1 - \frac{t}{100}\right)$$

$$\varepsilon = \frac{-d\phi}{dt}$$

$$\varepsilon = \frac{-d}{dt}\left(4 \times 10^{-3}\left(1 - \frac{t}{100}\right)\right)$$

$$\varepsilon = 4 \times 10^{-3}\left(\frac{1}{100}\right) = 4 \times 10^{-5} V$$

When B = 0

$$1 - \frac{t}{100} = 0$$

t = 100 sec

$$\text{Heat} = \frac{\varepsilon^2}{R} t$$

$$\text{Heat} = \frac{(4 \times 10^{-5})^2}{2 \times 10^{-6}} \times 100 J$$

$$\text{Heat} = \frac{16 \times 10^{-10} \times 100}{2 \times 10^{-6}} J$$

Heat = 0.08 J

Heat = 80 mJ

25. When T_1 and T_2 are connected, then the steady state current in the inductor

$$I = \frac{6}{6} = 1A$$

When T_1 and T_3 are connected then current through inductor remains same. So potential difference across 3Ω

V = Ir = 1 × 3 = 3 volt

26. I = 2sin(t^2) ⇒ dI = 4t sin(t^2)dt

If I = 0 ⇒ t = 0 and I = 2 ⇒ 2 = 2sin t^2

$$t = \sqrt{\frac{\pi}{2}}$$

$$E = \int LI\, dI$$

$$= \int 2 \times 2\sin(t^2) \times 4t\cos(t^2)dt$$

$$= 8\int_0^{\sqrt{\pi/2}} t\sin(2t^2)\, dt$$

$$= 2\left[-\cos(2t^2)\right]_0^{\sqrt{\pi/2}}$$

= 2[–cosπ + cos0] = 4

27. $$< \varepsilon > = \frac{\int \varepsilon dt}{\int dt} = \frac{\int (Ldi/dt)dt}{\int dt} = \frac{L\int di}{\int dt}$$

$$< \varepsilon > = \frac{L\Delta i}{\Delta t}$$

$$i_0 = \frac{V}{R} = \frac{20}{10} = 2A \text{ , if } I = 0 \text{ A}$$

T = 100 μs, L = 20 mH

$$< \varepsilon > = \frac{20 \times 10^{-3} \times (2-0)}{100 \times 10^{-6}} = \frac{2 \times 10^3}{5}$$

< e >= 400V

28. $$\phi = \frac{2}{3}(9 - t^2) = 0$$

t = 3 sec

$$e = \frac{-d\phi}{dt} = -\frac{2}{3}(0 - 2t) = \frac{4t}{3}$$

Heat produced in 3 sec

$$= \int \frac{e^2}{r} dt = \int_0^3 \frac{16t^2}{9 \times 8} dt = 2J$$

29. Just after closing the switch S, inductor behaves like an open circuit.

$$I = \frac{6}{2+4} = 1A$$

30. After long time an inductor behaves as a resistance-less path.

So current through cell

$$I = \frac{12}{R/3} = 3A$$

$$\{\because R = 12\Omega\}$$

ALTERNATING CURRENT SOLUTION

1. $I = I_m \sin(100\pi t)$

$\Rightarrow \quad \frac{I_m}{2} = I_m \sin(100\pi t_1)$

$\Rightarrow \quad \frac{\pi}{6} = 100\pi t_1 \qquad \Rightarrow t_1 = \frac{1}{600}s$

$T = \frac{2\pi}{100\pi} = \frac{1}{50}s$

$\therefore$

$t_{req} = \frac{T}{4} - t_1 = \frac{1}{200} - \frac{1}{600} = \frac{2}{600} = \frac{1}{300}s = 3.3 \text{ ms}$

2. Current through 60Ω resistance = $\frac{15}{60} = \frac{1}{4}A$

thus capacitor current = $\frac{1}{4}A$

$\because V_C = I X_C$

$10 = \frac{1}{4} \times \frac{1}{\omega C}$

$\therefore C = \frac{1}{40\omega} = \frac{1}{4000} = 250 \mu F$

Now,

current through 40Ω resistance

$= \frac{20}{40} = \frac{1}{2}A$

thus current through inductor

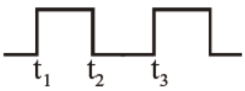
$= \frac{1}{2} - \frac{1}{4} = \frac{1}{4}A$

$V_L = IX_L = \frac{1}{4} \times \omega L$

$20 = \frac{1}{4} \times 100 \times L$

$\Rightarrow L = 0.8$ H

3.



For $\quad t_1 - t_2$ Charging graph

$t_2 - t_3$ Discharging graph

4. $V_S = \frac{P}{i} = \frac{60}{0.11} = 545.45$

$V_P = 220$

$V_S > V_P$

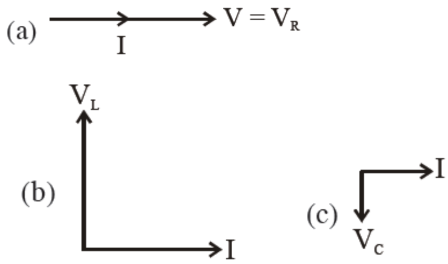
$\Rightarrow$ Step up transformer

5. $I = I_1 \sin\omega t + I_2 \cos\omega t$.

$\therefore I_0 = \sqrt{I_1^2 + I_2^2}$

$\therefore I_{rms} = \frac{I_0}{\sqrt{2}} = \sqrt{\frac{I_1^2 + I_2^2}{2}}$

6.



(d) $\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

7. $i = i_0 \cos(\omega t)$

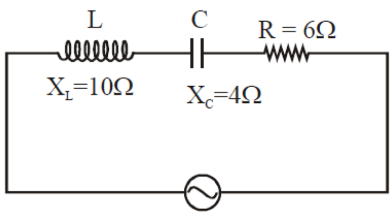
$i = i_0$ at $t = 0$

$i = \frac{i_0}{\sqrt{2}}$ at $\omega t = \frac{\pi}{4}$

$t = \frac{\pi}{4\omega} = \frac{\pi}{4(2\pi f)} = \frac{1}{8f}$

$t = \frac{1}{400} = 2.5$ ms

8.

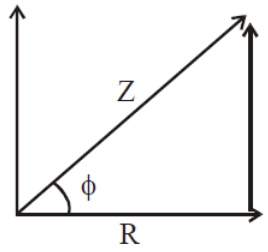


We know that power factor is $\cos\phi$,

$\cos\phi = \frac{R}{Z}$ ...(1)

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ ...(2)

$(\omega L - 1/\omega C)$



$\Rightarrow Z = \sqrt{6^2 + (10-4)^2}$

$\Rightarrow Z = 6\sqrt{2}\ |\cos\phi = \frac{6}{6\sqrt{2}}$

$\cos\phi = \frac{1}{\sqrt{2}}$

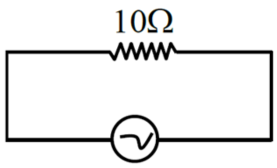
9. In capacitor, current lead voltage by $\frac{\pi}{2}$

10. (a) For $X_L > X_C$, voltage leads the current (ii)

(b) For $X_L = X_C$, voltage & current are in same phase (i)

(c) For $X_L < X_C$, current leads the voltage (iv)

(d) For resonant frequency $X_L = X_C$, current is maximum (iii)



11. V = 220V/50Hz

$\Rightarrow i = i_0 \sin\omega t$

when $i = i_0$

$i_0 = i_0 \sin \omega t_1 \Rightarrow \omega t_1 = \frac{\pi}{2}$ ....(i)

When $i = \frac{i_0}{\sqrt{2}}$

$\frac{i_0}{\sqrt{2}} = i_0 \sin\omega t_2 \Rightarrow \omega t_2 = \frac{\pi}{4}$ ....(ii)

Time taken by current from maximum value to rms value

$(t_1 - t_2) = \frac{\pi}{2\omega} - \frac{\pi}{4\omega} = \frac{\pi}{4\omega} = \frac{\pi}{4 \times 2\pi f}$

$= \frac{1}{8 \times 50} = \frac{1}{400}$ sec

= 2.5 ms

12. $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$ $X_L = \omega L$

$X_L = 2 \times \frac{22}{7} \times 50 \times 0.07 = 22\Omega$

$\phi = \tan^{-1}\left(\frac{22}{12}\right)$ R = 12 Ω

$\phi = \tan^{-1}\left(\frac{11}{6}\right)$

$Z = \sqrt{X_L^2 + R^2} = 25.059$

$I = \frac{V}{Z} = \frac{220}{25.059} = 8.77A$

13. For maximum average power

$X_L = X_C$

$250\pi = \frac{1}{2\pi(50)C}$

$C = 4 \times 10^{-6}$

Option (1)

14. $Z_C = \sqrt{\left(\frac{1}{\omega C}\right)^2 + R^2}$

$= \sqrt{\left(\frac{1}{100 \times 100 \times 10^{-6}}\right)^2 + 100^2}$

$Z_C = \sqrt{(100)^2 + (100)^2} = 100\sqrt{2}$

$Z_L = \sqrt{(\omega L)^2 + R^2}$

$\sqrt{(100 \times 0.5)^2 + 50^2}$

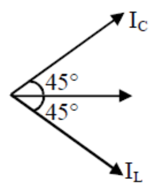
$= 50\sqrt{2}$

$i_C = \frac{200}{Z_C} = \frac{200}{100\sqrt{2}} = \sqrt{2}$

$i_L = \frac{200}{Z_L} = \frac{200}{100\sqrt{2}} = 2\sqrt{2}$

$\cos\phi_1 = \frac{100}{10\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_1 = 45°$

$\cos\phi_2 = \frac{50}{50\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_2 = 45°$



$I = \sqrt{I_C^2 + I_L^2} = \sqrt{2+8} = \sqrt{10}$

I = 3.16 A

15. if R = 0, P = 0

16. $X_L = 10^{-2} \times 3000 = 30\ \Omega$

$$X_C = \frac{1}{3000 \times 25 \times 10^{-6}} = \frac{40}{3}\Omega$$

$X = X_L - X_C$

$$= 30 - \frac{40}{3} = \frac{50}{3}$$

$$\tan\phi = \frac{X}{R} = \frac{50}{3 \times 100} = \frac{1}{6}$$

$$\phi = \tan^{-1}\left(\frac{1}{6}\right) = \tan^{-1}(0.17)$$

17. at ω_r, $X_C = X_L$

$$\Rightarrow \frac{1}{\omega_r C} = \omega_r L$$

So if $\omega < \omega_r$ then x_C will increase and X_L will decrease.

