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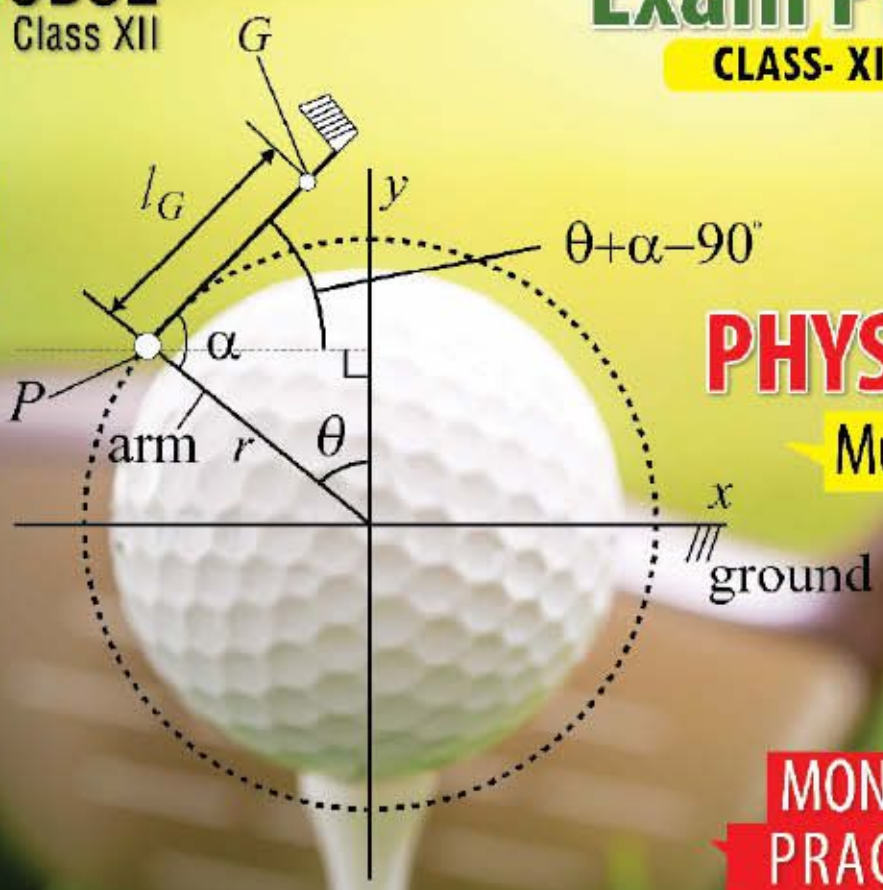

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BRAIN Map

MONTHLY PRACTICE PROBLEMS (XI & XII)

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Volume 25 No. 6 June 2017

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CONTENTS

Competition Edge

NEET Solved Paper 2017 21
WB JEE Solved Paper 2017 31
Olympiad Problems 42
Kerala PET Solved Paper 2017 48
Physics Musing Solution Set 46 61
Karnataka CET Solved Paper 2017 63
Physics Musing Problem Set 47 80

Class 11

Exam Prep 8
MPP-2 17
Brain Map 46

Class 12

Brain Map 47
Ace Your Way CBSE : Series 1 71
MPP-2 82

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EXAM PREP 2018

CLASS XI

Useful for Medical/Engg. Entrance Exams

CHAPTERWISE MCQs FOR PRACTICE

UNITS AND MEASUREMENT

1. One nautical mile is equal to 6080 feet. 18 nautical mile per hour is equal to

(a) 1.46 m s^{-1} (b) 9.26 m s^{-1}

(c) 4.28 m s^{-1} (d) 7.36 m s^{-1}

2. A physical quantity z, depends upon two other physical quantities x and y, as follows $z = ax^2y^{1/2}$ where, a is a constant. In an experiment, the quantity x is determined by measuring z and y, and using the above expression. If the percentage error in the measurement of z and y are 10% and 12% respectively, then the percentage error in the determined value of x is

(a) 2% (b) 8%

(c) 15%

(d) without the value of the constant a, the percentage error cannot be calculated

3. A student writes four different expressions for the displacement y in a periodic motion as a function of time t, a as amplitude, T as time period. Which of the following can be correct?

(a) $y = aT\sin\frac{2\pi t}{T}$ (b) $y = \frac{a}{T}\sin t$

(c) $y = \frac{a}{T}\sin\frac{t}{a}$

(d) $y = \frac{a}{\sqrt{2}}\left[\sin\frac{2\pi t}{T} + \cos\frac{2\pi t}{T}\right]$

4. The frequency υ of an oscillating drop may depend upon radius r of the drop, density ρ of the liquid and surface tension S of the liquid. An expression for υ dimensionally is

(a) $\upsilon = k\sqrt{\frac{S}{\rho r^2}}$ (b) $\upsilon = k\sqrt{\frac{S}{\rho r^3}}$

(c) $\upsilon = k\sqrt{\frac{S}{\rho r}}$ (d) $\upsilon = k\sqrt{\rho r S}$

5. In the formula $X = 3YZ^2$, X and Z have dimensions of capacitance and magnetic induction, respectively. The dimensions of Y is (Q denotes charge)

(a) $[M^{-3} L^{-1} T^3 Q^4]$ (b) $[M^{-3} L^{-2} T^4 Q^4]$

(c) $[M^{-2} L^{-2} T^4 Q^4]$ (d) $[M^{-3} L^{-2} T^4 Q]$

6. If voltage, $V = (100 \pm 5)$ V and current, $I = (10 \pm 0.2)$ A, the percentage error in resistance R is

(a) 5.2% (b) 25%

(c) 7% (d) 10%

7. In an experiment, the period of oscillation of a simple pendulum was observed to be 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s. The mean absolute error is

(a) 0.11 s (b) 0.12 s

(c) 0.13 s (d) 0.14 s

8. The mass of a box measured by a grocer's balance is 2.3 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is the total mass of the box and the difference in the masses of the pieces to correct significant figures

(a) 2.34 kg, 0 g (b) 2.3 kg, 0.02 g

(c) 2.34 kg, 0.02 g (d) 2.3 kg, 0 g

9. The unit of length is 5 cm, unit of mass is 100 g, and unit of time is 0.01 s. In a system of measurement, how many newton will the unit of force contains?

(a) 5×10^5 (b) 5×10^{-5}

(c) 50 (d) 10

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10. Which one of the following is not correct?

(a) Dimensional formula of thermal conductivity (K) is $[M^1L^1T^{-3}K^{-1}]$.

(b) Dimensional formula of potential (V) is $[M^1L^2T^3A^{-1}]$.

(c) Dimensional formula of permeability of free space(μ_0) is $[M^1L^1T^{-2}A^{-2}]$.

(d) Dimensional formula of RC is $[M^0L^0T^1]$.

11. Which of the following product of e, h, μ, G (where μ is the permeability) be taken so that the dimensions of the product are same as that of the speed of light?

(a) $he^{-2}\mu^{-1}G^0$ (b) $h^2eG^0\mu$

(c) $h^0e^2G^{-1}m$ (d) $hGe^{-2}m^0$

12. A parsec is a convenient unit of length on the astronomical scale. It is the distance of an object that will show a parallax of 1″ (s) of arc from opposite ends of a baseline equal to the distance from the earth to the sun. The order of magnitude of parsec in terms of m is

(a) 16 (b) 20 (c) 14 (d) 23

13. Suppose a quantity y can be dimensionally represented in terms of M, L and T, that is $[y] = [M^a\ L^b\ T^c]$ then M

(a) may be represented in terms of L, T and y if $a = 0$

(b) may be represented in terms of L, T and y if $a \neq 0$

(c) can always be dimensionally represented in terms of L, T and y

(d) can never be dimensionally represented in terms of L, T and y.

14. The equation of state of a gas is given by

$\left(P+\frac{a}{V^3}\right)(V-b^2)=cT$, where P, V, T are pressure, volume and temperature respectively and a, b, c are constants. The dimensions of a and b are respectively

(a) $[ML^8T^{-2}]$ and $[L^{3/2}]$

(b) $[ML^5T^{-2}]$ and $[L^3]$

(c) $[ML^5T^{-2}]$ and $[L^6]$

(d) $[ML^6T^{-2}]$ and $[L^{3/2}]$

15. A new system of units is proposed in which unit of mass is α kg, unit of length is β m and unit of time is γ s. What will be value of 5 J in this new system?

(a) $5\alpha\beta^2\gamma^{-2}$ (b) $5\alpha^{-1}\beta^{-2}\gamma^2$

(c) $5\alpha^{-2}\beta^{-1}\gamma^{-2}$ (d) $5\alpha^{-1}\beta^2\gamma^2$

MOTION IN A STRAIGHT LINE

16. A point moves with uniform acceleration and v_1, v_2 and v_3 denote the average velocities in the three successive intervals of time t_1, t_2 and t_3. Which of the following relations is correct?

(a) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_2 + t_3)$

(b) $(v_1 - v_2) : (v_2 - v_3) = (t_1 + t_2) : (t_2 + t_3)$

(c) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_1 - t_3)$

(d) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_2 - t_3)$

17. A particle moves along x-axis and its displacement at any time is given by $x(t) = 2t^3 - 3t^2 + 4t$ in SI units. The velocity of the particle when its acceleration is zero, is

(a) 2.5 m s^{-1} (b) 3.5 m s^{-1}

(c) 4.5 m s^{-1} (d) 8.5 m s^{-1}

18. A rocket is fired vertically from the ground with a resultant vertical acceleration of 10 m s^{-2}. The fuel is finished in 1 min and it continues to move up. What is the maximum height reached?

(a) 42.3 km (b) 48.4 km

(c) 36.4 km (d) 25.6 km

19. A particle moves along a straight line such that its position x at any time t is $x = 6t^2 - t^3$ where x is in m and t is in s. Then

(a) at $t = 0$ acceleration is 12 m s^{-2}.

(b) x - t curve has maxima at 4 s.

(c) both (a) and (b) are wrong.

(d) both (a) and (b) are correct.

20. A particle starts from rest and has an acceleration of 2 m s^{-2} for 10 s. After that, the particle travels for 30 s with constant speed and then undergoes a retardation of 4 m s^{-2} and comes back to rest. The total distance covered by the particle is

(a) 650 m (b) 700 m

(c) 750 m (d) 800 m

21. A body starts from rest with an acceleration of 2 m s^{-2}. After 5 s, the direction of acceleration reverses again for 5 s. The displacement is

(a) 0 m (b) 50 m (c) 55 m (d) 500 m

22. A parachutist jump first freely from an aeroplane for 10 s and then his parachute opens out. Now he descends with a net retardation of 2.5 m s^{-2}. If he bails out of the plane at a height of 2495 m and g = 10 m s^{-2}, his velocity on reaching the ground will be

(a) 5 m s^{-1} (b) 10 m s^{-1}

(c) 15 m s^{-1} (d) 20 m s^{-1}

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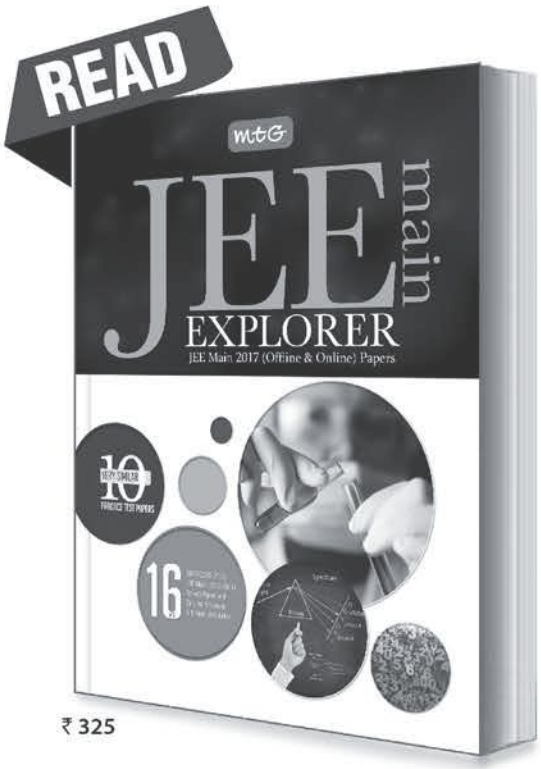
JEE Main



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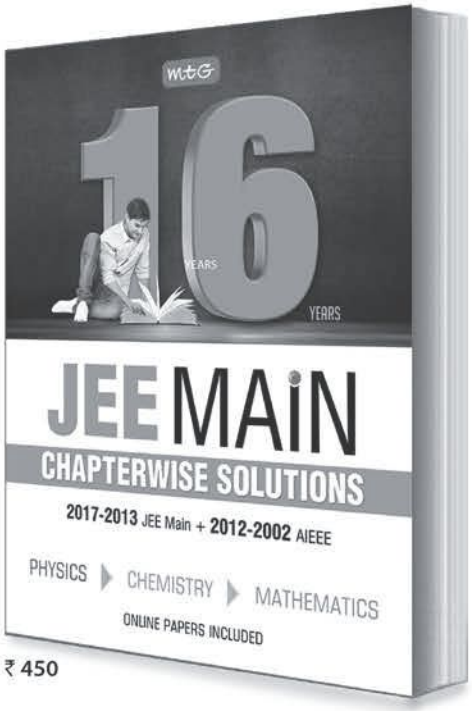

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23. A car A is travelling on a straight level road with a speed of 60 km h^{-1}. It is followed by another car B which is moving with a speed of 70 km h^{-1}. When the distance between them is 2.5 km, the car B is given a deceleration of 20 km h^{-2}. After what distance will the car B catch up with car A?

(a) 28.4 km (b) 36.4 km
(c) 22.6 km (d) 32.5 km

24. A body travelling with uniform acceleration crosses two points A and B with velocities 20 m s^{-1} and 30 m s^{-1} respectively. The speed of the body at the midpoint of A and B is nearest to

(a) 25.5 m s^{-1} (b) 25 m s^{-1}
(c) 24 m s^{-1} (d) $10\sqrt{6}$ m s^{-1}

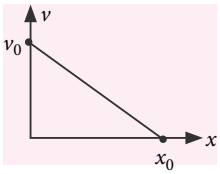
25. A car moving on a straight road covers $(1/3)^{rd}$ of the distance with 25 km h^{-1} and rest with 75 km h^{-1}. The average speed is

(a) 25 km h^{-1} (b) 45 km h^{-1}
(c) 55 km h^{-1} (d) 75 km h^{-1}

26. A body starts from rest and travels a distance s with uniform acceleration, then moves uniformly a distance $2s$ and finally comes to rest after moving further $5s$ under uniform retardation. The ratio of the average velocity to maximum velocity is

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{4}{7}$ (d) $\frac{5}{7}$

27. The velocity-displacement graph of a particle moving along a straight line is shown. The most suitable acceleration-displacement graph will be



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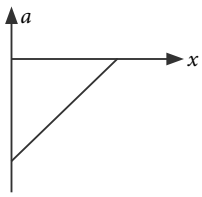

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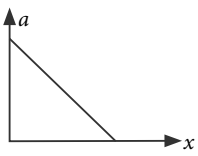

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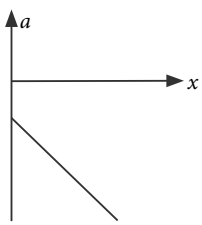

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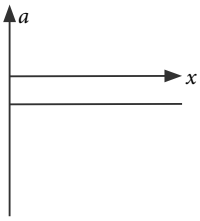

28. From a building two balls A and B are thrown such that A is thrown upwards and B downwards with the same speed (both vertically). If v_A and v_B are their respective velocities on reaching the ground then,

(a) $v_B > v_A$ (b) $v_A = v_B$
(c) $v_A > v_B$
(d) their velocities depend on their masses

29. A man runs at a speed of 4.0 m s^{-1} to overtake a standing bus. When he is 6.0 m behind the door of the bus (at t = 0), the bus moves forward and continues with a constant acceleration of 1.2 m s^{-2}. The man shall reach the door at time t equal to

(a) 5.2 s (b) 4.3 s (c) 2.3 s
(d) the man shall never gain the door

30. A train 100 m long travelling at 40 m s^{-1} starts overtaking another train 200 m long travelling at 30 m s^{-1}. The time taken by the train to pass the second train completely is

(a) 30 s (b) 40 s (c) 50 s (d) 60 s

SOLUTIONS

1. (b): Given : One nautical mile = 6080 feet

$$n_1u_1 = n_2u_2 \quad \text{or } 18\left(\frac{\text{nautical mile}}{\text{hour}}\right) = n_2\frac{\text{m}}{\text{s}}$$

$$\therefore \quad n_2 = 18\times\frac{6080\text{ ft}}{60\times60}$$

$$= \frac{18\times6080\times12\times2.54\times10^{-2}\text{ m}}{60\times60\text{ s}} = 9.26\text{ m s}^{-1}$$

2. (b): Given : $z = ax^2y^{1/2}$

$$\therefore x^2 = \frac{z}{ay^{1/2}} \text{ or } x = \frac{z^{1/2}}{a^{1/2}y^{1/4}} \text{ where } a \text{ is a constant.}$$

Relative error in x is

$$\frac{\Delta x}{x} = \frac{1}{2}\frac{\Delta z}{z} + \frac{1}{4}\frac{\Delta y}{y}$$

Percentage error in x is

$$\frac{\Delta x}{x}\times100 = \left(\frac{1}{2}\frac{\Delta z}{z} + \frac{1}{4}\frac{\Delta y}{y}\right)\times100$$

$$= \frac{1}{2}\times10\% + \frac{1}{4}\times12\%$$

$$= 5\% + 3\% = 8\%$$

3. (d)

MPP-2 CLASS XII ANSWER KEY

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

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About the mentor:

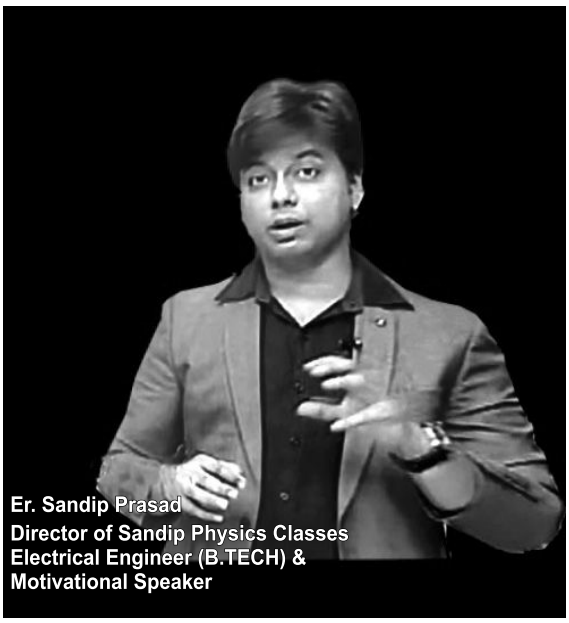
Er.Sandip Prasad is one of the most sought after and famous Physics teachers of India for IIT-JEE, Engineering and medical Entrance Examinations, who founded Sandip Physics Classes (SPC) 8 years ago. SPC which has several centres in Kolkata and patna has been guiding students, aspiring to be IITians and for all other medical and engineering entrance examinations. Many of his students have successfully cracked the IIT, AIIMS, AIPMT, WBJEE, and other exams.

His superhit show **"IIT Made Easy by Sandip Sir"**, is a unique initiative which stressed on the importance of motivation along with the knowledge of the subject, as an essential raw material to crack the exams. The 35-episodes long show, which he recently wrapped used to be telecasted on **Taaza tv (Eastern India's only Hindi news channel),** every Sunday. The show gained unprecedented popularity and viewership.

He is also a columnist of one of West Bengal's highest selling Hindi daily Prabhat Khabar ,where his career counseling articles are published every Saturday.(The e-paper of Kolkata Edition of Prabhat Khabar can be found at www.prabhatkhabar.com. You may also mail your career related queries to the given address).

An eminent speaker,he has conducted several motivational seminars in some of the most reputed schools of Kolkata. News about his seminars, results and contribution have also been printed in dailies like Sanmarg, Dainik Jagran, Chapte Chapte.

A man of absolute devotion, he leaves no stone unturned to help his students with his deep understanding of the subject and amazing problem-solving tricks. It is not surprising that the best and most brilliant of students hold him as their ideal.



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4. (b): Let $\upsilon = k\, r^a \rho^b S^c$ ...(i)

where k = a dimensionless constant.

Dimensions of various quantities are

$[\upsilon] = [T^{-1}]$, $[r] = [L]$, $[\rho] = [ML^{-3}]$, $[S] = [MT^{-2}]$

Substituting these dimensions in eqn (i), we get

$[T^{-1}] = [L]^a [ML^{-3}]^b [MT^{-2}]^c$

or $[M^0L^0T^{-1}] = [M^{b+c} L^{a-3b} T^{-2c}]$

Equating the powers of M, L and T on both sides,

$b + c = 0$, $a - 3b = 0$, $-2c = -1$

On solving these equations, we get

$$a = -\frac{3}{2}, b = -\frac{1}{2}, c = \frac{1}{2}$$

$$\therefore \quad \upsilon = kr^{-3/2}\rho^{-1/2}S^{1/2} = k\sqrt{\frac{S}{\rho r^3}}$$

5. (b): The given formula is, $X = 3YZ^2$

$$Y = \left[\frac{X}{Z^2}\right] = \left[\frac{\text{Capacitance}}{(\text{Magnetic induction})^2}\right]$$

$$= \left[\frac{M^{-1}L^{-2}Q^2T^2}{M^2Q^{-2}T^{-2}}\right] = [M^{-3}L^{-2}T^4Q^4]$$

Hence, the correct answer is (b).

6. (c): Given : Voltage, $V = (100 \pm 5)$ V

Current, $I = (10 \pm 0.2)$ A

According to Ohm's law, $V = IR$ or $R = \frac{V}{I}$

Relative error in R is

$$\frac{\Delta R}{R} = \frac{\Delta V}{V} + \frac{\Delta I}{I}$$

Percentage error in resistance R is

$$\frac{\Delta R}{R}\times 100 = \frac{\Delta V}{V}\times 100 + \frac{\Delta I}{I}\times 100$$

$$= \frac{5}{100}\times 100 + \frac{0.2}{10}\times 100 = 7\%$$

7. (a): The mean period of oscillation of the pendulum is

$$T_{mean} = \frac{\sum_{i=1}^{n} T_i}{n} = \frac{(2.63+2.56+2.42+2.71+2.80)}{5}\text{ s}$$

$$= \frac{13.12}{5}\text{ s} = 2.624\text{ s} = 2.62\text{ s}$$

(Rounded off to two decimal places)

The absolute errors in the measurement are

$\Delta T_1 = 2.62$ s – 2.63 s = – 0.01 s

$\Delta T_2 = 2.62$ s – 2.56 s = 0.06 s

$\Delta T_3 = 2.62$ s – 2.42 s = 0.20 s

$\Delta T_4 = 2.62$ s – 2.71 s = – 0.09 s

$\Delta T_5 = 2.62$ s – 2.80 s = – 0.18 s

Mean absolute error is

$$\Delta T_{mean} = \frac{\sum_{i=1}^{n}|\Delta T_i|}{n}$$

$$= \frac{(0.01+0.06+0.20+0.09+0.18)}{5} = \frac{0.54}{5}\text{ s} = 0.11\text{ s}$$

8. (b): Total mass = 2.3 kg + 0.02015 kg + 0.02017 kg

= 2.34032 kg = 2.3 kg

Difference of mass of the gold pieces

= 20.17 g –20.15 g = 0.02 g

9. (c) **10. (b)**

11. (a): Here $v = e^a h^b \mu^c G^d$. Taking the dimensions,

$[M^0LT^{-1}A^0] = [AT^1]^a [ML^2T^{-1}]^b [MLT^{-2}A^{-2}]^c [M^{-1}L^3T^{-2}]^d$

There will be four simultaneous equations by equating the dimensions of M, L, T and A. These are $a - 2c = 0$. $a - b - 2c - 2d = -1$, $b + c - d = 0$ and $2b + c + 3d = 1$.

Solving for a, b, c and d, we get

$a = -2$, $b = 1$, $c = -1$, $d = 0$

Thus, $v = he^{-2}\mu^{-1}G^0$

12. (a): One parsec is the distance at which an arc of length 1 AU makes an angle of 1 second of an arc.

As $\theta(\text{rad}) = \frac{\text{Arc}}{\text{Radius}} = \frac{l}{r}$ $\therefore$ $r = \frac{l}{\theta}$

Here $l = 1$ AU $= 1.496 \times 10^{11}$ m

$\theta = 1$ s of arc $= \frac{\pi}{60\times 60\times 180}$ rad $= 4.85 \times 10^{-6}$ rad

$$\therefore \quad 1\text{ parsec} = r = \frac{1.496\times 10^{11}}{4.85\times 10^{-6}} = 3.08\times 10^{16}\text{ m}$$

Order of magnitude of parsec = 16.

13. (b): $M = L^{-\frac{b}{a}} T^{-\frac{c}{a}} y^{\frac{1}{a}}$ if $a \neq 0$.

14. (a): Given, $\left(P + \frac{a}{V^3}\right)(V - b^2) = cT$

Dimension of $\frac{a}{V^3}$ = dimensions of P

$\therefore$ Dimensions of a = dimensions of PV^3

$$[a] = \left[\frac{F}{A}V^3\right] \qquad \left(\because P = \frac{F}{A}\right)$$

$$= \frac{[MLT^{-2}]}{[L^2]}\times[L^3]^3 = [ML^8T^{-2}]$$

Dimensions of b^2 = dimensions of V

$\therefore$ $[b] = [V]^{1/2} = [L^3]^{1/2}$ or $[b] = [L^{3/2}]$

15. (b): Joule is a unit of energy.

SI	New system
$n_1 = 5$	$n_2 = ?$
$M_1 = 1$ kg	$M_2 = \alpha$ kg
$L_1 = 1$ m	$L_2 = \beta$ m
$T_1 = 1$ s	$T_2 = \gamma$ s

Dimensional formula of energy is $[ML^2T^{-2}]$. Comparing with $[M^aL^bT^c]$, we get

$a = 1, b = 2, c = -2$

$$\text{As } n_2 = n_1\left(\frac{M_1}{M_2}\right)^a\left(\frac{L_1}{L_2}\right)^b\left(\frac{T_1}{T_2}\right)^c$$

$$= 5\left(\frac{1\text{ kg}}{\alpha\text{ kg}}\right)^1\left(\frac{1\text{ m}}{\beta\text{ m}}\right)^2\left(\frac{1\text{ s}}{\gamma\text{ s}}\right)^{-2} = \frac{5\gamma^2}{\alpha\beta^2} = 5\alpha^{-1}\beta^{-2}\gamma^2$$

16. (b): Suppose u be the initial velocity.

Velocity after time t_1 : $v_{11} = u + at_1$

Velocity after time $t_1 + t_2$: $v_{22} = u + a(t_1 + t_2)$

Velocity after time $t_1 + t_2 + t_3$:

$v_{33} = u + a(t_1 + t_2 + t_3)$

Now, $v_1 = \frac{u+v_{11}}{2} = \frac{u+u+at_1}{2} = u + \frac{1}{2}at_1$

$v_2 = \frac{v_{11}+v_{22}}{2} = u + at_1 + \frac{1}{2}at_2$

$v_3 = \frac{v_{22}+v_{33}}{2} = u + at_1 + at_2 + \frac{1}{2}at_3$

So $v_1 - v_2 = -\frac{1}{2}a(t_1 + t_2)$

$v_2 - v_3 = -\frac{1}{2}a(t_2 + t_3)$

$(v_1 - v_2) : (v_2 - v_3) = (t_1 + t_2) : (t_2 + t_3)$

17. (a)

18. (c) : Height covered in 1 min,

$s_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}\times 10\times(60)^2 = 18000$ m

Velocity attained after 1 min,

$v = u + at = 0 + 10 \times 60 = 600$ m s^{-1}

After the fuel is finished, $u = 600$ m s^{-1}, $v = 0$

$v^2 - u^2 = 2gs_2$

or $0 - (600)^2 = 2 \times (-9.8) \times s_2$

or $s_2 = \frac{(600)^2}{2\times 9.8} = 18367.3$ m

Maximum height reached

$= s_1 + s_2 = 36367.3$ m $\simeq 36.4$ km

19. (d): Given, $x = 6t^2 - t^3$ $\therefore$ $\frac{dx}{dt} = 12t - 3t^2$

For maximum or minimum

$\frac{dx}{dt} = 0 \Rightarrow 12t - 3t^2 = 0$ or $t = 4$ s

Again differentiating, we get $\frac{d^2x}{dt^2} = 12 - 6t$

At $t = 4$ s, $\frac{d^2x}{dt^2} = 12 - 6(4) = -12$

Since $\frac{d^2x}{dt^2}$ is negative, hence $t = 4$ s gives the maximum value for x-t curve.

Acceleration, $a = \frac{d^2x}{dt^2} = 12 - 6t$, At $t = 0$, $a = 12$ m s^{-2}

20. (c) : Given, $u = 0$, $a = 2$ m s^{-2}, $t = 10$ s.

$\therefore$ $s_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}\times 2\times(10)^2 = 100$ m

$v = u + at = 0 + 10 \times 2 = 20$ m s^{-1}

For motion with constant speed : $t = 30$ s

$s_2 = vt = 20 \times 30 = 600$ m

For motion with retardation :

$u = 20$ m s^{-1}, $a = 4$ m s^{-2}, $v = 0$

As $v^2 - u^2 = 2as_3$

$\therefore$ $0 - 20^2 = 2(-4) \times s_3$

$s_3 = 50$ m

Total distance covered

$s = s_1 + s_2 + s_3 = 100 + 600 + 50 = 750$ m

21. (a)

22. (a) : The velocity v acquired by the parachutist after 10 s is

$v = u + gt = 0 + 10 \times 10 = 100$ m s^{-1}

Then, $s_1 = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2}\times 10\times 10^2 = 500$ m

The distance travelled by the parachutist under retardation is

$s_2 = 2495 - 500 = 1995$ m

Let v_g be the velocity on reaching the ground. Then

$v_g^2 - v^2 = 2as_2$

or $v_g^2 - (100)^2 = 2 \times (-2.5) \times 1995$ or $v_g = 5$ m s^{-1}

23. (d): Relative velocity of car B w.r.t. A

$= 70 - 60 = 10$ km h^{-1}

$\therefore$ For car B,

$u = 10$ km h^{-1}, $s = 2.5$ km, $a = -20$ km h^{-2}

As $s = ut + \frac{1}{2}at^2$

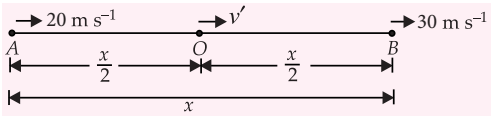
$\therefore$ $2.5 = 10\,t - \frac{1}{2} \times 20 \times t^2$ or $t = 0.5$ h

Actual distance travelled by car B during this time,

$s = ut + \frac{1}{2}at^2 = 70\times 0.5 - \frac{1}{2}\times 20\times(0.5)^2$

$= 35 - 2.5 = 32.5$ km

24. (a) :



Let x be the distance between two points A and B and O is the midpoint of AB. Let a be the uniform acceleration of the body and v' be velocity of the body at point O.

Using $v^2 - u^2 = 2as$

According to given problem

$$(v')^2 - (20)^2 = 2a\frac{x}{2} \quad ...(i)$$

and $$(30)^2 - (v')^2 = 2a\frac{x}{2} \quad ...(ii)$$

Equating eqns (i) and (ii), we get

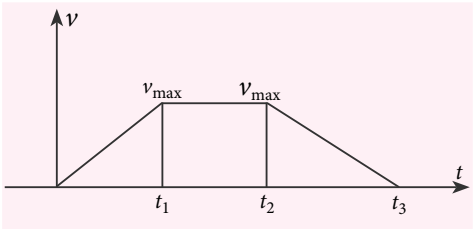
$$(v')^2 - (20)^2 = (30)^2 - (v')^2 \quad \text{or} \quad 2(v')^2 = (30)^2 + (20)^2$$

$$v' = \sqrt{\frac{(30)^2 + (20)^2}{2}} = \sqrt{\frac{900+400}{2}} = 25.5 \text{ m s}^{-1}$$

25. (b)

26. (c) : Graphically, the area of v–t curve represents displacement:

$$s = \frac{1}{2}v_{max}t_1 \quad \text{or} \quad t_1 = \frac{2s}{v_{max}}$$



$$2s = v_{max}t_2 \quad \text{or} \quad t_2 = \frac{2s}{v_{max}}; 5s = \frac{1}{2}v_{max}t_3 \quad \text{or} \quad t_3 = \frac{10s}{v_{max}}$$

$$v_{av} = \frac{\text{Total displacement}}{\text{Total time}} = \frac{s+2s+5s}{\frac{2s}{v_{max}} + \frac{2s}{v_{max}} + \frac{10s}{v_{max}}}$$

$$\frac{v_{av}}{v_{max}} = \frac{8s}{14s} = \frac{4}{7}$$

27. (a) : From the given velocity-displacement graph,

Slope $= -\frac{v_0}{x_0}$, intercept on y-axis $= v_0$

Thus the equation for this graph is

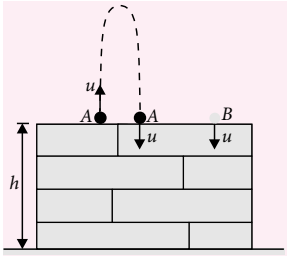
$$v = -\frac{v_0}{x_0}\cdot x + v_0 \quad \therefore \quad \frac{dv}{dt} = -\frac{v_0}{x_0}\cdot\frac{dx}{dt}$$

or $$a = -\frac{v_0}{x_0}\cdot v = -\frac{v_0}{x_0}\left(-\frac{v_0}{x_0}x + v_0\right)$$

or $$a = -\frac{v_0^2}{x_0^2}\cdot x - \frac{v_0^2}{x_0^2}$$

Clearly, the a-x graph must have a positive slope (v_0^2/x_0^2) and negative intercept $(-v_0^2/x_0)$ on y-axis.

28. (b) : Let the ball A is thrown vertically upwards with speed u and ball B is thrown vertically downwards with the same speed u. After reaching the highest point, A comes back to its point of projection with the same speed u in the downward direction.



If h be height of the building, then velocity of A on reaching the ground is

$$v_A^2 = u^2 + 2gh \quad \text{or} \quad v_A = \sqrt{u^2 + 2gh} \quad ...(i)$$

and that of B on reaching the ground is

$$v_B^2 = u^2 + 2gh \quad \text{or} \quad v_B = \sqrt{u^2 + 2gh} \quad ...(ii)$$

From eqns. (i) and (ii), we get $v_A = v_B$

29. (c) : At $t = 0$, let the man's position be the origin.

$\therefore \quad x_{0m} = 0$

The bus door is then at $x_{b0} = 6.0$ m.

The equation of motion for the man is

$$x_m = x_{m0} + v_{m0}t + \frac{1}{2}a_m t^2$$

Here, $x_{0m} = 0$, $v_{0m} = 4.0$ m s^{-1}, $a_m = 0$

$\therefore \quad x_m = 4t \quad ...(i)$

The equation of motion for the bus is

$$x_b = x_{0b} + v_{0b}t + \frac{1}{2}a_b t^2$$

Here, $x_{0b} = 6.0$ m, $v_{0b} = 0$, $a_b = 1.2$ m s^{-2}

$\therefore \quad x_b = 6 + \frac{1}{2}(1.2)t^2 \quad \text{or} \quad x_b = 6 + 0.6t^2 \quad ...(ii)$

When the man catches the bus, $x_m = x_b$

$\therefore \quad 4t = 6 + 0.6t^2$ Using eqn. (i) and (ii)

or $\quad 0.6t^2 - 4t + 6 = 0; 3t^2 - 20t + 30 = 0$

$$\therefore \quad t = \frac{20 \pm \sqrt{400-360}}{6} = \frac{10 \pm \sqrt{10}}{3} = 2.3 \text{ s}, 4.4 \text{ s}$$

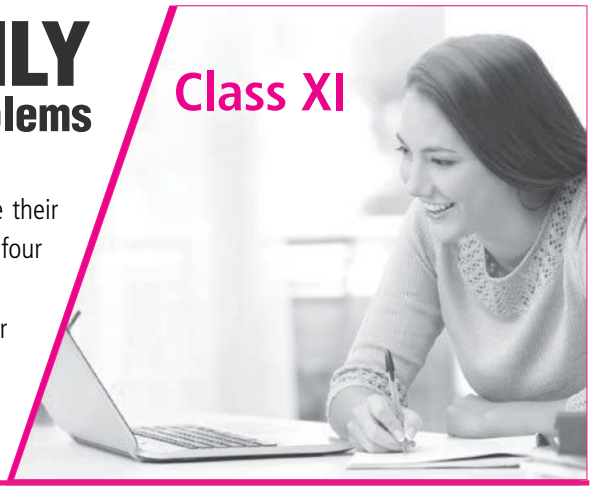
30. (a) : Relative velocity of overtaking $= 40 - 30 = 10$ m s^{-1}.