Hence to left of ω_r circuit is capacitive

$Z = \sqrt{R^2 + (X_C - X_L)^2}$ at

$\omega_r, Z = \sqrt{R^2 + O^2} = R$

18. In case of L-R circuit

$Z = \sqrt{X_L^2 + R^2}$ & power factor

$$P_1 = \cos\phi = \frac{R}{Z}$$

As $X_L = R$

$\Rightarrow Z = \sqrt{2}R$

$$\Rightarrow P_1 = \frac{R}{\sqrt{2}R} \Rightarrow P_1 = \frac{1}{\sqrt{2}}$$

In case of L-C-R circuit

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

As $X_L = X_C$

$\Rightarrow Z = R$

$$\Rightarrow P_2 = \cos\phi = \frac{R}{R} = 1$$

$$\Rightarrow \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

19. $$J_C = \frac{E}{\rho} = \frac{V}{\rho d}$$

$$J_d = \frac{1}{A}\frac{dq}{dt}$$

$$= \frac{C}{A}\frac{dV_c}{dt}$$

$$= \frac{\in}{d}\frac{dV_c}{dt}$$

$$\Rightarrow \frac{V_0 \sin 2\pi ft}{\rho d} = 10^x \times \frac{80\,\varepsilon_0}{d} V_0 (2\pi f) \cos 2\pi ft$$

$$\tan\left(2\pi \times \frac{900}{800}\right) = 10^x \times \frac{40}{9 \times 10^9} \times 900$$

= x = 6

20. $\tan\phi = \dfrac{x_C - x_L}{R}$, $\tan 45 = \dfrac{x_C - x_L}{R}$

$x_C - x_L = R$

$$\frac{1}{\omega C} - \omega L = R$$

$$\frac{1}{\omega C} - 300 \times 0.30 = 1$$

$$\frac{1}{\omega C} = 10$$

$$C = \frac{1}{10\omega} = \frac{1}{10 \times 300}$$

$$C = \frac{1}{3} \times 10^{-3}, \ X = 3$$

21. For figure (a)

$$P_{avg} = \frac{v_{rms}^2}{R}$$

$$\frac{v_{rms}^2}{Z^2} \times R = \frac{v_{rms}^2}{R} \times 1$$

$R^2 = Z^2$

$$25 = \left(\sqrt{(x_C - x_L)^2 + 5^2}\right)^2$$

$25 = (x_C - x_L)^2 + 25$

$$x_C - x_L \Rightarrow \frac{1}{\omega C} = \omega L$$

$$\omega^2 = \frac{1}{LC} = \frac{10^6}{0.1 \times 40}$$

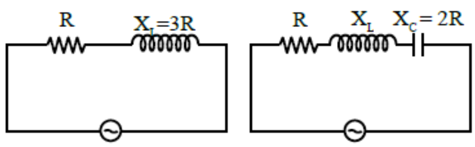
$\omega = 500$

22. $f_{rms}^2 = f_{1rms}^2 + f_{2rms}^2$

$$= \left(\frac{\sqrt{42}}{\sqrt{2}}\right)^2 + 10^2$$

$= 121 \Rightarrow f_{rms} = 11$ A

23.



$$\cos\phi = \frac{R}{\sqrt{R^2 + 3R^2}} \quad \cos\phi' = \frac{R}{\sqrt{R^2 + R^2}}$$

$$= \frac{1}{\sqrt{10}} \quad \frac{1}{\sqrt{2}}$$

$$\frac{\cos\phi'}{\cos\phi} = \frac{\sqrt{10}}{\sqrt{2}} = \frac{\sqrt{5}}{1} \qquad \therefore x = 1$$

24. $X_L = 2\pi fL$

f is very large

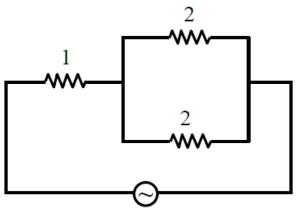
$\therefore$ X_L is very large hence open circuit.

$$X_C = \frac{1}{2\pi fC}$$

f is very large.

$\therefore$ X_C is very small, hence short circuit.

Final circuit



$$Z_{eq} = 1 + \frac{2\times 2}{2+2} = 2$$

25. f = 50Hz

$X_L = 2\pi fL$

$= 2\pi\,(50)\,(200 \times 10^{-3})$

$= 20\pi\Omega$

$$i_0 = \frac{V_0}{X_L} \Rightarrow \frac{V_{rms}\sqrt{2}}{X_L}$$

$$= \frac{(200)\sqrt{2}}{20\pi} = \frac{11\sqrt{2}}{\pi}$$

$$i_0 = \frac{\sqrt{242}}{\pi}$$

26. $X_L = \omega L = 2\pi \times 50 \times 10^{-1} = 10\pi$

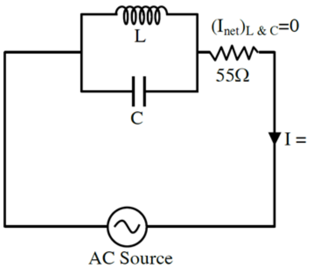
$$X_C = \frac{1}{\omega c} = \frac{1}{2\pi \times 50} \times 10^4 = \frac{100}{\pi}$$

$R = 10\Omega$

$$Z = \sqrt{\left(10\pi - \frac{100}{\pi}\right)^2 + 10^2} = 10\Omega$$

$$i = \frac{E}{2} = \frac{220}{10} = 22\,\text{Amp}$$

27. At resonance $I_L = I_C$



Alternatively,

$$\frac{1}{Z} = \sqrt{\left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

At resonance, $X_L = X_C$ & $Z \to \infty$

$\therefore$ $Z_{\text{total circuit}} \to \infty$ i.e, I = 0

Ans. 0

28. $V_L = V_C = 2V_R$

$X_L = X_C = 2R$

$X_L = 10\Omega$

$\omega L = 10$

$2\pi fL = 10$

$$L = \frac{10}{2\pi f} = \frac{1}{10\pi}H = \frac{1000}{10\pi}mH$$

$$L = \frac{1}{\frac{1}{100}\pi};\; K = \frac{1}{100} = 0.01 \approx 0$$

29. $$\Delta\omega = \frac{R}{L}$$

$$Q = \frac{\omega_0}{\Delta\omega} = \omega_0\frac{R}{L}$$

$$\omega_0 = \frac{1}{\sqrt{3\times 27\times 10^{-6}}} = \frac{1}{9\times 10^{-3}}$$

$$\frac{Q}{\Delta\omega} = \frac{\omega_0\frac{L}{R}}{\frac{R}{L}} = \omega_0\frac{L^2}{R^2} = \sqrt{\frac{1}{LC}\frac{L^2}{R^2}}$$

$$= \frac{1}{9\times 10^{-3}} \times \frac{9}{100} = 10s$$

30. $$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_C - X_L)^2}}$$

$$\cos\phi = \frac{80}{\sqrt{(80)^2 + (60)^2}}$$

$$\cos\phi = \frac{80}{100} \Rightarrow \frac{8}{10}$$

So, x = 8

ELECTROMAGNETIC WAVE SOLUTION

1. C = Speed in air

V = Speed in medium

$$\frac{V}{C}=\frac{1}{2}$$

μ_{r_2} = 1 (Non-magnetic)

$$\frac{V}{C}=\sqrt{\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}}=\frac{1}{2} \Rightarrow \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}=\frac{1}{4}$$

2. $E_0 = B_0 C$ ...(i)

E = B V

$E = B \times \frac{C}{n}$ ...(ii)

$$\left(\frac{E_0}{E}\right)=\frac{(B_0)}{B}\times n$$

The only option which satisfy is option (2)

3. $$\vec{B}=\left|\frac{\vec{E}}{c}\hat{k}\right|$$

$$=\frac{6.3}{3\times10^{8}}\hat{k} \quad =2.1\times10^{-8}\hat{k}$$

4. $U_E=\frac{1}{2}\varepsilon_0 E^2 \qquad U_B=\frac{1}{2}\times\frac{B^2}{\mu_0}$

$$\frac{U_E}{U_B}=\frac{E^2}{B^2}\varepsilon_0\mu_0 \qquad \frac{U_E}{U_B}=c^2\varepsilon_0\mu_0$$

$$c=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

5. Amplitude of electric field, E = B_0C

= $1.6\times10^{-6}\times\sqrt{5}\times3\times10^{8}$

= $4.8\times10^{2}\sqrt{5}$ V/m

Also $\vec{E}\times\vec{B}$ is along $-\hat{k}$ (the direction of propagation)

6. $\vec{E}=E_0\hat{i}\cos(kz)\cos(\omega t)$

$\nabla\times\vec{E}=\nabla\times(\vec{E}_0\hat{i}\cos(kz)\cos(\omega t))$

$$=\left(\frac{\partial}{\partial x}\hat{i}+\frac{\partial}{\partial y}\hat{j}+\frac{\partial}{\partial z}\hat{k}\right)\times E_0\hat{i}\cos(kz)\cos(\omega t)$$

$= E_0\hat{j}(-\sin kz)k\cos(\omega t)$

$\nabla\times\vec{E}=-E_0 k\hat{j}\sin(kz)\cos(\omega t)$

as we know $\nabla\times\vec{E}=\frac{-\partial\vec{B}}{\partial t}$

$$-\frac{-\partial\vec{B}}{\partial t}=-E_0 k\hat{j}\sin(kz)\cos(\omega t)$$

$$\vec{B}=E_0\frac{k}{\omega}\hat{j}\sin(kz)\sin(\omega t)$$

$$\vec{B}=\frac{E_0}{C}\hat{j}\sin(kz)\sin(\omega t)$$

7. $E_0 = B_0 C$ ...(i)

E = B V

$E = B \times \frac{C}{n}$ ...(ii)

$$\left(\frac{E_0}{E}\right)=\frac{(B_0)}{B}\times n$$

The only option which satisfy is option (2)

8. $\vec{E}$ at t = 0 at z = π/k is given by

$$\vec{E}=\frac{E_0}{\sqrt{2}}(\hat{i}+\hat{j})\cos[\pi]=-\frac{E_0}{\sqrt{2}}(\hat{i}+\hat{j})$$

$\vec{F}_E = e\vec{E}$

⇒ Force due to electric field,

$\vec{F}_E$ is antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$.

$\vec{F}_{mag}=q(\vec{v}\times\vec{B})$

$\vec{B}(\text{at } t=0,\ z=\pi/k)$ is $\frac{B_0}{\sqrt{2}}(-\hat{i}+\hat{j})$

$\vec{F}_{mag}=q\,v_0\hat{k}\times\frac{B_0}{\sqrt{2}}(-\hat{i}+\hat{j})$ which is antiparallel to $\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$

$\vec{F}_{net}=\vec{F}_E+\vec{F}_B$ is Antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

9. $\vec{B} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{i}\ T$

$\Rightarrow$ Wave is travelling along –y direction with B pointing along x-axis

$E_0 = cB_0 = 9\dfrac{V}{m}$

$\vec{E}\times\vec{B}$ gives direction of propagation of wave,

so $\vec{E}$ must be along –z axis.

$\vec{E} = 9\sin[200\pi(y+ct)]\left(-\hat{k}\right)\dfrac{V}{m}$

10. Theoretical

11. $\vec{E}\times\vec{B}$ is along $\vec{C}$

$\hat{E}\times\hat{B} = \hat{C}$

$\Rightarrow \vec{B} = \dfrac{E_0}{C}\left(-\hat{x}+\hat{y}\right)\sin(kz-\omega t)$

12. $\vec{B} = 1.2\times10^{-7}\sin(0.5\times10^{3}x+1.5\times10^{11}t)\hat{k}\,T$

Wave is travelling along –x axis and $\vec{B}$ is along +z axis.

$E_0 = cB_0 = 36\dfrac{V}{m}$

$\vec{E}$ must be along –y axis

13. f = 5 × 10^8 Hz

EM wave is travelling towards + $\hat{j}$

$\vec{B} = 8.0\times10^{-8}\hat{z}T$

$\vec{E} = \vec{B}\times\vec{C} = (8\times10^{-8}\,\hat{z})\times(3\times10^{8}\,\hat{y})$

$= -24\hat{x}\ V/m$

14. In EMW, Average energy density due to electric (U_e) and magnetic (U_m) fields is same.

15. $\dfrac{E_0}{C} = B_0$

$F_{max} = eB_0V$

$= 1.6\times10^{-19}\times\dfrac{800}{3\times10^{8}}\times3\times10^{7}$

= 12.8 × 10^{-18} N

16. $V = \dfrac{\omega}{K} = \dfrac{10\times10^{10}}{500} = 2\times10^{8}$

$V = \dfrac{2C}{3}$

17. $\vec{F} = q\left(\vec{V}\times\vec{B}\right)$

$\vec{F}_1 = 4\pi\left[0.5c\hat{i}\times B_0\left(\dfrac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\dfrac{\pi}{K}-0.\right)\right]$

$\vec{F}_2 = 2\pi\left[0.5c\hat{i}\times B_0\left(\dfrac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\dfrac{3\pi}{K}-0.\right)\right]$

$\cos\pi = -1, \quad \cos3\pi = -1$

$\therefore \dfrac{F_1}{F_2} = 2$

18. V = 2 × 10^8 m/s

C = 3 × 10^8 m/s

$\dfrac{C}{V} = \sqrt{\mu_r \in_r}$

$\dfrac{9}{4} = 1\times \in_r$

$\in_r = \dfrac{9}{4} = 2.25$

19.

$\vec{E} = 301.6\sin(kz-\omega t)(-\hat{a}_x) + 452.4\sin(kz-\omega t)\hat{a}_y$

$\vec{B} = \dfrac{301.6}{C}\sin(kz-\omega t)(-\hat{a}_y)$

$+\dfrac{452.4}{C}\sin(kz-\omega t)(-\hat{a}_x)$

$\vec{H} = \dfrac{\vec{B}}{\mu_0} = \dfrac{301.6}{\mu C}\sin(kz-\omega t)(-\hat{a}_y)$

$+\dfrac{452.4}{\mu C}\sin(kz-\omega t)(-\hat{a}_x)$

$\vec{H} = -0.8\sin(kz-\omega t)(-\hat{a}_y) - 1.2\sin(kz-\omega t)\hat{a}_x$

For direction

$\vec{E}\times\vec{B}$ -is direction of $\vec{C}$

For first part $\hat{E} = -\hat{i}, \hat{B} = ?$

$\hat{E}\times\hat{B} = \hat{k} \Rightarrow \hat{B} = -\hat{j}$

Similarly for second

$\hat{E}\times\hat{j}, \hat{B} = ?$

$\hat{E} \times \hat{B} = \hat{k} \Rightarrow \hat{B} = -\hat{i}$

20. The statement II is wrong as the velocity of εm

wave in a medium is $\frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}$.

21. $c = \frac{E_0}{B_0} \Rightarrow E_0 = cB_0$

$E_0 = (3 \times 10^8)(2 \times 10^{-8})$

$E_0 = 6\ Vm^{-1}$

As, $\vec{B}$ = along y-axis

$\vec{v}$ = along negative x-axis

Hence $\vec{E}_0$ = along z-axis

22. $C = \frac{\omega}{K} = \frac{E_0}{B_0}$

23. Magnetic field vector will be in the direction of magnitude of $\vec{K} \times \vec{E}$ magnitude of

$$B = \frac{E}{C} = \frac{K}{\omega}E$$

or $$\vec{B} = \frac{1}{\omega}(\vec{K} \times \vec{E})$$

24. As , poynting vector $\vec{S} = \vec{E} \times \vec{H}$

Given energy transport = negative z direction Electric field = positive y direction

$$(-\hat{k}) = (+\hat{j}) \times [\hat{i}]$$

Hence according to vector cross product magnetic field should be positive x direction.

25. **Statement-I** is correct as EMW are neutral.

Statement-II is wrong.

$$E_0 = \sqrt{\frac{1}{\mu_0\varepsilon_0}}B_0$$

26. λ in vacuum = $\frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1m$

∴ λ in medium = $\frac{0.1}{\mu}$

Where refractive index

$$\mu = \sqrt{\mu_r\varepsilon_r}$$

Assuming non-magnetic material $\mu_r = 1$

∴ $\mu = \sqrt{2.25} = 1.5$

$\lambda_m = \frac{0.1}{1.5} = \frac{1}{15}m = 6.67\ cm$

$= 667 \times 10^{-2}$ cm

27. $I = \frac{1}{2}c \in_0 E_0^2$

$$\frac{8}{4\pi \times 10^2} \times \frac{1}{2} = \frac{1}{4} \times c \times \frac{1}{\mu_0 c^2} \times E_0^2$$

$$E_0 = \frac{2}{10} \times \sqrt{\frac{\mu_0 c}{\pi}} \Rightarrow x = 2$$

28. $E = 50 \sin\left(\omega t - \frac{\omega}{c}.x\right)$

Energy density $= \frac{1}{2} \in_0 E_0^2$

Energy for volume

$V = \frac{1}{2} \in_0 E_0^2.V = 5.5 \times 10^{-12}$

$\frac{1}{2}8.8 \times 10^{-12} \times 2500V = 5.5 \times 10^{-12}$

$V = \frac{5.5 \times 2}{2500 \times 8.8} = .0005m^3$

$= .0005 \times 10^6 (c.m)^3$

$= 500\ (c.m)^3$

29. $I = \left(\frac{1}{2}\varepsilon_0 E_0^2\right)C$

$\Rightarrow E_0 \Rightarrow \sqrt{\frac{2I}{\varepsilon_0 C}} \Rightarrow \sqrt{\frac{2 \times 0.22}{8.85 \times 10^{-12} \times 3 \times 10^8}} = 12.873$

$B \Rightarrow \frac{E_0}{C} \Rightarrow \frac{12.873}{3 \times 10^8} = 4.291 \times 10^{-8} = 43 \times 10^{-9}$

30. Displacement Current = Conduction Current

$= \frac{dq}{dt}$

$I_d = \frac{\in_0 A}{d}\frac{dV}{dt}$

$d = \frac{8.85 \times 10^{-12} \times 4 \times 10^{-3} \times 10^6}{4.425 \times 10^{-6}}$

= 8 mm

X = 8

MODERN PHYSICS_I (ATOMIC PHYSICS) SOLUTION

1. $V = \frac{eE}{m}t$

$\lambda = \frac{h}{eEt}$

$\frac{d\lambda}{dt} = \frac{-h}{eEt^2}$

2. $E = -E_0 \times \frac{1}{n^2}$

$\Rightarrow \Delta E = -E_0 \times \frac{2}{n^3} \times (\Delta n)$

$\Rightarrow h\nu = 2E_0 \times 1 \times \frac{1}{n^3}$

$\Rightarrow \nu \propto \frac{1}{n^3}$

3. We know velocity of electron in nth shell of hydrogen atom is given by

$v = \frac{2\pi kZe^2}{nh}$

$\therefore v \propto \frac{1}{n}$

4.

1.51 ———————— n = 3

3.4 ———————— n =

13.6 ———————— n = 1

$3 \rightarrow 2 \Rightarrow 1.89$ eV

5×10^{-4} T

$r = \frac{mv}{qB} \Rightarrow mv = qrB$

$\Rightarrow E = \frac{P^2}{2m} = \frac{(qRB)^2}{2m}$

$= \frac{\left(1.6\times10^{-19}\times7\times10^{-3}\times5\times10^{-4}\right)^2}{2\times9.1\times10^{-31}\,\text{Joule}}$

$= \frac{3136\times10^{-52}}{18.2\times10^{-31}\times1.6\times10^{-19}}\,\text{eV}$

= 1.07eV

We know work function = energy incident – $(KE)_{electron}$

$\phi = 1.89 - 1.077 = 0.813\,\text{eV}$

5. $f = f_0\sqrt{\frac{1+\beta}{1-\beta}}$, $\beta = \frac{v}{c}$, $\frac{f}{f_0}\sqrt{\frac{1+\beta}{1-\beta}}$

$\left(1+\frac{\Delta f}{f_0}\right)^2 = (1+\beta)(1-\beta)^{-1}$

β is small compared to 1

$\left(1+\frac{\Delta f}{f_0}\right)^2 = (1+2\beta)$

$\beta = \frac{\Delta f}{f_0} = \frac{v}{c}$

$v = 6 \times \frac{c}{5890} = 305.6\ \text{km/s}$

6. $\lambda = \frac{h}{mv}$

Kinetice energy, $\frac{P^2}{2m} = \frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_c}$

$\lambda_c = \frac{2m\lambda^2 c}{h}$

7. $\lambda_e = \lambda_{Ph}$

$\frac{h}{p_e} = \frac{h}{p_{ph}}$

$\sqrt{2mk_e} = \frac{E_{ph}}{c}$

$2mk_e = \frac{(E_{ph})^2}{c^2}$

$\frac{k_e}{E_{ph}} = \frac{E_{ph}}{c^2}\left(\frac{1}{2m}\right)$

$= \frac{p_{ph}}{c}\left(\frac{1}{2m}\right) = \frac{p_e}{c}\left(\frac{1}{2m}\right) = \frac{mv}{c}\frac{1}{2m} = \frac{v}{2c}$

8. $V_S = h\nu - \phi$

$4.8 = \frac{hc}{\lambda} - \phi$ .....(i)

$1.6 = \frac{hc}{2\lambda} - \phi$ ....(ii)

Using above equation (i) - (ii)

$3.2 = \frac{hc}{\lambda} - \frac{hc}{2\lambda}$

$$3.2 = \frac{hc}{2\lambda} \qquad .....(iii)$$

$$\left[\lambda = \frac{hc}{6.4}\right]$$

Put in equation (ii)

$\phi = 1.6$

$$\frac{hc}{\lambda_{th}} = 1.6$$

$$\lambda_{th} = \frac{hc}{1.6} = \left(\frac{hc}{6.4}\right) \times 4 = 4\lambda$$

9. $\Delta x . \Delta p \geq \frac{h}{4\pi}$

$$\Delta x = \frac{h}{4\pi m \Delta v} \qquad v = \sqrt{\frac{3KT}{m}}$$

$$\frac{\Delta x_e}{\Delta x_p} = \sqrt{\frac{m_p}{m_e}}$$

10. Based on theory

11. $\lambda_e = \lambda_{photon}$

$$\frac{h}{mv} = \frac{h}{P_{photon}} \Rightarrow P_{photon} = mv$$

$$\frac{E_e}{E_{ph}} = \frac{\frac{1}{2}mv^2}{\frac{hc}{\lambda}} = \frac{1}{2}\frac{mv}{P_{ph}C} \times v = \frac{v}{2c}$$

12. $\lambda = 4500$ Å

B = 2mT, R = 2mm

$$R = \frac{\sqrt{2Km}}{qB} \frac{(qBR)^2}{2m} = K$$

$$\frac{(1.6 \times 10^{-19} \times 2 \times 10^{-3} \times 2 \times 10^{-3})}{2 \times 9.1 \times 10^{-31}} = K$$

$$\frac{(6.4)^2}{2 \times 9.1} \times \frac{10^{-50}}{10^{-31}} = K$$

$K = 2.25 \times 10^{-19}$ J

$$= \frac{2.25 \times 10^{-19}}{1.6 \times 10^{-19}} eV = 1.40eV$$

$$E = \frac{12400}{4500} = 2.76eV$$

$\phi = E - K = (2.76 - 1.40)$ eV = 1.36 eV

13. (Fact)

14. $k = \frac{P^2}{2m} \Rightarrow P \alpha \sqrt{m}$

Now $\lambda = \frac{h}{p}$

So, $\lambda \alpha \frac{1}{p} \Rightarrow \lambda \alpha \frac{1}{\sqrt{m}}$

$$\frac{\lambda_\alpha}{\lambda_{C12}} = \frac{\sqrt{3}}{1}$$

15. $\lambda_p = \frac{h}{\sqrt{2mk}}$

Also for photon $k = \frac{hc}{\lambda_p}$

$$\lambda_e = \frac{h\sqrt{\lambda_p}}{\sqrt{2m\,hc}}$$

$\lambda_p \propto \lambda e^2$

16. radius of paerticle in cyclotron

$$r = \frac{\sqrt{2mK.E.}}{qB}$$

So ratio of new radius to original

$$\frac{r_n}{r_0} = \sqrt{\frac{(K.E.)_n}{(K.E)_0}} = \sqrt{4} \Rightarrow 2:1$$

17. Angular momentum is integral multiple of $\frac{h}{2\pi}$

$$mvr = \frac{nh}{2\pi} \qquad \text{So momentum } mv = \frac{nh}{2\pi r}$$

18. Ratio of magnetic moment and angular momentum

$$\frac{\vec{\mu}}{\vec{L}} = \frac{q}{2m}$$

For e^-

$$\vec{\mu} = -\frac{e}{2m}\vec{L}$$

19. Kinetic energy gained by a charged particle accelerated by a potential V is qV

KE = qV

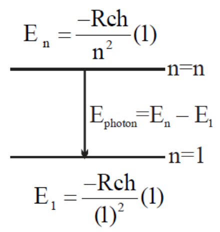
$$\Rightarrow \frac{p^2}{2m} = qV \Rightarrow p = \sqrt{2mqV}$$

$$p = \frac{h}{\lambda}, \text{ thus } \lambda = \frac{h}{\sqrt{2mqV}}$$

$$\text{now } \frac{\lambda_p}{\lambda_d} = \sqrt{\frac{m_d V_d}{m_p V_p}}$$

$$\Rightarrow \frac{1}{\sqrt{2}} = \sqrt{\frac{2V_d}{V_p}} \Rightarrow \frac{V_p}{V_d} = 4$$