Total relative distance covered with this relative velocity during overtaking = 100 + 200 = 300 m

So time taken = 300/10 = 30 s.

MPP-2 MONTHLY Practice Problems

Class XI



This specially designed column enables students to self analyse their extent of understanding of specified chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer.

Self check table given at the end will help you to check your readiness.

Kinematics

Total Marks : 120 **Time Taken : 60 min**

NEET / AIIMS

Only One Option Correct Type

1. A parachutist after bailing out, falls 50 m without friction. When parachute opens, it decelerates at 2 m s^{-2}. He reaches the ground with a speed of 3 m s^{-1}. At what height did he bail out?

(a) 111 m (b) 293 m
(c) 182 m (d) 91 m

2. A person travelling eastward with a speed of 3 km h^{-1} finds that wind seems to blow from north. On doubling his speed, the wind appears to flow from north-east. Find the magnitude of the actual velocity of the wind.

(a) 4 km h^{-1} (b) $2\sqrt{3}$ km h^{-1}
(c) 3 km h^{-1} (d) $3\sqrt{2}$ km h^{-1}

3. What is the resultant of three coplanar forces 300 N at 0°, 400 N at 30° and 400 N at 150°?

(a) 400 N, 45° (b) 500 N, 50°
(c) 500 N, 53° (d) 550 N, 60°

4. A particle is projected from the ground with an initial speed of v at an angle θ with horizontal. The average velocity of the particle between its point of projection and highest point of trajectory is

(a) $\frac{v}{2}\sqrt{1 + 2\cos^2\theta}$ (b) $\frac{v}{2}\sqrt{1 + \cos^2\theta}$
(c) $\frac{v}{2}\sqrt{1 + 3\cos^2\theta}$ (d) $v\cos\theta$

5. A body dropped from top of a tower falls through 40 m during the last two seconds of its fall. The height of the tower (in m) is [Take g = 10 m s^{-2}]

(a) 60 m (b) 45 m
(c) 80 m (d) 50 m

6. A stone with weight W is thrown vertically upwards into air from ground level with initial velocity v_0. If a constant force f due to air drag acts on the stone throughout flight, the speed of the stone just before impact with the ground is

(a) $v_0\left(\frac{W-f}{W+f}\right)^{1/2}$ (b) $v_0\left(\frac{W+f}{W-f}\right)^{1/2}$
(c) $v_0\left(\frac{W-f}{W}\right)^{1/2}$ (d) $v_0\left(\frac{W+f}{f}\right)^{1/2}$

7. A projectile can have the same range R for two angles of projection. If T_1 and T_2 be the time of flights in the two cases, then the product of the two time of flights is directly proportional to

(a) $1/R^2$ (b) $1/R$
(c) R (d) R^2

8. At a height 0.4 m from the ground, the velocity of a projectile in vector form is $\vec{v} = (6\hat{i} + 2\hat{j})$ m s^{-1}. The angle of projection is

(a) 45° (b) 60°
(c) 30° (d) $\tan^{-1}(3/4)$

9. A threaded rod with 12 turns per cm and diameter 1.18 cm is mounted horizontally. A bar with a threaded hole to match the rod is screwed onto the rod. The bar spins at the rate of 216 rpm. How long will it take for the bar to move 1.50 cm along the rod?

(a) 3 s (b) 5 s
(c) 7 s (d) 4 s

10. A cannon on a level plain is aimed at an angle θ above the horizontal and a shell is fired with a muzzle velocity v_0 towards a cliff at a distance R away. The height from the bottom at which the shell strikes the side walls of the cliff is

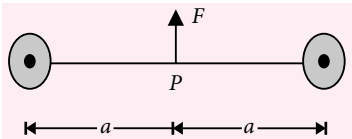
(a) $R \sin\theta - \dfrac{gR^2}{2v_0^2 \sin^2\theta}$

(b) $R \cos\theta - \dfrac{gR^2}{2v_0^2 \cos^2\theta}$

(c) $R \tan\theta - \dfrac{gR^2}{2v_0^2 \cos^2\theta}$

(d) $R \tan\theta - \dfrac{gR^2}{2v_0^2 \sin^2\theta}$

11. Two particles of mass m each are tied at the ends of a light string of length $2a$. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance a from the centre P as shown in figure. Now the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other at the surfaces. The magnitude of acceleration, when the separation between them becomes $2x$ is



(a) $\dfrac{Fa}{2m\sqrt{a^2 - x^2}}$ (b) $\dfrac{Fx}{2m\sqrt{a^2 - x^2}}$

(c) $\dfrac{Fx}{\sqrt{2ma}}$ (d) $\dfrac{F\sqrt{a^2 - x^2}}{2mx}$

12. Two trains take 3 s to pass one another when going in the opposite direction but only 2.5 s if the speed of one is increased by 50%. The time one would take to pass the other when going in the same direction at their original speeds is

(a) 10 s (b) 12 s
(c) 15 s (d) 18 s

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** The time of flight of a body becomes n times the original value if its speed is made n times.
Reason : This is due to the range of the projectile which becomes n times.

14. **Assertion :** When the displacement of a body is directly proportional to the square of the time. Then the body is moving with uniform acceleration.
Reason : The slope of velocity-time graph with time axis gives acceleration.

15. **Assertion :** If dot product and cross product of $\vec{P}$ and $\vec{Q}$ are zero, it implies that one of the vector $\vec{P}$ and $\vec{Q}$ must be null vector.
Reason : A null vector is a vector of zero magnitude.

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JEE MAIN / JEE ADVANCED

Only One Option Correct Type

16. A ball rolls from the edge of the top step of a stair case with horizontal speed 5 m s^{-1}. Each step is of 2 m high and 1m width. The ball hits

(a) 10th step (b) 5th step

(c) 2nd step (d) 3rd step

17. A policeman moving on a highway with a speed of 30 km h^{-1} fires a bullet at thief's car speeding away in the same direction with a speed of 192 km h^{-1}. If the muzzle speed of the bullet is 150 m s^{-1}, with what speed does the bullet hit the thief's car?

(a) 120 m s^{-1} (b) 90 m s^{-1}

(c) 125 m s^{-1} (d) 105 m s^{-1}

18. The speed of a projectile when it is at its greatest height is $\sqrt{2/5}$ times its speed at half the maximum height. The angle of projection is

(a) 30° (b) 60°

(c) 45° (d) $\tan^{-1}(3/4)$

19. A particle is projected horizontally with a speed v_0 from the top of a plane inclined at an angle θ with the horizontal. How far from the point of projection will the particle strike the plane?

(a) $\dfrac{2v_0^2 g \sec\theta}{\tan\theta}$ (b) $\dfrac{2v_0^2 g \tan\theta}{\sec\theta}$

(c) $\dfrac{2v_0^2 \tan\theta \sec\theta}{g}$ (d) $\dfrac{2v_0^2 g}{\tan\theta}$

More than One Options Correct Type

20. A train is passing through a platform of length 50 m with uniform velocity. It takes 15 s to cross the platform and 5 s to cross a man standing on the platform. Mark the correct option(s).

(a) The length of train is 25 m

(b) The length of train is 50 m

(c) The speed of train is 10 m s^{-1}

(d) The speed of train is 5 m s^{-1}

21. If a particle is projected with speed 20 m s^{-1} making angle 37° with horizontal. At $t = \dfrac{10}{3}$ s, (Take cosθ = 4/5)

(a) the velocity of the particle is horizontally directed

(b) the velocity is perpendicular to initial velocity

(c) the magnitude of velocity is $\dfrac{80}{3}$ m s^{-1}

(d) the magnitude of velocity is 16 m s^{-1}

22. Two cities A and B are connected by a regular bus service with buses plying in either direction every T seconds. The speed of each bus is uniform and equal to v_b. A cyclist cycles from A to B with a uniform speed of v_c. A bus goes past the cyclist in T_1 seconds in the direction A to B and every T_2 seconds in the direction B to A. Then

(a) $T_1 = \dfrac{v_b T}{v_b + v_c}$ (b) $T_2 = \dfrac{v_b T}{v_b - v_c}$

(c) $T_1 = \dfrac{v_b T}{v_b - v_c}$ (d) $T_2 = \dfrac{v_b T}{v_b + v_c}$

23. The coordinates of a particle moving in a plane given by $x = a\cos pt$ and $y = b\sin pt$ where a, b ($< a$) and p are positive constants of appropriate dimensions. Then,

SOLUTION OF MAY 2017 CROSSWORD

	1 P			2 F							3 M				4 F	A	R	A	D	5 R
6 C	O	S	M	O	L	O	G	Y			7 F	U	L	C	R	U	M			O
	L			L		8 A						L								C
	A			I		C		9 H	A	L	A	T	I	O	N					H
	R			A		T						I					10 T			E
	I			T		I			11 T	R	O	P	O	S	P	H	E	R	E		L
	S			I		V						L						O			I
	A			O		I	12 O	R	B	T	T	E	R			13 I		U			M
	T			N		T						X				N		G			I
	I					Y						E				T		H	14 S		T
	O				15 R		16 G	A	M	M	A	R	A	Y	S	R			U	17 G	
	N				A											A			S	O	
		18 L	O	R	D	R	A	Y	L	E	19 I	G	H			N			C	N	
20 H					I						S					E	21 S		E	I	
Y					O						O					T	H		P	O	
22 P	H	O	T	O	M	E	T	R	Y		L						U		T	M	
E					E						A						N		A	E	
R		23 I	S	O	T	O	N	E	S		T			24 S	E	X	T	A	N	T	
O					E						O								C	R	
N				25 E	R	G					26 R	E	S	O	N	A	N	C	E	Y	

Solution Senders (May 2017)

- Bhaibhab Chakraborty, Assam
- Neel Kamal, Kanpur

Solution Senders of Physics Musing

SET-46

1. Abha, Haryana
2. Ishaan Mishra, Kota
3. Yatin Shankar, Kerala

(a) the path of the particle is an ellipse
(b) the velocity and acceleration of the particle are normal to each other at $t = \pi/2p$
(c) the acceleration of the particle is always directed towards a fixed point
(d) the distance travelled by the particle in time interval $t = 0$ to $t = \pi/2p$ is a

Integer Answer Type

24. A 200 m long train starts from rest at $t = 0$ with constant acceleration 4 cm s^{-2}. The head light of its engine is switched ON at $t = 60$ s and its tail light is switched ON at $t = 120$ s. The distance between these two events for an observer standing on platform is $(2)^n$ m. Find the value of n.

25. A stone is dropped from certain height which can reach the ground in 5 s. If the stone is stopped after 3 s of its fall and then allowed to fall again. Find the time taken (in second) by the stone to reach the ground for the remaining distance.

26. A particle is moving in a circle of radius R with constant speed. The time period (T) is 1 s. In a time $t = T/6$, if the difference between average speed and average velocity of the particle is 2 m s^{-1}, the radius of the circle (in m) is

Comprehension Type

To a stationary man, rain appears to be falling at his back at an angle 30° with the vertical. As he starts moving forward with a speed of 0.5 m s^{-1}, he finds that the rain is falling vertically.

27. The speed of rain with respect to the stationary man is
(a) 0.5 m s^{-1} (b) 1.0 m s^{-1}
(c) $0.5\sqrt{3}$ m s^{-1} (d) 0.43 m s^{-1}

28. The speed of rain with respect to the moving man is
(a) 0.5 m s^{-1} (b) 1.0 m s^{-1}
(c) $0.5\sqrt{3}$ m s^{-1} (d) 0.45 m s^{-1}

Matrix Match Type

29. A ball is projected from the ground with velocity v such that its range is maximum.

Column-I	Column-II
(A) Velocity at half of the maximum height	(P) $\frac{\sqrt{3}v}{2}$
(B) Velocity at the maximum height	(Q) $\frac{v}{\sqrt{2}}$
(C) Change in its velocity when it returns to the ground	(R) $v\sqrt{2}$
(D) Average velocity when it reaches the maximum height	(S) $\frac{v}{2}\sqrt{\frac{5}{2}}$

	A	B	C	D
(a)	P	S	Q	R
(b)	P	Q	R	S
(c)	P	S	R	Q
(d)	R	P	S	Q

30. A balloon rises up with constant net acceleration of 10 m s^{-2} from the ground. After 2 s a particle drops from the balloon. After further 2 s match the following.
(Take $g = 10$ m s^{-2}).

Column-I	Column-II
(A) Height of particle from ground	(P) Zero
(B) Speed of particle	(Q) 10 SI units
(C) Height of the balloon	(R) 40 SI units
(D) Acceleration of particle	(S) 80 SI units

	A	B	C	D
(a)	R	P	S	Q
(b)	S	P	R	Q
(c)	P	S	Q	R
(d)	P	Q	R	S

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted .....
No. of questions correct .....
Marks scored in percentage .....

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

NEET

SOLVED PAPER 2017

Hurray!! We are happy to inform our readers that out of the 45 questions asked in NEET 2017, more than 60% questions were either exactly same or of similar type from the **MTG Books.** Hurray!!

Here, the references of few are given :

Exact Questions

Exam Q. No.	MTG Book	Q. No.	P. No.
14	NEET Guide	6	734
16	NCERT Fingertips	6	43
33	MTG Excel	25	462
34	NEET Champion	16	248
36	NEET Guide	59	181
41	29 Years NEET-AIPMT	5	95
42	NCERT Fingertips	56	301

Similar Questions

Exam Q. No.	MTG Book	Q. No.	P. No.
1	NEET Guide	51	343
2	NEET Guide	194	620
6	NEET Champion	76	305
7	29 Years NEET-AIPMT	53	141
8	NEET Champion	124	517
9	NEET Champion	90	337
11	NEET Guide	62	449
12	NEET Guide	62	721
13	29 Years NEET-AIPMT	10	236
17	NEET Guide	67	611
20	NEET Champion	246	432
21	NEET Guide	67	106
22	29 Years NEET-AIPMT	29	219
23	NEET Guide	14	213
25	NEET Guide	197	263
27	NCERT Fingertips	53	293
28	NCERT Fingertips	3	42
37	NCERT Fingertips	72	153
40	29 Years NEET-AIPMT	2	250
44	NCERT Fingertips	11	232
45	NCERT Fingertips	26	149

and more such questions .....

1. A spring of force constant k is cut into lengths of ratio 1 : 2 : 3. They are connected in series and the new force constant is k'. Then they are connected in parallel and force constant is k''. Then $k' : k''$ is
(a) 1 : 9 (b) 1 : 11 (c) 1 : 14 (d) 1 : 6

2. The ratio of resolving powers of an optical microscope for two wavelengths λ_1 = 4000 Å and λ_2 = 6000 Å is
(a) 9 : 4 (b) 3 : 2 (c) 16 : 81 (d) 8 : 27

3. The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system?
(a) 20 Hz (b) 30 Hz
(c) 40 Hz (d) 10 Hz

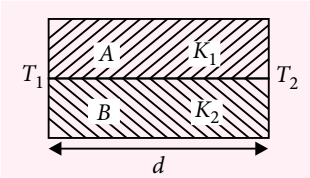
4. Consider a drop of rain water having mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 m s^{-1}. Take 'g' constant with a value 10 m s^{-2}. The work done by the (i) gravitational force and the (ii) resistive force of air is
(a) (i) 1.25 J (ii) –8.25 J
(b) (i) 100 J (ii) 8.75 J
(c) (i) 10 J (ii) –8.75 J
(d) (i) –10 J (ii) –8.25 J

5. A physical quantity of the dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is universal constant of gravitation and e is charge]

(a) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (b) $\frac{1}{c^2}\left[\frac{e^2}{G\,4\pi\varepsilon_0}\right]^{1/2}$

(c) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$ (d) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

6. Two rods A and B of different materials are welded together as shown in figure. Their thermal conductivities are K_1 and K_2. The thermal conductivity of the composite rod will be



(a) $\frac{3(K_1+K_2)}{2}$ (b) $K_1 + K_2$

(c) $2(K_1 + K_2)$ (d) $\frac{K_1+K_2}{2}$

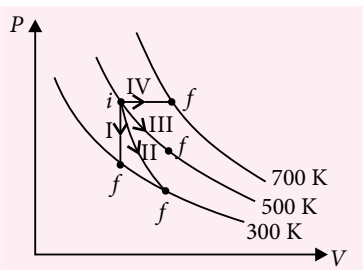
7. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system

(a) decreases by a factor of 2
(b) remains the same
(c) increases by a factor of 2
(d) increases by a factor of 4

8. In a common emitter transistor amplifier the audio signal voltage across the collector is 3 V. The resistance of collector is 3 kΩ. If current gain is 100 and the base resistance is 2 kΩ, the voltage and power gain of the amplifier is

(a) 15 and 200 (b) 150 and 15000
(c) 20 and 2000 (d) 200 and 1000

9. Thermodynamic processes are indicated in the following diagram.



Match the following

	Column-1		Column-2
P.	Process I	A.	Adiabatic
Q.	Process II	B.	Isobaric
R.	Process III	C.	Isochoric
S.	Process IV	D.	Isothermal

(a) P→C, Q→A, R→D, S→B
(b) P→C, Q→D, R→B, S→A
(c) P→*D*, Q→*B*, R→*A*, S→*C*
(d) P→A, Q→C, R→D, S→B

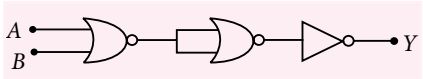
10. Suppose the charge of a proton and an electron differ slightly. One of them is $-e$, the other is $(e + \Delta e)$. If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero, then Δe is of the order of [Given mass of hydrogen $m_h = 1.67 \times 10^{-27}$ kg]

(a) 10^{-23} C (b) 10^{-37} C
(c) 10^{-47} C (d) 10^{-20} C

11. The resistance of a wire is 'R' ohm. If it is melted and stretched to 'n' times its original length, its new resistance will be

(a) R/n (b) n^2R (c) R/n^2 (d) nR

12. The given electrical network is equivalent to



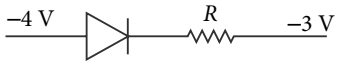
(a) OR gate (b) NOR gate
(c) NOT gate (d) AND gate

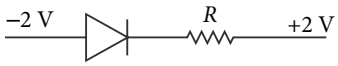
13. The de-Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature T (kelvin) and mass m, is

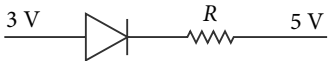
(a) $\frac{h}{\sqrt{3mkT}}$ (b) $\frac{2h}{\sqrt{3mkT}}$

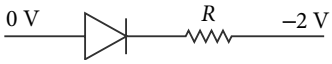
(c) $\frac{2h}{\sqrt{mkT}}$ (d) $\frac{h}{\sqrt{mkT}}$

14. Which one of the following represents forward bias diode?

(a) 

(b) 

(c) 

(d) 

15. A long solenoid of diameter 0.1 m has 2×10^4 turns per meter. At the centre of the solenoid, a coil of 100 turns and radius 0.01 m is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to 0 A from 4 A in 0.05 s. If the resistance of the coil is $10\,\pi^2\,\Omega$, the total charge flowing through the coil during this time is

(a) 16 μC (b) 32 μC
(c) 16 π μC (d) 32 π μC

16. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be

(a) $\frac{t_1 t_2}{t_2 - t_1}$ (b) $\frac{t_1 t_2}{t_2 + t_1}$ (c) $t_1 - t_2$ (d) $\frac{t_1 + t_2}{2}$

17. Young's double slit experiment is first performed in air and then in a medium other than air. It is found that 8th bright fringe in the medium lies where 5th dark fringe lies in air. The refractive index of the medium is nearly

(a) 1.59 (b) 1.69 (c) 1.78 (d) 1.25

18. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source L. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by

(a) $\frac{y}{x}$ (b) $\frac{x}{2y}$ (c) $\frac{x}{y}$ (d) $\frac{y}{2x}$

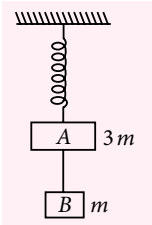
19. If θ_1 and θ_2 be the apparent angles of dip observed in two vertical planes at right angles to each other, then the true angle of dip θ is given by

(a) $\tan^2\theta = \tan^2\theta_1 + \tan^2\theta_2$
(b) $\cot^2\theta = \cot^2\theta_1 - \cot^2\theta_2$
(c) $\tan^2\theta = \tan^2\theta_1 - \tan^2\theta_2$
(d) $\cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$

20. Two cars moving in opposite directions approach each other with speed of 22 $m\,s^{-1}$ and 16.5 $m\,s^{-1}$ respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is
[velocity of sound is 340 $m\,s^{-1}$]

(a) 361 Hz (b) 411 Hz (c) 448 Hz (d) 350 Hz

21. Two blocks A and B of masses $3m$ and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut, are respectively



(a) $\frac{g}{3}, g$ (b) g, g (c) $\frac{g}{3}, \frac{g}{3}$ (d) $g, \frac{g}{3}$

22. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be

(a) 6° (b) 8° (c) 10° (d) 4°

23. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then

(a) d = 1 km (b) $d = \frac{3}{2}$ km
(c) d = 2 km (d) $d = \frac{1}{2}$ km

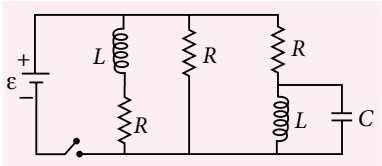
24. A potentiometer is an accurate and versatile device to make electrical measurements of EMF because the method involves

(a) potential gradients
(b) a condition of no current flow through the galvanometer
(c) a combination of cells, galvanometer and resistances
(d) cells

25. A spherical black body with a radius of 12 cm radiates 450 watt power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be

(a) 450 (b) 1000 (c) 1800 (d) 225

26. Figure shows a circuit that contains three identical resistors with resistanace $R = 9.0\,\Omega$ each, two identical inductors with inductance L = 2.0 mH each, and an ideal battery with emf ε = 18 V. The current i through the battery just after the switch closed is

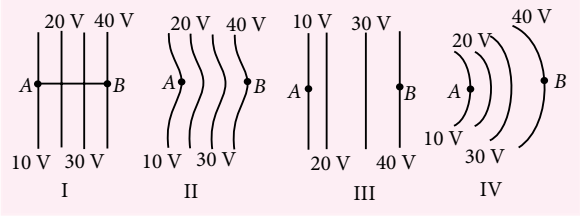


(a) 0.2 A (b) 2 A
(c) 0 ampere (d) 2 mA

27. Radioactive material 'A' has decay constant '8 λ' and material 'B' has decay constant 'λ'. Initially they have same number of nuclei. After what time, the ratio of number of nuclei of material 'B' to that 'A' will be $\frac{1}{e}$?

(a) $\frac{1}{7\lambda}$ (b) $\frac{1}{8\lambda}$ (c) $\frac{1}{9\lambda}$ (d) $\frac{1}{\lambda}$

28. The diagrams below show regions of equipotentials.



A positive charge is moved from A to B in each diagram.

(a) In all the four cases the work done is the same.
(b) Minimum work is required to move q in figure (I).
(c) Maximum work is required to move q in figure (II).
(d) Maximum work is required to move q in figure (III).

29. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will

(a) move towards each other.
(b) move away from each other.
(c) will become stationary.
(d) keep floating at the same distance between them.

30. The x and y coordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in metres and t in seconds. The acceleration of the particle at $t = 2$ s is

(a) 5 m s^{-2} (b) –4 m s^{-2}
(c) –8 m s^{-2} (d) 0

31. One end of string of length l is connected to a particle of mass 'm' and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed 'v', the net force on the particle (directed towards centre) will be (T represents the tension in the string)

(a) $T + \frac{mv^2}{l}$ (b) $T - \frac{mv^2}{l}$
(c) zero (d) T

32. A particle executes linear simple harmonic motion with an amplitude of 3 cm. When the particle is at 2 cm from the mean position, the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is

(a) $\frac{\sqrt{5}}{2\pi}$ (b) $\frac{4\pi}{\sqrt{5}}$ (c) $\frac{2\pi}{\sqrt{3}}$ (d) $\frac{\sqrt{5}}{\pi}$

33. Two polaroids P_1 and P_2 are placed with their axis perpendicular to each other. Unpolarised light I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its axis makes an angle 45° with that of P_1. The intensity of transmitted light through P_2 is

(a) $\frac{I_0}{4}$ (b) $\frac{I_0}{8}$ (c) $\frac{I_0}{16}$ (d) $\frac{I_0}{2}$

34. The bulk modulus of a spherical object is 'B'. If it is subjected to uniform pressure 'p', the fractional decrease in radius is

(a) $\frac{B}{3p}$ (b) $\frac{3p}{B}$ (c) $\frac{p}{3B}$ (d) $\frac{p}{B}$

35. In an electromagnetic wave in free space the root mean square value of the electric field is $E_{rms} = 6$ V m^{-1}. The peak value of the magnetic field is

(a) 2.83×10^{-8} T (b) 0.70×10^{-8} T
(c) 4.23×10^{-8} T (d) 1.41×10^{-8} T

36. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?

(a) 0.25 rad s^{-2} (b) 25 rad s^{-2}
(c) 5 m s^{-2} (d) 25 m s^{-2}

37. Two discs of same moment of inertia rotating about their regular axis passing through centre and perpendicular to the plane of disc with angular velocities ω_1 and ω_2. They are brought into contact face to face coinciding the axis of rotation. The expression for loss of energy during this process is

(a) $\frac{1}{4} I (\omega_1 - \omega_2)^2$ (b) $I(\omega_1 - \omega_2)^2$
(c) $\frac{1}{8} I (\omega_1 - \omega_2)^2$ (d) $\frac{1}{2} I (\omega_1 + \omega_2)^2$

38. The photoelectric threshold wavelength of silver is 3250×10^{-10} m. The velocity of the electron

ejected from a silver surface by ultraviolet light of wavelength 2536×10^{-10} m is
[Given $h = 4.14 \times 10^{-15}$ eV s and $c = 3 \times 10^{8}$ m s^{-1}]
(a) $\approx 0.6 \times 10^{6}$ m s^{-1} (b) $\approx 61 \times 10^{3}$ m s^{-1}
(c) $\approx 0.3 \times 10^{6}$ m s^{-1} (d) $\approx 6 \times 10^{5}$ m s^{-1}

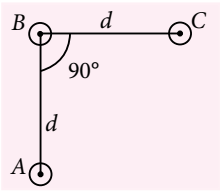
39. A 250-turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85 μA and subjected to a magnetic field of strength 0.85 T. Work done for rotating the coil by 180° against the torque is
(a) 4.55 μJ (b) 2.3 μJ
(c) 1.15 μJ (d) 9.1 μJ

40. The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is
(a) 1 (b) 4 (c) 0.5 (d) 2

41. A carnot engine having an efficiency of $\frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is
(a) 90 J (b) 99 J (c) 100 J (d) 1 J

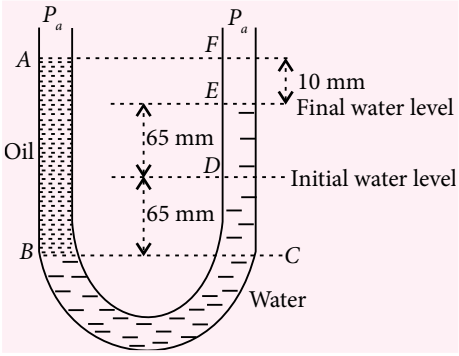
42. A gas mixture consists of 2 moles of O_2 and 4 moles of Ar at temperature T. Neglecting all vibrational modes, the total internal energy of the system is
(a) 15 RT (b) 9 RT
(c) 11 RT (d) 4 RT

43. An arrangement of three parallel straight wires placed perpendicular to plane of paper carrying same current 'I' along the same direction as shown in figure. Magnitude of force per unit length on the middle wire 'B' is given by



(a) $\frac{2\mu_0 I^2}{\pi d}$ (b) $\frac{\sqrt{2}\mu_0 I^2}{\pi d}$ (c) $\frac{\mu_0 I^2}{\sqrt{2}\pi d}$ (d) $\frac{\mu_0 I^2}{2\pi d}$

44. A U tube with both ends open to the atmosphere, is partially filled with water. Oil, which is immiscible with water, is poured into one side until it stands at a distance of 10 mm above the water level on the other side. Meanwhile the water rises by 65 mm from its original level (see diagram). The density of the oil is



(a) 425 kg m^{-3} (b) 800 kg m^{-3}
(c) 928 kg m^{-3} (d) 650 kg m^{-3}

45. Which of the following statements are correct?
(1) Centre of mass of a body always coincides with the centre of gravity of the body.
(2) Centre of mass of a body is the point at which the total gravitational torque on the body is zero.
(3) A couple on a body produces both translational and rotational motion in a body.
(4) Mechanical advantage greater than one means that small effort can be used to lift a large load.
(a) (1) and (2) (b) (2) and (3)
(c) (3) and (4) (d) (2) and (4)

SOLUTIONS

1. **(b):** Let us assume, the length of spring be l.
When we cut the spring into ratio of length 1 : 2 : 3, we get three springs of lengths $\frac{l}{6}, \frac{2l}{6}$ and $\frac{3l}{6}$ with force constant,

$$\therefore \quad k_1 = \frac{kl}{l_1} = \frac{kl}{l/6} = 6k\,;\; k_2 = \frac{kl}{l_2} = \frac{kl}{2l/6} = 3k$$

$$k_3 = \frac{kl}{l_3} = \frac{kl}{3l/6} = 2k$$

When connected in series,

$$\frac{1}{k'} = \frac{1}{6k} + \frac{1}{3k} + \frac{1}{2k} = \frac{1+2+3}{6k} = \frac{1}{k}$$

$$\therefore \quad k' = k$$

When connected in parallel, $k'' = 6k + 3k + 2k = 11k$

$$\frac{k'}{k''} = \frac{k}{11k} = \frac{1}{11}$$

2. **(b):** The resolving power of an optical microscope,

$$\text{RP} = \frac{2\mu \sin\theta}{\lambda}\,;\; \therefore \frac{\text{RP}_1}{\text{RP}_2} = \frac{6000}{4000} = \frac{3}{2}$$

3. **(a):** Nearest harmonics of an organ pipe closed at one end is differ by twice of its fundamental frequency.
$\therefore$ 260 – 220 = 2υ, υ = 20 Hz

4. (c) : Here, $m = 1$ g $= 10^{-3}$ kg, $h = 1$ km $= 1000$ m, $v = 50$ m s^{-1}, $g = 10$ m s^{-2}.

(i) The work done by the gravitational force

$$= mgh = 10^{-3} \times 10 \times 1000 = 10\,\text{J}$$

(ii) The total work done by gravitational force and the resistive force of air is equal to change in kinetic energy of rain drop.

$$\therefore \quad W_g + W_r = \frac{1}{2}mv^2 - 0$$

$$10 + W_r = \frac{1}{2}\times 10^{-3} \times 50 \times 50 \quad \text{or} \quad W_r = -8.75\ \text{J}$$

5. (d): Dimensions of

$$\frac{e^2}{4\pi\varepsilon_o} = [F \times d^2] = [\text{ML}^3\text{T}^{-2}]$$

Dimensions of $G = [\text{M}^{-1}\text{L}^3\text{T}^{-2}]$,

Dimensions of $c = [\text{LT}^{-1}]$

$$l \propto \left(\frac{e^2}{4\pi\varepsilon_o}\right)^p G^q c^r$$

$$\therefore \quad [\text{L}^1] = [\text{ML}^3\text{T}^{-2}]^p\,[\text{M}^{-1}\text{L}^3\text{T}^{-2}]^q\,[\text{LT}^{-1}]^r$$

On comparing both sides and solving, we get

$$p = \frac{1}{2}, \quad q = \frac{1}{2} \text{ and } r = -2$$

$$\therefore \quad [l] = \frac{1}{c^2}\left[\frac{Ge^2}{4\pi\varepsilon_o}\right]^{1/2}$$

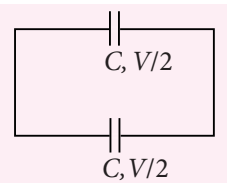
6. (d): Equivalent thermal conductivity of the composite rod in parallel combination will be,

$$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2}$$

7. (a) : When the capacitor is charged by a battery of potential V, then energy stored in the capacitor,

$$U_i = \frac{1}{2}CV^2 \qquad \text{...(i)}$$

When the battery is removed and another identical uncharged capacitor is connected in parallel



Common potential,

$$V' = \frac{CV}{C + C} = \frac{V}{2}$$

$\therefore$ Then the energy stored in the capacitor,

$$U_f = \frac{1}{2}(2C)\left(\frac{V}{2}\right)^2 = \frac{1}{4}CV^2 \qquad \text{...(ii)}$$

$\therefore$ From eqns. (i) and (ii)

$$U_f = \frac{U_i}{2}$$

that means the total electrostatic energy of resulting system will decreases by a factor of 2.

8. (b): Given: $V_i = 3$ V, $R_C = 3\,\text{k}\Omega$, $R_B = 2\,\text{k}\Omega$, $\beta = 100$

Voltage gain of the CE amplifier,

$$A_V = -\beta_{ac}\left(\frac{R_C}{R_B}\right) = -100\left(\frac{3}{2}\right) = -150$$

Power gain, $A_P = \beta \times A_V = 100 \times (-150) = -15000$

Negative sign represents that output voltage is in opposite phase with the input voltage.

9. (a) : In process I, volume is constant

$\therefore$ Process I $\rightarrow$ Isochoric; P $\rightarrow$ C

As slope of curve II is more than the slope of curve III.

Process II $\rightarrow$ Adiabatic and Process III $\rightarrow$ Isothermal

$\therefore$ Q $\rightarrow$ A, R $\rightarrow$ D

In process IV, pressure is constant

Process IV $\rightarrow$ Isobaric; S $\rightarrow$ B

10. (b): A hydrogen atom consists of an electron and a proton.

$\therefore$ Charge on one hydrogen atom

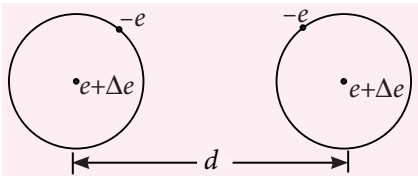
$$= q_e + q_p = -e + (e + \Delta e) = \Delta e$$

Since a hydrogen atom carry a net charge Δe,

$\therefore$ Electrostatic force,

$$F_e = \frac{1}{4\pi\varepsilon_o}\frac{(\Delta e)^2}{d^2} \qquad \text{...(i)}$$

will act between two hydrogen atoms.



The gravitational force between two hydrogen atoms is given as

$$F_g = \frac{Gm_hm_h}{d^2} \qquad \text{...(ii)}$$

Since, the net force on the system is zero, $F_e = F_g$

Using eqns. (i) and (ii), we get

$$\frac{(\Delta e)^2}{4\pi\varepsilon_o d^2} = \frac{Gm_h^2}{d^2}$$

$$(\Delta e)^2 = 4\pi\varepsilon_o G m_h^2$$

$$= 6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2/(9 \times 10^9)$$

$$\Delta e \approx 10^{-37}\ \text{C}$$

11. (b): The resistance of a wire of length l and area A and resistivity ρ is given as $R = \rho l/a$

Given, $l' = nl$

As the volume of the wire remains constant

$\therefore \quad A'l' = Al;\ A' = \dfrac{Al}{l'} = \dfrac{Al}{nl} = \dfrac{A}{n}$

$\therefore \quad R' = \dfrac{\rho l'}{A'} = \dfrac{n^2 \rho l}{A} = = n^2 R$

12. (b)

13. (a): Kinetic energy of a neutron in thermal equilibrium with heavy water at a temperature T is given as

$$K = \frac{3}{2}kT \qquad ...(i)$$

Also momentum (p) is, $p = \sqrt{2mK}$

From eqn. (i)

$$p = \sqrt{2m.\frac{3}{2}kT} = \sqrt{3mkT}$$

Required de-Broglie wavelength is given as

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{3mkT}}$$

14. (d): A diode is said to be forward biased if p-side is at higher potential than n-side of p-n junction.