20.



$$E_1 = \frac{-Rch}{(1)^2}(1)$$

$$\frac{-Rch}{(n)^2} + \frac{Rch}{1} = \frac{hc}{\lambda}$$

$$\frac{-R}{n^2} + R = \frac{1}{\lambda}$$

$$R - \frac{1}{\lambda} = \frac{R}{n^2}$$

$$\frac{\lambda R - 1}{\lambda} = \frac{R}{n^2}$$

$$n^2 = \frac{\lambda R}{\lambda R - 1} \Rightarrow n = \sqrt{\frac{\lambda R}{\lambda R - 1}}$$

21. Wavelength of incident beam $\lambda = 900 \times 10^{-9}$ m

Intensity of incident beam = I = 100 W/m²

No. of photons crossing per unit sec

$$= n = \frac{E_{net}}{E_{single\ photon}} = \frac{I A \lambda}{hc}$$

$$= \frac{(100)(1 \times 10^{-4})(900 \times 10^{-9})}{6.62 \times 10^{-34} \times 3 \times 10^{8}} = 4.5 \times 10^{16}$$

22. ⓔ $\longrightarrow V_0$

$$E = -E_0 \hat{i}$$

$$\lambda_0 = \frac{h}{mv_0}$$

$$v = v_0 + \frac{eE_0 t}{m}$$

$$\lambda = \frac{h}{mv} = \frac{h}{m\left(v_0 + \frac{eE_0}{m}t\right)}$$

$$\lambda' = \frac{h}{mv_0\left(1 + \frac{eE_0}{mv_0}t\right)}$$

$$\lambda' = \frac{\lambda_0}{\left(1 + \frac{eE_0}{mv_0}t\right)}$$

23. $\frac{I}{C} \times \text{area} = \text{force}$

$$\frac{I}{C} \times 36 \times 10^{-4} = 7.2 \times 10^{-9}$$

$$I = \frac{7.2 \times 10^{-9} \times 3 \times 10^{8}}{36 \times 10^{-9} \times 10} = \frac{6 \times 10^{-1}}{10^{-3}}$$

$$I = 6 \times 10^2 \frac{w}{m^2} = 0.06 \frac{w}{cm^2}$$

24. $E = \frac{hc}{\lambda} - \phi$ .....(i)

$2E = \frac{hc}{\lambda'} - \phi$ .....(ii)

(ii) - (i)

$$E = hc\left(\frac{1}{\lambda'} - \frac{1}{\lambda}\right) \Rightarrow \lambda' = \frac{hc\lambda}{E\lambda + hc}$$

25. $\frac{hc}{\lambda} = \left[1 - \frac{1}{16}\right](13.6 \text{ eV})$

So, λ = 94.1nm

26. (A) Stopping potential depends on both frequency of light and work function.

(B) Saturation current $\propto$ intensity of light

(C) Maximum KE depends on frequency

(D) Photoelectric effect is explained using particle theory

27. $\frac{\Delta\lambda}{\lambda} c = v$

$$\Delta\lambda = \frac{v}{c} \times \lambda = \frac{286}{3 \times 10^5} \times 630 \times 10^{-9} = 6 \times 10^{-10}$$

28. $I = \frac{e}{T} = \frac{e\omega}{2\pi} = \frac{eV}{2\pi r}$

$I = \frac{1.6 \times 10^{-19} \times 2.2 \times 10^{6} \times 7}{2 \times 22 \times 0.5 \times 10^{-10}}$

= 1.12 mA

112×10^{-2} mA

29. $E_{k\alpha} = E_k - E_L$

$\frac{hc}{\lambda_{k_\alpha}} = E_k - E_L$

$E_L = E_k - \frac{hc}{\lambda_{k_\alpha}}$

$= 27.5\text{KeV} - \frac{12.42 \times 10^{-7}\,\text{eVm}}{0.071 \times 10^{-9}\,\text{m}}$

E_L = (27.5 – 17.5) keV

= 10 keV

30. For first line of Lyman

$\frac{1}{\lambda} = R\left(1 - \frac{1}{4}\right) = R\left(\frac{3}{4}\right)$

$\Rightarrow \lambda = \frac{4}{3R}$ ...(1)

3rd line (Paschen)

$\frac{1}{\lambda_3} = R\left(\frac{1}{3^2} - \frac{1}{6^2}\right) = \frac{R}{9} \times \frac{3}{4}$

2nd line (Balmer)

$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{R}{4} \times \frac{3}{4}$

Thus $\lambda_3 - \lambda_2 = \frac{12}{R} - \frac{16}{3R} = \frac{20}{3R}$ putting (1)

$a\left(\frac{4}{3R}\right) = \frac{20}{3R} \Rightarrow a = 5$

MODERN PHYSICS_II (NUCLEAR PHYSICS) SOLUTION

1. 10 mCi = $\lambda_A N_A(t)$ ....(1)

20 mCi = $\lambda_A N_B(t)$ ....(2)

As $N_A(t) = 2N_B(t)$

$\therefore \frac{1}{2} = \frac{\lambda_A . N_A(t)}{\lambda_B . N_B(t)} \Rightarrow \frac{1}{2} = \frac{\lambda_A}{\lambda_B}.2$

$\Rightarrow \lambda_B = 4\lambda_A \Rightarrow t_{1/2}(B) = \frac{t_{1/2}(A)}{4}$

$t_{\frac{1}{2}}(A) = 4t_{\frac{1}{2}}(B)$

2. $(2)^N = \left(\frac{1600}{100}\right)$

N = 4

4t = 8

T = 2 s

Count Rate = $\frac{1600}{(2)^3} = 200$

3. 232 – 6 × 4 = A

A = 208

Z = 90 – 6 × 2 + 4 × 1

= 82

4. $\lambda_A = \frac{h}{mV_A}$

Conservation of linear momentum

$\Rightarrow mV_A = \frac{m}{2}V - \frac{m}{2}\cdot\frac{V}{2} = \frac{mV}{4}$

$\Rightarrow \lambda_A = \frac{4h}{mV}$

$\therefore V_A = \frac{V}{4}$

$\lambda_B = \frac{h}{\frac{m}{2}V} = \frac{2h}{mV} = \frac{\lambda_A}{2}$

$\lambda_c = \frac{h}{\frac{m}{2}\cdot\frac{V}{2}} = \frac{4h}{mV} = \lambda_A$

5. Number of nuclei present at any time t

$N = N_0 e^{-\lambda t}$

$\therefore \frac{N_A}{N_B} = e^{(\lambda_B - \lambda_A)t} = \frac{1}{e}$

$(\lambda_A - \lambda_B)\cdot t = 1$

$\therefore t = \frac{1}{-\lambda + 10\lambda} = \frac{1}{9\lambda}$

6. $n = n_0 e^{-\alpha r^4}$

$\Rightarrow \int dN = \int n_0 e^{-\alpha r^4} \times 4\pi r^2 dr$

$\Rightarrow n = 4\pi n_0 \cdot \int_0^\infty r^2 e^{-\alpha r^4} dr$

Put $\sqrt{\alpha}\, r^2 = t$

$2\sqrt{\alpha}\, r\, dr = dt$

$N = \frac{4\pi n_0}{2\sqrt{\alpha}} \int_0^\infty \frac{t^{\frac{1}{2}} e^{-t^2}}{\alpha^{\frac{1}{4}}} dt$

$= \frac{4\pi n_0}{2\alpha^{\frac{3}{4}}} \int t^{\frac{1}{2}} e^{-t^2} dt$

$N \propto n_0 \alpha^{-\frac{3}{4}}$

7. Power $= \frac{\text{Energy released}}{\text{time}}$

$= \frac{1}{30 \times 24 \times 60 \times 60}\left(\frac{2 \times 6.023 \times 10^{26}}{235} \times 200 \times 1.6 \times 10^{-19}\right) \text{M J/s}$

; 60 MW

8. $R = \lambda N_0 e^{-\lambda t}$

$\Rightarrow$ $\text{In}R = \text{In}\lambda N_0 - \lambda t$

$\Rightarrow$ Slope of curves = $-\lambda$

also $\lambda = \frac{\text{In}2}{t_{½}}$

$\left.\begin{array}{l} \text{for A slope} = -\frac{6}{10} \\ \text{for B slope} = -\frac{6}{5} \\ \text{for C slope} = -\frac{2}{5} \end{array}\right] \Rightarrow T_{½}(A) : T_{½}(B) : T_{½}(C) = 2:1:3$

9. Δm should be positive

$(m_p + m_n) > m_d$

$\Rightarrow$ only (2) is possible

10. Let initial activity be A_0

$A = A_0 e^{-\lambda t_1}$ ...(i)

$\frac{A}{5} = A_0 e^{-\lambda t_2}$ ...(ii)

(i) ÷ (ii)

$5 = e^{\lambda(t_2 - t_1)}$

$\lambda = \frac{\ell n5}{t_2 - t_1} = \frac{1}{\tau}$

$\tau = \frac{t_2 - t_1}{\ell n5}$

11. $N_1 = N_0 e^{-\lambda t_1}$

$\frac{N_1}{N_0} = e^{-\lambda t_1}$

$0.67 = e^{-\lambda t_1}$

$\ln(0.67) = -\lambda t_1$

$N_2 = N_0 e^{-\lambda t_2}$

$\frac{N_2}{N_0} = e^{-\lambda t_2} \quad \Rightarrow \quad 0.33 = e^{-\lambda t_2}$

$\ln(0.33) = -\lambda t_2$

$\ln(0.67) - \ln(0.33) = \lambda t_1 - \lambda t_2$

$\lambda(t_1 - t_2) = \ln\left(\frac{0.67}{0.33}\right)$

$\lambda(t_1 - t_2) \cong \ln 2$

$t_1 - t_2 \ ; \ \frac{\ln 2}{\lambda} = t_{1/2}$

Half life = $t_{1/2}$ = 20 minutes.

12. If is possible only inside the nucleus and not otherwise.

13. Energy of γ ray [$E\gamma$] = hv

Momentum of γ ray [$P\gamma$] = $\frac{h}{\lambda} = \frac{hv}{C}$

Total momentum is conserved.

$\vec{P}\gamma + \vec{P}_{Nu} = 0$

Where $\vec{P}_{Nu}$ = Momentum of decayed nuclei

$\Rightarrow P_\gamma = P_{Nu}$

$\Rightarrow \frac{hv}{C} = P_{Nu}$

$\Rightarrow$ K.E. of nuclei

$= \frac{1}{2}Mv^2 = \frac{(P_{Nu})^2}{2M} = \frac{1}{2M}\left[\frac{hv}{C}\right]^2$

Loss in internal energy = E_γ + K.E_{Nu}

$= hv + \frac{1}{2M}\left[\frac{hv}{C}\right]^2, = hv\left[1 + \frac{hv}{2MC^2}\right]$

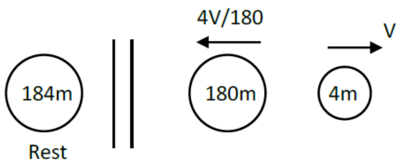
14. $R = R_0 e^{-\lambda t}$

$\ell nR = \ell nR_0 - \lambda t$

$-\lambda$ is slope of straight line

$\lambda = \frac{3}{20} \ , \ t_{1/2} = \frac{\ell n2}{\lambda} = 4.62$

15.



$\frac{1}{2}(4m)v^2 + \frac{1}{2}(180m)\left(\frac{4v}{180}\right)^2 = 5.5\text{MeV}$

$\Rightarrow \frac{1}{2}4mv^2\left[1 + 45\left(\frac{4}{180}\right)^2\right] = 5.5\text{MeV}$

$\Rightarrow K.E_\alpha = \frac{5.5}{1 + 45.\left(\frac{4}{180}\right)^2}\text{MeV}$

$K.E_\alpha$ = 5.38 MeV

16. $A \to B, B \to C$

$\frac{dN_B}{dt} = \lambda N_A - \lambda N_B$

$\frac{dN_B}{dt} = 2\lambda N_{B_0} e^{-\lambda t} - \lambda N_B$

$e^{\lambda t}\left(\frac{dN_B}{dt} + \lambda N_B\right) = 2\lambda N_{B_0} e^{-\lambda t} \times e^{\lambda t}$

$\frac{d}{dt}(N_B e^{\lambda t}) = 2\lambda N_{B_0}$, on integrating

$N_B e^{\lambda t} = 2\lambda t N_{B_0} + N_{B_0}$

$N_B = N_{B_0}[1 + 2\lambda t]e^{-\lambda t}$

$\frac{dN_B}{dt} = 0 \ \text{at} \ -\lambda[1 + 2\lambda t]e^{-\lambda t} + 2\lambda e^{-\lambda t} = 0$

$N_{B_{max}}$ at $t = \frac{1}{2\lambda}$

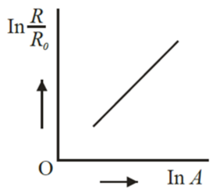
17. Q = $(B.E)_P - (B.E)_R$

= (105 + 115)(6.4) – (220)(5.6)

= 176 MeV

18. $R = R_0 A^{\frac{1}{3}}$

$\ln\frac{R}{R_0} = \frac{1}{3}\ln A$



19. $\lambda_{eq} = \lambda_1 + \lambda_2$

$\frac{\ln 2}{(t_{1/2})_{eq}} = \frac{\ln 2}{(t_{1/2})_1} + \frac{\ln 2}{(t_{1/2})_2}$

$(t_{1/2})_{eq} = \frac{(t_{1/2})_1 \times (t_{1/2})_2}{(t_{1/2})_1 + (t_{1/2})_2}$

$= \frac{3 \times 4.5}{3 + 4.5} = \frac{3 \times 4.5}{7.5} = \frac{3 \times 3}{5} = 1.8\text{hr}$

20. $x + p \to \gamma + b$

$Q = k_\gamma + k_b - k_p$

$Q + k_p = k_\gamma + k_b$

$Q + k_p > 0$

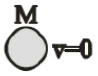
21. Say for D_4 Atomic No = Z

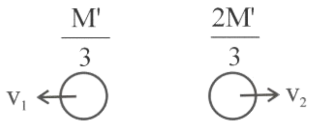
Mass Number = A

A = 182 – 4 – 4 = 174

Z = 74 – 2 + 1 – 2 = 71

22.





$|\vec{P}_1| = |\vec{P}_2|$

Here $\vec{P}$ is momentum

So $\lambda = \frac{h}{P}$

Hence both will have same de broglie wavelength.

23. $R \propto A^{1/3}$

$V = \frac{4}{3}\pi R^3 \propto A$

Mass $\propto$ A

So density is independent of A.

24. $\lambda_D = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

$\therefore \qquad \lambda \propto \frac{1}{\sqrt{m}}$

$\lambda_e > \lambda_p > \lambda_\alpha$

25. $\Delta m = (Zm_P + (A - Z)m_n) - M_{A\ell}$

= (13 ×1.00726 + 14 × 1.00866) – 27.18846

= 27.21562 – 27.18846

= 0.02716 u

E = 27.16 x × 10^{-3} J

26. T_m = 30 ms

C = 200 μF

$\frac{q}{N} = \frac{Q_0 e^{-t/RC}}{N_0 e^{-\lambda t}} = \frac{Q_0}{N_0} e^{t\left(\lambda - \frac{1}{RC}\right)}$

Since q/N is constant hence

$\lambda = \frac{1}{RC}$

$R = \frac{1}{\lambda C} = \frac{T_m}{C} = \frac{30 \times 10^{-3}}{200 \times 10^{-6}} = 150\Omega$

27. Energy released in the given process

= Binding energy of product – Binding energy of reactants

= 7.6 × 4 – (1.1 × 2) × 2

= 30.4 – 4.4

=26 MeV

28. $A = A_0 \times 2^{-t/T}$

$\frac{A_0}{64} = A_0 \times 2^{-t/T}$

$\therefore$ t = 6T = 6 × 2.5 = 15 hours

29. $N = N_0 e^{-\lambda t}$

$\frac{N_B}{N_A} = \frac{e^{-\lambda_2 t}}{e^{-\lambda_1 t}} = e^{-\lambda_2 t}.e^{\lambda_1 t}$

$e^1 = e^{(\lambda_1 - \lambda_2)t}$

$(\lambda_1 - \lambda_2)$ t = 1

$t = \frac{1}{\lambda_1 - \lambda_2} = \frac{1}{25\lambda - 16\lambda} = \frac{1}{9\lambda}$

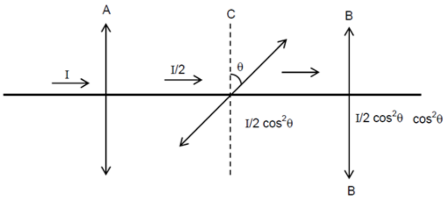
30. No. of mole = $\frac{120}{240} = \frac{1}{2}$

No. of molecules = $\frac{1}{2} \times N_A$

Energy released = $\frac{1}{2} \times 6 \times 10^{23} \times 200$

WAVE OPTICS SOLUTION

1.



$$\frac{I}{2}\cos^2\theta = \frac{I}{8}$$

$$\cos^2\theta = \frac{1}{4}$$

$$\cos\theta = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$$

2. Semi-angular width = 30° $a\sin\theta = \lambda$

A sin30° = λ

Fringe width $\beta = \frac{\lambda D}{d}$

$$10^{-2} = \frac{10^{-6} \times \frac{1}{2} \times 0.5}{d}$$

$$d = \frac{5}{2} \times 10^{-5} = 25\ \mu m$$

3 $$\frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = 16$$

$$\Rightarrow \frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}} = 4$$

$$\Rightarrow \frac{\sqrt{I_1}}{\sqrt{I_2}} = \frac{4+1}{4-1} = \frac{5}{3}$$

$$\Rightarrow \frac{I_1}{I_2} = \frac{25}{9}$$

4 $$N = \frac{d\sin\theta}{\lambda} = \frac{0.320 \times 10^{-3}}{500 \times 10^{-9}} \times \frac{1}{2}$$

Number of Bright fringes = 2 × 320 + 1

= 641

5. For 1st minima

$$\sqrt{d^2 + (2d)^2} - 2d = \frac{\lambda}{2}$$

$$\Rightarrow \sqrt{5}\,d - 2d = \frac{\lambda}{2}$$

$$\Rightarrow d = \frac{\lambda}{2\left(\sqrt{5}-2\right)}$$

6. $$\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{8} = \frac{\pi}{4}$$

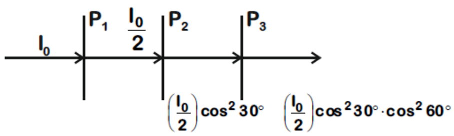
$I = 4I_0 \cos^2(\pi/8)$

$$\frac{I}{4I_0} = \cos^2(\pi/8) = 0.85$$

7. $\mu t - t = \lambda$

$$\Rightarrow t(\mu - 1) = \lambda \Rightarrow t = \frac{\lambda}{(\mu - 1)}$$

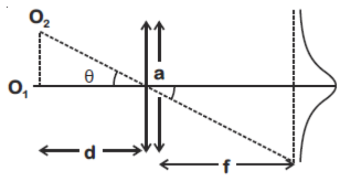
8. Angle between pass axes of P_1 and P_2 is 30°.



$$I = \frac{I_0}{2} \cdot \cos^2 30° \cdot \cos^2 60° = \frac{I_0}{2} \times \frac{3}{4} \times \frac{1}{4} = \frac{3I_0}{32}$$

$$\Rightarrow \frac{I_0}{I} = \frac{32}{3} = 10.67$$

9.



$$\theta = 1.22\frac{\lambda}{a}$$

Distance $O_1O_2 = (\theta)d$

$$= \left(1.22\frac{\lambda}{a}\right)d$$

$$= \frac{(1.22)(5500 \times 10^{10}) \times 4 \times 10^5 \times 10^3}{5}$$

$= 5368 \times 10^{-2}$ m

= 53.68 m

10. $N_1\lambda_1 = N_2\lambda_2$

$16 \times 700 = N_2 \times 400$

$\Rightarrow N_2 = 28$

11. Phase difference = $\frac{2\pi}{\lambda}$ optical path difference

$$= \frac{2\pi}{\lambda}(n_1L_1 - n_2L_2)$$

12. $\phi_C = \frac{\pi}{2} - \frac{2\pi}{20} \times 5 = 0$

$\phi_B = \frac{\pi}{2}$

$\phi_A = \frac{\pi}{2} + \frac{2\pi}{20} \times 5 = \pi$

$I_C = 4I_0$

$I_B = 2I_0$

$I_A = 0$

13. Resolving power $\propto \frac{1}{\lambda}$

Since wavelength of electron is much less than visible light, its resolving power will be much more.

14. Fringe Width, $\beta = \frac{\lambda D}{d}$

$\beta_{max} \Rightarrow d_{min}$ and $\beta_{min} \Rightarrow d_{max}$

$d = d_0 + a_0 \sin\omega t$

$d_{max} = d_0 + a_0$ and $d_{min} = d_0 - a_0$

$\therefore \beta_{min} = \frac{\lambda D}{d_0 + a_0}$ and $\therefore \beta_{max} = \frac{\lambda D}{d_0 - a_0}$

$$\beta_{max} - \beta_{min} = \frac{\lambda D}{d_0 - a_0} - \frac{\lambda D}{d_0 + a_0} = \frac{2\lambda D a_0}{d_0^2 - a_0^2}$$

15. $\frac{I_1}{I_2} = 4$

$$\frac{I_{max}}{I_{min}} = \left[\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right]^2$$

$$\frac{I_{max}}{I_{min}} = \left[\frac{2\sqrt{I_2} + \sqrt{I_2}}{2\sqrt{I_2} - \sqrt{I_2}}\right]^2$$

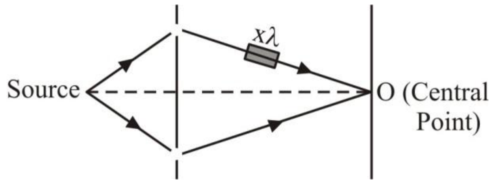
$\frac{I_{max}}{I_{min}} = 9$

$\frac{I_{max} + I_{min}}{I_{max} - I_{min}} = \frac{10}{8}$

$\frac{5}{x} = \frac{10}{8}$

$x = 4$

16.



Path difference at O = $(\mu - 1)t$.

If the intensity at O remains (maximum) unchanged, path difference must be n λ.

$\Rightarrow (\mu - 1)t = n\lambda$

$(1.5 - 1)x\lambda = n\lambda$

$\Rightarrow x = 2n$

For n = 1, x = 2

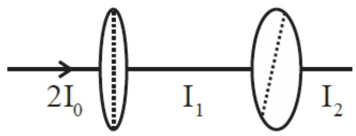
17. For a given light wavelength corresponding a medium of refractive index μ

$\lambda_{med} = \frac{\lambda_{vacuum}}{\mu}$

and we know that fringe width $\beta = \frac{\lambda D}{d}$

Therefore, $\beta_{med} = \frac{\beta_{vacuum}}{\mu} = \frac{12}{\frac{4}{3}} = 9\text{mm}$

18.