15. (b): Given $n = 2 \times 10^4$; $I = 4$ A

Initially $\quad I = 0$ A

$\therefore \quad B_i = 0$ or $\phi_i = 0$

Finally, the magnetic field at the centre of the solenoid is given as

$B_f = \mu_o nI = 4\pi \times 10^{-7} \times 2 \times 10^4 \times 4 = 32\pi \times 10^{-3}$ T

Final magnetic flux through the coil is given as

$\phi_f = NBA = 100 \times 32\,\pi \times 10^{-3} \times \pi \times (0.01)^2$

$\phi_f = 32\pi^2 \times 10^{-5}$ T m^2

$$\text{Induced charge, } q = \frac{|\Delta\phi|}{R} = \frac{|\phi_f - \phi_i|}{R} = \frac{32\pi^2 \times 10^{-5}}{10\pi^2}$$

$$= 32 \times 10^{-6}\ \text{C} = 32\ \mu\text{C}$$

16. (b): Let v_1 is the velocity of Preeti on stationary escalator and d is the distance travelled by her

$\therefore \quad v_1 = d/t_1$

Again, let v_2 is the velocity of escalator

$\therefore \quad v_2 = d/t_2$

$\therefore$ Net velocity of Preeti on moving escalator with respect to the ground

$$v = v_1 + v_2 = \frac{d}{t_1} + \frac{d}{t_2} = d\left(\frac{t_1 + t_2}{t_1 t_2}\right)$$

The time taken by her to walk up on the moving escalator will be

$$t = \frac{d}{v} = \frac{d}{d\left(\dfrac{t_1 + t_2}{t_1 t_2}\right)} = \frac{t_1 t_2}{t_1 + t_2}$$

17. (c): Position of 8th bright fringe in medium,

$$x = \frac{8\lambda_m D}{d}$$

Position of 5th dark fringe in air,

$$x' = \frac{\left(5 - \dfrac{1}{2}\right)\lambda_{air} D}{d} = \frac{4.5\,\lambda_{air} D}{d}$$

Given $x = x'$

$$\therefore \quad \frac{8\lambda_m D}{d} = \frac{4.5\lambda_{air} D}{d}$$

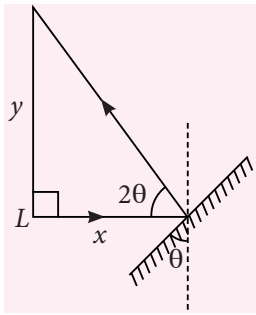
$$\mu_m = \frac{\lambda_{air}}{\lambda_m} = \frac{8}{4.5} \simeq 1.78$$

18. (d): When mirror is rotated by θ angle reflected ray will be rotated by 2θ.

For small angle θ,

$$\tan 2\theta \approx 2\theta = \frac{y}{x}$$

$$\therefore \quad \theta = \frac{y}{2x}$$



19. (d): Let B_H and B_V be the horizonal and vertical components of earth's magnetic field $\vec{B}$. Since θ is the angle of dip

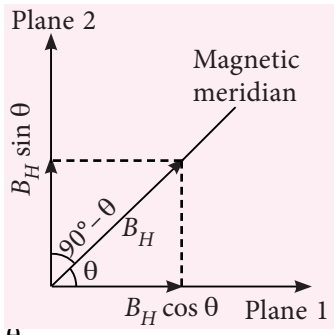
$$\therefore \quad \tan\theta = \frac{B_V}{B_H} \quad \text{or} \quad \cot\theta = \frac{B_H}{B_V} \qquad ...(i)$$

Suppose planes 1 and 2 are two mutually perpendicular planes and respectively make angles θ and 90°–θ with the magnetic meridian. The vertical components of earth's magnetic field remain same in the two planes but the effective horizontal components in the planes will be

$B_1 = B_H \cos\theta$

and $B_2 = B_H \sin\theta$

The angles of dip θ_1 and θ_2 in the two planes are given by



$$\tan\theta_1 = \frac{B_V}{B_1}$$

$$\tan\theta_1 = \frac{B_V}{B_H \cos\theta}$$

$$\text{or} \quad \cot\theta_1 = \frac{B_H \cos\theta}{B_V} \qquad ...(ii)$$

Similarly,

$$\cot\theta_2 = \frac{B_H \sin\theta}{B_V} \qquad ...(iii)$$

From eqns. (ii) and (iii)

$$\cot^2\theta_1 + \cot^2\theta_2 = \frac{B_H^2}{B_V^2}(\cos^2\theta + \sin^2\theta) = \frac{B_H^2}{B_V^2}$$

$\therefore\ \cot^2\theta_1 + \cot^2\theta_2 = \cot^2\theta$ [from eqn. (i)]

20. (c) : The required frequency of sound heard by the driver of second car is given as

$$\upsilon' = \upsilon\left(\frac{v + v_o}{v - v_s}\right)$$

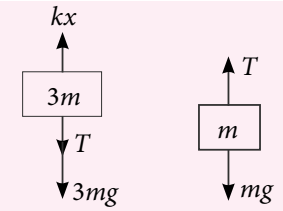
where v = velocity of sound

v_o = velocity of observer, *i.e.*, second car

v_s = velocity of source *i.e.*, first car

$$\upsilon' = 400\left(\frac{340 + 16.5}{340 - 22}\right) = 400\left(\frac{356.5}{318}\right) \approx 448 \text{ Hz}$$

21. (a) : Before the string is cut



Before the string is cut

$kx = T + 3mg$ ...(i)

$T = mg$ ...(ii)

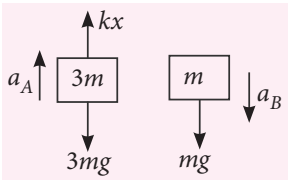
From eqns. (i) and (ii)

$kx = 4mg$

Just after the string is cut $T = 0$

$$a_A = \frac{kx - 3mg}{3m}$$

$$a_A = \frac{4mg - 3mg}{3m} = \frac{mg}{3m} = \frac{g}{3}$$



After the string is cut

and also $a_B = g$

22. (a) : The condition for dispersion without deviation is given as $(\mu - 1)A = (\mu' - 1)A'$

Given $\mu = 1.42$, $A = 10°$, $\mu' = 1.7$, $A' = ?$

$\therefore\ (1.42 - 1) \times 10 = (1.7 - 1)A'$

$(0.42) \times 10 = 0.7 \times A'$

or, $A' = \dfrac{0.42 \times 10}{0.7} = 6°$

23. (c) : The acceleration due to gravity at a height h is given as $g_h = g(1 - 2h/R_e)$

where R_e is radius of earth.

The acceleration due to gravity at a depth d is given as $g_d = g(1 - d/R_e)$

Given, $g_h = g_d$

$$\therefore\ g\left(1 - \frac{2h}{R_e}\right) = g\left(1 - \frac{d}{R_e}\right)$$

$\therefore\ d = 2h = 2 \times 1 = 2$ km $(\because\ h = 1 \text{ km})$

24. (b) : A potentiometer is an accurate and versatile device to make electrical measurements of emf because the method involves a condition of no current flow through the galvanometer, the device can be used to measure potential difference, internal resistance of a cell and compare emf's of two sources.

25. (c) : According to Stefan-Boltzman law, rate of energy radiated by a black body is given as

$$E = \sigma A T^4 = \sigma 4\pi R^2 T^4$$

Given $E_1 = 450$ W, $T_1 = 500$ K, $R_1 = 12$ cm

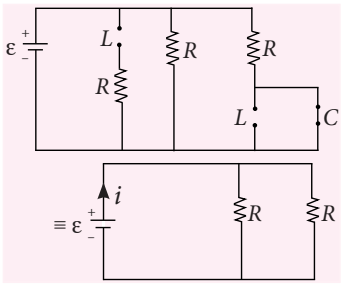
$R_2 = \dfrac{R_1}{2}$, $T_2 = 2T_1$, $E_2 = ?$

$$\frac{E_2}{E_1} = \frac{\sigma 4\pi R_2^2 T_2^4}{\sigma 4\pi R_1^2 T_1^4} = \left(\frac{R_2}{R_1}\right)^2\left(\frac{T_2}{T_1}\right)^4 = \frac{1}{4} \times 16 = 4$$

$E_2 = E_1 \times 4 = 450 \times 4 = 1800$ W

26. (*) : At time, $t = 0$ *i.e.*, when switch is closed, inductor in the circuit provides very high resistance (open circuit) while capacitor starts charging with maximum current (low resistance).

Equivalent circuit of the given circuit



Current drawn from battery,

$$i = \frac{\varepsilon}{(R/2)} = \frac{2\varepsilon}{R} = \frac{2 \times 18}{9} = 4 \text{ A}$$

*None of the given options is correct.

27. (*) : The number of radioactive nuclei 'N' at any time t is given as $N(t) = N_0 e^{-\lambda t}$

where N_0 is number of radioactive nuclei in the sample at some arbitrary time $t = 0$ and λ is the radioactive decay constant.

Given: $\lambda_A = 8\lambda$, $\lambda_B = \lambda$, $N_{0A} = N_{0B} = N_0$

$$\therefore\ \frac{N_B}{N_A} = \frac{e^{-\lambda t}}{e^{-8\lambda t}} \Rightarrow \frac{1}{e} = e^{-\lambda t} e^{8\lambda t} = e^{7\lambda t}$$

$\Rightarrow\ -1 = 7\lambda t$ or $t = \dfrac{-1}{7\lambda}$

Negative value of time is not possible.

So given ratio in question should be $\dfrac{N_B}{N_A} = e$.

*Question is not properly framed.

28. (a): Work done is given as $W = q\Delta V$

In all the four cases the potential difference from A to B is same.

$\therefore$ In all the four cases the work done is same.

29. (a): Since two astronauts are floating in gravitational free space. The only force acting on the two astronauts is the gravitational pull of their masses,

$$F = \frac{Gm_1m_2}{r^2},$$

which is attractive in nature.

Hence they move towards each other.

30. (b): $x = 5t - 2t^2, \quad y = 10t$

$$\frac{dx}{dt} = 5 - 4t, \quad \frac{dy}{dt} = 10$$

$$\therefore \quad v_x = 5 - 4t, \quad v_y = 10$$

$$\frac{dv_x}{dt} = -4, \quad \frac{dv_y}{dt} = 0$$

$$\therefore \quad a_x = -4, \quad a_y = 0$$

Acceleration, $\vec{a} = a_x\hat{i} + a_y\hat{j} = -4\hat{i}$

$\therefore$ The acceleration of the particle at $t = 2$ s is -4 m s^{-2}.

31. (d): Centripetal force (mv^2/l) is provided by tension so net force on the particle will be equal to tension T.

32. (b): Given, $A = 3$ cm, $x = 2$ cm

The velocity of a particle in simple harmonic motion is given as

$$v = \omega\sqrt{A^2 - x^2}$$

and magnitude of its acceleration is

$$a = \omega^2 x$$

Given, $|v| = |a|$

$$\therefore \omega\sqrt{A^2 - x^2} = \omega^2 x$$

$$\omega x = \sqrt{A^2 - x^2} \quad \text{or} \quad \omega^2 x^2 = A^2 - x^2$$

$$\omega^2 = \frac{A^2 - x^2}{x^2} = \frac{9-4}{4} = \frac{5}{4}$$

$$\omega = \frac{\sqrt{5}}{2}$$

Time period, $T = \frac{2\pi}{\omega} = 2\pi \cdot \frac{2}{\sqrt{5}} = \frac{4\pi}{\sqrt{5}}$ s

33. (b): The intensity of transmitted light through P_1,

$$I_1 = \frac{I_o}{2}$$

The intensity of transmitted light through P_3,

$$I_2 = I_1 \cos^2 45° = \frac{I_o}{2}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_o}{2} \cdot \frac{1}{2} = \frac{I_o}{4}$$

Angle between polaroids P_3 and $P_2 = (90° - 45°) = 45°$

$\therefore$ Intensity of transmitted light through P_2,

$$I_3 = I_2 \cos^2 45° = \frac{I_o}{4}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_o}{8}$$

34. (c): Bulk modulus B is given as

$$B = \frac{-pV}{\Delta V} \quad \text{...(i)}$$

The volume of a spherical object of radius r is given as

$$V = \frac{4}{3}\pi r^3, \Delta V = \frac{4}{3}\pi(3r^2)\Delta r \quad \therefore \frac{V}{\Delta V} = \frac{r}{3\Delta r}$$

Put this value in eqn. (i), we get

$$B = -\frac{pr}{3\Delta r}$$

Fractional decrease in radius is, $-\frac{\Delta r}{r} = \frac{p}{3B}$.

35. (a)

36. (b): $m = 3$ kg, $r = 40$ cm $= 40 \times 10^{-2}$ m, $F = 30$ N

Moment of inertia of hollow cylinder about its axis

$= mr^2 = 3 \text{ kg} \times (0.4)^2 \text{ m}^2 = 0.48 \text{ kg m}^2$

The torque is given by,

$\tau = I\alpha$

where I = moment of inertia,

α = angular acceleration

In the given case, $\tau = rF$, as the force is acting perpendicularly to the radial vector.

$$\therefore \quad \alpha = \frac{\tau}{I} = \frac{Fr}{mr^2} = \frac{F}{mr} = \frac{30}{3 \times 40 \times 10^{-2}} = \frac{30 \times 100}{3 \times 40}$$

$\alpha = 25$ rad s^{-2}

37. (a): Initial angular momentum $= I\omega_1 + I\omega_2$

Let ω be angular speed of the combined system.

Final angular momentum $= 2I\omega$

$\therefore$ According to conservation of angular momentum

$$I\omega_1 + I\omega_2 = 2I\omega \quad \text{or} \quad \omega = \frac{\omega_1 + \omega_2}{2}$$

Initial rotational kinetic energy

$$E_i = \frac{1}{2}I(\omega_1^2 + \omega_2^2)$$

Final rotational kinetic energy

$$E_f = \frac{1}{2}(2I)\omega^2 = \frac{1}{2}(2I)\left(\frac{\omega_1 + \omega_2}{2}\right)^2 = \frac{1}{4}I(\omega_1 + \omega_2)^2$$

$\therefore$ Loss of energy $\Delta E = E_i - E_f$

$$= \frac{I}{2}(\omega_1^2 + \omega_2^2) - \frac{I}{4}(\omega_1^2 + \omega_2^2 + 2\omega_1\omega_2)$$

$$= \frac{I}{4}\left[\omega_1^2 + \omega_2^2 - 2\omega_1\omega_2\right] = \frac{I}{4}(\omega_1 - \omega_2)^2$$

38. (a,d) : The maximum kinetic energy is given as

$$K_{max} = h\upsilon - \phi_0 = h\upsilon - h\upsilon_o = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where λ_0 = threshold wavelength

or $$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

Here, $h = 4.14 \times 10^{-15}$ eV s, $c = 3 \times 10^8$ m s^{-1}

$\lambda_o = 3250 \times 10^{-10}$ m = 3250 Å

$\lambda = 2536 \times 10^{-10}$ m = 2536 Å, $m = 9.1 \times 10^{-31}$ kg

$hc = 4.14 \times 10^{-15}$ eV s $\times 3 \times 10^8$ m s^{-1} = 12420 eV Å

$$\therefore \quad \frac{1}{2}mv^2 = 12420\left[\frac{1}{2536} - \frac{1}{3250}\right]\text{eV} = 1.076 \text{ eV}$$

$$v^2 = \frac{2.152 \text{ eV}}{m} = \frac{2.152 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$$\therefore \quad v \approx 6 \times 10^5 \text{ m s}^{-1} = 0.6 \times 10^6 \text{ m s}^{-1}$$

Note: Options (a) and (d) are same. So both are correct.

39. (d): Work done in a coil

$$W = mB(\cos\theta_1 - \cos\theta_2)$$

When it is rotated by angle 180° then

$$W = 2mB = 2(NIA)B \quad ...(i)$$

Given: $N = 250$, $I = 85$ μA $= 85 \times 10^{-6}$ A

$A = 1.25 \times 2.1 \times 10^{-4}$ m$^2 \approx 2.5 \times 10^{-4}$ m^2

$B = 0.85$ T

Putting these values in eqn. (i), we get

$$W = 2 \times 250 \times 85 \times 10^{-6} \times 2.5 \times 10^{-4} \times 0.85$$
$$\approx 9.1 \times 10^{-6} \text{ J} = 9.1 \ \mu\text{J}$$

40. (b): The wavelength of last line of Balmer series

$$\frac{1}{\lambda_B} = Rc\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{Rc}{4}$$

The wavelength of last line of Lyman series

$$\frac{1}{\lambda_L} = Rc\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = Rc$$

$$\therefore \quad \frac{\lambda_B}{\lambda_L} = \frac{4}{1} = 4$$

41. (a) : The relation between coefficient of performance and efficiency of carnot engine is given as

$$\beta = \frac{1-\eta}{\eta}$$

Given $\eta = \frac{1}{10}$, $W = 10$ J

$$\beta = \frac{1 - \frac{1}{10}}{\frac{1}{10}} = \frac{9}{10}.10 = 9$$

Since, $\beta = \frac{Q_2}{W}$, where Q_2 is the amount of energy absorbed from the reservoir

$\therefore \quad Q_2 = \beta W = 9 \times 10 = 90$ J

42. (c) : The internal energy of 2 moles of O_2 atom is

$$U_{O_2} = \frac{n_1 f_1}{2}RT = 2 \times \frac{5}{2} \times RT$$

$$U_{O_2} = 5\,RT$$

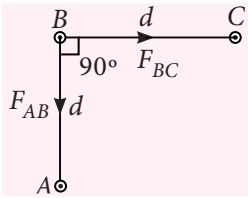
The internal energy of 4 moles of Ar atom is

$$U_{Ar} = \frac{n_2 f_2 RT}{2} = 4 \times \frac{3}{2} \times RT = 6RT$$

$\therefore$ The total internal energy of the system is

$$U = U_{O_2} + U_{Ar} = 5RT + 6RT = 11RT$$

43. (c) : Force between wires A and B = force between wires B and C



$$\therefore F_{BC} = F_{AB} = \frac{\mu_o I^2 l}{2\pi d}$$

As $\vec{F}_{AB} \perp \vec{F}_{BC}$, net force on wire B,

$$F_{net} = \sqrt{2}F_{BC} = \frac{\sqrt{2}\mu_o I^2 l}{2\pi d}$$

$$F_{net} = \frac{\mu_o I^2 l}{\sqrt{2}\pi d} \text{ or } \frac{F_{net}}{l} = \frac{\mu_o I^2}{\sqrt{2}\pi d}$$

44. (c) : Pressure at point C,

$$P_C = P_a + \rho_{water}\, g h_{water},$$

where $h_{water} = CE = (65 + 65)$ mm = 130 mm

Pressure at point B, $P_B = P_a + \rho_{oil}\, g h_{oil}$

where $h_{oil} = AB = (65 + 65 + 10)$ mm = 140 mm

In liquid, pressure is same at same level of liquid,

$$P_B = P_C$$

$$\rho_{oil}\, g h_{oil} = \rho_{water}\, g\, h_{water}$$

$$\rho_{oil} = \frac{130 \times 10^3}{140} = \frac{13}{14} \times 10^3 = 928.57 \text{ kg m}^{-3}$$

45. (*) : Centre of gravity of a body is the point at which the total gravitational torque on body is zero.

Centre of mass and centre of gravity coincides only for symmetrical bodies.

Hence statements (1) and (2) are incorrect.

A couple of a body produces rotational motion only.

Hence statement (3) is incorrect.

Mechanical advantage greater than one means that the system will require a force that is less than the load in order to move it.

Hence only statement (4) is correct.

*None of the given options is correct.

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CATEGORY-I (Q. 1 to Q. 30)

Only one answer is correct. Correct answer will fetch full marks +1. Incorrect answer or any combination of more than one answer will fetch –1/4 marks. No answer will fetch 0 marks.

1. When light of frequency υ_1 is incident on a metal with work function W (where $h\upsilon_1 > W$), the photo current falls to zero at a stopping potential of V_1. If the frequency of light is increased to υ_2, the stopping potential changes to V_2. Therefore, the charge of an electron is given by

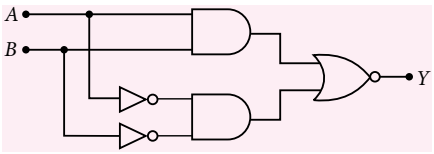
(a) $\dfrac{W(\upsilon_2+\upsilon_1)}{\upsilon_1 V_2+\upsilon_2 V_1}$ (b) $\dfrac{W(\upsilon_2+\upsilon_1)}{\upsilon_1 V_1+\upsilon_2 V_2}$

(c) $\dfrac{W(\upsilon_2-\upsilon_1)}{\upsilon_1 V_2-\upsilon_2 V_1}$ (d) $\dfrac{W(\upsilon_2-\upsilon_1)}{\upsilon_1 V_2-\upsilon_1 V_1}$

2. Radon-222 has a half-life of 3.8 days. If one starts with 0.064 kg of Radon-222, the quantity of Radon-222 left after 19 days will be

(a) 0.002 kg (b) 0.062 kg
(c) 0.032 kg (d) 0.024 kg

3. In the given circuit, the binary inputs at A and B are both 1 in one case and both 0 in the next case. The respective outputs at Y in these two cases will be:



(a) 1,1 (b) 0,0
(c) 0,1 (d) 1,0

4. When a semiconducting device is connected in series with a battery and a resistance, a current is found to flow in the circuit. If, however, the polarity of the battery is reversed, practically no current flows in the circuit. The device may be

(a) a p-type semiconductor
(b) a n-type semiconductor
(c) an intrinsic semiconductor
(d) a p-n junction

5. The dimension of the universal constant of gravitation, G, is

(a) $[ML^2T^{-1}]$ (b) $[M^{-1}L^3T^{-2}]$
(c) $[M^{-1}L^2T^{-2}]$ (d) $[ML^3T^{-2}]$

6. Two particles A and B (both initially at rest) start moving towards each other under a mutual force of attraction. At the instant when the speed of A is v and the speed of B is $2v$, the speed of the centre of mass is

(a) zero (b) v (c) $\dfrac{3v}{2}$ (d) $-\dfrac{3v}{2}$

7. Three vectors $\vec{A}=a\hat{j}+\hat{j}+\hat{k}; \vec{B}=\hat{i}+b\hat{j}+\hat{k}$ and $\vec{C}=\hat{i}+\hat{j}+c\hat{k}$ are mutually perpendicular ($\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along X, Y and Z axis respectively). The respective values of a, b and c are

(a) 0,0,0 (b) $-\dfrac{1}{2},-\dfrac{1}{2},-\dfrac{1}{2}$

(c) 1,–1,1 (d) $\dfrac{1}{2},\dfrac{1}{2},\dfrac{1}{2}$

8. A block of mass 1 kg starts from rest at $x = 0$ and moves along the x-axis under the action of a force $F = kt$, where t is time and $k = 1$ N s^{-1}.The distance the block will travel in 6 seconds is

(a) 36 m (b) 72 m (c) 108 m (d) 18 m

9. The velocity of a particle executing a simple harmonic motion is 13 m s^{-1}, when its distance from the equilibrium position (Q) is 3 m and its velocity is 12 m s^{-1}, when it is 5 m away from Q. The frequency of the simple harmonic motion is

(a) $\dfrac{5\pi}{8}$ (b) $\dfrac{5}{8\pi}$ (c) $\dfrac{8\pi}{5}$ (d) $\dfrac{8}{5\pi}$

10. A uniform string of length L and mass M is fixed at both ends while it is subject to a tension T. It can vibrate at frequencies (υ) given by the formula (where n = 1,2,3.....)

(a) $\upsilon = \frac{n}{2}\sqrt{\frac{T}{ML}}$ (b) $\upsilon = \frac{n}{2L}\sqrt{\frac{T}{M}}$

(c) $\upsilon = \frac{1}{2n}\sqrt{\frac{T}{ML}}$ (d) $\upsilon = \frac{n}{2}\sqrt{\frac{TL}{M}}$

11. A uniform capillary tube of length l and inner radius r with its upper end sealed is submerged vertically into water. The outside pressure is p_0 and surface tension of water is γ. When a length x of the capillary is submerged into water, it is found that water levels inside and outside the capillary coincide. The value of x is

(a) $\frac{l}{\left(1+\frac{p_0 r}{4\gamma}\right)}$ (b) $l\left(1-\frac{p_0 r}{4\gamma}\right)$

(c) $l\left(1-\frac{p_0 r}{2\gamma}\right)$ (d) $\frac{l}{\left(1+\frac{p_0 r}{2\gamma}\right)}$

12. A liquid of bulk modulus k is compressed by applying an external pressure such that its density increases by 0.01%. The pressure applied on the liquid is

(a) $\frac{k}{10000}$ (b) $\frac{k}{1000}$

(c) 1000 k (d) 0.01 k

13. Temperature of an ideal gas, initially at 27 °C, is raised by 6 °C. The rms velocity of the gas molecules will

(a) increase by nearly 2%
(b) decrease by nearly 2%
(c) increase by nearly 1%
(d) decrease by nearly 1%

14. 2 moles of ideal monatomic gas is carried from a state (P_0, V_0) to a state ($2P_0$, $2V_0$) along a straight line path in a P-V diagram. The amount of heat absorbed by the gas in the process is given by

(a) $3P_0V_0$ (b) $\frac{9}{2}P_0V_0$

(c) $6P_0V_0$ (d) $\frac{3}{2}P_0V_0$

15. A solid rectangular sheet has two different coefficients of linear expansion α_1 and α_2 along its length and breadth respectively. The coefficient of surface expansion is (for $\alpha_1 t << 1$, $\alpha_2 t << 1$)

(a) $\frac{\alpha_1+\alpha_2}{2}$ (b) $2(\alpha_1+\alpha_2)$

(c) $\frac{4\alpha_1\alpha_2}{\alpha_1+\alpha_2}$ (d) $\alpha_1+\alpha_2$

16. A positive charge Q is situated at the centre of a cube. The electric flux through any face of the cube is (in SI units)

(a) $\frac{Q}{6\varepsilon_0}$ (b) $4\pi Q$ (c) $\frac{Q}{4\pi\varepsilon_0}$ (d) $\frac{Q}{6\pi\varepsilon_0}$

17. Three capacitors of capacitance 1.0, 2.0 and 5.0 μF are connected in series to a 10 V source. The potential difference across the 2.0 μF capacitor is

(a) $\frac{100}{17}$ V (b) $\frac{20}{17}$ V (c) $\frac{50}{17}$ V (d) 10 V

18. A charge of 0.8 coulomb is divided into two charges Q_1 and Q_2. These are kept at a separation of 30 cm. The force on Q_1 is maximum when

(a) $Q_1 = Q_2 = 0.4$ C
(b) $Q_1 \approx 0.8$ C, Q_2 negligible
(c) Q_1 negligible, $Q_2 \approx 0.8$ C
(d) $Q_1 = 0.2$ C, $Q_2 = 0.6$ C

19. The magnetic field due to a current in a straight wire segment of length L at a point on its perpendicular bisector at a distance r ($r >> L$)

(a) decreases as $\frac{1}{r}$. (b) decreases as $\frac{1}{r^2}$.

(c) decreases as $\frac{1}{r^3}$.

(d) approaches a finite limit as $r \to \infty$

20. The magnets of two suspended coil galvanometers are of the the same strength so that they produce identical uniform magnetic fields in the region of the coils. The coil of the first one is in the shape of a square of side a and that of the second one is circular of radius $\frac{a}{\sqrt{\pi}}$. When the same current is passed through the coils, the ratio of the torque experienced by the first coil to that experienced by the second one is

(a) $1:\frac{1}{\sqrt{\pi}}$ (b) 1 : 1 (c) π : 1 (d) 1 : π

21. A proton is moving with a uniform velocity of 10^6 m s^{-1} along the Y-axis, under the joint action of a magnetic field along Z-axis and an electric field of magnitude 2×10^4 V m^{-1} along the negative X-axis. If the electric field is switched off, the proton starts moving in a circle. The radius of the circle is nearly (given: $\frac{e}{m}$ ratio for proton $\approx 10^8$ C kg^{-1})

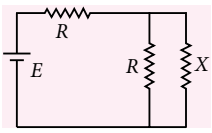
(a) 0.5 m (b) 0.2 m
(c) 0.1 m (d) 0.05 m

22. When the frequency of the AC voltage applied to a series LCR circuit is gradually increased from a low value, the impedance of the circuit
(a) monotonically increases
(b) first increases and then decreases
(c) first decreases and then increases
(d) monotonically decreases

23. Six wires, each of resistance r, are connected so as to form a tetrahedron. The equivalent resistance of the combination when current enters through one corner and leaves through some other corner is

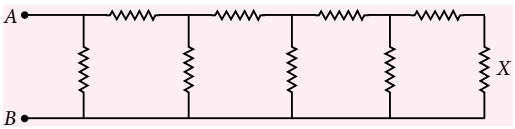
(a) r (b) $2r$ (c) $\frac{r}{3}$ (d) $\frac{r}{2}$

24. Consider the circuit shown in the figure. The value of the resistance X for which the thermal power generated in it is practically independent of small variation of its resistance is



(a) $X = R$ (b) $X = \frac{R}{3}$
(c) $X = \frac{R}{2}$ (d) $X = 2R$

25. Consider the circuit shown in the figure where all the resistances are of magnitude 1 kΩ. If the current in the extreme right resistance X is 1 mA, the potential difference between A and B is



(a) 34 V (b) 21 V
(c) 68 V (d) 55 V

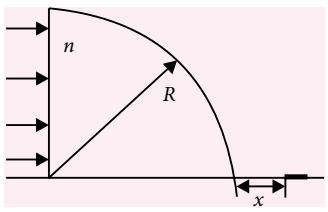
26. The ratio of the diameter of the sun to the distance between the earth and the sun is approximately 0.009. The approximate diameter of the image of the sun formed by a concave spherical mirror of radius of curvature 0.4 m is
(a) 4.5×10^{-6} m (b) 4.0×10^{-6} m
(c) 3.6×10^{-3} m (d) 1.8×10^{-3} m

27. The monochromatic coherent light beams A and B have intensities L and $\frac{L}{4}$ respectively. If these beams are superposed, the maximum and minimum intensities will be

(a) $\frac{9L}{4}, \frac{L}{4}$ (b) $\frac{5L}{4}, 0$
(c) $\frac{5L}{2}, 0$ (d) $2L, \frac{L}{2}$

28. A point object is held above a thin equiconvex lens at its focus. The focal length is 0.1 m and the lens rests on a horizontal thin plane mirror. The final image will be formed at
(a) infinite distance above the lens.
(b) 0.1 m above the centre of the lens.
(c) infinite distance below the lens.
(d) 0.1 m below the centre of the lens.

29. A parallel beam of light is incident on a glass prism in the shape of a quarter cylinder of radius $R = 0.05$ m and refractive index $n = 1.5$, placed on a horizontal table as shown in the figure. Beyond the cylinder, a patch of light is found whose nearest distance x from the cylinder is



(a) $(3\sqrt{3}-4)\times10^{-2}$ m
(b) $(2\sqrt{3}-2)\times10^{-2}$ m
(c) $(3\sqrt{5}-5)\times10^{-2}$ m
(d) $(3\sqrt{2}-3)\times10^{-2}$ m

30. The de Broglie wavelength of an electron is 0.4×10^{-10} m when its kinetic energy is 1.0 keV. Its wavelength will be 1.0×10^{-10} m, when its kinetic energy is
(a) 0.2 keV (b) 0.8 keV
(c) 0.63 keV (d) 0.16 keV

CATEGORY-II (Q. 31 to Q. 35)

Only one answer is correct. Correct answer will fetch full marks 2. Incorrect answer or any combination of more than one answer will fetch – 1/2 marks. No answer will fetch 0 marks.

31. A unit negative charge with mass M resides at the midpoint of the straight line of length $2a$ adjoining two fixed charges of magnitude $+Q$ each. If it is given a very small displacement $x(x<<a)$ in a direction perpendicular to the straight line, it will

(a) come back to its original position and stay there

(b) execute oscillations with frequency

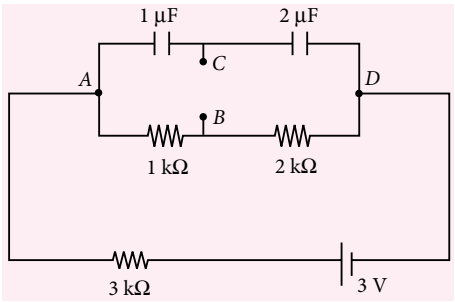
$$\frac{1}{2\pi}\sqrt{\frac{Q}{4\pi\varepsilon_0 Ma^3}}$$

(c) fly to infinity

(d) execute oscillations with frequency

$$\frac{1}{2\pi}\sqrt{\frac{Q}{4\pi\varepsilon_0 Ma^2}}$$

32. Consider the circuit given here. The potential difference V_{BC} between the points B and C is



(a) 1 V (b) 0.5 V (c) 0 V (d) –1 V

33. A particle with charge Q coulomb, tied at the end of an inextensible string of length R meter, revolves in a vertical plane. At the centre of the circular trajectory there is a fixed charge of magnitude Q coulomb. The mass of the moving charge M is such that $Mg = \frac{Q^2}{4\pi\varepsilon_0 R^2}$. If at the highest position of the particle, the tension of the string just vanishes, the horizontal velocity at the lowest point has to be

(a) 0 (b) $2\sqrt{gR}$ (c) $\sqrt{2gR}$ (d) $\sqrt{5gR}$

34. A bullet of mass 4.2×10^{-2} kg, moving at a speed of 300 m s^{-1}, gets stuck into a block with a mass 9 times that of the bullet. If the block is free to move without any kind of friction, the heat generated in the process will be

(a) 45 cal (b) 405 cal

(c) 450 cal (d) 1701 cal

35. A particle with charge e and mass m, moving along the X-axis with a uniform speed u, enters a region where a uniform electric field E is acting along the Y-axis. The particle starts to move in a parabola. Its focal length (neglecting any effect of gravity) is

(a) $\frac{2mu^2}{eE}$ (b) $\frac{eE}{2mu^2}$ (c) $\frac{mu}{2eE}$ (d) $\frac{mu^2}{2eE}$

CATEGORY-III (Q. 36 to Q. 40)

One or more answer (s) is (are) correct. Correct answer (s) will fetch full marks 2. Any combination containing one or more incorrect answer will fetch 0 marks. Also no answer will fetch 0 marks. If all correct answers are not marked and also no incorrect answer is marked then score = 2 × number of correct answers marked ÷ actual number of correct answers.

36. Let v_n and E_n be the respective speed and energy of an electron in the nth orbit of radius r_n, in a hydrogen atom, as predicted by Bohr's model. Then

(a) plot of $E_n r_n / E_1 r_1$ as a function of n is a straight line of slope 0.

(b) plot of $r_n v_n / r_1 v_1$ as a function of n is a straight line of slope 1.

(c) plot of $\ln\left(\frac{r_n}{r_1}\right)$ as a function of $\ln(n)$ is a straight line of slope 2.

(d) plot of $\ln\left(\frac{r_n E_1}{E_n r_1}\right)$ as a function of $\ln(n)$ is a straight line of slope 4.

37. A small steel ball bounces on a steel plate held horizontally. On each bounce the speed of the ball arriving at the plate is reduced by a factor e (coefficient of restitution) in the rebound, so that $V_{upward} = eV_{downward}$. If the ball is initially dropped from a height of 0.4 m above the plate and if 10 seconds later the bouncing ceases, the value of e is

(a) $\sqrt{\frac{2}{7}}$ (b) $\frac{3}{4}$ (c) $\frac{13}{18}$ (d) $\frac{17}{18}$

38. If the pressure, temperature and density of an ideal gas are denoted by P, T and ρ, respectively, the velocity of sound in the gas is

(a) proportional to $\sqrt{P}$, when T is constant

(b) proportional to $\sqrt{T}$.

(c) proportional to $\sqrt{P}$, when ρ is constant

(d) proportional to T.

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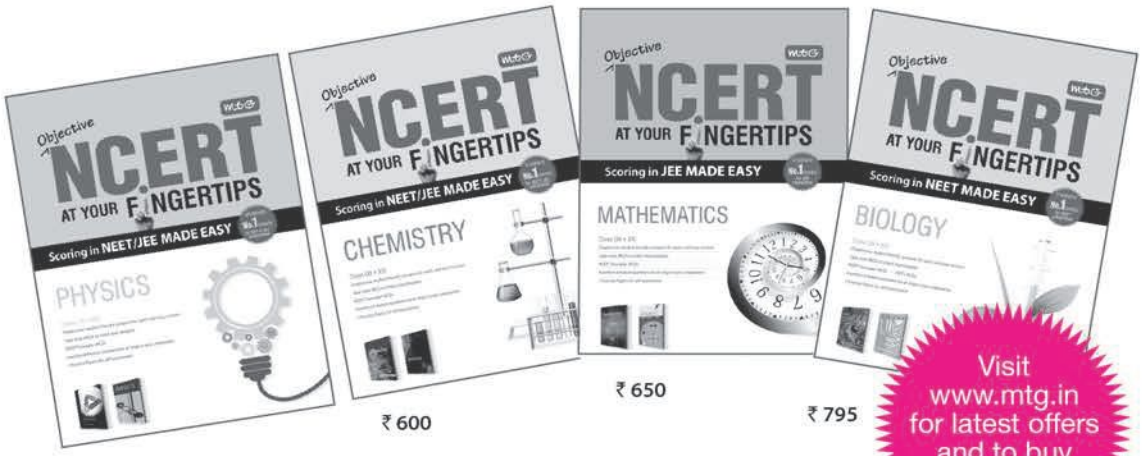

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39. Two long parallel wires separated by 0.1 m carry currents of 1 A and 2 A respectively in opposite directions. A third current-carrying wire parallel to both of them is placed in the same plane such that it feels no net magnetic force. It is placed at a distance of

(a) 0.5 m from the 1st wire, towards the 2nd wire.
(b) 0.2 m from the 1st wire, towards the 2nd wire.
(c) 0.1 m from the 1st wire, away from the 2nd wire.
(d) 0.2 m from the 1st wire, away from the 2nd wire.

40. If χ stands for the magnetic susceptibility of a substance, μ for its magnetic permeability and μ_0 for the permeability of free space, then

(a) for a paramagnetic substances : $\chi > 0, \mu > 0$
(b) for a paramagnetic substance : $\chi > 0, \mu > \mu_0$
(c) for a diamagnetic substances : $\chi < 0, \mu < 0$
(d) for a ferromagnetic substance : $\chi > 1, \mu > \mu_0$

SOLUTIONS

1. **(c) :** Using Einstein's equation, $h\upsilon = W + eV_0$

When the incident light frequency is υ_1, then stopping potential is V_1

$\therefore \quad h\upsilon_1 = W + eV_1$ ...(i)

And when the incident light frequency is υ_2, then stopping potential is V_2

$\therefore \quad h\upsilon_2 = W + eV_2$ ...(ii)

From eqns. (i) and (ii)

$$\frac{\upsilon_1}{\upsilon_2} = \frac{W + eV_1}{W + eV_2}$$

On solving, $W\upsilon_1 + eV_2\upsilon_1 = W\upsilon_2 + eV_1\upsilon_2$

$$\Rightarrow \quad e = \frac{W(\upsilon_2 - \upsilon_1)}{\upsilon_1 V_2 - \upsilon_2 V_1}$$

2. **(a) :** Given : For Radon-222,

$T_{1/2} = 3.8$ days, $t = 19$ days

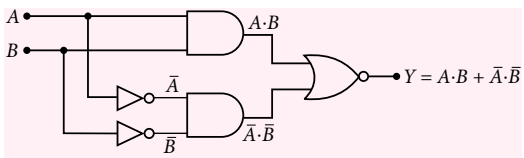
$\therefore$ Number of half lives in time t, $n = \frac{19}{3.8} = 5$

The remaining quantity of Radon-222 after 5 half lives,

$$N = \left(\frac{1}{2}\right)^5 N_0 \qquad (\because N_0 = 0.064 \text{ kg})$$

$$= \left(\frac{1}{2}\right)^5 \times 0.064 \text{ kg} = 0.002 \text{ kg}$$

3. **(b) :**



For $A = 1, B = 1$, the output, $Y = 0$

For $A = 0, B = 0$, the output, $Y = 0$

4. **(d)**

5. **(b) :** The universal constant of gravitation G is given by $G = \frac{Fr^2}{m_1 m_2}$

$$\therefore \quad [G] = \left[\frac{MLT^{-2}L^2}{M^2}\right] = [M^{-1}L^3T^{-2}]$$

6. **(a) :** As no external force is acting on the system, the centre of mass must be at rest *i.e.*, $v_{cm} = 0$

7. **(b) :** Here; $\vec{A} = (a\hat{i} + \hat{j} + \hat{k})$

$\vec{B} = (\hat{i} + b\hat{j} + \hat{k})$ and $\vec{C} = (\hat{i} + \hat{j} + c\hat{k})$ are mutually perpendicular,

$\therefore \quad \vec{A}\cdot\vec{B} = 0$ *i.e.*, $a + b + 1 = 0$ ...(i)

$\vec{B}\cdot\vec{C} = 0$ *i.e.*, $1 + b + c = 0$ ...(ii)

$\vec{C}\cdot\vec{A} = 0$ *i.e.*, $a + 1 + c = 0$ ...(iii)

From eqn. (i), (ii) and (iii)

$$a = -\frac{1}{2}, b = -\frac{1}{2}, c = -\frac{1}{2}$$

8. **(a) :** Block of mass 1 kg moves along x-axis under a force, $F = kt$

$\therefore \quad F = ma = kt$

$$\Rightarrow \quad 1 \times \frac{dv}{dt} = kt$$

By integrating both sides, we get

$$v = \frac{kt^2}{2} \text{ or } \frac{dx}{dt} = \frac{kt^2}{2} \qquad (\because k = 1 \text{ N s}^{-1})$$

$$\therefore \quad x = \frac{t^3}{6} \qquad (\text{at } t = 6 \text{ s})$$

$$x = \frac{(6)^3}{6} = 36 \text{ m}$$

9. **(b) :** For a particle executing simple harmonic motion, the velocity, $v = \omega\sqrt{A^2 - x^2}$

When the velocity at 3 m is 13 m s^{-1}, then,

$13^2 = \omega^2(A^2 - 3^2)$ ...(i)

When the velocity at 5 m is 12 m s^{-1}, then

$12^2 = \omega^2 (A^2 - 5^2)$ ...(ii)

From eqns. (i) and (ii)

$$\omega = \frac{5}{4} \text{ rad s}^{-1}$$

$$\upsilon = \frac{\omega}{2\pi} = \frac{5}{8\pi}$$

10. (a) : The frequency of a uniform string,

$$\upsilon = \frac{n}{2L}\sqrt{\frac{T}{\mu}}, \text{ where string, } \mu = \frac{M}{L}$$

$$\therefore \quad \upsilon = \frac{n}{2L}\sqrt{\frac{TL}{M}} = \frac{n}{2}\sqrt{\frac{T}{ML}}$$

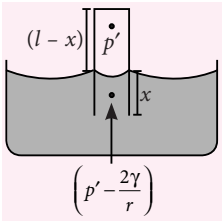
11. (d) : Let p' be the pressure of air inside the sealed capillary tube.

Here, $p' = \left(p_0 + \frac{2\gamma}{r}\right)$

Using Boyle's law, $p_0V_0 = p'V'$

$$\therefore \quad p_0(lA) = p'(l-x)A \Rightarrow p' = \frac{p_0 l}{l-x} \quad \text{...(i)}$$

where A is the cross sectional area of capillary tube.



Now since level of water inside capillary coincides with outside,

$$\therefore \quad p' - p_0 = \frac{2\gamma}{r}$$

$$\therefore \quad \frac{p_0 l}{(l-x)} - p_0 = \frac{2\gamma}{r} \quad \text{(from eqn. (i))}$$

$$p_0\left(\frac{l}{l-x} - 1\right) = \frac{2\gamma}{r} \Rightarrow p_0 x = \frac{2\gamma}{r}(l-x)$$

$$\Rightarrow \quad x = \left(\frac{l}{1+\frac{p_0 r}{2\gamma}}\right)$$

12. (a) : The bulk modulus, $k = -\frac{P}{\frac{\Delta V}{V}}$

where $\frac{\Delta V}{V}$ is fractional change in volume and P is external pressure.

$$k = \frac{-P}{\frac{\Delta V}{V}} \Rightarrow \frac{-\Delta V}{V} = \frac{P}{k} \text{ or } \frac{P}{k} = \frac{\Delta\rho}{\rho}$$

$$\therefore \quad P = \frac{k\Delta\rho}{\rho} = \frac{k \times 0.01}{100} = \frac{k}{10000}$$

13. (c) : $\because \; v_{rms} = \sqrt{\frac{3k_BT}{m}}$ *i.e.* $v_{rms} \propto \sqrt{T}$

$\therefore$ Percentage increase in velocity v_{rms},

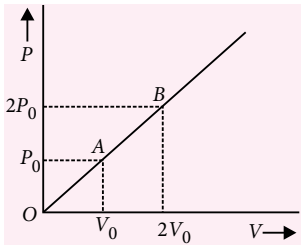
$$\frac{\Delta v_{rms}}{v_{rms}} \times 100 = \frac{1}{2}\frac{\Delta T}{T} \times 100$$

or $$\frac{\Delta v_{rms}}{v_{rms}} \times 100 = \frac{1}{2} \times \frac{6}{300} \times 100$$

$$\frac{\Delta v_{rms}}{v_{rms}} \times 100 = 1\%$$

Hence, the rms velocity increases by 1%.

14. (c) : Total work done for path AB,



W_{AB} = area under curve AB

$$= P_0V_0 + \frac{1}{2}P_0V_0 = \frac{3}{2}P_0V_0$$

Change in internal energy for path AB

$$\Delta U_{AB} = nC_v\Delta T$$

($\because$ for monatomic gas, $C_v = \frac{3}{2}R$)

$$\therefore \quad \Delta U_{AB} = n\frac{3}{2}R\left(\frac{4P_0V_0}{nR} - \frac{P_0V_0}{nR}\right)$$

$$\Delta U_{AB} = \frac{9P_0V_0}{2}$$

$\therefore$ The amount of heat absorbed by the gas in the process is,

$$\Delta Q = W_{AB} + \Delta U_{AB} = \frac{3}{2}P_0V_0 + \frac{9}{2}P_0V_0 = 6P_0V_0$$

15. (d)

16. (a) : Total electric flux through the cube $= \frac{Q}{\varepsilon_0}$

Hence the electric flux through any face of the cube $= \frac{Q}{6\varepsilon_0}$

17. (c) : $\because$ The capacitors are connected in series, then total capacitance is given by,

$$\frac{1}{C} = \frac{1}{1} + \frac{1}{2} + \frac{1}{5} \quad \Rightarrow \quad C = \frac{10}{17}\ \mu\text{F}$$

Now, total charge $Q = CV = \frac{10}{17} \times 10^{-6} \times 10$

$$= \frac{1}{17} \times 10^{-4}\text{ C or } \frac{100}{17}\ \mu\text{C}$$

Potential difference across the 2 μF capacitor,

$$V = \frac{Q}{C} = \frac{100}{17 \times 2}\text{V} = \frac{50}{17}\text{V}$$

18. (a) : Let one charge is Q coulomb then another charge is $(0.8 - Q)$ coulomb.

$\therefore$ Force of attraction, $F = k\frac{Q_1 \times Q_2}{r^2}$

$$F = \frac{kQ(0.8-Q)}{r^2}$$

For maximum force, $\frac{dF}{dQ} = 0$

$$\therefore \quad \frac{dF}{dQ} = \frac{k}{r^2}(0.8-2Q) = 0 \Rightarrow Q = 0.4\text{ C}$$

$\therefore \quad Q_1 = 0.4$ C, $Q_2 = 0.4$ C

19. (b): From Biot-savart's law,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \quad i.e. \quad dB \propto \frac{1}{r^2}$$

Hence option (b) is correct.

20. (b): Given : Radius of the circular ring = $\frac{a}{\sqrt{\pi}}$

Side of the square = a

The strength of magnetic field produced by two coils is same.

As torque experienced by any coil, $\tau = BIA\cos\theta$

$\therefore$ Magnetic field is uniform

$$\therefore \quad \frac{\text{Torque experienced by the first rectangular coil}}{\text{Torque experience by the circular coil}} = \frac{BIA_1\cos\theta}{BIA_2\cos\theta}$$

$$= \frac{a^2}{\pi(\frac{a}{\sqrt{\pi}})^2} = \frac{1}{1}$$

21. (a): Given : $\vec{v} = 10^6\hat{j}$ m s^{-1},

$\vec{E} = -2 \times 10^4\ \hat{i}$ V m^{-1}, $\vec{B} = B\hat{k}$

$\frac{e}{m}$ (for proton) = 10^8 C kg^{-1}

Force on Proton, $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$= e(-2 \times 10^4 + 10^6 B)\hat{i}$

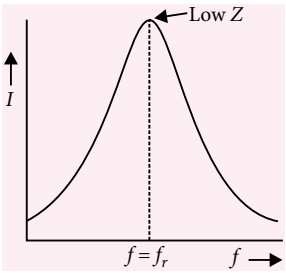
For undeflected proton, $\vec{F} = 0$

$$\therefore \quad B = \frac{2\times10^4}{10^6} = 2\times10^{-2}\text{T}$$

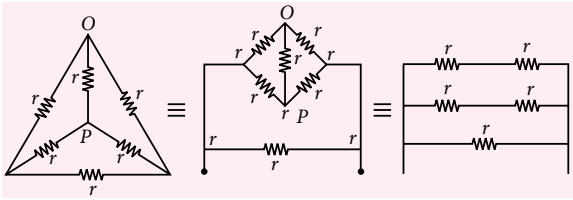
Radius of the circular path, $r = \frac{m}{e}\frac{v}{B}$

$$r = \frac{1}{10^8} \times \frac{10^6}{2\times10^{-2}} = 0.5\text{ m}$$

22. (c): From the graph, we concluded that with the increase in frequency, the current increases, attains a maximum value ($f = f_r$) and then decreases. It implies that the impedance first decreases, becomes minimum for maximum value of current and then increases.



23. (d): The equivalent circuits are shown below, the resistance r in arm OP of the balanced Wheatstone bridge is ineffective.

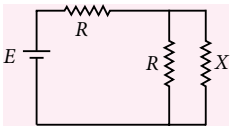


The equivalent resistance r' across AB is given by

$$\frac{1}{r'} = \frac{1}{2r} + \frac{1}{2r} + \frac{1}{r} = \frac{4}{2r} \text{ or } r' = \frac{r}{2}$$

24. (c) : The total resistance of the circuit,

$$R' = R + \frac{RX}{R+X}$$



The current of the circuit will be,

$$i = \frac{V}{R'} = \frac{E}{R + \frac{RX}{R+X}}$$

The potential drop across the resistance R and X will be equal *i.e.*,

$$V_{RX} = iR_{XR} = \left(\frac{E}{R + \frac{RX}{R+X}}\right)\left(\frac{RX}{R+X}\right) = \frac{EX}{R+2X}$$

The power generated across resistance X,

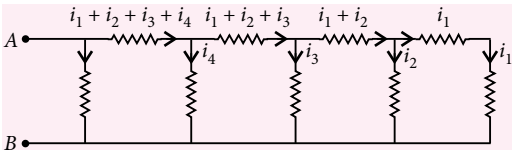
$$P_X = \frac{V^2{}_{RX}}{X} = \frac{E^2X}{(R+2X)^2}$$

Differentiating with respect to X

$$\frac{dP_X}{dX} = \frac{E^2(R-2X)}{(R+2X)^3} \quad \because \quad \frac{dP_X}{dx} = 0$$

$$\therefore \quad R - 2X = 0 \text{ or } X = \frac{R}{2}$$

25. (a): Let us use Kirchhoff's junction law,



Now, $i_1 = 1$ mA (Given)

Potential difference is same for resistance connected in parallel.

$\therefore \quad i_1(1+1) = i_2(1) \Rightarrow i_2 = 2$ mA

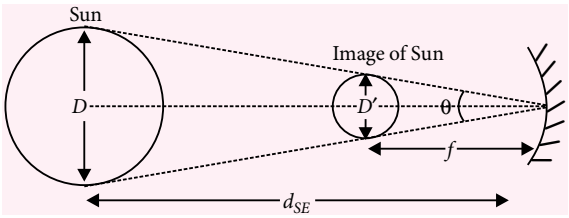
$(i_1 + i_2)1 + i_2(1) = i_3(1) \Rightarrow i_3 = 5$ mA

$(i_1 + i_2 + i_3)1 + i_3(1) = i_4(1) \Rightarrow i_4 = 13$ mA

$(i_1 + i_2 + i_3 + i_4)1 + i_4(1) = V_{AB}$

$\Rightarrow \quad V_{AB} = 34$ V

26. (d):



Here, $\dfrac{D}{d_{SE}} = 0.009, R = 0.4$ m

From figure, $\theta \approx \dfrac{D}{d_{SE}}$ and $\theta \approx \dfrac{D'}{f}$

$\therefore \quad \dfrac{D}{d_{SE}} = \dfrac{D'}{f}$ or $0.009 = \dfrac{D'}{R/2}$

[$\because$ focal length is half of radius of curvature]

or $\quad D' = 0.009 \times \dfrac{0.4}{2} = 1.8 \times 10^{-3}$ m

27. (a): The maximum intensity will be given by

$$I_{max} = \left(\sqrt{L} + \sqrt{\frac{L}{4}}\right)^2 = L + \frac{L}{4} + 2 \times \frac{L}{2} = \frac{9L}{4}$$

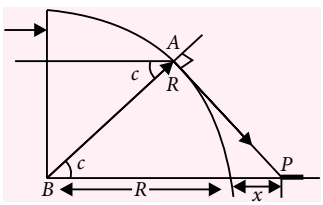
$$I_{min} = \left(\sqrt{L} - \sqrt{\frac{L}{4}}\right)^2 = L + \frac{L}{4} - L = \frac{L}{4}$$

$\therefore$ The maximum and minimum intensities will be $\dfrac{9L}{4}$ and $\dfrac{L}{4}$.

28. (b)

29. (c): $\therefore$ Refractive index of the medium is given by,

$n = \dfrac{1}{\sin c}$ or $\sin c = \dfrac{1}{n} = \dfrac{2}{3}$



In ΔABP, $\cos c = \dfrac{R}{R+x}$

or $\quad \sqrt{1-\sin^2 c} = \dfrac{R}{R+x}$

$\sqrt{1-\dfrac{4}{9}} = \dfrac{R}{R+x}$ or $\dfrac{\sqrt{5}}{3} = \dfrac{R}{R+x}$

$\Rightarrow \quad x = (3\sqrt{5} - 5) \times 10^{-2}$ m $\qquad$ [$\because R = 0.05$ m]

30. (d): When de Broglie wavelength of an electron is 0.4×10^{-10} m then kinetic energy, $K = 1.0$ keV

$\because \quad \lambda = \dfrac{h}{\sqrt{2mK}}$ or $0.4 \times 10^{-10} = \dfrac{h}{\sqrt{2mK}}$ $\qquad$ ...(i)

when wavelength is 1×10^{-10} m, then kinetic energy will be K'

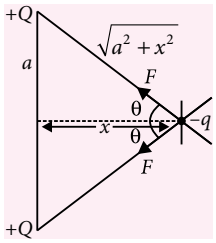
$\therefore \quad 1.0 \times 10^{-10} = \dfrac{h}{\sqrt{2mK'}}$ $\qquad$ ...(ii)

On dividing eqn. (i) with eqn. (ii)

$$\frac{0.4 \times 10^{-10}}{1 \times 10^{-10}} = \frac{\sqrt{2mK'}}{\sqrt{2mK}}$$

or $\quad K' = (0.4)^2 K = 0.16$ keV.

31. (*): Let F_{net} be the resultant force,



$F_{net} = 2F\cos\theta$

$$= \frac{2 \times Q}{4\pi\varepsilon_0 (x^2 + a^2)} . \cos\theta$$

$$= \frac{2 \times Q}{4\pi\varepsilon_0 (x^2 + a^2)} . \frac{x}{\sqrt{x^2 + a^2}}$$

$$\therefore \quad F_{net} = \frac{2}{4\pi\varepsilon_0} . \frac{Qx}{(x^2 + a^2)^{3/2}} = \frac{2}{4\pi\varepsilon_0} . \frac{Qx}{a^3}$$

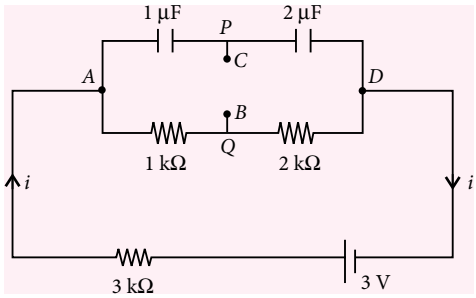
($\because x << a$)

A unit negative charge execute oscillations with frequency, $\upsilon = \dfrac{1}{2\pi}\sqrt{\dfrac{F_{net}}{Mx}}$

$$= \frac{1}{2\pi}\sqrt{\frac{2.Q}{4\pi\varepsilon_0 Ma^3}} = \frac{1}{2\pi}\sqrt{\frac{Q}{2\pi\varepsilon_0 Ma^3}}$$

None of the given option is correct.

32. (b):



Current flowing in the circuit,

$$i = \frac{V}{R_1 + R_2 + R_3} = \frac{3}{(1+2+3)\times 10^3} = \frac{3}{6\times 10^3}$$

$i = 0.5 \times 10^{-3}$A

Potential drop across the arm AD,

$$V_{AD} = iR = 0.5 \times 10^{-3} \times 3 \times 10^3 = 1.5 \text{ V}$$

The charge is given by, $Q = CV = \left(\frac{1\times 2}{2+1}\right)\times 1.5$

$$= \frac{2}{3}\times 1.5 = 1\,\mu\text{C}$$

Potential at point B, $V_B = V_{AD} - V_{AQ}$

$= 1.5 \text{ V} - (0.5 \text{ mA} \times 1 \text{ k}\Omega) = 1 \text{ V}$

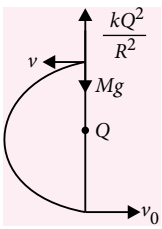
Potential at point C, $V_C = V_{AD} - V_{AP}$

$$= 1.5 \text{ V} - \frac{1\,\mu\text{C}}{1\,\mu\text{F}} = 1.5 \text{ V} - 1 \text{ V} = 0.5 \text{ V}$$

$\therefore \quad V_B - V_C = 1 \text{ V} - 0.5 \text{ V} = 0.5 \text{ V}$

33. (b): Given : At the highest position of the particle, tension, $T = 0$

$\therefore$ The mass of the moving charge M is such that



$$Mg = \frac{Q^2}{4\pi\varepsilon_0 R^2}$$

At the highest point, centrifugal force is,

$$Mg - \frac{kQ^2}{R^2} = \frac{Mv^2}{R} \qquad \left(\text{here}, k = \frac{1}{4\pi\varepsilon_0}\right)$$

$\therefore \quad v = 0$

Gain in potential energy = Loss in kinetic energy

$\Rightarrow \quad Mg(2R) = \frac{1}{2} Mv_0^2$

$\therefore$ Velocity at the lowest point, $v_0 = 2\sqrt{gR}$

34. (b): If V is the velocity of the combined system (*i.e.* block + bullet) after collision and v is the velocity of bullet before collision.

By the law of conservation of momentum,

$$mv + M \times 0 = (M + m)V \text{ or } V = \frac{mv}{m+M} \qquad \text{...(i)}$$

Loss of kinetic energy = Heat generated in the process

$$\therefore \quad \Delta K = \frac{1}{2}mv^2 - \frac{1}{2}(M+m)V^2 \qquad \text{[From eqn. (i)]}$$

$$= \frac{1}{2}mv^2\left(\frac{M}{M+m}\right) = \frac{mMv^2}{2(M+m)} \qquad \text{...(ii)}$$

$\because \quad m = 4.2 \times 10^{-2}$ kg ; $v = 300$ m s^{-1},

$M = 9m = 9 \times 4.2 \times 10^{-2}$ kg

Substituting the values in eqn. (ii), we get

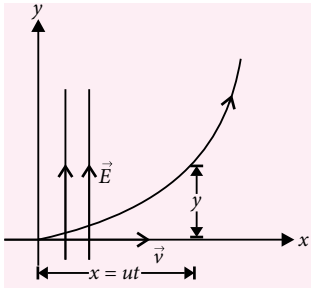
$$\Delta K = 1701 \text{ J} = \frac{1701}{4.2} \text{ cal} = 405 \text{ cal}$$

35. (d): Suppose a particle of mass m, moving along X-axis experiences a force, $F = qE = eE$.

It covers distance along X-axis, $x = ut + 1/2\, a_x t^2$

$$x = ut \text{ or } t = \frac{x}{u} \qquad \text{...(i)}$$

Particle enters a region where a uniform electric field E is acting along the y-axis,



$$y = u_y t^2 + \frac{1}{2} a_y t^2$$

$$y = 0 + \frac{1}{2}\times\frac{eE}{m}\times\left(\frac{x}{u}\right)^2 = \frac{eE.x^2}{2mu^2}$$

[From eqn. (i)]

For parabola, $x^2 = 4ay$

$$\therefore \quad x^2 = \frac{4a\times eE\times x^2}{2mu^2} \text{ or } a = \frac{mu^2}{2eE}$$

Focal length of the parabolic path is $\frac{mu^2}{2eE}$.

36. (a,b,c,d) : The speed of an electron, $v_n = \frac{v_1}{n}$

The energy of an electron, $E_n = \frac{E_1}{n^2}$

The radius of electron, $r_n = n^2 r_1$

$$\therefore \quad E_n r_n = \frac{E_1}{n^2}.r_1 n^2 = E_1 r_1 \text{ or } \frac{E_n r_n}{E_1 r_1} = 1$$

Hence, option (a) is correct.

$$\therefore \quad r_n v_n = n^2 r_1 \frac{v_1}{n} = n v_1 r_1 \text{ or } \frac{r_n v_n}{r_1 v_1} = n$$

Hence, option (b) is correct.

$$\therefore \quad \frac{r_n}{r_1} = n^2 \text{ or } \ln\left(\frac{r_n}{r_1}\right) = 2\ln(n)$$

Hence, option (c) is correct.

$$\therefore \quad \frac{r_n}{E_n} = \frac{n^2 r_1}{E_1 / n^2} \Rightarrow \frac{r_n E_1}{E_n r_1} = n^4$$

$$\text{or} \quad \ln\left(\frac{r_n E_1}{E_n r_1}\right) = 4\ln(n)$$

Hence, option (d) is correct.

37. (d): A ball dropped from a height h and attaining height h_n after n rebounds. Then $h_n = e^{2n}.h$ and total time taken by the ball in coming to rest is, $t = \left(\frac{1+e}{1-e}\right)\sqrt{\frac{2h}{g}}$

$\therefore \quad t = 10$ s, $h = 0.4$ m. Putting these values, we get,

$$\therefore \quad 10 = \frac{1+e}{1-e}\sqrt{\frac{2\times 0.4}{9.8}}$$

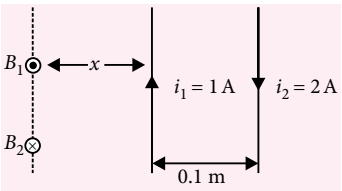
$$\frac{1+e}{1-e} = 35 \Rightarrow e = \frac{17}{18}$$

38. (b,c) : Speed of the sound in the gas is given by,

$$v = \sqrt{\frac{\gamma RT}{m}} = \sqrt{\frac{\gamma P}{\rho}}$$

From this we conclude that velocity of sound in gas is proportional to $\sqrt{T}$ and also proportional to $\sqrt{P}$, when ρ is constant.

39. (c) : Suppose the third current-carrying wire placed x cm from the first current - carrying wire.



Magnetic field due to first wire at the location of third wire,

$$B_1 = \frac{\mu_0 i_1}{2\pi x} \odot$$

Magnetic field due to second wire at the location of third wire,

$$B_2 = \frac{\mu_0 i_2}{2\pi(x+0.1)} \otimes$$

Net magnetic field at the location of third wire would be zero if there is no net magnetic force,

$$\therefore \quad B_1 = B_2 \Rightarrow \frac{\mu_0 i_1}{2\pi x} = \frac{\mu_0 i_2}{2\pi(x+0.1)}$$

$[\because i_1 = 1\text{A and } i_2 = 2\text{A}]$

$$\frac{1}{x} = \frac{2}{x+0.1} \text{ or } x = 0.1 \text{ m}$$

40. (b,d) : $\because$ Magnetic susceptibility is given by,

$$\chi = \mu_r - 1, \ \mu_r = \frac{\mu}{\mu_0}$$

For paramagnetic, $\chi > 0$

$\therefore \quad \mu_r > 1$ or $\mu > \mu_0$

For diamagnetic, $-1 \le \chi < 0$

$\therefore \quad 0 \le \mu_r < 1$ or $\mu < \mu_0$

For ferromagnetic, $\chi >> 1$

$\therefore \quad \mu >> \mu_0$

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OLYMPIAD PROBLEMS

1. Two spherical planets P and Q have the same uniform density ρ, masses M_P and M_Q, and surface areas A and $4A$, respectively. A spherical planet R also has uniform density ρ and its mass is $(M_P + M_Q)$. The escape velocities from the planets P, Q and R are v_P, v_Q and v_R, respectively. Then

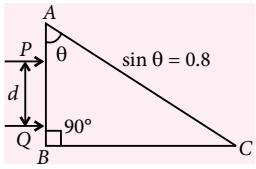
(a) $v_Q > v_R > v_P$ (b) $v_R > v_Q > v_P$

(c) $\frac{v_R}{v_P} = 3$ (d) $\frac{v_P}{v_Q} = \frac{1}{\sqrt{2}}$

2. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7} \times 10^5$ V m^{-1}. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} m s^{-1}.
Given: $g = 9.8$ m s^{-2}, viscosity of the air $= 1.8 \times 10^{-5}$ N s m^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is

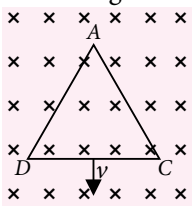
(a) 1.6×10^{-19} C (b) 3.2×10^{-19} C
(c) 4.8×10^{-19} C (d) 8.0×10^{-19} C

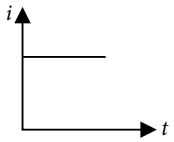
3. Two parallel beams of light P and Q (separation d) containing radiations of wavelengths 4000 Å and 5000Å(which are mutually coherent in each wavelength separately) are incident normally on a prism as shown in figure. The refractive index of the prism as a function of wavelength is given by the relation, $\mu(\lambda) = 1.20 + \frac{b}{\lambda^2}$ where λ is in Å and b is positive constant. The value of b is such that the condition for total internal reflection of the face AC is just satisfied for one wavelength and is not satisfied for the other. The value of b and deviation δ of beam transmitted through the face AC are

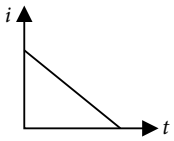


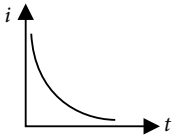
(a) $b = 1.25 \times 10^{-14}$ m^2, $\delta = 38.7°$
(b) $b = 8 \times 10^{-15}$ m^2, $\delta = 27.2°$
(c) $b = 4 \times 10^{-15}$ m^2, $\delta = 38.7°$
(d) $b = 1.25 \times 10^{-14}$ m^2, $\delta = 27.2°$

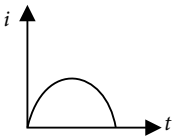
4. An equilateral triangular loop ADC having some resistance is pulled with a constant velocity v out of a uniform magnetic field directed into the paper as shown in figure. At time $t = 0$, side DC of the loop is at edge of the magnetic field. The induced current (i) versus time (t) graph will be as



(a)


(b)


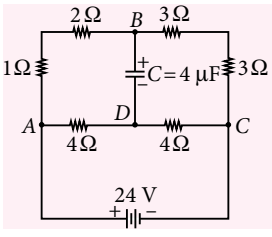
(c)


(d)


5. The electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$ where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are

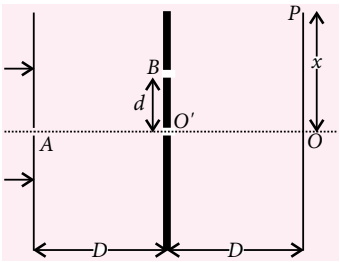
(a) $n_1 = 4, n_2 = 8$ (b) $n_1 = 8, n_2 = 2$
(c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

6. For the given circuit in the steady state condition, charge on the capacitor is $q_0 = 16$ μC. If now the battery is removed and the nodes A and C are shorted. The time during which charge on the capacitor becomes 4 μC is



(a) 32 ln 2 μs (b) 4 μs
(c) 4 ln 2 μs (d) 2 μs

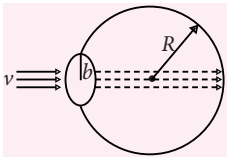
7. The minimum value of d so that there is a dark fringe at O is d_{min}, the distance at which the next bright fringe is formed is x. Then



(a) $d_{min} = \sqrt{\lambda D}$ (b) $d_{min} = \sqrt{\frac{\lambda D}{2}}$

(c) $x = \frac{d_{min}}{2}$ (d) $x = 2d_{min}$

8. A bubble having surface tension T and radius R is formed on a ring of radius b ($b << R$). Air is blown inside the tube with velocity v as shown. The air molecule collides perpendicularly with the wall of the bubble and stops. Calculate the radius at which the bubble separates from the ring.



(a) $\frac{\rho v^2}{T}$ (b) $\frac{4\rho v^2}{T}$ (c) $\frac{4T}{\rho v^2}$ (d) $\frac{2T}{\rho v^2}$

9. Two vibrating strings of the same material but lengths L and $2L$ have radii $2r$ and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental nodes, one of length L with frequency υ_1 and the other with frequency υ_2. The ratio $\frac{\upsilon_1}{\upsilon_2}$ is given by

(a) 2 : 1 (b) 4 : 1 (c) 8 : 1 (d) 1 : 1

10. Two different coils have self-inductances $L_1 = 8$ mH and $L_2 = 2$ mH. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same constant rate. At a certain instant of time, the power is given to the two coils is the same. At that time, the current, the induced voltage and the energy stored in the first coil are i_1, V_1 and U_1 respectively. Corresponding values for the second coil at the same instant are i_2, V_2 and U_2 respectively. Which of the following statements is incorrect?