$I_1 = \frac{1}{2}(2I_0) = I_0$

$I_2 = I_1 \cos^2 30^\circ$

$= I_1 . \frac{3}{4} = \frac{3I_0}{4}$

19. Given, D = 1m

λ 600 × 10^{-9} m

n = 5

As $\quad y_{nth} = \frac{n\lambda D}{d}$

$\Rightarrow \quad \frac{5 \times 600 \times 10^{-9} \times 1}{d} = 5 \times 10^{-2}$

$\Rightarrow \quad d = \frac{5 \times 600 \times 10^{-9} \times 1}{5 \times 10^{-2}} = 60 \times 10^{-6}\text{ m}$

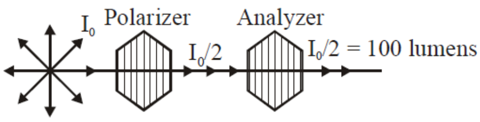
$\Rightarrow \quad d = 6\ \mu\text{m}$

20. $I_A = \frac{I_0}{2}$

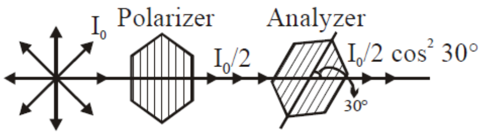
$I_C = \frac{I_0}{2}\cos^2 45 = \frac{I_0}{4}$

$I_B = I_C \cos^2 45 = \frac{I_0}{8}$

21.



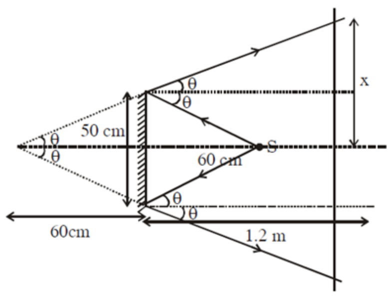
Assuming initially axis of Polarizer and Analyzer are parallel



Now emerging intensity = $\frac{I_0}{2}\cos^2 30°$

$= 100\left(\frac{\sqrt{3}}{2}\right)^2 = 100 \times \frac{3}{4} = 75$

22.



$\tan\theta = \frac{25}{60} = \frac{x}{180}$

x = 75 cm

so distance between extreme point

= 2x = 2 × 75 = 150 cm

23. Thickness t = $n\lambda$

So, $n\ \lambda_{vac} = (n + 1)\ \lambda_{air}$

$n\ \lambda = (n + 1)\ \frac{\lambda}{\mu_{air}}$

$n = \frac{1}{\mu_{air} - 1} = \frac{10^4}{3}$

$t = n\lambda$

$= \frac{10^4}{3} \times 6000\text{Å}$

= 2 mm

24. Position of bright fringe $y = n\frac{D\lambda}{d}$

y_1 of red = $= \frac{D\lambda_r}{d} = 3.5\text{mm}$

$\lambda_r = 3.5 \times 10^{-3}\frac{d}{D}$

similarly $\lambda_v = 2 \times 10^{-3}\frac{d}{D}$

$\lambda_r - \lambda_v = (1.5 \times 10^{-3})\left(\frac{0.3 \times 10^{-3}}{1.5}\right)$

= 3 × 10^{-7} = 300 nm

Ans. 300.0

25. d = 0.6 × 10^{-3}

D = 80 × 10^{-2}

1st Dark fringe $= \frac{D\lambda}{2d} = \frac{d}{2}, \lambda = \frac{d^2}{D}$

= 450 × 10^{-9} m

26. $\beta = \frac{\lambda D}{d}$

$\Delta\beta = \frac{\lambda}{d}\Delta D$

$\lambda = \frac{\Delta\beta \cdot d}{\Delta D}$

$= \frac{3 \times 10^{-5} \times 1 \times 10^{-3}}{5 \times 10^{-2}}$

= 60 × 10^{-8} = 600 × 10^{-9} m

= 600 nm

27. $\phi_A = \frac{\pi}{2}$

$\phi_B = \frac{\pi}{3}$

$I_A = I + 4I + 2\sqrt{I}\sqrt{4I}\cos\left(\frac{\pi}{2}\right)$

= 5I + 4I (0) = 5I

$I_B = I + 4I + 2\sqrt{I}\sqrt{4I}\cos(60^\circ)$

$= 5I + 4I \times \frac{1}{2} = 7I$

$I_B - I_A = 7I - 5I = 2I$, (x = 2)

28. $\frac{I_1}{I_2} = \frac{1}{4}$

$I_2 = 4I_1$

$I_{max} = I_1 + 4I_1 + 2\sqrt{I_1 4I_1} = 9I_1$

$I_{min} = I_1 + 4I_1 - 2\sqrt{I_1 4I_1} = I_1$

$\therefore \frac{9I_1 + I_1}{9I_1 - I_1} = \frac{10}{8} = \frac{5}{4} = \frac{2\alpha + 1}{\beta + 1}$

$\alpha = 2 \quad \beta = 1$

$\therefore \frac{\alpha}{\beta} = \frac{2}{1} = 2$

29. $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

$\frac{\pi}{3} = \frac{2\pi}{\lambda}(6m)$

$\Rightarrow \quad \lambda = 36m$

V = fλ = (500 Hz) (36m) = 18000 m/s = 18 km/s

30. Fringe shift = $\frac{t(\mu - 1)}{\lambda}B$

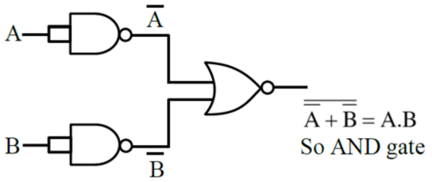
$= \frac{10 \times 10^{-6}(1.2 - 1)}{5 \times 10^{-7}}B$

$= \frac{10^{-5} \times 0.2}{5 \times 10^{-7}} = 4$

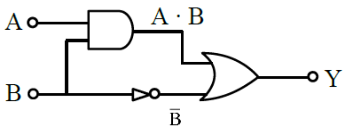
SOLID & SEMICONDUCTORS SOLUTION

1. Conceptual

2.



3.



$Y = A.B + \overline{B}$

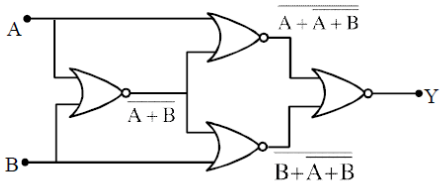
A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

4. Pentavalent activities have excess free e^-

So e^- density increases but overall semiconductor is neutral.

Option (1)

5.



$$y = \overline{\overline{(A+\overline{A+B})}+\overline{(B+\overline{A+B})}}$$

$$y = (A+\overline{A+B}).(B+\overline{A+B})$$

A	B	y
0	0	1
0	1	0
1	0	0
1	1	1

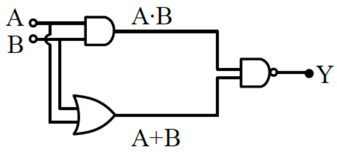
6. $\alpha = \frac{I_C}{I_E}, \beta = \frac{I_C}{I_B}; I_E = I_C + I_B$

$$\alpha = \frac{I_C}{I_C + I_B} = \frac{I_C / I_B}{\frac{I_C}{I_B}+1} = \frac{\beta}{\beta+1} + 1 + \frac{1}{\beta} = \frac{1}{\alpha}$$

$$\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

7.



$$Y = \overline{(A \cdot B)\cdot(A+B)}$$

$Y)_{(0,0)} = 1$

$Y)_{(0,1)} = 1$

$Y)_{(1,0)} = 1$

$Y)_{(1,1)} = 1$

Option (3) is correct

8. $V_A = 5V \Rightarrow A = 1$

$V_A = 0V \Rightarrow A = 0$

$V_B = 5V \Rightarrow B = 1$

$V_B = 0V \Rightarrow B = 0$

If A = B = 0, there is no potential anywhere here $V_0 = 0$

If A = 1, B = 0, Diode D_1 is forward biased, here $V_0 = 5V$

If A = 0, B = 1, Diode D_2 is forward biased hence $V_0 = 5V$

If A = 1, B = 1, Both diodes are forward biased hence $V_0 = 5V$

Truth table for I[st]

A	B	output
0	0	0
0	1	1
1	0	1
1	1	1

∵ Given circuit is OR gate

For II[nd] circuit

$V_B = 5V, \quad A = 1$

$V_B = 0V, \quad A = 0$

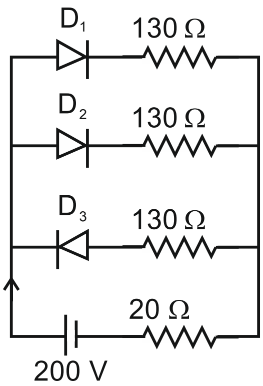
When A = 0, E – B junction is unbiased there is no current through it

$\therefore$ $V_0 = 1$

When A = 1 , E – B junction is forward biased $V_0 = 0$

$\therefore$ Hence this circuit is not gate.

9.

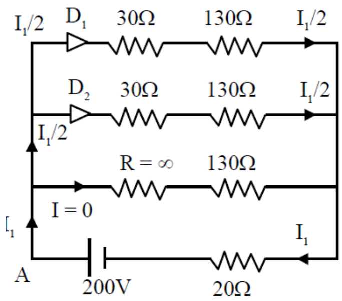


As per diagram,

Diode D_1 & D_2 are in forward bias i.e. R = 30Ω whereas diode D_3 is in reverse bias i.e. R = infinite

$\Rightarrow$ Equivalent circuit will be

Applying KVL starting from point A



$$-\left(\frac{I_1}{2}\right)\times 30-\left(\frac{I_1}{2}\right)\times 130-I_1\times 20+200=0$$

$\Rightarrow$ $-100\ I_1 + 200 = 0$

$I_1 = 2A$ Option (3)

10. When the amplifier connects with positive feedback, it acts as the oscillator the feedback hear is positive feedback which means some amount of voltage is given to the input.

11. This is NAND gate

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

12. In + ve half cycle

$D_1 \to$ F.B.; $D_2 \to$ R.B.

0 – 0.6 V

V_{out} same as V_{in}

In –ve half cycle

$D_2 \to$ F.B.; $D_1 \to$ R.B.

13. When both A and B have logical value '1' both diode are reverse bias and current will flow in resistor hence output will be 5 volt i.e. logical value '1'.

In all other case conduction will take place, hence output will be zero volt i.e. logical value '0'.

So truth table is

A	B	Y	
0	0	0	
0	1	0	(AND gate)
1	0	0	
1	1	1	

14. By making Truth table

A	B	Output
0	0	0
1	1	1
0	1	0
1	0	0

Comparing with output of AND gate

A	B	AND
0	0	0
0	1	0
1	0	0
1	1	1

$\Rightarrow$ logic gate present is AND gate

15. $V_{CE} = 8\ V = I_C = 6\ \mu A$ from $4\ \mu A$, $I_B = 20\ \mu A$ from $25\ \mu A$

Current gain $\beta_{av} = \dfrac{I_C' - I_C}{I_B' - I_B} = \dfrac{2mA}{5\mu A}$

$\beta_{av} = \dfrac{2}{5} \times 10^3 = \dfrac{2000}{5} = 400$

16. $\dfrac{v_{out}}{v_{in}} = \beta \dfrac{R_{out}}{R_{in}}$

$v_{out} = \dfrac{100 \times 10 \times 10^3}{10^3} \times 10^{-3}$

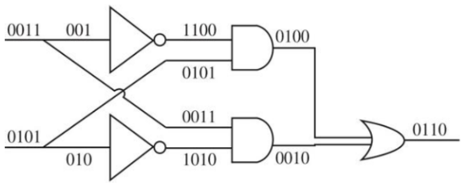
= 1 V

17.

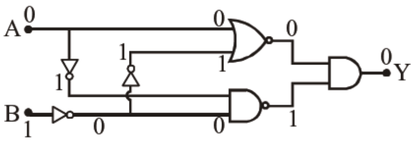
A_1	B_1	Y
0	0	1
0	1	1
1	0	0
1	1	0

$Y = \overline{A_1 \; e \; B_1}$ NAND

18.



19.



20. $10^6 = \beta^2 \times \dfrac{R_0}{R_i}$

$10^6 = \beta^2 \times \dfrac{10^4}{10^2}$

$\beta^2 = 10^4 \Rightarrow \beta = 100$

21. P = Vi , 0.5 = 8i

$i = \dfrac{1}{16} A$

E = 20 = 8 + i Rp

Rp = 12 × 16 = 192Ω

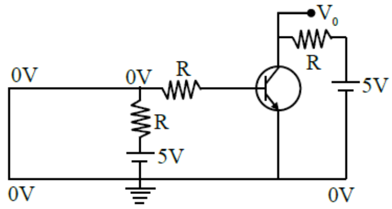
22. $n_e n_h = n_i^2$

$n_e = \dfrac{n_i^2}{n_h} = \dfrac{(1.5 \times 10^{16})^2}{4.5 \times 10^{22}} = \dfrac{1.5 \times 1.5 \times 10^{32}}{4.5 \times 10^{22}}$

$5 \times 10^9/m^3$

23. As diodes D_1 and D_2 are in forward bias, so they acted as negligible resistances

⇒ Input voltage become zero



⇒ Input current is zero

⇒ Output current is zero

⇒ V_0 = 5 volt

24. When unregulated voltage is 14 V voltage across zener diode must be 10 V So potential difference across resistor

$\Delta V_{Rs} = 4V$

and Pzener = 2Ω

VI = 2

$I = \dfrac{2}{10} = 0.2A$

$\Delta V_{RS} = IR$

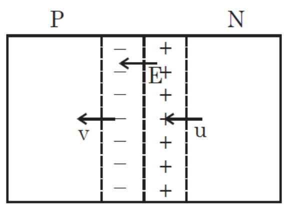
$4 \times 0.2\, R_S \Rightarrow R_S = \dfrac{40}{2} = 20\Omega$

25. $r_1 = \dfrac{10mV}{10\mu A} = 10^3 \Omega$

$\beta = \dfrac{1.5mA}{10\mu A} = 150$

$A_v = \left(\dfrac{R_0}{r_i}\right)\beta = \left(\dfrac{5000}{1000}\right) \times 150 = 750$

26.



Work done by Electric field = $K_f - K_i$

$\dfrac{1}{2}mv^2 - \dfrac{1}{2}mu^2 = -1.6 - 10^{-19} \times 0.4$

$\dfrac{1}{2} 9 \times 10^{-31}(v^2 - u^2) = -0.64 \times 10^{-19}$

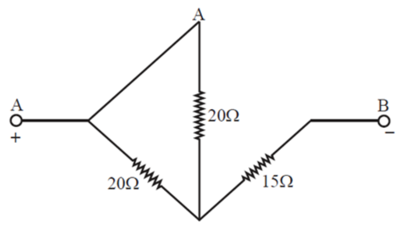
$$u^2 - v^2 = \frac{2 \times 0.64 \times 10^{12}}{9}$$

$$v^2 = \left(36 - \frac{128}{9}\right) \times 10^{10}$$

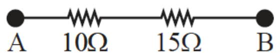
$$v = \frac{14}{3} \times 10^5 \, m/s$$

x = 14

27.



The forward biased diode will conduct while the reverse biased will not



∴ Equivalent resistance = 10 + 15 = 25Ω

28. Current gain in C-E configuration

$$\Rightarrow \beta = \frac{\Delta I_C}{\Delta I_B}$$

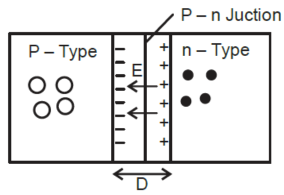
R_C = 2k Ω, R_B = 0.50 k Ω

Voltage gain

$$= \frac{\Delta I_C R_C}{\Delta I_B R_B} = \frac{5 \times 10^{-3}}{100 \times 10^{-6}} \times \frac{2}{0.5}$$

$$= \frac{10^{-2}}{5 \times 10^{-5}} = \frac{1000}{5} = 200$$

29.



$$E = \frac{V}{d} = \frac{\text{Potential barrier Across Junction}}{\text{width of depletion layer}}$$

$$= \frac{0.6V}{6 \times 10^{-6} m} = 1 \times 10^5 \, V/m$$

= 1 × 10^5 N/C

30. ε – IR – V_Z = 0

20 – IR – 6 = 0

IR = 12

25 × 10^{-3} R = 12

$$R = \frac{12}{25 \times 10^{-3}} = 480\,\Omega$$

PRINCIPLE OF COMMUNICATION SOLUTION

1. $N = \frac{1}{10}\frac{(10\text{GHz})}{(5\text{kHz})}$

$= \frac{10^9}{5\times10^3} = \frac{10^6}{5} = 2\times10^5$

2. $\nu = \frac{3\times10^8}{800}\times10^9 = \frac{3\times10^{15}}{8}$

Singal bandwidth = $\frac{3\times10^{15}}{8}\times0.01$

No. of Channels = $\frac{3\times10^{13}}{8\times6\times10^6}$ = 6.25×10^5

3. $\omega_U = (2.2 \times 10^4 + 5.5 \times 10^5)$ rad/s

$\omega_L = (5.5 \times 10^5 - 2.2 \times 10^4)$ rad/s

$\omega_U = (2.2 + 55) \times 10^4 = 57.2 \times 10^4$ rad/s

$f_U = \frac{572}{2\pi}\text{kHz} ;\ 91\text{kHz}$

$f_L = \frac{528}{2\pi}\text{kHz} ;\ 84\text{kHz}$

4. $C_m = (A_C + A_m \sin\omega_m t)\sin\omega_C t$

From the graph $A_C + A_m = 10$

$A_C - A_m = 8$

$\Rightarrow A_C = 9$ V, $A_m = 1$ V

$\omega_m = \frac{2\pi}{100\times10^{-6}} = 2\pi\times10^4 s^{-1}$

$\omega_C = \frac{2\pi}{8\times10^{-6}} = 2.5\pi\times10^5 s^{-1}$

$\Rightarrow$ $C_m = (9 + \sin2\pi \times 10^4 t) \sin (2.5\pi \times 10^5 t)$ V

5. $A = (v_o + A\cos \omega t) \sin \omega_o t$

$= v_0 \sin(\omega_0 t) + \frac{A}{2}[\sin(\omega_0 - \omega)t + \sin(\omega_0 + \omega)t]$

6. Optical Fibre Communication – Infrared Light

Radar – Radio Waves

Sonar – Ultrasound

Mobile Phones – Microwaves

7. Theory based

8. $\lambda = \frac{v}{f} = \frac{c}{f_c}$

9. Radius covered $r = \sqrt{2RH_T}$

$150\text{km} = \sqrt{2\times(6.5\times10^6)H_T}$

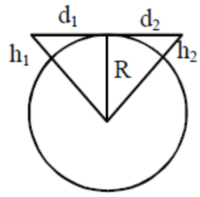
$(150 \text{ km} \times 10^3)^2 = 2 \times 6.5 \times 10^6 H_T$

$H_T = 1731$ m

Population covered = (πr^2) $(2000/\text{km}^2)$

$= 3.14 \times (150)^2 \times 2000 = 1413 \times 10^5$

10.



$d_t = \sqrt{2Rh_1} + \sqrt{2Rh_2}$

$= \sqrt{2R}\ (\sqrt{h_1} + \sqrt{h_2})$

$= (2\times6400\times10^3)^{1/2}\ (\sqrt{50} + \sqrt{80})$

$= 3578 (7.07 + 8.94) = 57283.78$ m

$= 57.28$ Km

11. h : height of antenna

λ : wavelength of signal

$\lambda > h$

$\lambda > 400$ m

12. Question based on the theory given in NCERT.

13. In amplitude modulation the amplitude of high frequency carrier wave is varied in accordance with message signal

14. (a) For low frequency or high wavelength size of antenna required is high.

(b) E P R is low for longer wavelength.

(c) yes we want to avoid mixing up signals transmitted by different transmitter simultaneously.

(d) Low frequency signals sent to long distance by superimposing with high frequency.

15. Theory

16. Bandwidth = 2 f_m

= 2 × 10^4 Hz = 20 × 10^3 Hz

= 20 kHz

17. Metal detector works on the principle of transmitting an electromagnetic signal and analyses a return signal from the target. So it works on the principle of resonance in AC circuit.

18. V_{max} = 60

V_{min} = 20

% modulation =

$$\left(\frac{V_{max}-V_{min}}{V_{max}+V_{min}}\right)100 \Rightarrow \left(\frac{60-20}{60+20}\right)100 \Rightarrow \left(\frac{40}{80}\right)100 \Rightarrow 50\%$$

19. Given

FM broadcast

Modulating frequency = 20 k Hz = f

$$\text{Deviation ratio} = \frac{\text{frequency deviation}}{\text{modulating frequency}} = \frac{\Delta f}{f}$$

Frequency deviation Δf = f × 10

= 20 kHz × 10 = 200 kHz

$\Rightarrow$ Bandwidth = 2 (f + Δf)

= 2 (20 + 200) kHz

= 440 kHz

20. (a) uv rays – used for water purification

(b) x-rays used for diagnosing fracture

(c) Microwaves are used for mobile and radar communication

(d) Infrared show less scattering therefore used in foggy days

21. Modulation index : $m = \frac{A_m}{A_c}$

Given $2A_m$ = 8

$A_m + A_c = 9 \qquad \Rightarrow A_c = 5$

$\therefore m = \frac{4}{5} = 0.8$

22. AM Broadast $\rightarrow$ 540 – 1600 KHz

FM Broadcast $\rightarrow$ 88 – 108 MHz

Television $\rightarrow$ 54 – 890 MHz

Salellite communication $\rightarrow$ 3.7 – 4.2 GHz

$\therefore$ A–II, B–I, C–IV, D–III

23. Modulation index

$$= \frac{\text{Amplitude of modulating signal}}{\text{Amplitude of carrier wave}}$$

$\mu = \frac{1}{2}$

24. NCERT fact based

25. Given, Signal frequency f_m = 5kHz

Carrier wave frequency f_c = 2MHz

f_c = 2000KHz

The resultant signal will have band width of frequency given by

$[(f_c + f_m) - (f_c - f_m)]$

$\Rightarrow$ [(2000 + 5) – (2000 – 5)] kHz

$\Rightarrow$ 10 kHz

26. Maximum amplitude

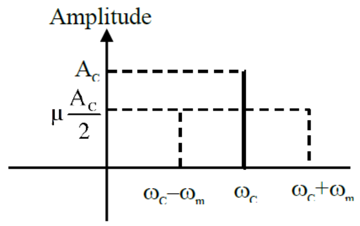
$A_{max} = A_m + A_C$

$200 = A_m + 160$

$A_m = 40$

$\therefore$ Peak voltage A_m = 40

Ans. 40



27.

$$\frac{a}{10} = \frac{b}{10} = \frac{\mu A_C}{2} \Rightarrow \frac{a}{b} = 1$$

28. $LOS = \sqrt{2Rh_r} + \sqrt{2Rh_R}$

$= \sqrt{2R}\left(\sqrt{h_r} + \sqrt{h_R}\right)$

$= \sqrt{2 \times 64 \times 10^5}(\sqrt{25} + \sqrt{49})$

$= 192\sqrt{5} \times 10^2 m$

K = 192

29. $d = \sqrt{2Rh}$

$d = \sqrt{2 \times 6400 \times h \times 10^{-3}}$ (h in m)

Area = πd^2

= ($\pi \times 2 \times 6400 \times h \times 10^{-3}$) km^2

$6.03 \times 100000 = 100 \times \pi \times 2 \times 6400 \times 10^{-3}$

h

$h = \dfrac{6.03 \times 10^5}{10 \times \pi \times 128}$

h = 150 m

30. Frequencies present in output of square law device

$2f_c$, $f_c + f_m$, f_e, $f_c - f_m$, $2f_m$, f_m

After passing through band bass filte.