(a) $\frac{i_1}{i_2} = \frac{1}{4}$ (b) $\frac{i_1}{i_2} = 4$ (c) $\frac{U_1}{U_2} = \frac{1}{4}$ (d) $\frac{V_1}{V_2} = 4$

SOLUTIONS

1. **(b):** The escape velocity for the surface of planet is

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \cdot G\rho \frac{4}{3}\pi R^3}{R}}$$

(Since ρ is same for all planet)

$v_e \propto R$ ...(i)

Surface area of P, $4\pi R_P^2 = A$

Surface area of Q, $4\pi R_Q^2 = 4A$ ...(ii)

$\therefore \frac{R_P}{R_Q} = \frac{1}{2} \Rightarrow R_Q = 2R_P$

The spherical planet R has mass

$M_R = M_P + M_Q$

$\frac{4}{3}\rho\pi R_R^3 = \frac{4}{3}\rho\pi R_P^3 + \frac{4}{3}\rho\pi R_Q^3 \Rightarrow R_R^3 = R_P^3 + R_Q^3$

or $R_R^3 = R_P^3 + (2R_P)^3$ (Using (ii))

So, $R_R = (9)^{1/3} R_P$

Therefore, $R_R > R_Q > R_P$

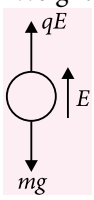
From equation (i), $v_R > v_Q > v_P$

and from equation (ii), $\frac{v_P}{v_Q} = \frac{1}{2}$ and $\frac{v_R}{v_P} = (9)^{1/3}$

2. **(d):** In presence of electric field,

In equilibrium,

Force on the drop due to electric field (E) = Weight of the drop



$qE = mg$

$qE = \frac{4}{3}\pi r^3 \rho g$ ...(i)

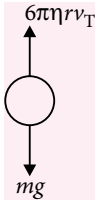
where, r = radius of oil drop,

ρ = density of oil, q = charge on the oil drop

In the absence of electric field,

In equilibrium,

Viscous force on the drop = Weight of the drop



$6\pi\eta r v_T = mg$

$6\pi\eta r v_T = \frac{4}{3}\pi r^3 \rho g$ ...(ii)

where, v_T = terminal velocity,

η = coefficient of viscosity of air

or $r^2 = \frac{18 \times \eta \times v_T}{4 \times \rho \times g}$

Substituting the given values, we get

$r^2 = \frac{18 \times 1.8 \times 10^{-5} \times 2 \times 10^{-3}}{4 \times 900 \times 9.8}$ or $r = \frac{3}{7} \times 10^{-5}$ m

From equation (i), we get $q = \dfrac{4\pi r^3 \rho g}{3E}$

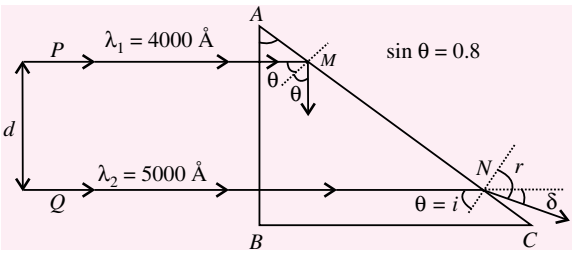
Substituting the given values, we get

$$q = \frac{4 \times \pi \times \left(\frac{3}{7} \times 10^{-5}\right)^3 \times 900 \times 9.8}{3 \times \left(\frac{81\pi}{7} \times 10^5\right)}$$

$$= \frac{4 \times \pi \times 7 \times 3 \times 3 \times 3 \times 10^{-15} \times 900 \times 9.8}{3 \times 81\pi \times 10^5 \times 7 \times 7 \times 7}$$

$$= 8.0 \times 10^{-19}\ \text{C}$$

3. (b): Two parallel beams of light, P and Q, are incident normally on a prism.



One of the beams undergoes total internal reflection at the face AC of prism. The other beam emerges out of prism and suffers deviation δ at the face AC.

Let C = critical angle

$$\therefore \quad \mu = \frac{1}{\sin C} = \frac{1}{\sin\theta} = \frac{1}{0.8} = \frac{5}{4} = 1.25$$

Since, $\mu = \dfrac{1}{\sin C}$ or $1.2 + \dfrac{b}{\lambda^2} = \dfrac{1}{\sin C}$

$\therefore$ C will be smaller for smaller λ. Total internal reflection will therefore occur for $\lambda_1 = 4000$ Å and not for $\lambda_2 = 5000$ Å.

$$\because \quad \mu = 1.2 + \frac{b}{\lambda^2} \quad \therefore \quad 1.25 = 1.2 + \frac{b}{\lambda^2} \text{ or } 0.05 = \frac{b}{\lambda^2}$$

or $\quad b = \lambda^2 \times 0.05$ or $b = (4000 \times 10^{-10})^2 \times 0.05$

or $\quad b = 8 \times 10^{-15}\text{m}^2$

Beam with $\lambda = 5000$ Å is transmitted at the face AC of prism.

According to Snell's law,

$\mu = \dfrac{\sin r}{\sin i}$, ray travels from glass to air

$$1.2 + \frac{b}{(5000 \times 10^{-10})^2} = \frac{\sin r}{0.8}$$

$$\text{or} \quad 1.2 + \frac{8 \times 10^{-15}}{25 \times 10^{-14}} = \frac{\sin r}{0.8}$$

$$\text{or} \quad (1.2 + 0.032) = \frac{\sin r}{0.8}$$

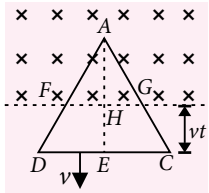
or $\quad \sin r = 1.232 \times 0.8 = 0.9856.$

or $\quad \sin r = \sin 80.3$ or $r = 80.3°$

$\therefore \quad \delta = (r - i) = 80.3° - 53.1° = 27.2°$

or $\quad \delta = 27.2°$

4. (b): Let $2a$ be the side of the triangle and b be the length AE.



$$\frac{AH}{AE} = \frac{GH}{EC} \Rightarrow GH = \left(\frac{AH}{AE}\right)EC$$

$$\text{or} \quad GH = \frac{(b - vt)}{b}a = a - \left(\frac{a}{b}vt\right)$$

$$\therefore \quad FG = 2GH = 2\left[a - \frac{a}{b}vt\right]$$

$$\therefore \quad \text{Induced emf, } \varepsilon = Bv\,(FG) = 2Bv\left(a - \frac{a}{b}vt\right)$$

$$\therefore \quad \text{Induced current, } i = \frac{\varepsilon}{R} = \frac{2Bv}{R}\left[a - \frac{a}{b}vt\right]$$

or $\quad i = k_1 - k_2 t$

Thus i - t graph is a straight line with negative slope and positive intercept.

5. (d): According to Bohr model,

$r_n \propto n^2$ ...(i)

$v_n \propto \dfrac{1}{n}$ ...(ii)

Now $T_n = \dfrac{2\pi}{\omega} = \dfrac{2\pi r_n}{v_n}$ or $T_n \propto \dfrac{r_n}{v_n}$

or $T_n \propto \dfrac{n^2}{1/n}$, (using (i) and (ii)) or $T_n \propto n^3$

$$\therefore \quad \frac{(T_n)_1}{(T_n)_2} = \frac{n_1^3}{n_2^3} \text{ or } 8 = \left(\frac{n_1}{n_2}\right)^3$$

or $\quad n_1 = 2n_2$ ...(iii)

Option (d): $n_1 = 6$, $n_2 = 3$. It fulfils condition.

6. (a): Potential difference across the capacitor is

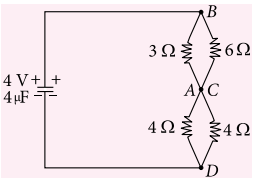
$$\frac{q_0}{C} = \frac{16}{4} = 4\ \text{V}$$

Equivalent resistance, $R = \left(\frac{6\times3}{6+3}\right)+\left(\frac{4\times4}{4+4}\right) = 4\,\Omega$

Time constant,

$\tau = RC = (4\,\Omega)\,(4\,\mu F) = 16\,\mu s$

Equation of discharging a capacitor



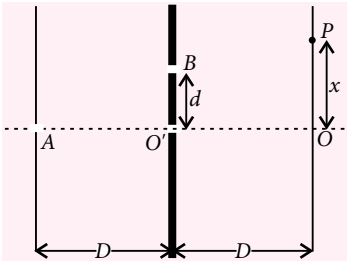
$q = q_0 e^{-t/\tau}$

$4\,\mu C = (16\,\mu C)\; e^{\left(-\frac{t}{16}\right)}$

$t = 32 \ln 2\ \mu s$

7. (b): There is a dark fringe at O if the path difference

$\Delta x = ABO - AO'O = \frac{\lambda}{2}$



$$\Delta x = 2D\left(1+\frac{d^2}{D^2}\right)^{1/2} - 2D$$

$$\simeq 2D\left(1+\frac{1}{2}\frac{d^2}{D^2}\right) - 2D = \frac{d^2}{D}$$

$$\therefore \quad \frac{\lambda}{2} = \frac{d_{min}^2}{D} \quad \text{or} \quad d_{min} = \sqrt{\frac{\lambda D}{2}}$$

The bright fringe is formed at P if the path difference $= AO'P - ABP = 0$

$$\Rightarrow \quad D + \sqrt{D^2+x^2} - \sqrt{D^2+d^2} - \sqrt{D^2+(x-d)^2} = 0$$

$$\Rightarrow \quad \frac{x^2}{2D} - \frac{d^2}{2D} - \frac{(x^2+d^2-2xd)}{2D} = 0$$

Given : $d = d_{min}$

On solving, $x = d_{min} = \sqrt{\frac{\lambda D}{2}}$

8. (c) : Excess pressure inside a bubble $= \frac{4T}{R}$

Let area of bubble at wall where air strikes be A.

$\therefore$ Force due to excess pressure $= \frac{4TA}{R}$

Let ρ = density of air,

Force due to striking air $= \rho A v^2$

For bubble to separate from the ring,

$$\rho A v^2 = \frac{4TA}{R} \quad \text{or} \quad \rho A v^2 R = 4TA \quad \text{or} \quad R = \frac{4T}{\rho v^2}.$$

9. (d): For a vibrating string, in fundamental mode,

$$\upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \quad \because \quad \mu = \frac{\text{Mass}}{\text{length}}$$

$$\therefore \quad \mu = \frac{\text{volume} \times \text{density}}{\text{length}} = \frac{\pi r^2 l \rho}{l} = \pi r^2 \rho.$$

$$\therefore \quad \upsilon = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} = \frac{1}{2lr}\sqrt{\frac{T}{\pi\rho}}$$

$$\therefore \quad \frac{\upsilon_1}{\upsilon_2} = \left(\frac{l_2}{l_1}\right)\left(\frac{r_2}{r_1}\right) \quad \text{as } T,\ \rho \text{ are same.}$$

For υ_1, quantities are L and $2r$

For υ_2, quantities are $2L$ and r.

$$\therefore \quad \frac{\upsilon_1}{\upsilon_2} = \left(\frac{2L}{L}\right)\left(\frac{r}{2r}\right) \quad \therefore \quad \frac{\upsilon_1}{\upsilon_2} = 1.$$

10. (b): Induced emf in first coil $= V_1$

$$\therefore \quad V_1 = -L_1\frac{di}{dt}$$

Induced emf in second coil $= V_2$

$$\therefore \quad V_2 = -L_2\frac{di}{dt}$$

$$\therefore \quad \frac{V_1}{V_2} = \frac{L_1}{L_2}, \text{ as } \frac{di}{dt} \text{ is same.}$$

$$\text{or} \quad \frac{V_1}{V_2} = \frac{8}{2} = \frac{4}{1} \qquad \ldots\text{(i)}$$

Power given to coils is same.

$$\therefore \quad V_1 i_1 = V_2 i_2$$

$$\text{or} \quad \left(8\times10^{-3}\times\frac{di}{dt}\right)i_1 = \left(2\times10^{-3}\times\frac{di}{dt}\right)i_2$$

$$\therefore \quad \frac{i_1}{i_2} = \frac{1}{4} \qquad \ldots\text{(ii)}$$

$$\therefore \quad \text{Energy stored} = U = \frac{1}{2}Li^2$$

$$\therefore \quad \frac{U_2}{U_1} = \frac{L_2}{L_1}\times\left(\frac{i_2}{i_1}\right)^2$$

$$\text{or} \quad \frac{U_2}{U_1} = \frac{2\times10^{-3}}{8\times10^{-3}}\times\left(\frac{4}{1}\right)^2$$

$$\text{or} \quad \frac{U_2}{U_1} = \frac{4}{1} \text{ or } \frac{U_1}{U_2} = \frac{1}{4} \qquad \ldots\text{(iii)}$$

From (i), (ii) and (iii), it is clear that options (a), (c) and (d) are correct.

BRAIN MAP

OSCILLATIONS

Class XI

Class XII

SEMICONDUCTOR ELECTRONICS

BRAIN MAP

Periodic Motion

A motion that repeats itself at regular interval of time is called periodic motion. The displacement is represented by a periodic function of time with time period T. *i.e.*, $f(t) = f(t+T) = f(t+2T) = ...$

Oscillatory Motion

If the body is given a small displacement from the position, a force comes into play which tries to bring the body back to the equilibrium point. Such motions are called oscillatory motion.

Simple Harmonic Motion

The motion arises when the force on the oscillating body is directly proportional to its displacement from mean position. Such motion is called simple harmonic motion.

System Excuting SHM

SHM IN SPRING

- Equation of motion

$$\frac{d^2y}{dt^2} = \frac{-ky}{m} = -\omega^2 y$$

- If the spring is not light but has a definite mass m_s then

$$T = 2\pi\sqrt{\frac{m + \frac{m_s}{3}}{k}}$$

- Two bodies of masses m_1 and m_2 are attached through a light spring of spring constant k, the time period of oscillation

$$T = 2\pi\sqrt{\frac{\mu}{k}} \quad \text{where } \mu = \frac{m_1 m_2}{m_1 + m_2}$$

SIMPLE PENDULUM

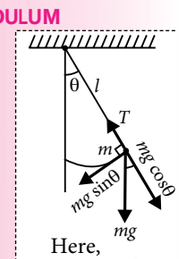
- Time period

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

- If the length of simple pendulum is very large,

$$T = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{l} + \frac{1}{R}\right)}}$$

where R is the radius of length of pendulum



Here, $\alpha = -\frac{mgl}{I}\theta$

Dynamic of SHM

FORCE LAW IN SHM

- The force acting on a particle of mass m in SHM is
  $\vec{F} = -m\omega^2\vec{x}$ or $\vec{F} = -k\vec{x}$
  where, $k = m\omega^2$ = force constant
- Linear SHM :
  - Angular velocity, $\omega = \sqrt{\frac{k}{m}}$
  - Time period, $T = 2\pi\sqrt{\frac{m}{k}}$
- Angular SHM :
  - Torque, $\tau = -k\theta$
  - Angular velocity, $\omega = \sqrt{k/I}$
  - Angular acceleration, $\alpha = -\frac{k\theta}{I}$
  - Time period, $T = 2\pi\sqrt{\frac{I}{k}}$
  where I = moment of inertia

ENERGY IN SHM

- Linear SHM :
  - Kinetic energy $(K) = \frac{1}{2}m\omega^2A^2\cos^2\omega t$
  - Potential energy $(U) = \frac{1}{2}m\omega^2A^2\sin^2\omega t$
  - Total energy $(E) = \frac{1}{2}m\omega^2A^2$
- Angular SHM :
  - Kinetic energy $(K) = \frac{1}{2}I\omega^2$
  - Potential energy $(U) = \frac{1}{2}k\theta^2 = \frac{1}{2}I\omega^2\theta^2$
  - Total energy $(E) = \frac{1}{2}I\omega^2\theta_0^2$

Charact-eristics of SHM

GENERAL EQUATIONS OF SHM

- Linear SHM:
  - Differential equation $\frac{d^2y}{dt^2} + \omega^2 y = 0$
  - Displacement $y = A\sin(\omega t + \phi)$
  - Velocity, $v = \omega\sqrt{A^2 - y^2}$
  - Acceleration, $a = -\omega^2 y$
- Angular SHM :
  - Differential equation
  $\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$
  - Displacement $\theta = \theta_0\sin(\omega t + \delta)$

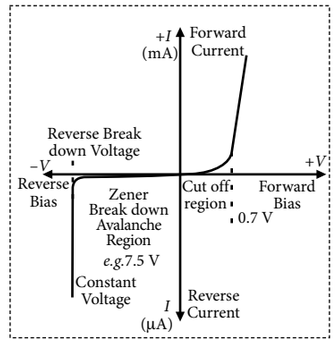
DAMPED AND FORCED OSCILLATIONS

- Damped oscillations
  - Angular frequency $(\omega') = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$
  - Mechanical energy $E(t) = \frac{1}{2}kA^2e^{\frac{-bt}{m}}$
  - Amplitude $A' = Ae^{-bt/2m}$
  where b is damping constant.
- Forced oscillations
  - When driving frequency ω_d far from natural frequency ω:
  Amplitude $A' = \frac{F_0}{m(\omega^2 - \omega_d^2)}$
  - When driving frequency ω_d closed to natural frequency ω:
  Amplitude $A' = \frac{F_0}{\omega_d b}$

TYPES OF SEMICONDUCTORS

INTRINSIC SEMICONDUCTORS

The pure semiconductors have thermally generated current carriers. Here, $n_e = n_h = n_i$



EXTRINSIC SEMICONDUCTORS

The semiconductor whose conductivity is mainly due to doping of impurity.

***p*-type semiconductor**

- Doped with trivalent atom.
- Here, $n_h >> n_e$

***n*-type semiconductor**

- Doped with pentavalent atom.
- Here, $n_e >> n_h$

SEMICONDUCTOR DIODE

***p–n* junction diode :** A *p*-type semiconductor is brought into contact with an *n*-type semiconductor such that structure remains continuous at boundary.

BIASING CHARACTERSTICS

Forward bias characteristic

- Width of depletion layer decreases
- Effective barrier potential decreases
- Low resistance at junction
- High current flow of the order of mA.

Reverse bias characteristic

- Width of depletion layer increases
- Effective barrier potential increases
- High resistance at the junction
- Low current flow of the order of μA.
- Reverse break down occurs at a high reverse bias voltage.

APPLICATIONS OF DIODE

- **Diode as a rectifier**
  - Half wave rectifier
  - Full wave rectifier
- **Zener diode** as a voltage regulator.
- **Photo diode** for detecting light signals.
- **LED:** light emitting diode.
- **Solar cells:** Generates emf from solar radiations.

JUNCTION TRANSISTOR

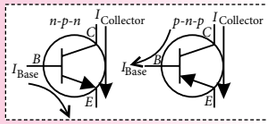
A semiconductor device possessing fundamental action of transfer resistor.

Junction transistors are of two types

- ***n-p-n* transistor:** A thin layer of *p*-type semiconductor is sandwiched between two *n*-type semiconductors.
- ***p-n-p* transistor:** A thin layer of *n*-type semiconductor is sandwiched between two *p*-type semiconductors.

There are three configurations of transistors

- CB (Common Base)
- CE (Common Emitter)
- CC (Common Collector).



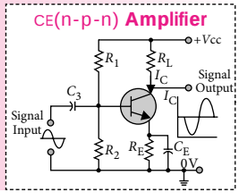
Transistor characteristics

- Input resistance $(r_i)_{(CE)} = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}=\text{constant}}$
- Output resistance $(r_o)_{(CE)} = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B=\text{constant}}$
- Current amplification factor

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}=\text{constant}} \qquad \alpha_{ac} = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}=\text{constant}}$$

APPLICATIONS OF TRANSISTOR

- **Transistor as an Amplifier**
  - Its operating voltage is fix in active region.
  - Voltage gain,
  $A_v = \frac{V_o}{V_i} = -\beta_{ac}\frac{R_{out}}{R_{in}}$
  - Power gain, $A_p = A_v \times \beta_{ac}$
- **Transistor as a Switch**
- **Transistor as an Oscillator**



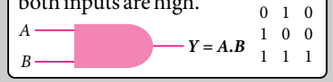
DIGITAL ELECTRONICS AND LOGIC GATES

VARIOUS TYPES OF LOGIC GATE

AND Gate

Output is high only when both inputs are high.

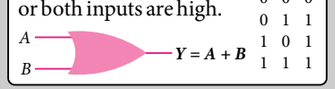
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

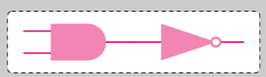


OR Gate

Output is high if any one or both inputs are high.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

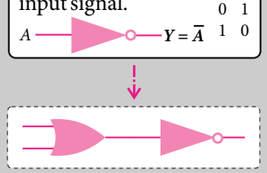




NOT Gate

It just inverts the input signal.

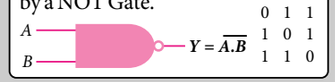
A	Y
0	1
1	0



NAND Gate

An AND Gate followed by a NOT Gate.

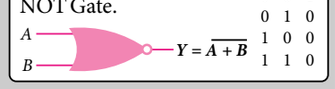
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0



NOR Gate

An OR Gate followed by a NOT Gate.

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0



SOLVED PAPER **2017**

Kerala PET

1. A person observes that the full length of a train subtends an angle of 15 degrees. If the distance between the train and the person is 3 km, the length of the train, calculated using parallax method, in meters is

(a) 45 (b) 45π (c) 250π (d) 250
(e) 450

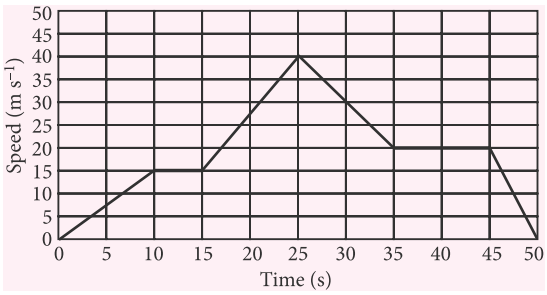
2. In a measurement, the random error

(a) can be decreased by increasing the number of readings and averaging them
(b) can be decreased by changing the person who takes the reading
(c) can be decreased by using new instrument
(d) can be decreased by using a different method in taking the reading
(e) can never be decreased.

3. In order to measure the period of a single pendulum using a stop clock, a student repeated the experiment for 10 times and noted down the time period for each experiment as 5.1, 5.0, 4.9, 4.9, 5.1, 5.0, 4.9, 5.1 5.0, 4.9 s. The correct way of expressing the result for the period is

(a) 4.99 s (b) 5.0 s (c) 5.00 s (d) 4.9 s
(e) 5.1 s

4. The following figure gives the movement of an object. Select the correct statement from the given choices.



(a) The total distance travelled by the object is 975 m
(b) The maximum acceleration of the object is 2 m s^{-2}
(c) The maximum deceleration happened between 25th and 35th seconds
(d) The object was at rest between 10th and 15th seconds.
(e) At 40th second, the object was decelerating

5. Two objects, P and Q, travelling in the same direction starts from rest. While the object P starts at time $t = 0$ and the object Q starts later at $t = 30$ min. The object P has an acceleration of 40 km h^{-2}. To catch P at a distance of 20 km, the acceleration of Q should be

(a) 40 km h^{-2} (b) 80 km h^{-2}
(c) 100 km h^{-2} (d) 120 km h^{-2}
(e) 160 km h^{-2}

6. A train of length L moves with a constant speed v_t. A person at the back of the train fires a bullet at time $t = 0$ towards a target which is at a distance of D (at time $t = 0$) from the front of the train (on the same direction of motion). Another person at the front of the train fires another bullet at time $t = T$ towards the same target. Both bullets reach the target at the same time. Assuming the speed of the bullets, v_b, are same, the length of the train is

(a) $T \times (v_b + 2v_t)$ (b) $T \times (v_b + v_t)$
(c) $2 \times T \times (v_b \times v_t)$ (d) $2 \times T \times (v_b - v_t)$
(e) $T \times (v_b - v_t)$

7. From the ground, a projectile is fired at an angle of 60° to the horizontal with a speed of 20 m s^{-1}. Take acceleration due to gravity as 10 m s^{-2}. The horizontal range of the projectile is

(a) $10\sqrt{3}$ m (b) 20 m
(c) $20\sqrt{3}$ m (d) $40\sqrt{3}$ m
(e) $400\sqrt{3}$ m

8. A person from a truck, moving with a constant speed of 60 km h^{-1}, throws a ball upwards with a speed of 60 km h^{-1}. Neglecting the effect of rotation of Earth, choose the correct answer from the given choices.
   (a) The person cannot catch the ball when it comes down since the truck is moving
   (b) The person can catch the ball when it comes down, if the truck is stopped immediately after throwing the ball
   (c) The person can catch the ball when it comes down, if the truck moves with speed less than 60 km h^{-1} but does not stop
   (d) The person can catch the ball when it comes down, if the truck moves with speed more than 60 km h^{-1}
   (e) The person can catch the ball when it comes down, if the truck continues to move with a constant speed of 60 km h^{-1}

9. A body of mass $2m$ moving with velocity v makes a head on elastic collision with another body of mass m which is initially at rest. Loss of kinetic energy of the colliding body (mass $2m$) is
   (a) 1/9 of its initial kinetic energy
   (b) 1/6 of its initial kinetic energy
   (c) 1/4 of its initial kinetic energy
   (d) 1/2 of its initial kinetic energy
   (e) 8/9 of its initial kinetic energy

10. Displacement x (in meters) of a body of mass 1 kg as a function of time t, on a horizontal smooth surface is given as $x = 2t^2$. The work done in the first one second by the external force is
   (a) 1 J (b) 2 J (c) 4 J (d) 8 J
   (e) 16 J

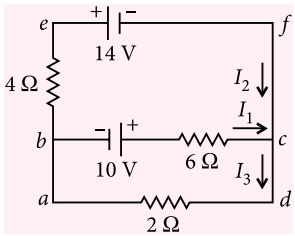
11. A massless spring of length l and spring constant k is placed vertically on a table. A ball of mass m is just kept on top of the spring. The maximum velocity of the ball is
   (a) $g\sqrt{\frac{m}{k}}$ (b) $g\sqrt{\frac{2m}{k}}$ (c) $2g\sqrt{\frac{m}{k}}$ (d) $\frac{g}{2}\sqrt{\frac{m}{k}}$
   (e) $g\sqrt{\frac{m}{2k}}$

12. Under the action of a constant force, a particle is experiencing a constant acceleration. The power is
   (a) zero
   (b) positive constant
   (c) negative constant
   (d) increasing uniformly with time
   (e) decreasing uniformly with time

13. A copper wire with a cross-sectional area of 2×10^{-6} m^2 has a free electron density equal to 5×10^{22} cm^{-3}. If this wire carries a current of 16 A, the drift velocity of the electron is
   (a) 1 m s^{-1} (b) 0.1 m s^{-1}
   (c) 0.01 m s^{-1} (d) 0.001 m s^{-1}
   (e) 0.0001 m s^{-1}

14. The resistance of the tungsten wire in the light bulb, which is rated at 120 V, 75 W and powered by a 120 V direct-current supply, is
   (a) 0.37 Ω (b) 1.2 Ω
   (c) 2.66 Ω (d) 192 Ω
   (e) 9×10^3 Ω

15. The values of the currents I_1, I_2, and I_3 flowing through the circuit given below is



   (a) $I_1 = -3$ A, $I_2 = 2$ A, $I_3 = -1$ A
   (b) $I_1 = 2$ A, $I_2 = -3$A, $I_3 = -1$ A
   (c) $I_1 = 3$ A, $I_2 = -1$A, $I_3 = -2$ A
   (d) $I_1 = 1$ A, $I_2 = -3$ A, $I_3 = -2$ A
   (e) $I_1 = 2$ A, $I_2 = -1$ A, $I_3 = -3$ A

16. A silver wire has temperature coefficient of resistivity 4×10^{-3} °C^{-1} and its resistance at 20 °C is 10 Ω. Neglecting any change in dimensions due to the change in temperature, its resistance at 40 °C is
   (a) 0.8 Ω (b) 1.8 Ω (c) 9.2 Ω (d) 10.8 Ω
   (e) 11.6 Ω

17. A charge Q placed at the center of a metallic spherical shell with inner and outer radii R_1 and R_2 respectively. The normal component of the electric field at any point on the Gaussian surface with radius between R_1 and R_2 will be
   (a) zero (b) $\frac{Q}{4\pi R_1^2}$

(c) $\frac{Q}{4\pi R_2^2}$ (d) $\frac{Q}{4\pi(R_1 - R_2)^2}$

(e) $\frac{Q}{4\pi(R_2 - R_1)^2}$

18. A sphere of radius R has a uniform volume charge density, ρ. The magnitude of electric field at a distance r from the center of the sphere, where $r > R$, is

(a) $\frac{\rho}{4\pi\varepsilon_0 r^2}$ (b) $\frac{\rho R^2}{\varepsilon_0 r^2}$

(c) $\frac{\rho R^3}{\varepsilon_0 r^2}$ (d) $\frac{\rho R^3}{3\varepsilon_0 r^2}$

(e) $\frac{\rho R^2}{4\varepsilon_0 r^2}$

19. Five equal point charges with charge $Q = 10$ nC are located at $x = 2, 4, 5, 10$ and 20 m. If $\varepsilon_0 = [10^{-9}/36\pi]$ F m^{-1}, then the potential at the origin ($x = 0$) is

(a) 9.9 V (b) 11.1 V (c) 90 V (d) 99 V

(e) 111 V

20. Two infinitely long parallel plates of equal areas, 6 cm^2, are separated by a distance of 1 cm. While one of the plates has a charge of +10 nC and the other has –10 nC. The magnitude of the electric field between the plates, if $\varepsilon_0 = \frac{10^{-9}}{36\pi}$ F m^{-1}, is

(a) 0.6π kV m^{-1} (b) 6π kV m^{-1}

(c) 600π kV m^{-1} (d) 60π V m^{-1}

(e) 6π V m^{-1}

21. A proton moves with a speed of 5.0×10^6 m s^{-1} along the x-axis. It enters a region where there is a magnetic field of magnitude 2.0 tesla directed at an angle of 30° to the x-axis and lying in the xy plane. The magnitude of the magnetic force on the proton is

(a) 0.8×10^{-13} N (b) 1.6×10^{-13} N

(c) 4.0×10^{-13} N (d) 8.0×10^{-13} N

(e) 16×10^{-13} N

22. A long straight wire of radius R carries a steady current, I_0, uniformly distributed throughout the cross-section of the wire. The magnetic field at a radial distance r from the center of the wire, in the region $r > R$, is

(a) $\frac{\mu_0 I_0}{2\pi r}$ (b) $\frac{\mu_0 I_0}{2\pi R}$ (c) $\frac{\mu_0 I_0 R^2}{2\pi r}$ (d) $\frac{\mu_0 I_0 r^2}{2\pi R}$

(e) $\frac{\mu_0 I_0 r^2}{2\pi R^2}$

23. If the cyclotron oscillator frequency is 16 MHz, then what should be the operating magnetic field for accelerating the proton of mass 1.67×10^{-27} kg?

(a) 0.334π T (b) 3.34π T

(c) 33.4π T (d) 334π T

(e) 3340π T

24. The speed of light in vacuum is equal to

(a) $\mu_0\varepsilon_0$ (b) $\mu_0^2\varepsilon_0^2$ (c) $\sqrt{\mu_0\varepsilon_0}$ (d) $\frac{1}{\mu_0\varepsilon_0}$

(e) $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

25. A comet orbits around Sun in an elliptical orbit. Which of the following quantities remains constant during the course of its motion?

(a) Linear velocity

(b) Angular velocity

(c) Angular momentum

(d) Kinetic energy

(e) Potential energy

26. Consider a satellite moving in a circular orbit around Earth. If K and V denote its kinetic energy and potential energy respectively then (Choose the convention where $V = 0$ as $r \to \infty$)

(a) $K = V$ (b) $K = 2V$

(c) $V = 2K$ (d) $K = -2V$

(e) $V = -2K$

27. Assuming the mass of Earth to be ten times the mass of the Mars and its radius to be twice the radius of Mars and the acceleration due to gravity on the surface of Earth to be 10 m s^{-2}, the acceleration due to gravity on the surface of Mars is given by

(a) 0.2 m s^{-2} (b) 0.4 m s^{-2}

(c) 2 m s^{-2} (d) 4 m s^{-2}

(e) 5 m s^{-2}

28. The semi-major axis of the orbit of Saturn is approximately nine times that of Earth. The time period of revolution of Saturn is approximately equal to

(a) 81 years (b) 27 years

(c) 729 years (d) $\sqrt[3]{81}$ years

(e) 9 years

29. A particle of mass 3 kg, attached to a spring with force constant 48 N m^{-1} executes simple harmonic motion on a frictionless horizontal surface. The time period of oscillation of the particle, in seconds, is

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) 2π (d) 8π
(e) $\frac{\pi}{8}$

30. The position and velocity of a particle executing simple harmonic motion at $t = 0$ are given by 3 cm and 8 cm s^{-1} respectively. If the angular frequency of the particle is 2 rad s^{-1} then the amplitude of oscillation, in centimeters, is

(a) 3 (b) 4 (c) 5 (d) 6
(e) 8

31. A simple harmonic motion is represented by, $x(t) = \sin^2 \omega t - 2\cos^2 \omega t$. The angular frequency of oscillation is given by

(a) ω (b) 2ω (c) 4ω (d) $\frac{\omega}{2}$
(e) $\frac{\omega}{4}$

32. A transverse wave is propagating on a stretched string whose mass per unit length is 32 g m^{-1}. The tension on the string is 80 N. The speed of the wave in the string is

(a) $\frac{5}{2}$ m s^{-1} (b) $\sqrt{\frac{5}{2}}$ m s^{-1}
(c) $\frac{2}{5}$ m s^{-1} (d) $\sqrt{\frac{2}{5}}$ m s^{-1}
(e) 50 m s^{-1}

33. Consider the propagation of sound (with velocity 330 m s^{-1}) in a pipe of length 1.5 m with one end closed and the other open. The frequency associated with the fundamental mode is

(a) 11 Hz (b) 55 Hz (c) 110 Hz (d) 165 Hz
(e) 265 Hz

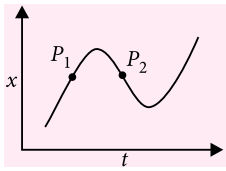
34. A standing wave propagating with velocity 330 m s^{-1} in an open pipe of length 4 m has four nodes. The frequency of the wave is

(a) 75 Hz (b) 100 Hz (c) 150 Hz (d) 300 Hz
(e) 600 Hz

35. Consider a vehicle emitting sound wave of frequency 700 Hz moving towards an observer at a speed 22 m s^{-1}. Assuming the observer as well as the medium to be at rest and velocity of sound in the medium to be 330 m s^{-1}, the frequency of sound as measured by the observer is

(a) $\frac{2525}{4}$ Hz (b) $\frac{1960}{3}$ Hz
(c) $\frac{2240}{3}$ Hz (d) 750 Hz
(e) $\frac{5625}{7}$ Hz

36. The x-t plot shown in the figure below describes the motion of the particle, along x-axis, between two positions A and B.



The particle passes through two intermediate points P_1 and P_2 as shown in the figure.

(a) The instantaneous velocity is positive at P_1 and negative at P_2.
(b) The instantaneous velocity is negative at both P_1 and P_2
(c) The instantaneous velocity is negative at P_1 and positive at P_2
(d) The instantaneous velocity is positive at both P_1 and P_2
(e) The instantaneous velocity is always positive

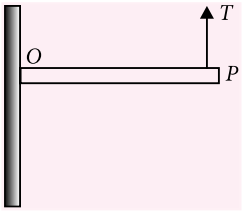
37. A ball falls from a table top with initial horizontal speed v_0. In the absence of air resistance, which of the following statement is correct.

(a) The vertical component of the acceleration changes with time.
(b) The horizontal component of the velocity does not change with time.
(c) The horizontal component of the acceleration is non-zero and finite.
(d) The time taken by the ball to touch the ground depends on v_0.
(e) The vertical component of the acceleration varies with time.

38. A man of mass 60 kg climbed down using an elevator. The elevator had an acceleration 4 m s^{-2}. If the acceleration due to gravity is 10 m s^{-2}, the man apparent weight on his way down is

(a) 60 N (b) 240 N (c) 360 N (d) 840 N
(e) 3600 N

39. A uniform rod of length of 1 m and mass of 2 kg is attached to a side support at O as shown in the figure. The rod is at equilibrium due to upward force T acting at P. Assume the acceleration due to gravity as 10 m s^{-2}. The value of T is



(a) 0
(b) 2 N
(c) 5 N
(d) 10 N
(e) 20 N

40. A capillary tube of radius 0.5 mm is immersed in a beaker of mercury. The level inside the tube is 0.8 cm below the resonance and angle of contact is 120°. What is the surface tension of mercury if the mass density of mercury is $\rho = 13.6 \times 10^3$ kg m^{-3} and acceleration due to gravity is $g = 10$ m s^{-2}?

(a) 0.225 N m^{-1} (b) 0.544 N m^{-1}
(c) 0.285 N m^{-1} (d) 0.375 N m^{-1}
(e) 0.425 N m^{-1}

41. Which of the following statements related to stress-strain relation is correct?

(a) Stress is linearly proportional to strain irrespective of the magnitude of the strain.
(b) Stress is linearly proportional to strain above the yield point.
(c) Stress is linearly proportional to strain for stress much smaller than at the yield point.
(d) Stress-strain curve is same for all materials.
(e) Stress is inversely proportional to strain.

42. The lower edge of a square slab of side 50 cm and thickness 20 cm is rigidly fixed to the base of a table. A tangential force of 30 N is applied to the slab. If the shear moduli of the material is 4×10^{10} N m^{-2}, then displacement of the upper edge, in meters, is

(a) 4×10^{-12} (b) 4×10^{-10}
(c) 6×10^{-10} (d) 6×10^{-12}
(e) 8×10^{-10}

43. Initially a beaker had 100 g of water at temperature 90 °C. Later another 600 g of water at temperature 20 °C was poured into the beaker. The temperature, T, of the water after mixing is

(a) 20°C (b) 30°C (c) 45°C (d) 55°C
(e) 90°C

44. Match the following :

P.	Isothermal process	(i)	$\Delta Q = 0$
Q.	Isobaric process	(ii)	$\Delta V = 0$
R.	Isochoric process	(iii)	$\Delta P = 0$
S.	Adiabatic process	(iv)	$\Delta T = 0$

(a) P - (iv), Q - (iii), R - (ii), S - (i)
(b) P - (iii), Q - (ii), R - (i), S - (iv)
(c) P - (i), Q - (ii), R - (iii), S - (iv)
(d) P - (iv), Q - (ii), R - (iii), S - (i)
(e) P - (i), Q - (iv), R - (ii), S - (iii)

45. For an ideal gas, the specific heat at constant pressure C_p is greater than the specific heat at constant volume C_v. This is because

(a) There is a finite work done by the gas on its environment when its temperature is increased while the pressure remains constant
(b) There is a finite work done by the gas on its environment when its pressure is increased while the volume remains constant
(c) There is a finite work done by the gas on its environment when its pressure is increased while the temperature remains constant
(d) The pressure of the gas remains constant when its temperature remains constant
(e) The internal energy of the gas at constant pressure is more than at constant volume

46. Which of the following statements is correct?

(a) Light waves are transverse but sound waves and waves on strings are longitudinal.
(b) Sound waves and waves on a string are transverse but light waves are longitudinal
(c) Light waves and waves on a string are transverse but sound waves are longitudinal
(d) Light waves and sound waves are transverse, but waves on strings are longitudinal
(e) Light waves, sound waves and waves on a string are all longitudinal

47. In Young's double slit experiment, if the separation between the slits is halved and the distance between the slits and the screen is doubled, then the fringe width compared to the unchanged one will be

(a) Unchanged (b) Halved
(c) Doubled (d) Quadrupled
(e) Fringes will disappear

48. The phase velocity of a wave described by the equation $\psi = \psi_0 \sin\left(kx + \omega t + \frac{\pi}{2}\right)$ is

(a) $\frac{x}{t}$ (b) $\frac{\psi_0}{\omega}$ (c) $\frac{\omega}{k}$ (d) $\frac{\pi}{2k}$
(e) ψ_0

49. The direction of propagation of electromagnetic wave is along

(a) Electric field vector, $\vec{E}$
(b) Magnetic field vector, $\vec{B}$
(c) $\vec{E} \cdot \vec{B}$
(d) $\vec{E} \times \vec{B}$
(e) $\vec{B} \times \vec{E}$

50. Assume that a radio station is about 200 km away from your location and the station operates at 972 kHz. How long does it take for an electromagnetic signal to travel from the station to you and how many wave crests does it send out per second

(a) 666 μs and 9.72×10^5 crests per second
(b) 666 μs and 972×10^5 crests per second
(c) 555 μs and 97.2×10^7 crests per second
(d) 555 μs and 0.972×10^5 crests per second
(e) 444 μs and 9×10^6 crests per second

51. What wavelength must electromagnetic radiation have if a photon in the beam has the same momentum as an electron moving with a speed 1.1×10^5 m s^{-1} (Planck's constant = 6.6×10^{-34} J s, rest mass of electron = 9×10^{-31} kg)?

(a) $\frac{2}{3}$ nm (b) $\frac{20}{3}$ nm (c) $\frac{4}{3}$ nm (d) $\frac{40}{3}$ nm
(e) $\frac{3}{20}$ nm

52. The electric field portion of an electromagnetic wave is given by (all variables in SI units) $E = 10^{-4} \sin(6 \times 10^5\, t - 0.01\, x)$. The frequency ($f$) and the speed ($v$) of electromagnetic wave are

(a) $f = 30/\pi$ kHz and $v = 1.5 \times 10^7$ m s^{-1}
(b) $f = 90/\pi$ kHz and $v = 6.0 \times 10^7$ m s^{-1}
(c) $f = 300/\pi$ kHz and $v = 6.0 \times 10^7$ m s^{-1}
(d) $f = 600/\pi$ kHz and $v = 7.5 \times 10^7$ m s^{-1}
(e) $f = 900/\pi$ kHz and $v = 8.0 \times 10^7$ m s^{-1}

53. Huygen's wave theory of light cannot explain

(a) Diffraction phenomena
(b) Interference phenomena
(c) Photoelectric effect
(d) Polarization of light
(e) Propagation of light

54. An electron, a neutron and an alpha particle have same kinetic energy and their de-Broglie wavelengths are λ_e, λ_n and λ_α respectively. Which statement is correct about their de-Broglie wavelengths?

(a) $\lambda_e > \lambda_n > \lambda_\alpha$ (b) $\lambda_e < \lambda_n > \lambda_\alpha$
(c) $\lambda_e < \lambda_n < \lambda_\alpha$ (d) $\lambda_e > \lambda_n < \lambda_\alpha$
(e) $\lambda_e = \lambda_n < \lambda_\alpha$

55. It takes 4.6 eV to remove one of the least tightly bound electrons from a metal surface. When monochromatic photons strike the metal surface, electrons having kinetic energy from zero to 2.2 eV are ejected. What is the energy of the incident photons?

(a) 2.4 eV (b) 2.2 eV (c) 6.8 eV (d) 4.6 eV
(e) 5.8 eV

56. If copper and silicon pieces are heated, the resistance of

(a) each will increase
(b) each will decrease
(c) copper will increase and silicon will decrease
(d) copper will decrease and silicon will increase
(e) both does not change

57. In an insulator, band gap is of the order of

(a) 0.1 eV (b) 1 eV (c) 5 eV (d) 100 eV
(e) 1 MeV

58. For a *P-N* junction diode

(a) Forward current is in mA and reverse current is in μA
(b) Forward current is in μA and reverse current is in mA
(c) Both forward and reverse currents are in μA
(d) Both forward and reverse currents are in mA
(e) No current flows in any direction

59. For a Zener diode

(a) both *p* and *n* regions are heavily doped
(b) *p* regions is heavily doped but *n* region is lightly doped
(c) *n* region is heavily doped but *p* region is lightly doped
(d) both *p* and *n* regions are lightly doped
(e) depletion region is very thick

60. Speech signal is in the range of
(a) 3700 to 7000 Å wavelength
(b) 20 Hz to 20 kHz frequency
(c) 300 to 3100 Hz frequency
(d) 540 to 1600 kHz frequency
(e) 88 to 108 MHz frequency

61. Wavelength of the wave with 30 MHz frequency is
(a) 1 cm (b) 10 cm (c) 100 cm (d) 1000 cm
(e) 10000 cm

62. To transmit a signal of frequency, ω_m, with a carrier frequency, ω_c, in AM transmission, the bandwith of the filter and amplifier is
(a) ω_m (b) $2\omega_m$ (c) ω_c (d) $\omega_c - \omega_m$
(e) $\omega_c + \omega_m$

63. If a magnet is dropped through a vertical hollow copper tube then
(a) the time taken to reach the ground is longer than the time taken if the tube was made out of plastic
(b) the magnet will get attracted and stick to the copper tube
(c) the time taken to reach the ground is longer than the time taken if the tube was made out of the stainless steel
(d) the time taken to reach the ground does not depend on the radius of the copper tube
(e) the magnet will be repelled away by the tube

64. Consider a circular wire loop of radius R spinning about a diametrical chord which is perpendicular to a uniform magnetic field $(\vec{B} = B_0\hat{k})$
(a) The magnitude of the induced EMF in the loop is maximum when the plane of the loop is perpendicular to $\vec{B}$
(b) Flux through the loop is minimum when the plane of the loop is perpendicular to $\vec{B}$
(c) The direction of induced current remains same during the spinning motion of the loop
(d) EMF induced will be the same for a larger radius of the loop in the same field
(e) No EMF will be induced since magnetic field is constant

65. An electric motor when loaded has an effective resistance of 30 Ω and an inductive reactance of 40 Ω. If the motor is powered by a source with maximum voltage of 420 V, the maximum current is
(a) 6 A (b) 8.4 A (c) 10 A (d) 12 A
(e) 13 A

66. Which of the following particle when bombards on ^{65}Cu will turn into ^{66}Cu
(a) Proton (b) Neutron
(c) Electron (d) Alpha particle
(e) Deutron

67. CO^- ion moving with kinetic energy of 20 keV dissociates into O^- and C which move along the parent ion direction. Assuming no energy is released during dissociation, the kinetic energies of the daughters $(K.E)_{O^-}$ and $(K.E)_C$ are related as
(a) $(K.E)_{O^-} = (K.E)_C$ (b) $\frac{(K.E)_{O^-}}{(K.E)_C} = \frac{16}{12}$
(c) $\frac{(K.E)_{O^-}}{(K.E)_C} = \frac{12}{16}$ (d) $\frac{(K.E)_{O^-}}{(K.E)_C} = \frac{16}{28}$
(e) $\frac{(K.E)_{O^-}}{(K.E)_C} = \frac{28}{16}$

68. If the rms value of sinusoidal input to a full wave rectifier is $\frac{V_0}{\sqrt{2}}$ then the rms value of the rectifier's output is
(a) $\frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0^2}{\sqrt{2}}$ (c) $\frac{V_0^2}{2}$ (d) $\sqrt{2}V_0^2$
(e) $2V_0^2$

69. Eight grams of Cu^{66} undergoes radioactive decay and after 15 minutes only 1 g remains. The half-life, in minutes, is then
(a) $\frac{15\ln(2)}{\ln(8)}$ (b) $\frac{15\ln(8)}{\ln(2)}$
(c) $\frac{15}{8}$ (d) $\frac{8}{15}$
(e) $15\ln(2)$

70. For a light nuclei, which of the following relation between the atomic number (Z) and mass number (A) is valid
(a) $A = \frac{Z}{2}$ (b) $Z = A$
(c) $Z = \frac{A}{2}$ (d) $Z = A^2$
(e) $A = Z^2$

71. A wheel rotating at 12 revolutions per second is brought to rest in 6 s. The average angular deceleration in rad s^{-2} of the wheel during this process is

(a) 4π (b) 4 (c) 72 (d) $1/\pi$
(e) π

72. A torque of 1 N m is applied to a wheel which is at rest. After 2 seconds the angular momentum in kg $m^2 s^{-1}$ is
(a) 0.5 (b) 1 (c) 2 (d) 4
(e) 3

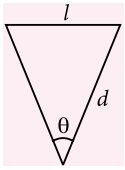
SOLUTIONS

1. (c) : $\theta = 15° = 15 \times \frac{2\pi}{360}$ rad, $d = 3$ km

$\therefore$ Length of train, $l = \theta \times d$

$$= 3 \times 15 \times \frac{2\pi}{360} \text{ km}$$

$$= \frac{\pi}{4} \text{ km} = 250\pi \text{ m}$$



2. (a) : If the same measurement is repeated a number of times and the result is taken as the average value of all the observations taken, the random error can be reduced.

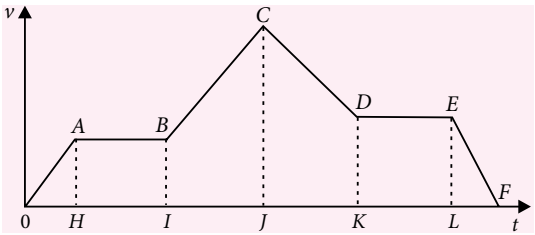
3. (b) : Total number of observations = 10
$\therefore$ Time period,

$$t = \frac{5.1 + 5.0 + 4.9 + 4.9 + 5.1 + 5.0 + 4.9 + 5.1 + 5.0 + 4.9}{10}$$

$$= \frac{49.9}{10} = 4.99 \text{ s}$$

Number of significant figures in the given data is 2
$\therefore$ The correct way of expressing the result for the period is 5.0 s

4. (a) : Total distance travelled by the particle
= Total area under curve = Area of *OAH* + Area of *ABIH* + Area of *BCJI* + Area of *CDKJ* + Area of *DELK* + Area of *EFL*



$$= \left(\frac{1}{2} \times 10 \times 15\right) + (5 \times 15) + \left(\frac{1}{2} \times 10 \times (15 + 40)\right)$$

$$+ \left(\frac{1}{2} \times 10 \times (20 + 40)\right) + (10 \times 20) + \left(\frac{1}{2} \times 5 \times 20\right)$$

= (75 + 75 + 275 + 300 + 200 + 50) m = 975 m

Hence option (a) is correct.
Object has variable accelerations and decelerations.

For OA : $a_1 = \frac{15}{10} = 1.5 \text{ m s}^{-2}$

For AB : $a_2 = 0 \text{ m s}^{-2}$

For BC : $a_3 = \frac{40 - 15}{25 - 15} = 2.5 \text{ m s}^{-2}$

For CD : $a_4 = \frac{20 - 40}{35 - 25} = -2 \text{ m s}^{-2}$

For DE : $a_5 = 0 \text{ m s}^{-2}$

For EF : $a_6 = \frac{0 - 15}{50 - 45} = -3 \text{ m s}^{-2}$

Hence options (b) and (c) are incorrect. The object was in motion in the whole journey.

5. (e) : Let acceleration of Q be a km h^{-2} and Q catches P at time t h.
$\therefore$ Time taken by P to cover 20 km

$$20 = \frac{1}{2} \times (40) \times t^2 = 20t^2$$

$\Rightarrow$ $t = 1$ h
Since Q starts travelling 30 min after P
Here, t = 1 h – 30 min = 30 min = 0.5 h
$\therefore$ acceleration of Q to catch P in 30 min is

$$\therefore \quad 20 = \frac{1}{2} a (0.5)^2$$

or $a = 160$ km h^{-2}

6. (e) : Let the bullet fired by the person sitting at the back of train reaches the target in time t_1
Speed of bullet with respect to the earth $v = v_b$

Distance travelled = $L + D$

$$\therefore \quad \text{Time taken } t_1 = \frac{L + D}{v_b}$$

Let the bullet fired by the person at the front of the train reaches the target in time t_2
Speed of bullet with respect to the earth = v_b
Distance travelled = $D - v_t T$

$$\therefore \quad \text{Time taken, } t_2 = \frac{D - v_t T}{v_b}$$

According to question,
$t_1 - t_2 = T$

$$\Rightarrow \quad \frac{L + D}{v_b} - \frac{D - v_t T}{v_b} = T$$

$\Rightarrow$ $L = T \times (v_b - v_t)$

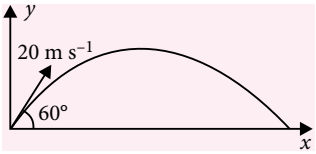
FIND
MORE
FREE
MAGAZINES

FREEMAGS.CC

7. (c) : Given : $g = 10\ \text{m s}^{-2}$

$u = 20\ \text{m s}^{-1}$

$\theta = 60°$



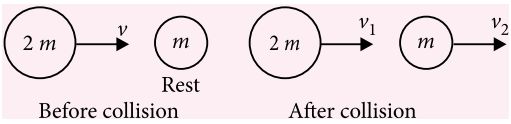
$$R = \frac{u^2 \sin 2\theta}{g}$$

$$= \frac{(20)^2 \sin 2(60°)}{10} = 20\sqrt{3}\ \text{m}$$

8. (e) : When the person is sitting in truck and throws a ball upward, then ball gains velocity in two directions but the only acceleration present in the upward motion.

$\therefore$ The ball will trace a parabola and the range of ball and distance travelled by the person in truck is same. Hence, the person can catch the ball when it comes down, if the truck continues to move with a constant speed of 60 km h^{-1}.

9. (e) :



Let the velocities of two masses $2m$ and m be v_1 and v_2 respectively.

For elastic collision :

$$\frac{1}{2}(2m)v^2 = \frac{1}{2}(2m)v_1^2 + \frac{1}{2}(m)v_2^2$$

$\Rightarrow\ 2v^2 = 2v_1^2 + v_2^2$ ...(i)

Using conservation of momentum

$2mv = 2mv_1 + mv_2$

$\Rightarrow\ 2v = 2v_1 + v_2$

or $v_2 = 2v - 2v_1$ ...(ii)

Solving eqn. (i) and (ii), we get

$2v^2 = 2v_1^2 + (2v - 2v_1)^2$

$\therefore\ 0 = 6v_1^2 - 8vv_1 + 2v^2$

$\therefore\ v_1 = \frac{v}{3}$ or v

Since the kinetic energy of $2m$ is reduced, so $v_1 = \frac{v}{3}$

Loss in kinetic energy $= \frac{1}{2}(2m)v^2 - \frac{1}{2}(2m)v_1^2$

$$= \frac{1}{2}(2m)\left[v^2 - \left(\frac{v}{3}\right)^2\right]$$

$$= \frac{8}{9}\left[\frac{1}{2}(2m)v^2\right]$$

10. (d) : Given : $m = 1$ kg

$x = 2t^2$

$\therefore\ \frac{dx}{dt} = 4t$ or $\frac{d^2x}{dt^2} = 4$

$\Rightarrow$ Acceleration, $a = \frac{d^2x}{dt^2} = 4\ \text{m s}^{-2}$

Work done = Force × Displacement

$W = m\,a\,x$

$W = 1 \times 4 \times 2t^2 = 8t^2$ J

At $t = 1$ s, $W = 8$ J

11. (a) : Let the maximum displacement be x from equilibrium position

$\therefore\ kx = mg;\ x = mg/k$

Maximum speed, $v = \omega A = \omega x$

$$= \sqrt{\frac{k}{m}}\,\frac{mg}{k} = g\sqrt{\frac{m}{k}}$$

12. (d) : F = constant = $k = ma$

$\Rightarrow\ a = k/m$ or v is increasing uniformly with time

$P = Fv$

$\therefore\ P$ is increasing uniformly with time.

13. (d) : Given : $A = 2 \times 10^{-6}\ \text{m}^2$, $n_e = 5 \times 10^{22}\ \text{cm}^{-3}$

$I = 16$ A

$\because\ I = n_e e A v_d$

$16\ \text{A} = (5 \times 10^{22}\ \text{m}^{-3})\ (1.6 \times 10^{-19}\text{C})\ (2 \times 10^{-6}\ \text{m}^2) \times v_d$

$\Rightarrow\ v_d = 1 \times 10^{-3}\ \text{m s}^{-1}$

$= 0.001\ \text{m s}^{-1}$

14. (d) : $P = 75$ W, $V = 120$ V

As, $P = \frac{V^2}{R}$

$$75 = \frac{(120)^2}{R}$$

$$\Rightarrow\ R = \frac{(120)^2}{75} = 192\ \Omega$$

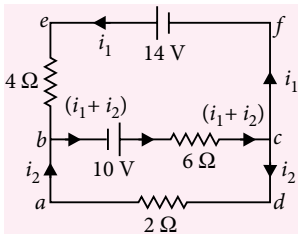
15. (b) : Apply KVL in the loops *feadf* and *bcdab*

$14 = 4i_1 - 2i_2$ ...(i)

$10 = 6(i_1 + i_2) + 2i_2$ ...(ii)

Solving (i) and (ii), we get

$i_1 = 3,\ i_2 = -1$



Comparing with the figure given in question

$\Rightarrow\ I_1 = (i_1 + i_2)$

$= (3 - 1) = 2$ A

$I_2 = -i_1 = -3$ A

$I_3 = i_2 = -1$ A

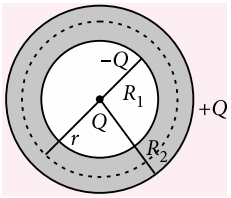
16. (d) : Given : $\alpha = 4 \times 10^{-3}\ °\text{C}^{-1}$

$R(20°\text{C}) = 10\ \Omega$

$R(40°\text{C}) = ?$

Resistance at any temperature T is given by
$R = R_0(1 + \alpha\Delta T)$
where R_0 is the resistance of wire at 20° C.
Here, $R_0 = 10\ \Omega$ and $\Delta T = 40\,°C - 20\,°C = 20\,°C$
$R = 10(1 + (4 \times 10^{-3} \times 20)) = 10.8\ \Omega$

17. (a) : Electric field at any point of gaussian surface of radius r is zero as the net charge enclosed in the surface $= (Q - Q) = 0$

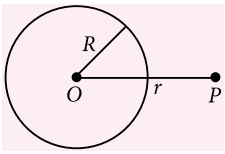


18. (d) : Electric field at any point outside the sphere,

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

where Q is total charge enclosed in the sphere

$$Q = \int \rho dV = \frac{4}{3}\pi R^3 \rho$$



$$\Rightarrow \quad E = \frac{\frac{4}{3}\pi R^3 \rho}{4\pi\varepsilon_0 r^2} = \frac{\rho R^3}{3\varepsilon_0 r^2}$$

19. (d) : Potential due to a point charge

$$V = \frac{q}{4\pi\varepsilon_0 r}$$

Total potential at origin ($x = 0$),

$$V = \frac{10 \times 10^{-9}}{4\pi\varepsilon_0}\left[\frac{1}{2} + \frac{1}{4} + \frac{1}{5} + \frac{1}{10} + \frac{1}{20}\right]$$

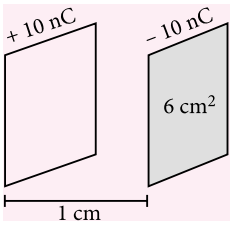
$$= \left(\frac{10 \times 10^{-9}}{4\pi \times 10^{-9} / 36\pi}\right)\left[\frac{10 + 5 + 4 + 2 + 1}{20}\right]$$

$$= 90 \times \frac{22}{20} = 99\,V$$

20. (c) : $A = 6\ cm^2$, $d = 1$ cm, $Q = 10$ nC
The system will act as a parallel plate capacitor,

$$E = \frac{Q}{\varepsilon_0 A} = \frac{10 \times 10^{-9}}{\frac{10^{-9}}{36\pi} \times (6 \times 10^{-4})}$$

$= 6\pi \times 10^5\ V\ m^{-1}$
$= 600\ \pi\ kV\ m^{-1}$



21. (d) : $v = 5 \times 10^6\ m\ s^{-1}$, $B = 2$ T, $\theta = 30°$
$q = 1.6 \times 10^{-19}$ C

$$F = |q(\vec{v} \times \vec{B})| = qvB\sin\theta$$

$= 1.6 \times 10^{-19} \times 5 \times 10^6 \times 2\ \sin 30°$
$= 8 \times 10^{-13}$ N

22. (a)

23. (a) : $\upsilon = 16$ MHz, $m = 1.67 \times 10^{-27}$ kg,
$q = 1.6 \times 10^{-19}$ C

For cyclotron, $\upsilon = \dfrac{qB}{2\pi m}$

$$\Rightarrow \quad B = \frac{2\pi m \upsilon}{q} = \left(\frac{2 \times \pi \times 1.67 \times 10^{-27} \times 16 \times 10^6}{1.6 \times 10^{-19}}\right) T$$

$= 0.334\ \pi$ T

24. (e) : $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

25. (c) : For closed orbits, angular momentum is always conserved.

26. (e) : For a satellite

$$K = \frac{GM_E m}{2(R_E + h)},\ V = \frac{-GM_E m}{(R_E + h)}$$

$$\Rightarrow \quad K = \frac{-V}{2} \quad \text{or} \quad V = -2K$$

27. (d) : $M_E = 10\ M_M$, $R_E = 2R_M$, $g_E = 10\ m\ s^{-2}$, $g_M = ?$

$$g_E = \frac{GM_E}{R_E^2}$$

$$\frac{g_E}{g_M} = \frac{M_E}{R_E^2} \cdot \frac{R_M^2}{M_M} = \frac{10}{(2)^2} = 2.5$$

$$g_M = \frac{g_E}{2.5} = 4\ m\ s^{-2}$$

28. (b) : $R_S = 9\ R_E$
Using law of periods,

$$\left(\frac{T_S}{T_E}\right)^2 = \left(\frac{R_S}{R_E}\right)^3$$

$$T_S = T_E\left(\frac{R_S}{R_E}\right)^{3/2} = 27\,T_E = 27 \text{ years}$$

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29. (b): $m = 3$ kg, $k = 48$ N m^{-1}

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{3}{48}} = \frac{\pi}{2}\text{ s}$$

30. (c): $x = x_0 \sin(\omega t + \phi)$, $v = v_0 \cos(\omega t + \phi)$

At $t = 0$, $x = x_0 \sin\phi = 3$ cm ...(i)

and $v = v_0 \cos\phi = 8$ cm s^{-1}

or $x_0\omega \cos\phi = 8$ cm s^{-1}

or $x_0 \cos\phi = 4$ cm ...(ii)

$$\Rightarrow \quad x_0 = \sqrt{(3)^2 + (4)^2} = 5 \text{ cm}$$

31. (b): $x(t) = \sin^2\omega t - 2\cos^2\omega t$

$$= \left(\frac{1 - \cos 2\omega t}{2}\right) - (1 + \cos 2\omega t) = -\frac{1}{2} - \frac{3}{2}\cos 2\omega t$$

32. (e): $\mu = 32$ g m^{-1}, $T = 80$ N

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{80}{32} \times 1000} = 50 \text{ m s}^{-1}$$

33. (b): Frequency of fundamental mode,

$$\upsilon = \frac{v}{4L} = \frac{330 \text{ m s}^{-1}}{4 \times 1.5 \text{ m}} = 55 \text{ Hz}$$

34. (c): For open pipe, $\upsilon_n = \dfrac{nv}{2L}$

$$\upsilon_4 = \frac{4 \times 300}{2 \times 4} = 150 \text{ Hz}$$

35. (d): $v_s = 22$ m s^{-1}, $\upsilon_0 = 700$ Hz, $v = 330$ m s^{-1}

$$\upsilon' = \frac{v}{v - v_s}\upsilon = \left(\frac{330}{330 - 22}\right)700 = 750 \text{ Hz}$$

36. (a): Instantaneous velocity at any time is given by the slope of x-t curve at that point.

$\therefore$ The instantaneous velocity is positive at P_1 and negative at P_2

37. (b): Let h be the height of table,

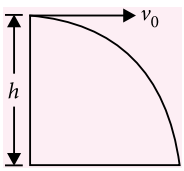
So, acceleration, $\vec{a} = -g\hat{j}$

$\therefore$ The vertical components of velocity only changes.

Using second equation of motion in vertical direction,

$$h = \frac{1}{2}gT^2$$

$$T = \sqrt{\frac{2h}{g}}$$



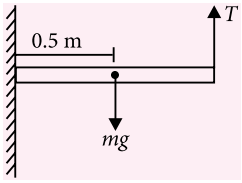
$\therefore$ Time of flight is independent of initial horizontal speed.

38. (c): Apparent weight on down way

$W = m(g - a) = 60(10 - 4) = 360$ N

39. (d): Since the rod is at equilibrium

$\therefore$ Net torque = 0



$\Rightarrow$ $1 \times T = 0.5 \times mg = 0.5 \times 2 \times 10 \Rightarrow T = 10$ N

40. (b): $a = 0.5$ mm $= 5 \times 10^{-4}$ m, $h = 0.8$ cm $= 8 \times 10^{-3}$ m, $\theta = 120°$, $\rho = 13.6 \times 10^3$ kg m^{-3}

As $h\rho g = 2s \cos\theta / a$

$$\Rightarrow \quad s = \frac{ah\rho g}{2\cos\theta} = \frac{5 \times 10^{-4} \times 8 \times 10^{-3} \times 13.6 \times 10^3 \times 10}{2 \times \cos 120°}$$

$$= -0.544 \text{ N m}^{-1}$$

Negative sign denotes that liquid meniscus is convex.

41. (c): Stress-strain curve gives the stiffness of the material which is different for different materials. Yield point is the point on this curve upto which stress is directly proportional to strain. Hence option (c) is correct.

42. (c): Area on which force is applied

$= 50$ cm $\times$ 50 cm $= 2500$ cm$^2 = 0.25$ m^2

$$\text{Stress, } \sigma_s = \frac{\text{Force}}{\text{Area}} = \frac{30 \text{ N}}{0.25 \text{ m}^2} = 120 \text{ N m}^{-2}$$

$$\text{Shearing strain} = \frac{\Delta x}{L}$$

$$\therefore \quad G = \frac{\sigma_s}{\Delta x / L}$$

$$\text{or} \quad \Delta x = \frac{\sigma_s L}{G} = \frac{120 \times 0.2}{4 \times 10^{10}} \text{ m} = 6 \times 10^{-10} \text{ m}$$

43. (b): Let temperature of mixture be T °C.

Heat lost = Heat gained

$100(90 - T) = 600(T - 20)$

$9000 - 100T = 600T - 12000$ or $700T = 21000$

$T = 30$ °C

44. (a)

45. (a): C_p is greater than C_v, because when heat is added at constant pressure, substance expands and work is done by gas but when heat is added at constant volume, no work is done.

$\because$ $Q = \Delta U + \Delta W$

$\therefore$ $Q_p > Q_v \Rightarrow C_p > C_v$

46. (c)

47. (d): $d' = \frac{d}{2}$ and $D' = 2D$

Fringe width, $\beta = \frac{\lambda D}{d}$

New fringe width $\beta' = \lambda\left(\frac{2D}{d/2}\right) = 4\beta$

48. (c): $\psi = \psi_0 \sin\left(kx + \omega t + \frac{\pi}{2}\right)$

Phase, $\theta = kx + \omega t + \frac{\pi}{2}$

$\because$ Phase is a constant

$\therefore \frac{d\theta}{dt} = \omega + \frac{kdx}{dt} = 0$ or $\frac{dx}{dt} = \frac{-\omega}{k} = v_{\text{phase}}$

Negative sign shows that wave is propagating along negative x-direction which is only a sign convention used in a wave propagation.

49. (d)

50. (a): Time taken by wave to travel

$$= \frac{200 \text{ km}}{3 \times 10^5 \text{ km s}^{-1}} = 6.667 \times 10^{-4} \text{ s} \approx 666 \ \mu\text{s}$$

Number of crests per second = Frequency

Frequency = 972 kHz = 9.72×10^5 Hz

$\therefore$ There are 9.72×10^5 crests per second.

51. (b): Momentum of photon = Momentum of electron

$= mv$

$= 9 \times 10^{-31} \times 1.1 \times 10^5$ kg m s^{-1}

$= 9.9 \times 10^{-26}$ kg m s^{-1}

Wavelength of radiation,

$$\lambda = \frac{h}{p} = \frac{6.6 \times 10^{-34}}{9.9 \times 10^{-26}} \text{ m} = \frac{2}{3} \times 10^{-8} \text{ m} = \frac{20}{3} \text{nm}$$

52. (c): $E = 10^{-4} \sin(6 \times 10^5 t - 0.01\, x)$

$\omega = 6 \times 10^5$ rad s^{-1}

$2\pi f = 6 \times 10^5$ rad s^{-1}

$f = \frac{300}{\pi}$ kHz

$$v = \frac{\omega}{k} = \frac{6 \times 10^5}{0.01} = 6 \times 10^7 \text{ m s}^{-1}$$

53. (c): Huygen's wave theory can explain only wave nature of light. Hence photoelectric effect cannot be explained using this theory.

54. (a): $\lambda = \frac{h}{\sqrt{2mK}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$

$\therefore$ Heavier particle will have lesser wavelength

$m_e < m_n < m_\alpha$

$\Rightarrow \lambda_e > \lambda_n > \lambda_\alpha$

55. (c): $K_{max} = 2.2$ eV, $\phi = 4.6$ eV

$\Rightarrow E = K_{max} + \phi = (2.2 + 4.6)$ eV $= 6.8$ eV

56. (c): In case of metals, electron are free to move. At higher temperatures, the atoms are vibrating more and starts interacting with electrons and hence the resistance increases. But for semiconductor, there are few conduction electrons available. On heating, more electrons gain enough energy to jump to conduction band and hence resistance decreases.

57. (c)

58. (a): In forward bias, the potential difference acts in opposite direction to the barrier potential which facilitates the movement of charges across the junction. This constitutes current flow in the forward direction. But the situation becomes opposite in case of reverse bias. Barrier strength increases as a result a very small current of the order of few microamperes flows in the circuit.

59. (a): Zener diode is a semiconductor device that permits current to flow in either a forward or reverse direction. The diode consists of a special, heavily doped p-n junction, designed to conduct in the reverse direction when a certain specified voltage is reached.

60. (c)

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61. (d): $\lambda = \frac{c}{\upsilon} = \frac{3\times10^8 \text{ m s}^{-1}}{30\times10^6 \text{ Hz}} = 10 \text{ m} = 1000 \text{ cm}$

62. (b)

63. (a): In the case of a magnet falling down a copper tube, the magnet slows down. This can be explained using Lenz's law. We know that a moving magnet will induce current in the copper tube to create a field that will try to cancel the magnet's increasing magnetic flux. The magnetic field induced in the tube attracts the falling magnet, creating resistance. This resistance slows down the magnet and increases the time taken to reach the ground.

64. (a): Emf induced in the loop,

$\varepsilon = BA\omega \cos\theta$

where θ is the angle between $\vec{B}$ and $\vec{A}$.

$|\varepsilon_{max}| = BA\omega$ for $\theta = 0°$ or $180°$

$\therefore$ The magnitude of induced emf in the loop is maximum when the plane of the loop is perpendicular to $\vec{B}$.

65. (b): $R = 30\ \Omega$, $X_L = 40\ \Omega$, $V = 420$ V

$Z = \sqrt{R^2 + X_L^2} = 50\ \Omega \Rightarrow I = \frac{V}{Z} = \frac{420}{50} \text{A} = 8.4 \text{ A}$

66. (b): $^{65}Cu + {}^{1}_{0}n = {}^{66}Cu$

Since the atomic number is same

$\therefore$ The particle bombarded is neutron.

67. (b): Using atomic masses, $m(CO^-) = 28$ g, $m(C) = 12$ g, $m(O^-) = 16$ g.

Applying conservation of momentum,

$28\,v = 12v_1 + 16v_2$ ...(i)

where v_1 and v_2 are velocities of C and O^- respectively.

Since, no energy is released.

$\therefore \frac{1}{2}(28)v^2 = \frac{1}{2}(12)v_1^2 + \frac{1}{2}(16)v_2^2$ ...(ii)

Solving eqns (i) and (ii), we get

$v_1^2 - 2v_1v_2 + v_2^2 = 0$

$\Rightarrow (v_1 - v_2)^2 = 0$ or $v_1 = v_2$

$$\frac{(K.E)_{O^-}}{(K.E)_C} = \frac{\frac{1}{2}(16)v_2^2}{\frac{1}{2}(12)v_1^2} = \frac{16}{12}$$

68. (a): The rms value of the output voltage at the load resistance, $V_{rms} = \frac{V_0}{\sqrt{2}}$.

69. (a): At $t = 15$ min

$N = N_0 e^{-\lambda t}$

$1 = 8e^{-(\ln 2/T_{1/2})t}; \ln 8 = \left(\frac{\ln 2}{T_{1/2}}\right)t$

$\Rightarrow T_{1/2} = t\left(\frac{\ln 2}{\ln 8}\right) = 15\left(\frac{\ln 2}{\ln 8}\right)$ min

70. (c)

71. (a): $\omega = 12$ rps $= 12 \times 2\pi$ rad s^{-1}

$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{12\times2\pi}{6} = 4\pi$ rad s^{-2}

72. (c): $\tau = \frac{\Delta L}{\Delta t}$

$\Rightarrow L = 1 \text{ N m} \times 2 \text{ s} = 2 \text{ kg m}^2 \text{ s}^{-1}$

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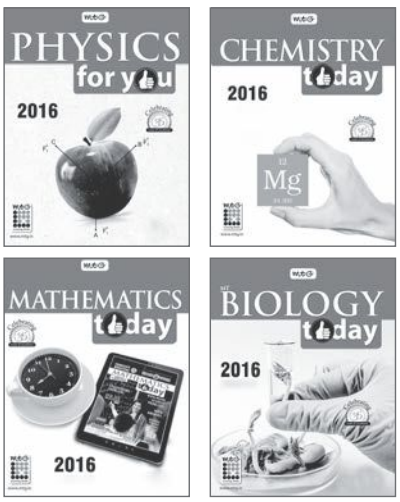

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PHYSICS MUSING

SOLUTION SET-46

1. **(a, b, d) :** For path AB

TV = constant

$\Rightarrow \quad PV^2$ = constant ...(i)

For polytropic process PV^m = constant ...(ii)

On comparing eqn. (i) and (ii)

$m = 2$

The molar heat capacity is given as

$$C = \frac{R}{\gamma - 1} - \frac{R}{m-1}, \text{ for monatomic } \gamma = \frac{5}{3}$$

$$C = \frac{3R}{2} - R = \frac{R}{2}$$

$$C = \frac{R}{\frac{5}{3} - 1} - \frac{R}{2-1} = \frac{3}{2}R - R = \frac{R}{2}$$

So option (a) is correct.