$f_c + f_m$, f_c, $f_c - f_m$

Band width = $2f_m$

$= \dfrac{2\omega_m}{2\pi} = \dfrac{6.28 \times 10^6}{3.14} = 2\text{MHz}$

MEASUREMENT ERROR & UNIT AND DIMENSIONS SOLUTION

1. $LC = \frac{0.5}{100} = 0.005mm$

Zero error, e = – 3 × 0.005 = –0.015 mm

Thickness = (5.5 + 48 × 0.005 – 0.015) mm

= 5.725 mm

2. $\rho = \frac{M}{V} \Rightarrow \left|\frac{\Delta\rho}{\rho}\times 100\right| = \left|\frac{\Delta v}{v}\times 100\right|$

$\left|\frac{\Delta\rho}{\rho}\times 100\right| = 3\alpha\Delta T \times 100$ ....(i)

Given $\frac{\Delta\ell}{\ell} = 2\times 10^{-4}$

$\Rightarrow \alpha\Delta T = 2 \times 10^{-4}$

$\Rightarrow \alpha = 2 \times 10^{-5}$

From (i) $\frac{\Delta\rho}{\rho}\times 100 = 6\times 10^{-5}\times 10\times 100$

= 0.06 Ans.

3. kT has dimension of energy

$\frac{\beta x^2}{kT}$ is dimensionless

$[\beta]\,[L^2] = [ML^2T^{-2}]$

$[\beta] = [MT^{-2}]$

$\alpha^2\beta$ has dimensions of work

$[\alpha^2][MT^{-2}] = [ML^2T^{-2}]$

$[\alpha] = [M^0LT^0]$

4. Least count

$= \frac{\text{Pitch}}{\text{Total division on circular scale}}$

In 5 revolution, distance travel, 5 mm

In 1 revolution, it will travel 1 mm.

So least count = $\frac{1}{50} = 0.02$

5. $L.C. = \frac{P}{N} = \frac{0.5mm}{50} = 0.01mm$

Length of wire = 6.8 cm

Diameter of wire = 1.5 mm + 7 × L.C

= 1.5 mm + 7 × .01 = 1.57 mm

Curved surface area = $\pi D\ell$

= 3.14 × 6.8 × 1.57 × 10^{-1} cm^2

= 3.352 cm^2 = 3.4 cm^2

6. 1 M.S.D = 1mm

9 M.S.D = 10 V.S.D

1 V.S.D = 0.9 M.S.D = 0.9 mm

L.C of vernier caliper = 1–0.9 = 0.1 mm

= 0.01 cm

zero error =–(10–4)×0.1mm = – 0.6 mm

Reading = M.S.R + V.S.R – Zero error

= 3cm + 6 × 0.01 – [–0.06]

= 3 + 0.06 + 0.06

= 3.12 cm

Nearest given answer in the options is 3.10

7. dimensional formula for Torque

$[\tau] = [ML^2T^{-2}]$

Now

Percentage error in torque = % τ

= % M + 2% L 2% T % τ =25%

8. $1MSD = \frac{1}{20}cm$

$1VSD = \frac{24}{25}MSD = \frac{24}{25}\times\frac{1}{20}cm$

$\therefore$ Least count $= \frac{1}{20}\left(1-\frac{24}{25}\right)cm$

$= \frac{1}{20}\times\frac{1}{25} = \frac{1}{500}cm$

= 0.002 cm

9. MSR = 2.5 mm

$CSR = 45\times\frac{0.5}{50}mm$

= 0.45 mm

Diameter reading = MSR + CSR – zero error

= 2.5 + 0.45 – (–0.03)

= 2.98 mm

10. $\frac{\Delta m}{m}\times 100 = 1.5$

$\frac{\Delta \ell}{\ell}\times 100 = 1$

d = $\frac{m}{\ell^3} \Rightarrow \frac{\Delta d}{d}\times 100 = \frac{\Delta m}{m}\times 100 + \frac{3\Delta \ell}{\ell}\times 100$

= 1.5 + 3 = 4.5%

11. $[x^2] = [\alpha KT]$ $\quad$ $[\alpha ML^2T^{-2}] = L^2$

$[\alpha] = M^{-1}T^2$ $\quad$ $[\alpha \cdot \beta] = MLT^{-2}$

$M^{-1}T{+}2[\beta] = MLT^{-2}$ $\quad$ $[\beta] = M^2LT^{-4}$

12. $\left[\frac{I}{rcv}\right] = \left[\frac{I}{TV}\right]$

$[ML^2T^{-2}] = [IA^2]$

$\Rightarrow [I] = [ML^2T^{-2}A^{-2}]$

$[V] = \frac{ML^2T^{-2}}{AT} = ML^2T^{-3}A^{-1}$

$\Rightarrow \left[\frac{I}{rcv}\right] = \frac{ML^2T^{-2}A^{-2}}{TML^2T^{-3}A^{-1}} = [A^{-1}]$

13. $\left[\sqrt{\frac{\epsilon_0}{\mu_0}}\right] = \left[\frac{\epsilon_0}{\sqrt{\mu_0\ \epsilon_0}}\right] = [LT^{-1}]\times[\epsilon_0]$

$\because \quad F = \frac{q^2}{4\pi \epsilon_0 r^2}$

$\Rightarrow \quad [\epsilon_0] = \frac{[AT]^2}{|MLT^{-2}|\times|L^2|}$

$\therefore \quad \left[\sqrt{\frac{\epsilon_0}{\mu_0}}\right] = [LT^{-1}]\times[A^2M^{-1}L^{-3}T^4]$

$= [M^{-1}L^{-2}T^3A^2]$

14. $x = \frac{IFv^2}{WL^4}$

$\therefore \quad [x] = \frac{(ML^2)\times(MLT^{-2})\times(LT^{-1})^2}{(ML^2T^{-2})\times L^4}$

$= ML^{-1}T^{-2}$

= [Energy density]

15. $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = x$

$C = \frac{E}{B} = Y$

$\tau = RC = t$

$\Rightarrow$ [X] = [Y] = [Z]

16. $\frac{x^2}{\alpha kT} \rightarrow$ dimensionless

$\Rightarrow [\alpha] = \frac{[x^2]}{[kT]} = \frac{L^2}{ML^2T^{-2}} = M^{-1}T^2$

Now $[W] = [\alpha][\beta]^2$

$[\beta] = \sqrt{\frac{ML^2T^{-2}}{M^{-1}T^2}} = MLT^{-2}$

17.

$S = \alpha^2\beta \ell n\left(\frac{\mu KR}{J\beta^2} + 3\right)$

$S = \frac{Q}{T} = \text{joulek} / k$

$[\alpha^2\beta] = \text{Joule}/k$

$PV = nRT \quad \left[\frac{\mu KR}{J\beta^2}\right] = 1$

$R = \frac{\text{Joule}}{K}$

$\Rightarrow R = \frac{\text{Joule}}{K},\ K = \frac{\text{Joule}}{R}$

$\Rightarrow \beta = \left(\frac{\text{Joule}}{K}\right)$

$\alpha^2\beta = \left(\frac{\text{Joule}}{K}\right)$

$\Rightarrow \alpha = \text{dimensionless}$

18. $m \propto t^a v^b \ell^c$

$m \propto [T]^a[LT^{-1}]^b[ML^2T^{-1}]^c$

$M^1L^0T^0 = M^cL^{b+2c}T^{a-b-c}$

Comparing powers

c = 1, b = -2, a = -1

$m \propto t^{-1}v^{-2}\ell^1$

19. Density = $[F^aL^bT^c]$

$[ML^{-3}] = [M^aL^aT^{-2a}L^bT^c]$

$[M^1L^{-3}] = [M^aL^{a+b}T^{-2a+c}]$

a = 1 ; a + b = – 3 ; – 2a + c = 0

1 + b = – 3 $\quad$ c = 2a

b = – 4 $\quad$ c = 2

so density = $[F^1L^{-4}T^2]$

20. $\frac{L_2}{T_2} = \frac{n}{m^2}\frac{L_1}{T_1}$

$$\frac{L_2}{T_2^2} = \frac{L_1}{T_1^2 \times mn}$$

$$\frac{n}{m^2} \times \frac{T_2}{T_1} = \frac{T_2^2}{T_1^2 \times mn}$$

$$\frac{n^2}{m} \times \frac{T_2}{T_1}$$

$$\frac{L_2}{L_1} = \frac{n^4}{m^2} \times \frac{1}{mn}$$

$$\frac{L_2}{L_1} = \frac{n^3}{m^3}$$

21. Viscosity = pascal.second

$P^x A^y T^z = [M^1 L^{-1} T^{-1}]$

$[M^1 L^{+1} T^{-1}]^x [L^2]^y [T^1]^z = M^1 L^{-1} T^{-1}$

$M^x L^{+x+2y} T^{-x+z} = M^1 L^{-1} T^{-1}$

$x = 1 \quad x + 2y = -1 \; -x + z = -1$

$y = -1$

$z = 0$

Viscosity = $P^1 A^{-1} T^0$

22. $$\frac{\alpha [L]}{[ML^2T^{-2}]} = [M^0L^0T^0]$$

$\alpha = [ML^1T^{-2}]$

$$\frac{\alpha}{\beta} = \frac{[ML^2T^{-2}]}{[L^3]} \Rightarrow \beta = \frac{[ML^1T^{-2}][L^3]}{ML^2T^{-2}}$$

23. $[\alpha\beta] = [\eta] = [\sin\theta]$ = dimensionless

$[\eta^{-1} \sin\theta] = [\alpha\beta]$ = DL

24. $$\left[T^{-1}\right] = \left[L^{-1}\right]^a \left[M^{-1}L^{-3}\right]^b \left[\frac{MLT^{-2}}{L}\right]^c$$

$\Rightarrow T^{-1} = M^{a+b} . L^{a-3b} \times T^{-2c}$

$$c = \frac{1}{2},\ b = -\frac{1}{2},\ a - 3b = 0$$

$$a + \frac{3}{2} = 0 \Rightarrow a = -\frac{3}{2}$$

25. $V = lbh$

$$\therefore \frac{\Delta V}{V} = \frac{\Delta \ell}{\ell} + \frac{\Delta b}{b} + \frac{\Delta h}{h}$$

$\Rightarrow \gamma = 5 \times 10^{-5} + 5 \times 10^{-6} + 5 \times 10^{-6}$

$= 60 \times 10^{-6}/^\circ C$

26. $$\rho = \frac{m}{\frac{4}{3}\pi\left(\frac{d}{2}\right)^3}$$

$$\therefore \ \% \frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3.\left(\frac{\Delta d}{d}\right)$$

$= 6 + 3 \times 1.5$

$= 10.5\%$

$$= \left(\frac{1050}{100}\right)\%$$

27. $\because \quad v = \frac{4}{3}\pi r^3$

taking log & then differentiate

$$\frac{dV}{V} = 3\frac{dr}{r}$$

$$= \frac{3 \times 0.85}{7.5} \times 100\% = 34\%$$

28. 9 MSD = 10 VSD

9 × 1 mm = 10 VSD

∴ 1 VSD = 0.9 mm

LC = 1 MSD – 1 VSD = 0.1 mm

Reading = MSR + VSR × LC

10 + 8 × 0.1 = 10.8 mm

Actual reading = 10.8 – 0.4 = 10.4 mm

$$\text{radius} = \frac{d}{2} = \frac{10.4}{2} = 5.2 \text{ mm}$$

$= 52 \times 10^{-2}$ cm

29. $$Z = a^2x^3y^{\frac{1}{2}}$$

$$\frac{\Delta z}{z} = \frac{2\Delta a}{a} + \frac{3\Delta x}{x} + \frac{1}{2}\frac{\Delta y}{y}$$

a is constant

$$\frac{\Delta z}{z} \times 100 = 3(4\%) + \frac{1}{2}(12\%) = 18\%$$

30. $$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$g = \frac{1}{4\pi^2}\frac{T^2}{\ell}$$

$$\frac{\Delta g}{g} = \frac{2\Delta T}{T} + \frac{\Delta \ell}{\ell}$$

$$\frac{\Delta g}{g} = 2.\frac{1}{100 \times 0.5} + \frac{1\text{mm}}{10\,\text{cm}}$$

$$\frac{\Delta g}{g} = \frac{5}{100}$$