For BC

It is an isochoric process and temperature is decreasing so option (b) is correct.

$C = C_V = \frac{3}{2}R$; so option (c) is wrong.

For process CA (isothermal)

$$W = nRT \ln\left(\frac{V_A}{V_C}\right)$$

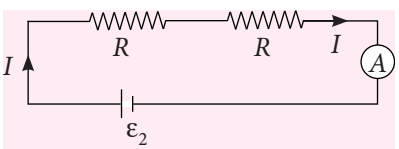
$$W = \frac{2}{3}\left(\frac{3}{2}nRT\right)\ln(4) \qquad \text{(As density at } C \text{ is } 4\,\rho_0)$$

$$= \frac{2}{3}U_0 \ln(4)$$

So, option (d) is correct.

2. **(a, c) :** When key K is open, current in the ammeter is

$$I = \frac{\varepsilon_2}{2R} \Rightarrow \varepsilon_2 = 2IR$$



When key K is closed.

Current in ammeter becomes $I' = \frac{\varepsilon_2 - \varepsilon_1}{R}$

When, $\varepsilon_1 = IR$, $I' = I$

Hence, option (a) is correct.

When, $IR < \varepsilon_1 < 2IR$, reading of the ammeter will be less than I.

When $\varepsilon_1 = 2IR$,

$$I' = \left(\frac{2IR - 2IR}{R}\right) = 0$$

Hence, option (c) is correct.

3. **(a, d) :** Given : $\rho = \rho_0\left(1 + \frac{x}{l}\right)$

$$\because \quad \vec{J} = \frac{\vec{E}}{\rho} \Rightarrow \vec{E} = \rho_0 \vec{J}\left(1 + \frac{x}{l}\right) \qquad \text{...(i)}$$

$$\text{As } V = \int E\,dx = \int \rho_0 J\left(1 + \frac{x}{l}\right)dx = \rho_0 J\left(x + \frac{x^2}{2l}\right)$$

Let the volume charge density be σ.

From Gauss law, $dE\,A = \frac{\sigma A\,dx}{\varepsilon_0}$

and $\quad \sigma = \varepsilon_0 \frac{dE}{dx} = \varepsilon_0 J \frac{\rho_0}{l}$ (From eqn. (i))

4. **(b, c, d) :** From $\vec{E}$ versus x graph

It is clear Q_A is positive and Q_B is negative charge.

At point O net electric field is zero

$$\text{So, } \frac{1}{4\pi\varepsilon_0}\frac{|Q_A|}{(l + x_1)^2} = \frac{1}{4\pi\varepsilon_0}\frac{|Q_B|}{x_1^2} \Rightarrow \left|\frac{Q_A}{Q_B}\right| = \left[\frac{l + x_1}{x_1}\right]^2$$

At point O' net field is maximum

$$\therefore \quad \frac{d}{dx_2}\left(\frac{Q_A}{(l + x_2)^2} - \frac{Q_B}{x_2^2}\right) = 0$$

$$\Rightarrow \quad \frac{Q_A}{(l + x_2)^3} - \frac{Q_B}{x_2^3} = 0 \Rightarrow \left(\frac{l}{x_2} + 1\right) = \left(\frac{Q_A}{Q_B}\right)^{1/3}$$

$$x_2 = \frac{l}{(Q_A / Q_B)^{1/3} - 1}$$

So option (d) is correct.

5. **(c, d) :** The capacitances of the sphere and shell are $C_1 = 4\pi\varepsilon_0 R$ and $C_2 = 4\pi\varepsilon_0 2R$

Since, the charge has tendency to move from higher potential to lower potential. Hence charge Q will flow from the sphere to the shell.

The initial energy, $E_i = \frac{Q^2}{2C_1} = \frac{Q^2}{2(4\pi\varepsilon_0 R)}$

The final energy, $E_f = \frac{Q^2}{2C_2} = \frac{Q^2}{2(4\pi\varepsilon_0 (2R))}$

The heat produced = $E_i - E_f$

$$= \frac{Q^2}{2}\left(\frac{1}{4\pi\varepsilon_0 R} - \frac{1}{2\times 4\pi\varepsilon_0 R}\right) \quad \left(\because\ k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$= k\frac{Q^2}{2R}\left(1-\frac{1}{2}\right) = \frac{kQ^2}{4R}$$

6. (a, b, c) : $ms\dfrac{dT}{dt} = 12 - K(T-15)$ ...(i)

At $T = 45\,°C$, $dT/dt = 0$

$\Rightarrow$ Rate of heat loss = $K(45 - 15) = 12$ W

or $K = \dfrac{12}{30} = \dfrac{2}{5}\ \text{W °C}^{-1}$

At $T = 20\,°C$, For T = 25°C,

Rate of heat loss = (2/5) (20 – 15) = 2 W

For $T = 25\,°C$, $t = 5$ min = $5 \times 60 = 300$ s

From eqn. (i)

$$ms\int_{15}^{25}\frac{dT}{12-\frac{2}{5}(T-15)} = \int_0^{300} dt$$

$$\Rightarrow\ ms\int_{15}^{25}\frac{5dT}{90-2T} = \int_0^{300} dt$$

On solving, we get

$$\Rightarrow\ s = \frac{240}{\ln(3/2)}\ \text{J kg}^{-1}\,°\text{C}^{-1}$$

7. (c) : For $t = 0$ to $t_0 = RC$, the circuit is charging type. The charging equation for this time is

$$q = C\varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$

Therefore the charge on capacitor at time $t_0 = RC$

$$q = C\varepsilon\left(1-\frac{1}{e}\right)$$

For time = RC to $2RC$, the circuit becomes discharging type

The discharging equation is, $q = q_0\, e^{-t/RC}$

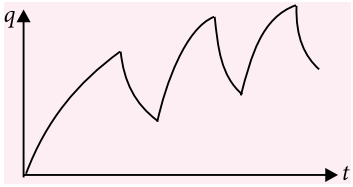
Where capacitor starts discharging, charge on the capacitor, (*i.e.*, at $t = RC$)

$$q_0 = C\varepsilon\left(1-\frac{1}{e}\right)$$

$\therefore$ Required charge on capacitor at time, $t = 2RC$, (*i.e.*, in next RC time)

$$q' = C\varepsilon\left(1-\frac{1}{e}\right)\frac{1}{e} \Rightarrow q' = C\varepsilon\left(\frac{1}{e}-\frac{1}{e^2}\right)$$

8. (c) : Since the capacitor gets more charged up from $t = 2RC$ to $t = 3RC$ than in the interval $t = 0$ to $t = RC$, the graph representing the charge variation is shown in figure.



9. (d) : It is clear from the given diagram, that the gas undergoes following processes during cycle.

$1 \to 2$	Isobaric
$2 \to 3$	Isochoric
$3 \to 4$	Isobaric
$4 \to 1$	Isothermal

$\therefore$ Option (d) depicts the correct P-V diagram for the given cyclic process.

10. (c) : Given: $P_1 = P_2 = 2P_3 = P$ ...(i)

Since $1 \to 2$ and $3 \to 4$ are isobaric processes.

$\therefore$ Heat received = $nC_p(T_f - T_i)$

According to question,

$C_p(T_2 - T_0) = C_p(T_0 - T_3)$ ...(ii)

($\because\ T_1 = T_4 = T_0$ and $n = 1$)

For process $2 \to 3$, *i.e.*, isochoric process

$$\frac{P_2}{T_2} = \frac{P_5}{T_5} = \frac{P_3}{T_3}$$

$\therefore\ \dfrac{P}{T_2} = \dfrac{P_5}{T_0} = \dfrac{P/2}{T_3}$ (From eqn. (i))

or $T_2 = 2T_3$ ...(iii)

and $P_5 = \dfrac{P}{2}\dfrac{T_0}{T_3}$ ...(iv)

Solving eqn. (ii) using eqn. (iii), we get

$$T_0 = \frac{3}{2}T_3$$

Putting value of T_0 in eqn. (iv), we get

$$P_5 = \frac{3}{4}P$$

$\therefore$ Pressure at point 5 is $\dfrac{3P}{4}$.

SOLVED PAPER **2017**

Karnataka CET

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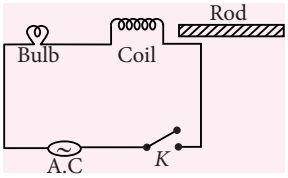
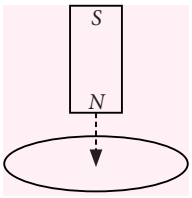


(a) gets damaged
(b) glows less brightly
(c) glows with same brightness (as before the rod is inserted)
(d) glows more brightly

2. A basic communication system consists of
(a) Transmitter
(b) Information source
(c) User of information
(d) Channel (e) Receiver
The correct sequence of the arrangement is
(a) b, e, a, d and c (b) b, a, d, e and c
(c) a, b, c, d and e (d) b, d, a, c and e

3. A bar magnet is allowed to fall vertically through a copper coil placed in a horizontal plane. The magnet falls with a net acceleration

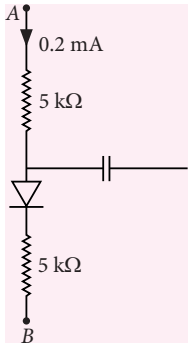


(a) $= g$ (b) Zero (c) $< g$ (d) $> g$

4. Two spheres of electric charges +2 nC and –8 nC are placed at a distance d apart. If they are allowed to touch each other, what is the new distance between them to get a repulsive force of same magnitude as before?
(a) $\frac{d}{2}$ (b) d (c) $\frac{3d}{4}$ (d) $\frac{4d}{3}$

5. The particles emitted in the decay of $^{238}_{92}U$ to $^{234}_{92}U$
(a) 2 α and 2 β (b) 1 α and 2 β
(c) 1 α and 1 β (d) 1 α only

6. In the figure shown, if the diode forward voltage drop is 0.2 V, the voltage difference between *A* and *B* is



(a) 1.3 V
(b) 2.2 V
(c) 0.5 V
(d) 0

7. In Young's double – slit experiment if yellow light is replaced by blue light, the interference fringes become
(a) wider (b) brighter
(c) narrower (d) darker

8. A system of 2 capacitors of capacitance 2 μF and 4 μF is connected in series across a potential difference of 6 V. The electric charge and energy stored in the system are
(a) 1 μC and 3 μJ (b) 8 μC and 24 μJ
(c) 10 μC and 30 μJ (d) 36 μC and 108 μJ

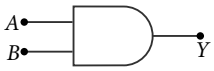
9. 4×10^{10} electrons are removed from a neutral metal sphere of diameter 20 cm placed in air. The magnitude of the electric field (in N C^{-1}) at a distance of 20 cm from its centre is
(a) Zero (b) 5760
(c) 640 (d) 1440

10. The S.I. unit of specific heat capacity is
(a) J kg^{-1} K^{-1} (b) J mol^{-1} K^{-1}
(c) J kg^{-1} (d) J K^{-1}

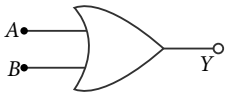
11. A coil of inductive reactance $1/\sqrt{3}\ \Omega$ and resistance $1\ \Omega$ is connected to a 200 V, 50 Hz A.C. supply. The time lag between maximum voltage and current is

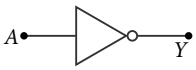
(a) $\frac{1}{600}$ s (b) $\frac{1}{200}$ s (c) $\frac{1}{300}$ s (d) $\frac{1}{500}$ s

12. Which of the following logic gates considered as universal?

(a) 

(b)

(c) 

(d) 

13. Which of the following semi-conducting devices is used as voltage regulator?

(a) Zener diode (b) LASER diode
(c) Photo diode (d) Solar cell

14. In metre bridge experiment, with a standard resistance in the right gap and a resistance coil dipped in water (in a beaker) in the left gap, the balancing length obtained is 'l'. If the temperature of water is increased, the new balancing length is

(a) $> l$ (b) $< l$ (c) $= 0$ (d) $= l$

15. The susceptibility of a ferromagnetic substance is

(a) > 1 (b) Zero (c) $>>1$ (d) < 1

16. For which combination of working temperatures, the efficiency of 'Carnot's engine' is the least?

(a) 40 K, 20 K (b) 60 K, 40 K
(c) 100 K, 80 K (d) 80 K, 60 K

17. The mean energy of a molecule of an ideal gas is

(a) kT (b) $\frac{1}{2}kT$ (c) $\frac{3}{2}kT$ (d) $2\,kT$

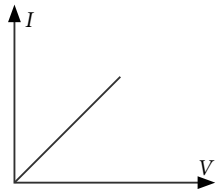
18. Hydraulic lift works on the basis of

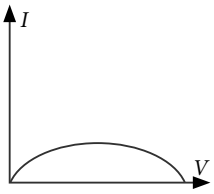
(a) Stoke's law (b) Bernoulli's law
(c) Toricelli's law (d) Pascal's law

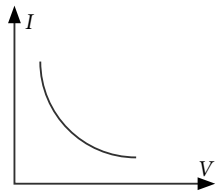
19. A car moving with a velocity of 20 m s^{-1} is stopped in a distance of 40 m. If the same car is travelling at double the velocity, the distance travelled by it for same retardation is

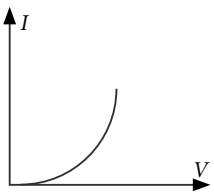
(a) 640 m (b) 320 m
(c) 1280 m (d) 160 m

20. Of the following graphs, the one that correctly represents the I-V characteristics of a Ohmic device is

(a) 

(b) 

(c) 

(d) 

21. In a system of two crossed polarisers, it is found that the intensity of light from the second polariser is half from that of first polariser. The angle between their pass axes is

(a) 30° (b) 0° (c) 45° (d) 60°

22. The magnetic field at the center of a current carrying loop of radius 0.1 m is $5\sqrt{5}$ times that at a point along its axis. The distance of this point from the centre of the loop is

(a) 0.2 m (b) 0.05 m (c) 0.1 m (d) 0.25 m

23. A proton, a deuteron and an α-particle are projected perpendicular to the direction of a uniform magnetic field with same kinetic energy. The ratio of the radii of the circular paths described by them is

(a) $1:\sqrt{2}:\sqrt{2}$ (b) $1:\sqrt{2}:1$
(c) $\sqrt{2}:\sqrt{2}:1$ (d) $\sqrt{2}:1:1$

24. The angle between velocity and acceleration of a particle describing uniform circular motion is

(a) 180° (b) 45° (c) 90° (d) 60°

25. Two point charges $A = +3$ nC and $B = +1$ nC are placed 5 cm apart in air. The work done to move charge B towards A by 1 cm is

(a) 2.0×10^{-7} J (b) 1.35×10^{-7} J
(c) 2.7×10^{-7} J (d) 12.1×10^{-7} J

26. During scattering of light, the amount of scattering is inversely proportional to …….. of wavelength of light.

(a) square (b) half
(c) cube (d) fourth power

27. Two simple pendulums A and B are made to oscillate simultaneously and it is found that A completes 10 oscillations in 20 s and B completes 8 oscillations in 10 s. The ratio of the lengths of A and B is

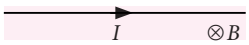
(a) $\frac{5}{4}$ (b) $\frac{8}{5}$ (c) $\frac{25}{64}$ (d) $\frac{64}{25}$

28. A particle is dropped from a height 'H'. The de Broglie wavelength of the particle depends on height as
(a) H (b) $H^{-1/2}$ (c) H^0 (d) $H^{1/2}$

29. The waves set up in a closed pipe are
(a) longitudinal and progressive
(b) longitudinal and stationary
(c) transverse and stationary
(d) transverse and progressive

30. According to Cartesian sign convention, in ray optics
(a) all distances in the direction of incident ray are taken positive.
(b) all distances are taken negative
(c) all distances in the direction of incident ray are taken negative
(d) all distances are taken positive

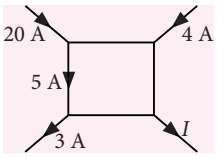
31. A straight wire of length 50 cm carrying a current of 2.5 A is suspended in mid-air by a uniform magnetic field of 0.5 T (as shown in figure). The mass of the wire is ($g = 10$ m s^{-2})
(a) 100 gm
(b) 125 gm
(c) 62.5 gm
(d) 250 gm



32. A magnetic dipole of magnetic moment 6×10^{-2} A m^2 and moment of inertia 12×10^{-6} kg m^2 performs oscillations in a magnetic field of 2×10^{-2} T. The time taken by the dipole to complete 20 oscillations is ($\pi \simeq 3$)
(a) 6 s (b) 12 s (c) 36 s (d) 18 s

33. The working of magnetic braking of trains is based on
(a) steady current (b) eddy current
(c) alternating current
(d) pulsating current

34. The value of I in the figure shown below is
(a) 19 A
(b) 21 A
(c) 8 A
(d) 4 A

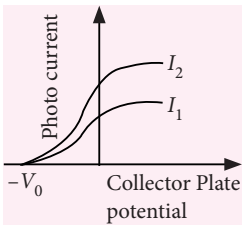


35. The output of a step down transformer is measured to be 48 V when connected to a 12 W bulb. The value of peak current is
(a) $\sqrt{2}$A (b) $\frac{1}{2\sqrt{2}}$A (c) $\frac{1}{4}$A (d) $\frac{1}{\sqrt{2}}$A

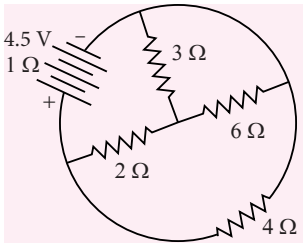
36. A linear object of height 10 cm is kept in front of a concave mirror of radius of curvature 15 cm, at a distance of 10 cm. The image formed is
(a) magnified and erect
(b) magnified and inverted
(c) diminished and erect
(d) diminished and inverted

37. In a nuclear reactor the function of the Moderator is to decrease
(a) number of neutrons
(b) speed of neutrons
(c) escape of neutrons
(d) temperature of the reactor

38. From the following graph of photo current against collector plate potential, for two different intensities of light I_1 and I_2, one can conclude
(a) $I_1 = I_2$
(b) $I_1 > I_2$
(c) $I_1 < I_2$
(d) Comparison is not possible



39. The power dissipated in 3 Ω resistance in the following circuit is



(a) 1 W (b) 0.5 W (c) 0.25 W (d) 0.75 W

40. A body of mass 50 kg is suspended using a spring balance inside a lift at rest. If the lift starts falling freely, the reading of the spring balance is
(a) = 0 (b) < 50 kg
(c) = 50 kg (d) > 50 kg

41. In the three parts of a transistor, 'Emitter' is of
(a) moderate size and heavily doped
(b) large size and lightly doped
(c) thin size and heavily doped
(d) large size and moderately doped

42. A piece of copper is to be shaped into a conducting wire of maximum resistance. The suitable length and diameter are _____ and _____ respectively.
(a) L and d (b) 2 L and $d/2$
(c) $L/2$ and 2 d (d) 2 L and d

43. If $\vec{A} = 2\hat{i} + 3\hat{j} + 8\hat{k}$ is perpendicular to $\vec{B} = 4\hat{j} - 4\hat{i} + \alpha\hat{k}$, then the value of 'α' is
(a) 1 (b) $\frac{1}{2}$ (c) –1 (d) $-\frac{1}{2}$

44. Which of the following properties is 'False' for a bar magnet?
(a) It doesn't produce magnetic field.
(b) Its poles cannot be separated.
(c) It points in North-South direction when suspended.
(d) Its like poles repel and unlike poles attract.

45. The energy gap in case of which of the following is less than 3 eV?
(a) Aluminium (b) Iron
(c) Germanium (d) Copper

46. The energy (in eV) required to excite an electron from $n = 2$ to $n = 4$ state in hydrogen atom
(a) +2.55 (b) –3.4 (c) +4.25 (d) –0.85

47. According to Huygens' principle, during refraction of light from air to a denser medium
(a) wavelength and speed increase
(b) wavelength decreases but speed increases
(c) wavelength and speed decrease
(d) wavelength increases but speed decreases

48. The value of acceleration due to gravity at a depth of 1600 km is equal to [Radius of earth = 6400 km]
(a) 9.8 m s^{-2} (b) 4.9 m s^{-2}
(c) 7.35 m s^{-2} (d) 19.6 m s^{-2}

49. A jet plane of wing span 20 m is travelling towards west at a speed of 400 m s^{-1}. If the earth's total magnetic field is 4×10^{-4} T and the dip angle is 30°, at that place, the voltage difference developed across the ends of the wing is
(a) 3.2 V (b) 6.4 V (c) 1.6 V (d) 0.8 V

50. A cylindrical conductor of diameter 0.1 mm carries a current of 90 mA. The current density (in A m^{-2}) is ($\pi \simeq 3$)
(a) 1.2×10^7 (b) 6×10^6
(b) 3×10^6 (d) 2.4×10^7

51. Two balls are thrown simultaneously in air. The acceleration of the centre of mass of the two balls when in air,
(a) is equal to g (Acceleration due to gravity)
(b) depends on the masses of the two balls
(c) depends on the direction of motion of the two balls.
(d) depends on the speeds of the two balls.

52. The scientist who is credited with the discovery of 'nucleus' in an atom is
(a) Niels Bohr (b) Rutherford
(c) J.J.Thomson (d) Balmer

53. Three point charges of +2q, +2q and –4q are placed at the corners A, B and C of an equilateral triangle ABC of side 'x'. The magnitude of the electric dipole moment of this system is.
(a) $2\sqrt{3}\,qx$ (b) 2 qx
(c) 3 qx (d) $3\sqrt{2}\,qx$

54. The mass defect of $^4_2$He is 0.03 u. The binding energy per nucleon of helium (in MeV) is
(a) 69.825 (b) 6.9825
(c) 2.793 (d) 27.93

55. 'Young's modulus' is defined as the ratio of
(a) bulk stress and longitudinal strain
(b) hydraulic stress and hydraulic strain
(c) shearing stress and shearing strain
(d) tensile stress and longitudinal strain

56. A motor pump lifts 6 tonnes of water from a well of depth 25 m to the first floor of height 35 m from the ground floor in 20 minutes. The power of the pump (in kW) is [g = 10 m s^{-2}]
(a) 6 (b) 1.5 (c) 12 (d) 3

57. A substance of mass 49.53 g occupies 1.5 cm^3 of volume. The density of the substance (in g cm^{-3}) with correct number of significant figures is
(a) 3.3 (b) 3.302 (c) 3.30 (d) 3.300

58. A galvanometer of resistance 50 Ω is connected to a battery of 3 V along with a resistance of 2950 Ω in series shows full-scale deflection of 30 divisions. The additional series resistance required to reduce the deflection to 20 divisions is
(a) 4440 Ω (b) 1500 Ω
(c) 7400 Ω (d) 2950 Ω

59. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of an electromagnetic wave, the direction of propagation of the wave is along

(a) $\vec{B}\times\vec{E}$ (b) $\vec{B}$

(c) $\vec{E}$ (d) $\vec{E}\times\vec{B}$

60. The minimum value of effective capacitance that can be obtained by combining 3 capacitors of capacitances 1 pF, 2 pF and 4 pF is

(a) $\frac{7}{4}$ pF (b) $\frac{4}{7}$ pF (c) 1 pF (d) 2 pF

SOLUTIONS

1. (b): As the iron rod is inserted, the magnetic field inside the coil magnetizes the iron increasing the magnetic field inside it. Hence, the inductance of the coil increases. As a result, a larger fraction of the applied ac voltage appears across the inductor, leaving less voltage across the bulb. Therefore, the blub glows less brightly.

2. (b)

3. (c): A bar magnet is allowed to fall through a conductor, *i.e.*, copper coil, and the magnetic flux linked with coil is changing, then eddy currents are induced in it, which according to Lenz's law will be produced in such a direction so as to oppose the change in magnetic flux and hence produce damping effect. Therefore, the net acceleration of magnet will be less than the acceleration due to gravity.

4. (c): Force on each sphere

$$= \frac{kq_1q_2}{r^2} = \frac{-16k}{d^2}\times10^{-18}\,\text{N}$$

When both the spheres are allowed to touch each other, the charges get redistributed.

Charge on each sphere $= \frac{(2-8)}{2}\,\text{nC} = -3\,\text{nC}$

Force on each sphere $= \frac{k(-3\,\text{nC})^2}{r^2} = \frac{9k}{r^2}\times10^{-18}\,\text{N}$

According to question,

$$\frac{16k}{d^2}\times10^{-18} = \frac{9k}{r^2}\times10^{-18};\ r = \frac{3}{4}d$$

5. (b): ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{92}\text{U} + x\,{}^{4}_{2}\alpha + y\,{}^{0}_{-1}\beta$

Using law of conservation of charges and masses.

$238 = 234 + 4x$ or $x = 1$

and $92 = 92 + 2x - y$ or $y = 2x = 2$

Therefore, one α and two β particles are emitted.

6. (b): Using Kirchhoff's law

$V_{AB} = 2(0.2\text{ mA} \times 5\text{ k}\Omega) + (0.2\text{ V}) = 2.2\text{ V}$

7. (c): Fringe width, $\beta = \frac{\lambda D}{d}$

$\therefore$ If we replace yellow light with blue light, *i.e.*, longer wavelength with shorter one, therefore the fringe width decreases.

8. (b): $C_1 = 2\ \mu\text{F}$, $C_2 = 4\ \mu\text{F}$

In series combination the equivalent capacitance will be, $C = \frac{C_1C_2}{C_1+C_2} = \left(\frac{2\times4}{2+4}\right)\mu\text{F} = \frac{4}{3}\mu\text{F}$

Potential difference applied, $V = 6$ V

Electric charged stored, $Q = CV = \left(\frac{4}{3}\times6\right)\mu\text{C}$

$= 8\ \mu\text{C}$

Energy stored in the system, $U = \frac{1}{2}CV^2$

$= \frac{1}{2}\times\frac{4}{3}\times10^{-6}\times(6)^2\text{ J} = 24\ \mu\text{J}$

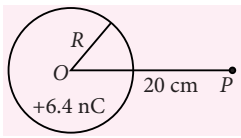
9. (d): Number of electrons removed $= 4 \times 10^{10}$

Charge on this sphere $= 4 \times 10^{10} \times 1.6 \times 10^{-19}$C

$= 6.4 \times 10^{-9}$C $= 6.4$ nC

Diameter of sphere, $D = 20$ cm $= 0.2$ m

Distance from the centre, $d = 20$ cm $= 0.2$ m



Electric field at point P, $E = \frac{q}{4\pi\varepsilon_0 d^2}$

$$= \left(\frac{9\times10^9\times6.4\times10^{-9}}{(0.2)^2}\right)\text{N C}^{-1} = 1440\text{ N C}^{-1}$$

10. (a)

11. (a): $X_L = \frac{1}{\sqrt{3}}\Omega$, $R = 1\ \Omega$, $V = 200$ V, $\upsilon = 50$ Hz

In series, LR circuit, phase lag, ϕ is given by

$$\tan\phi = \frac{X_L}{R} = \frac{\frac{1}{\sqrt{3}}}{1} = \frac{1}{\sqrt{3}} \quad \therefore \quad \phi = \frac{\pi}{6}$$

$\therefore \quad 2\pi\upsilon\Delta t = \frac{\pi}{6}$, (where, Δt is time lag)

$$\Delta t = \frac{\pi}{6\times2\times\pi\times50} = \frac{1}{600}\text{ s}$$

12. (b): NAND gate is the universal gate.

13. (a): Zener diode is a device which is used as voltage regular when operated in reverse bias.

14. (a)

15. (c) : For ferromagnetic substances, susceptibility is a large and positive value, *i.e.*, $\chi >> 1$

16. (c) : Efficiency, $\eta = 1 - \frac{T_2}{T_1}$

$\therefore$ For the combination (c) *i.e.*, 100 K, 80 K the efficiency will be least.

17. (c) : The mean energy of a molecule of an ideal gas is $\frac{3}{2}kT$.

18. (d): Whenever external pressure is applied on any part of a fluid contained in a vessel, it is transmitted undiminished and equally in all directions. This is the Pascal's law for transmission of fluid pressure. Hydraulic lift is one of the applications of Pascal's law.

19. (d): Initial velocity, $u = 20$ m s^{-1};
Final velocity, $v = 0$ m s^{-1};
Distance travelled, $s = 40$ m
Using third equation of motion,
$v^2 - u^2 = 2as$; $0 - 20^2 = 2 \times a \times 40$
We get, $a = -5$ m s^{-2}
For second case, $u = 2 \times 20$ m s^{-1} = 40 m s^{-1},
$v = 0$ m s^{-1} and $a = -5$ m s^{-2}
Using the third equation of motion,

$$s = \frac{0-(40)^2}{2(-5)} = 160 \text{ m}$$

$\therefore$ Distance travelled by the same car travelling at double velocity is 160 m.

20. (a) : For ohmic devices, $V \propto I$
$\therefore$ Graph (a) represents the correct *I-V* characteristics.

21. (c) : Given : $I = 50\%$ of $I_0 = I_0/2$
If the pass axis of P_2 makes an angle θ with the pass axis of P_1, then
$I = I_0 \cos^2\theta$ (By Malus' law)
$\therefore$ $I_0/2 = I_0 \cos^2\theta$

or $\cos^2\theta = \frac{1}{2}$ or $\cos\theta = \frac{1}{\sqrt{2}}$

or $\theta = 45°$

22. (a) : Let us consider a point *P* at a distance *x* from the centre of loop, where magnetic field is given by $B_0 = 5\sqrt{5}B$. (B_0 is the magnetic field at centre). If current *I* is flowing through loop and radius of loop is *R*, then

$$B = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}$$

According to question,

$$5\sqrt{5}\frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}} = \frac{\mu_0 I}{2R} \qquad \left[\because B_0 = \frac{\mu_0 I}{2R}\right]$$

$\Rightarrow$ $(\sqrt{5}R)^3 = (x^2+R^2)^{3/2}$ $\Rightarrow$ $5R^2 = (x^2 + R^2)$

or $x^2 = 4R^2$ or $x = \pm 2R$

Here, $R = 0.1$ m $\Rightarrow$ $x = 0.2$ m

23. (b): When particle is moving perpendicular to a magnetic field, then it moves in circular path of radius, $r = mv/qB$

$\because$ Kinetic energy of all the three particles is same.

$\therefore$ $\frac{1}{2}m_p v_p^2 = \frac{1}{2}m_d v_d^2 = \frac{1}{2}m_\alpha v_\alpha^2$

As we know $m_p = 1$ u, $m_d = 2$ u, $m_\alpha = 4$ u

$\therefore$ $v_p : v_d : v_\alpha = 2 : \sqrt{2} : 1$

or $v_d = \frac{1}{\sqrt{2}}v_p$ and $v_\alpha = \frac{1}{2}v_p$

$$r_p : r_d : r_\alpha = \frac{m_p v_p}{q_p B} : \frac{m_d v_d}{q_d B} : \frac{m_\alpha v_d}{q_\alpha B}$$

$$= \frac{1\times v_p}{1\times B} : \frac{2\times 1\times v_p}{1\times\sqrt{2}\times B} : \frac{4\times 1\times v_p}{2\times 2\times B} = 1 : \sqrt{2} : 1$$

24. (c)

25. (b): Required work done = Change in potential energy of the system

$$W = U_f - U_i = k\frac{q_1 q_2}{r_f} - k\frac{q_1 q_2}{r_i} = k\, q_1 q_2\left[\frac{1}{r_f} - \frac{1}{r_i}\right]$$

$\therefore$ $W = (9 \times 10^9)(3 \times 10^{-9} \times 1 \times 10^{-9})$

$$\times\left[\frac{1}{4\times10^{-2}} - \frac{1}{5\times10^{-2}}\right]$$

$= 27 \times 10^{-7} \times (0.05) = 1.35 \times 10^{-7}$ J

26. (d): Rayleigh's law of scattering of light states that the intensity of light of wavelength λ present in scattered light is inversely proportional to the fourth power of λ, provided the size of scattering particles are much smaller than λ. $I \propto \frac{1}{\lambda^4}$

27. (d): Frequency of oscillations made by a simple pendulum of length *l* is $\upsilon = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ $\Rightarrow$ $\upsilon \propto \frac{1}{\sqrt{l}}$

Since, *A* completes 10 oscillations in 20 s

$\Rightarrow$ $\upsilon_A = \frac{10}{20} = 0.5$ Hz. Similarly, $\upsilon_B = \frac{8}{10} = 0.8$ Hz

$\therefore$ $\frac{\upsilon_A}{\upsilon_B} = \frac{5}{8} = \sqrt{\frac{l_B}{l_A}}$ or $\frac{l_A}{l_B} = \frac{64}{25}$

28. (b): When the particle is dropped from height H, then the velocity at lowest point is $v=\sqrt{2gH}$

de Broglie's wavelength, $\lambda=\frac{h}{mv}=\frac{h}{m\sqrt{2gH}}$

$\Rightarrow \quad \lambda \propto \frac{h}{\sqrt{H}} \quad$ or $\quad \lambda \propto H^{\frac{-1}{2}}$

29. (b)

30. (a): According to Cartesian sign convention, the distances measured in the same direction as the incident light are taken as positive and those measured in the direction opposite to the direction of incident light are taken as negative.

31. (c): $\because$ l = 50 cm, I = 2.5 A, B = 0.5 T

Magnetic field $\vec{B}$ exerts force on straight wire given by $\vec{F}=I\vec{l}\times\vec{B}$

It is clear from the above expression that this force will act vertically upwards.

For mid-air suspension, this must be balanced by the force due to gravity.

$\therefore$ Weight of wire = force exerted by magnetic field.

$mg = IlB \sin 90°$

$$m=\frac{IlB\times 1}{g}=\frac{2.5\times 0.5\times 0.5}{10}=625\times 10^{-4}\,\text{kg}=62.5\,\text{g}$$

32. (b): The magnetic field $\vec{B}$ is given as $T=2\pi\sqrt{\frac{I}{mB}}$

Here; $B = 2 \times 10^{-2}$ T, $I = 12 \times 10^{-6}$ kg m^2, $m = 6 \times 10^{-2}$ A m^2

Putting these values we get,

$$T=2\pi\sqrt{\frac{12\times 10^{-6}}{6\times 10^{-2}\times 2\times 10^{-2}}}=\frac{2\times 3.14}{10}\approx 0.6\,\text{s}$$

The time taken by the dipole to complete 20 oscillations = 0.6 × 20 = 12 s

33. (b): The working of magnetic braking of trains is based on eddy current.

34. (b)

35. (b): Here , power = 12 W, output voltage = 48 V

$$i_{\text{rms}}=\frac{P}{V}=\frac{12}{48}=\frac{1}{4}\,\text{A}$$

Value of Peak current = $\sqrt{2}\,i_{\text{rms}}=\frac{\sqrt{2}}{4}=\frac{1}{2\sqrt{2}}$ A

36. (b): Object distance, u = –10 cm,

focal length, $f=\frac{R}{2}=\frac{-15}{2}=-7.5\,\text{cm}$

By mirror formula, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{(-7.5)}-\frac{1}{(-10)}$

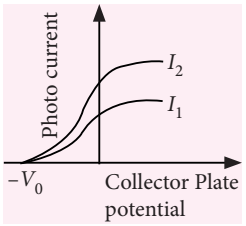
$\frac{1}{v}=\frac{-25}{750} \quad \Rightarrow \quad v=-30\,\text{cm}$

Magnification, $m=\frac{-v}{u}=-\frac{-30}{-10}=-3$

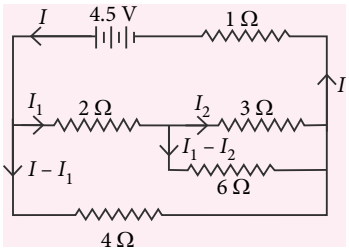
$\therefore$ The image formed is real, magnified and inverted.

37. (b): In a nuclear reactor, the moderator is used to decrease the speed of neutrons.

38. (c): For a given frequency of incident radiation, the photo current is directly proportional to the intensity of light *i.e.*, $I_2 > I_1$.



39. (d): The given circuit can be redrawn as shown in figure.



Equivalent resistance of middle branch in the circuit,

$$R_1=2+\frac{3\times 6}{3+6}=4\,\Omega$$

Now, R_1 = 4 Ω, and 4 Ω are in parallel, so equivalent resistance of the circuit is given by

$$R=1+\frac{4\times 4}{4+4}=3\,\Omega$$

Current drawn from battery, $I=\frac{V}{R}=\frac{4.5}{3}=\frac{3}{2}$ A

$I_1 = I - I_1$ (Both branches have same resistance)

$\therefore \quad I_1=\frac{I}{2}=\frac{3}{4}$ A

Current through 3 Ω resistance,

$$I_2=\frac{6}{3+6}I_1=\frac{6}{9}\times\frac{3}{4}=\frac{1}{2}\,\text{A}$$

Power dissipated in 3 Ω resistance, $P = I_2^2R$

$$=\left(\frac{1}{2}\right)^2\times 3=\frac{3}{4}\,\text{W}=0.75\,\text{W}$$

40. (a): Reading of the spring balance = apparent weight of mass = $m(g - a)$ = $50(g - g)$ = 0

41. (a): Emitter is of moderate size and heavily doped among the three parts of a transistor.

42. (b): Resistance, $R=\frac{\rho L}{A}=\frac{4\rho L}{\pi D^2}$

$\therefore$ Option (b) is suitable among the four options.

43. (d): $\vec{A}$ is perpendicular to $\vec{B}$. $\therefore$ $\vec{A}\cdot\vec{B}=0$

or $(2\hat{i}+3\hat{j}+8\hat{k})\cdot(-4\hat{i}+4\hat{j}+\alpha\hat{k})=0$

$-8 + 12 + 8\alpha = 0$ or $\alpha = -1/2$

44. (a): Bar magnet produces magnetic field.

45. (c): Since germanium is a semiconductor and its energy gap lies between 1 and 3 eV.

46. (a): In hydrogen atom, the energy required to excite an electron from $n = 2$ to $n = 4$ state,

$$E_4 - E_2 = \frac{-13.6}{4^2} - \frac{-13.6}{2^2} = -0.85 + 3.4 = 2.55 \text{ eV}$$

47. (c): According to Huygen's principle, during the refraction of light from air to a denser medium then both wavelength and speed decrease.

48. (c): The acceleration due to gravity at a depth below the earth's surface is,

$$g_d = g\left(\frac{R_e - d}{R_e}\right) = g\left(1 - \frac{d}{R_e}\right) = 9.8\left(1 - \frac{1600}{6400}\right)$$

$= 9.8 \times 0.75 = 7.35 \text{ m s}^{-2}$

49. (c): Here, $v = 400 \text{ m s}^{-1}$,

D = distance between the ends of wings = 20 m,

$B = 4 \times 10^{-4}$ T, angle of dip, $\delta = 30°$

Motional emf, $\varepsilon = B_v\, vl$

$= 4 \times 10^{-4} \times \sin 30° \times 400 \times 20 = 3.2 \times \frac{1}{2} = 1.6$ V

50. (a): Here; current = 90 mA, diameter of cylindrical conductor = 0.1 mm, $\pi \simeq 3$

$$\text{The current density} = \frac{I}{\pi\frac{D^2}{4}} = \frac{90\times10^{-3}}{3\times\frac{(0.1\times10^{-3})^2}{4}}$$

$$= 1.2\times10^{7} \text{ A m}^{-2}$$

51. (a): When two balls are thrown simultaneously in air, they will follow parabolic path and the force acting on the system is the gravitational pull.

$\therefore$ The force on centre of mass is the force due to gravity. This implies that the acceleration of the centre of mass is equal to the acceleration due to gravity.

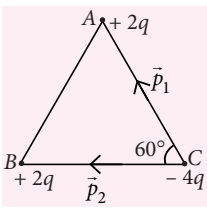
52. (b)

53. (a): Net dipole of the system, $\vec{p} = \vec{p}_1 + \vec{p}_2$

$$p = \sqrt{p_1^2 + p_2^2 + 2p_1p_2\cos\theta}$$

$(\because p_1 = p_2 = 2qx)$

$$= \sqrt{12q^2x^2} = 2\sqrt{3}\,qx$$



54. (b): The mass defect of $^4_2$He, Δm = 0.03 u

$$\text{The binding energy per nucleon} = \frac{\Delta m\times931}{4}\text{MeV}$$

$$= \frac{0.03\times931}{4}\text{MeV} = 6.9825 \text{ MeV}$$

55. (d): Young's modulus is elastic property of a material which is defined as the ratio of tensile stress and longitudinal strain.

$$Y = \frac{F/A}{\Delta l/l} = \frac{\text{Tensile stress}}{\text{Longitudinal strain}}$$

56. (d): m = 6 tonnes = 6000 kg,

h = 25 m + 35 m = 60 m,

t = 20 min = 20 × 60 s = 1200 s

$$\text{Power} = \frac{\text{Work done}}{\text{time taken}} = \frac{mgh}{20\times60}$$

$$= \frac{6000\times10\times60}{1200} = 3000 \text{ W} = 3 \text{ kW}$$

57. (*): Mass = 49.53 g, volume = 1.5 cm^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{49.53}{1.5} = 33.02 \text{ g cm}^{-3}$$

Number of significant figures in given data are 4 and 2 for mass and volume respectively.

The correct number of significant number in result must be 2.

$\therefore$ The density of substance is 3.3 g cm^{-3}

*None of the given options is correct.

58. (b): Let current per division be I

For full scale deflection,

$$30I = \frac{3}{50+2950} = \frac{3}{3000};\ I = \frac{1}{3}\times10^{-4}\text{ A}$$

When additional series resistance R is connected,

$$20I = \frac{3}{50+2950+R} \Rightarrow 20\times\frac{1}{3}\times10^{-4} = \frac{3}{3000+R}$$

$R = 1500\ \Omega$

59. (d): If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of an electromagnetic wave, the direction of propagation of the wave is along $\vec{E}\times\vec{B}$.

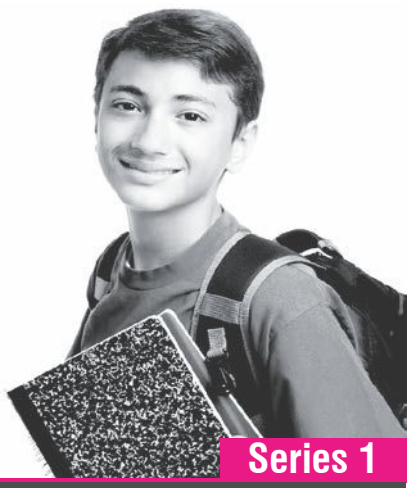
60. (b): C_1 = 1 pF, C_2 = 2 pF and C_3 = 4 pF

The combined capacitance is least when all the capacitors are connected in series combination.

The effective capacitance C' will be,

$$\frac{1}{C'} = 1 + \frac{1}{2} + \frac{1}{4} = \frac{7}{4} \quad \text{or} \quad C' = \frac{4}{7}\text{ pF}$$

ACE YOUR WAY CBSE XII



Series 1

CHAPTERWISE PRACTICE PAPER

ELECTRIC CHARGES AND FIELDS | ELECTROSTATIC POTENTIAL AND CAPACITANCE

Time Allowed : 3 hours | Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) All questions are compulsory.
(ii) Q.no.1 to 5 are very short answer questions and carry 1 mark each.
(iii) Q.no.6 to 10 are short answer questions and carry 2 marks each.
(iv) Q.no.11 to 20 are short answer questions and carry 3 marks each.
(v) Q.no.21 is a value based question and carries 4 marks.
(vi) Q.no.24 to 26 are long answer questions and carry 5 marks each.
(vii) Use of calculators is not allowed.

SECTION - A

1. An electric dipole of dipole moment 20×10^{-6} C m is enclosed by a closed surface. What is the net electric flux coming out of the surface?
2. Two charges q_1 and q_2, separated by a small distance, satisfy the equation $q_1 + q_2 = 0$. What does it tell about the charges?
3. Under what condition, does a charged sphere or spherical shell behave as a point charge for the purpose of determining electric field due to it?
4. A charged conical conductor loses its charge earlier than a similarly charged sphere. Why?
5. How is the number of electric field lines related to the field strength at a point?

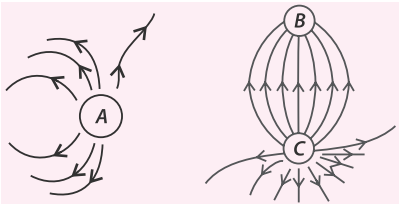
SECTION - B

6. Define electric flux. Write its SI unit.
   A charge q is enclosed by a spherical surface of radius R. If the radius is reduced to half, how would the electric flux through the surface change?
7. An electric dipole is a pair of equal and opposite charges, separated by a small fixed distance between them. The dipole is free to move. What is the action on it, when it is placed in
   (i) a uniform electric field, and
   (ii) a non-uniform electric field?
8. Two metal spheres, one of radius R and the other of radius $2R$, both have same surface charge density σ. They are brought in contact and separated. What will be new surface charge densities on them?
9. A 4 μF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 2 μF capacitor. How much electrostatic energy of the first capacitor is lost in the form of heat and electromagnetic radiation?

   OR

   If the total charge enclosed by a surface is zero, does it imply that the electric field everywhere on the surface is zero? Conversely, if the electric field everywhere on the surface is zero, does it imply that the charge inside is zero?

10. Figure shows the electric field lines around three point charges A, B and C.



(a) Which charges are positive?
(b) Which charge has the largest magnitude? Why?
(c) In which region or regions of the picture could the electric field be zero? Justify your answer.

SECTION - C

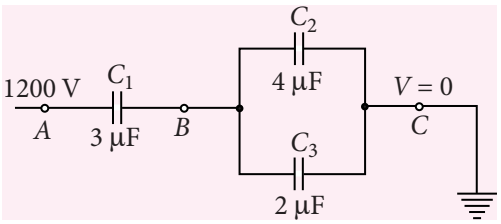
11. Two identical small-sized charged spheres are suspended by strings of equal length. Two strings make an angle of 30° with each other. When suspended in a liquid of density 800 kg m^{-3}, the angle remains the same. Find the value of dielectric constant of the liquid. Given that density of material of spheres is 1600 kg m^{-3}.

12. Deduce an expression for the capacitance of a parallel-plate capacitor when a dielectric slab is inserted between its plates. Assume the slab thickness to be less than plate separation.

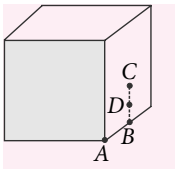
13. Two tiny spheres carrying charges 1.5 μC and 2.5 μC are located 30 cm apart. Find the potential and electric field:
(a) at the mid-point of the line joining the two charges, and
(b) at a point 10 cm from this mid-point in a plane normal to the line and passing through the mid-point.

14. An electric dipole of length 2 cm is placed with its axis making an angle of 60° to a uniform electric field of 10^5 N C^{-1}. If it experiences a torque of $8\sqrt{3}$ N m, calculate the
(i) magnitude of the charge on the dipole, and
(ii) potential energy of the dipole.

15. In the circuit shown in figure, if the point C is earthed and point A is given a potential of +1200 V, find the charge on each capacitor and the potential at the point B.



16. What will be the total flux through the faces of the cube with side of length a if a charge q is placed at



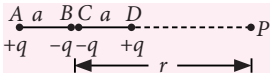
(a) A : a corner of the cube.
(b) B : mid-point of an edge of the cube.
(c) C : centre of a face of the cube.
(d) D : mid-point of B and C.

17. Calculate potential on the axis of a disc of radius R due to a charge Q uniformly distributed on its surface.

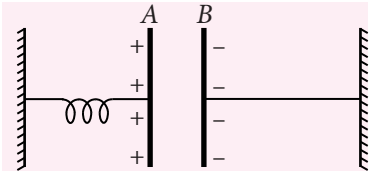
18. What is a spherical capacitor? Derive an expression for its capacitance.

19. Find the equation of the equipotentials for an infinite cylinder of radius r_0, carrying charge of linear density λ.

20. Figure shows a charge array known as an electric quadrupole. For a point on the axis of quadrupole, obtain the dependence of potential on r for $r/a >> 1$, and contrast your results with that due to an electric dipole, and an electric monopole (*i.e.*, a single charge).



21. The plate A of a parallel plate capacitor is connected to a spring of force constant k and can move, while the plate B is fixed. The arrangement is held between two rigid supports as shown in figure. If a charge $+q$ is placed on plate A and $-q$ on plate B, by how much does the spring elongate?



OR

Where is the energy stored in a capacitor? Derive an expression for the energy density of an electric field.

22. Two charged conducting spheres of radii a and b are connected to each other by a wire. What is the ratio of electric fields at the surfaces of the two spheres? Use the result obtained to explain why charge density on the sharp and pointed ends of a conductor is higher than that on its flatter portions.

SECTION - D

23. Father of Devansh is a surgeon and has a video monitor, Devansh observed that after the use the video monitor, surface remain charged for long. He further heard his father instructing his assistant not

to bring his finger close to the screen or touch the screen with contaminated gloves as the screen may become a source of bacteria.

Devansh asked for the explanation from his father and shared his learning with his classmates during the physics period. His teacher and classmates appreciated for him.

(i) What values had Devansh shown?

(ii) How did Devansh's father explain his observations?

SECTION - E

24. **(a)** "Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is". Justify this statement with the help of a suitable example.

(b) Use Gauss's law to find the electric field due to a uniformly charged spherical shell.

OR

(a) Derive the expression for the energy stored in a parallel plate capacitor.

(b) A fully charged parallel plate capacitor is connected across an uncharged identical capacitor. Show that the energy stored in the combination is less than that stored initially in the single capacitor.

25. Define dipole moment of an electric dipole. Show mathematically that the electric field intensity due to a short dipole at a distance 'd' along its axis is twice the intensity at the same distance along the equatorial axis.

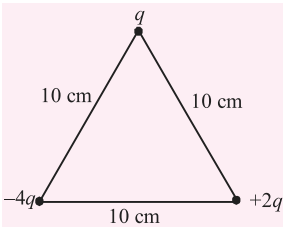
OR

(a) Show that the work done to move a charge around a closed path in electric field is zero.

(b) What are the properties of equipotential surfaces.

26. (a) Derive an expression for the torque experienced by an electric dipole kept in a uniform electric field.

(b) Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown. Here $q = 1.6 \times 10^{-10}$ C.



OR

What is electrostatic potential energy? Derive an expression of potential energy of a system.

(a) two point charges

(b) three point charges

SOLUTIONS

1. The net charge (q) on the dipole, comprising of two equal and opposite charges, is zero, $\phi_c = \frac{q}{\varepsilon_0} = 0$.

Thus, net electric flux coming out of the closed surface enclosing the electric dipole is zero.

2. The equation signifies that the electrical charges are algebraically additive and in the given case, q_1 and q_2 are equal in magnitude and opposite in sign.

3. When the electric field is to be found at a point outside the charged sphere or a charged spherical shell, we can presume whole charge of a sphere or spherical shell to be concentrated at its centre.

4. In case of a conical conductor, the charge density is maximum at its pointed end. Due to this large density, the charge leaks away from this end. But in case of a similarly charged sphere, the charge density is uniform over its surface. Thus, the charged conical conductor loses its charge earlier than a similarly charged sphere.

5. The number of electric field lines crossing per unit surface area around a given point is directly proportional to the strength of electric field at that point. Higher the field strength, more crowded the electric field lines around that point.

6. The electric flux through a given area represents the total number of electric lines of force passing normally through that area. If the electric field $\vec{E}$ makes an angle θ with the normal to the area elements ΔS, then the electric flux is

$$\Delta\phi_E = E\Delta S \cos\theta = \vec{E}.\Delta\vec{S}$$

The electric flux through any surface S, open or closed, is equal to the surface integral of $\vec{E}$ over the surface S.

$$\phi_E = \int_S \vec{E}.d\vec{S}$$

SI unit of electric flux = $\text{N m}^2\text{ C}^{-1}$

According to Gauss's law, electric flux through a closed surface is

$$\phi_E = \frac{q}{\varepsilon_0}$$

It depends only on charged enclosed in Gaussian surface not on its radius for sphere.

7. (i) In a uniform electric field, an electric dipole experiences two equal, opposite and parallel forces at its two ends. The net force on it is zero but it experiences a torque due to which it rotates about an axis perpendicular to the electric field and passing through its mid-point.

(ii) In a non-uniform electric field, an electric dipole experiences two unequal and non-parallel forces at its two ends. The two forces add up to give a resultant force and a torque. So the dipole will accelerate linearly in the direction of the resultant force and also accelerate angularity in the direction of the resultant torque.

8. Before contact, charges on the two spheres are $Q_1 = \sigma 4\pi R^2$, and $Q_2 = \sigma 4\pi (2R)^2 = 4\,Q_1$

When the two spheres are brought in contact, their charges are shared till their potentials become equal. If Q'_1 and Q'_2 are final charges on the two spheres after contact, then as $V_1 = V_2$

$$\frac{Q'_1}{4\pi\varepsilon_0 R} = \frac{Q'_2}{4\pi\varepsilon_0 (2R)} \quad \therefore \quad Q'_2 = 2Q'_1 \qquad \text{...(i)}$$

As there is no loss of charge in the process, therefore,

$$Q'_1 + Q'_2 = Q_1 + Q_2 = Q_1 + 4Q_1 = 5\,Q_1$$
$$= 5(\sigma \cdot 4\pi R^2)$$

Using eqn. (i), $Q'_1 + 2Q'_1 = 5\,\sigma\, 4\,\pi\, R^2$

$$Q'_1 = \frac{5}{3}\sigma 4\pi R^2 \text{ and } Q'_2 = 2Q'_1 = \frac{10}{3}\sigma 4\pi R^2$$

Hence, $\sigma_1 = \dfrac{Q'_1}{4\pi R^2} = \dfrac{5}{3}\sigma$ and $\sigma_2 = \dfrac{Q'_2}{4\pi (2R)^2} = \dfrac{5}{6}\sigma$

9. Initial electrostatic energy of the 4 μF capacitor is

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2}\times 4\times 10^{-6}\times (200)^2 = 8\times 10^{-2}\text{ J}$$

Charge on 4 μF capacitor

$$= CV = 4\times 10^{-6}\times 200 = 8\times 10^{-4}\text{ C}$$

When the 4 μF and 2 μF capacitors are connected together, both attain a common potential V. Thus

$$V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{8\times 10^{-4}\text{ C}}{(4+2)\times 10^{-6}\text{ F}} = \frac{400}{3}\text{ V}$$

Final electrostatic energy of the combination,

$$U_f = \frac{1}{2}\times (4+2)\times 10^{-6}\times \left(\frac{400}{3}\right)^2 \text{ J} = \frac{16}{3}\times 10^{-2}\text{ J}$$
$$= 5.33\times 10^{-2}\text{ J}$$

Electrostatic energy of the first capacitor lost in the form of heat and electromagnetic radiation is

$$\Delta U = U_i - U_f = (8 - 5.33)\times 10^{-2}\text{ J} = 2.67\times 10^{-2}\text{ J}$$

OR

As $q = 0$, so from the Gauss's theorem, we have

$$\phi_E = \oint \vec{E}\,.\,d\vec{S} = 0$$

Clearly, the above equation does not imply that $\vec{E}$ is necessarily zero at all points on the Gaussian surface. It may also be possible that $\vec{E}$ is non-zero but it is perpendicular to $d\vec{S}$ at all points on the surface, even then the integral

$\oint \vec{E}\,.\,d\vec{S}$ would be zero.

However, the converse is true. If $\vec{E}$ is zero at every point on Gaussian surface, then from Gauss's theorem

$$\phi_E = \oint \vec{E}\,.\,d\vec{S} = \frac{q}{\varepsilon_0}$$

we get, $q = 0$

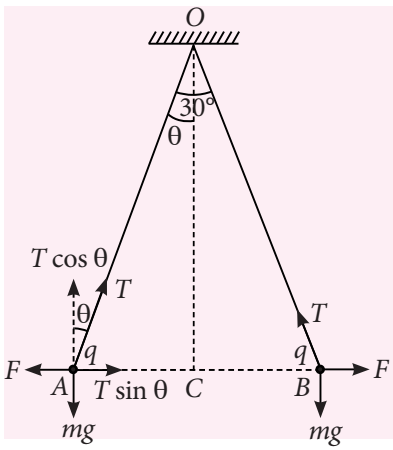
i.e., no net charge is enclosed by the Gaussian surface.

10. (a) Charges A and C are positive since electric lines of force emanate from them.

(b) Charge C has the largest magnitude since maximum number of field lines are associated with it.

(c) There is no neutral point between a positive and a negative charge. A neutral point may exist between two like charges. From the figure we see that a neutral point exists between charges A and C. Also between two like charges the neutral point is closer to the charge with smaller magnitude. Thus, electric field is zero near charge A.

11. Initially, forces acting on each charged sphere are electric force F, force due to gravity mg, and tension T in string as shown in the figure.



If each string subtends an angle θ with vertical, then

$$T\cos\theta = mg \quad \text{and} \quad T\sin\theta = F$$

$$\Rightarrow \quad \tan\theta = \frac{F}{mg} \qquad \text{...(i)}$$

When the charge spheres of density $\rho = 1600\,\text{kg m}^{-3}$ are suspended in a liquid of density $\sigma = 800\,\text{kg m}^{-3}$ and dielectric constant K, the electric force becomes,

$$F' = \frac{F}{K}$$

and force of gravity becomes,

$$mg' = mg\left(1-\frac{\sigma}{\rho}\right)$$

As even now angle θ remains unchanged, we have

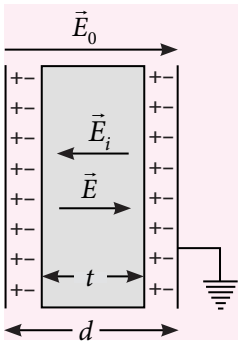
$$\tan\theta = \frac{F'}{mg'} = \frac{F}{K\,mg\left(1-\frac{\sigma}{\rho}\right)} \qquad \text{...(ii)}$$

On comparing eqn. (i) and (ii), we get

$$K\left(1-\frac{\sigma}{\rho}\right)=1$$

$$\Rightarrow \quad K = \frac{1}{\left(1-\frac{\sigma}{\rho}\right)} = \frac{1}{\left(1-\frac{800}{1600}\right)} = 2$$

12. Let a dielectric slab of thickness t be introduced between the plates of the capacitor which are at a distance d apart as shown in figure.



Here, E_0 is the external (*i.e.*, applied electric field), E_i is the induced electric field in the slab and E is the resulant electric field inside the slab, *i.e.*, $E = E_0 - E_i$. We know that

$$\varepsilon_r = E_0/E$$

If no dielectric is present, the potential difference is given by

$$V_0 = E_0 d$$

When the dielectric slab is present, the potential difference is given by

$$V = E_0(d-t) + Et$$

This is due to the reason that within the space $(d - t)$ not filled by the slab, the field is E_0 whereas within the slab of thickness t the field is E.

Let C and C_0 be the values of the capacitance of the capacitor with and without dielectric respectively between its plates.

Clearly, $$\frac{C}{C_0} = \frac{V_0}{V} = \frac{E_0 d}{E_0(d-t)+Et}$$

$$= \frac{d}{(d-t)+(E/E_0)t}$$

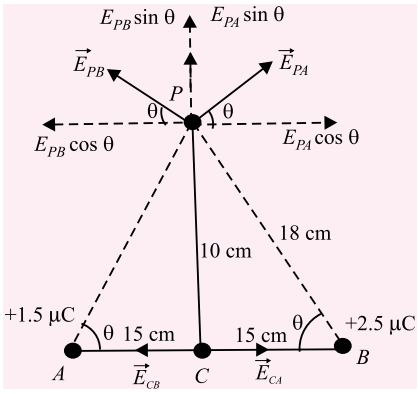
or $$\frac{C}{C_0} = \frac{d}{(d-t)+t/\varepsilon_r}$$

Further, as $C_0 = \dfrac{\varepsilon_0 A}{d}$,

$$C = \frac{(\varepsilon_0 A/d)d}{(d-t)+t/\varepsilon_r} = \frac{\varepsilon_0 A}{(d-t)+t/\varepsilon_r}$$

It is obvious that $C > C_0$. Thus, the presence of a dielectric slab between the plates of a capacitor increases its capacitance.

13. (a) At mid point C of line joining two charges, electric potential is $V_C = V_{CA} + V_{CB}$



or $$V_C = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_A}{r_{CA}} + \frac{q_B}{r_{CB}}\right]$$

$$= 9\times10^9\left[\frac{1.5}{15}+\frac{2.5}{15}\right]\times\frac{10^{-6}}{10^{-2}}$$

or $V_C = 2.4\times10^5$ V

Electric field at point C is $E_C = E_{CB} - E_{CA}$

($E_{CB} > E_{CA}$ and they are directed opposite to each other)

or $$E_C = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_B}{r_{CB}^2} - \frac{q_A}{r_{CA}^2}\right]$$

$$= 9\times10^9\left[\frac{2.5}{15^2}-\frac{1.5}{15^2}\right]\times\frac{10^{-6}\,\text{C}}{10^{-4}\,\text{m}^2}$$

or $E_C = 4\times10^5\ \text{V m}^{-1}$

Electric field is directed in direction of $\vec{E}_{CB}$ *i.e.* from C to A.

(b) At given point P on perpendicular bisector of line joining two charges, electric potential is

$$V_P = V_{PA} + V_{PB} \quad \text{or} \quad V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_A}{r_{PA}} + \frac{q_B}{r_{PB}}\right]$$

$$= 9 \times 10^9 \left[\frac{1.5}{18} + \frac{2.5}{18}\right] \times \frac{10^{-6}}{10^{-2}}$$

or $\quad V_P = 2.0 \times 10^5$ V

Horizontal component of net electric field at point P is

$E_x = E_{PA} \cos\theta - E_{PB} \cos\theta = (E_{PA} - E_{PB}) \cos\theta$

$$\text{or} \quad E_x = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_A}{r_{PA}^2} - \frac{q_B}{r_{PB}^2}\right]\cos\theta$$

$$= 9 \times 10^9 \left[\frac{1.5}{18^2} - \frac{2.5}{18^2}\right] \times \frac{10^{-6}}{10^{-4}} \times \frac{15}{18}$$

or $\quad E_x = -2.3 \times 10^5$ V m^{-1}

Vertical component of net electric field at point P is

$E_y = E_{PA} \sin\theta + E_{PB} \sin\theta = [E_{PA} + E_{PB}] \sin\theta$

$$\text{or} \quad E_y = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_A}{r_{PA}^2} + \frac{q_B}{r_{PB}^2}\right]\sin\theta$$

$$= 9 \times 10^9 \left[\frac{1.5}{18^2} + \frac{2.5}{18^2}\right] \times \frac{10^{-6}}{10^{-4}} \times \frac{10}{18}$$

or $\quad E_y = 6.2 \times 10^5$ V m^{-1}

So, magnitude of net electric field at point P is

$$E_P = \sqrt{E_x^2 + E_y^2} = \sqrt{2.3^2 + 6.2^2} \times 10^5 = 6.6 \times 10^5 \text{ Vm}^{-1}$$

$\therefore \quad \vec{E}_q = 6.6 \times 10^5$ V m^{-1} directed at an angle

$$\tan\theta = \frac{E_y}{E_x} = \frac{6.2 \times 10^5}{-2.3 \times 10^5} = -2.6956$$

or $\quad \theta = -69.6°$

with the horizontal in negative x-direction *i.e.* at 69.6° with BA.

14. Here, $2a = 2$ cm $= 0.02$ m, $\theta = 60°$, $E = 10^5$ N C^{-1}, $\tau = 8\sqrt{3}$ N m

(i) $\tau = pE \sin\theta = q \times 2a \times E \sin\theta$

$\therefore \; 8\sqrt{3} = q \times 0.02 \times 10^5 \times \sin 60°$

$$\text{or} \quad q = \frac{8\sqrt{3} \times 2}{0.02 \times 10^5 \times \sqrt{3}} = 8 \times 10^{-3} \text{ C}$$

(ii) P.E. of the dipole is

$$U = -pE\cos\theta = -q \times 2a \times E\cos\theta$$
$$= -8 \times 10^{-3} \times 0.02 \times 10^5 \times \cos 60°$$
$$= -8 \text{ J}$$

15. Capacitors C_2 and C_3 form a parallel combination. Their equivalent capacitance is

$$C' = C_2 + C_3 = (4 + 2)\ \mu\text{F} = 6\ \mu\text{F}$$

Now C_1 and C' form a series combination, therefore, the equivalent capacitance of the entire network is

$$C = \frac{C_1 C'}{C_1 + C'} = \frac{3 \times 6}{3 + 6} = 2\ \mu\text{F}$$

The charge on the equivalent capacitor is

$$q = CV = 2 \times 10^{-6} \times 1200 \text{ C} = 2.4 \times 10^{-3} \text{ C}$$

This must be equal to the charge on C_1 and also the sum of the charges on C_2 and C_3. Thus,

$$V_A - V_B = \frac{q}{C_1} = \frac{2.4 \times 10^{-3}}{3 \times 10^{-6}} = 800 \text{ V}$$

$V_A = 1200$ V

$\therefore \quad V_B = 1200 - 800 = 400$ V

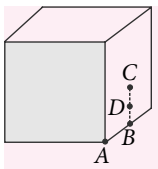
Hence, $V_B - V_C = 400 - 0 = 400$ V

$q_2 = C_2(V_B - V_C) = 4 \times 10^{-6} \times 400 \text{ C} = 1.6 \times 10^{-3}$ C

$q_3 = C_3(V_B - V_C) = 2 \times 10^{-6} \times 400 \text{ C} = 0.8 \times 10^{-3}$ C

$q_1 = q = 2.4 \times 10^{-3}$ C

16. (a) In figure when a charge q is placed at corner A of the cube, it is being shared equally by 8 cubes. Therefore, total flux through the faces of the given cube $= q/8\varepsilon_0$.



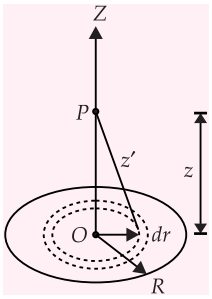
(b) When the charge q is placed at B, middle point of an edge of the cube, it is being shared equally by 4 cubes. Therefore, total flux through the faces of the given cube $= q/4\varepsilon_0$.

(c) When the charge q is placed at C, the centre of a face of the cube, it is being shared equally by 2 cubes. Therefore, total flux through the faces of the given cube $= q/2\varepsilon_0$.

(d) Similarly, when charge q is placed at D, the mid point of B and C, it is being shared equally by 2 cubes. Therefore, total flux through the faces of the given cube $= q/2\varepsilon_0$.

17. When a charge Q is distributed uniformly on the surface of a circular disc of radius R, surface charge density

$$\sigma = \frac{Q}{\pi R^2} \qquad \text{... (i)}$$



Consider a small element of the circular disc in the form of a circular strip of radius r and thickness dr.

Potential due to this element at any point P on the axis of the disc, where $OP = z$ is

$$dV = \frac{dq}{4\pi\varepsilon_0 z'} = \frac{\sigma 2\pi r\, dr}{4\pi\varepsilon_0\sqrt{r^2+z^2}}$$

Potential at P due to charge on the entire circular disc

$$V = \frac{\pi\sigma}{4\pi\varepsilon_0}\int_0^R \frac{2rdr}{\sqrt{r^2+z^2}} = \frac{2\pi\sigma}{4\pi\varepsilon_0}\left[\sqrt{r^2+z^2}\right]_0^R$$

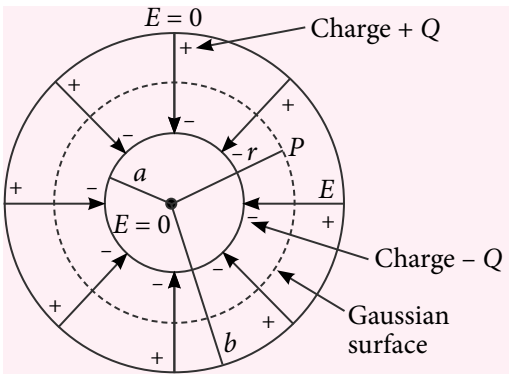
$$= \frac{2\pi\sigma}{4\pi\varepsilon_0}\left[\sqrt{R^2+z^2} - z\right]$$

Using eqn. (i), $V = \frac{2Q}{4\pi\varepsilon_0 R^2}[\sqrt{R^2+z^2} - z]$

18. A spherical capacitor consists of two concentric spherical shells of inner and outer radius a and b. The two shells carry charges $-Q$ and $+Q$ respectively. Since the electric field inside a hollow conductor is zero, so $\vec{E} = 0$ for $r < a$. Also the field is zero outside the outer shell, *i.e.*, $\vec{E} = 0$ for $r > b$. A radial field $\vec{E}$ exists in the region between the two shells due to the charge on the inner shell only.

To determine the electric field at any point P at a distance r from the centre, consider a concentric sphere of radius r as the Gaussian surface. Using Gauss's theorem,

$$\phi_G = E\,.\,4\pi r^2 = \frac{Q}{\varepsilon_0} \quad \text{or} \quad E = \frac{Q}{4\pi\varepsilon_0 r^2}$$



The potential difference (caused by the inner sphere alone) between the two shells will be

$$V = -\int_a^b \vec{E}\,.\,d\vec{r} = \int_a^b Edr = \int_a^b \frac{Q}{4\pi\varepsilon_0 r^2}dr$$

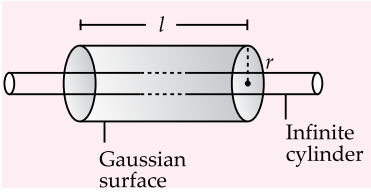
($\because$ $\vec{E}$ points radially inward and $d\vec{r}$ points outward so $\vec{E}\,.\,d\vec{r} = Edr = 180° = -Edr$)

$$V = \frac{Q}{4\pi\varepsilon_0}\int_a^b r^{-2}dr = \frac{Q}{4\pi\varepsilon_0}\left[-\frac{1}{r}\right]_a^b = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{b}\right]$$

The capacitance of the spherical capacitor is

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{b}\right]} \quad \text{or} \quad C = \frac{4\pi\varepsilon_0 ab}{b-a}$$

19. In the figure, shown an infinite cylinder of radius r_0 carrying charge of linear density λ. From symmetry, we find that the field lines must be radially outwards. Imagine a cylindrical Gaussian surface of radius r and length l.



According to Gauss's theorem,

$$\oint \vec{E}\cdot\vec{ds} = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

$$E(2\pi rl) = \frac{\lambda l}{\varepsilon_0} \quad \text{or} \quad E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\therefore \quad V(r) - V(r_0) = -\int_{r_0}^{r}\vec{E}\cdot\vec{dl} = \frac{\lambda}{2\pi\varepsilon_0}\ln\frac{r_0}{r}$$

The equipotential surfaces are cylinders of radius r is given by

$$\ln\frac{r}{r_0} = -\frac{2\pi\varepsilon_0}{\lambda}[V(r) - V(r_0)]$$

$$\therefore \quad r = r_0 e^{-2\pi\varepsilon_0[V(r)-V(r_0)]/\lambda}$$

20. $V_P = V_{PA} + V_{PB} + V_{PC} + V_{PD}$

$$\text{or} \quad V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{+q}{r+a} - \frac{q}{r} - \frac{q}{r} + \frac{q}{r-a}\right]$$

$$\text{or} \quad V_P = \frac{q}{4\pi\varepsilon_0}\left[\frac{r(r-a) - 2(r^2-a^2) + r(r+a)}{r(r^2-a^2)}\right]$$

$$\text{or} \quad V_P = \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2 - ra - 2r^2 + 2a^2 + r^2 + ra}{r(r^2-a^2)}\right]$$

$$\text{or} \quad V_P = \frac{1}{4\pi\varepsilon_0}\frac{q\cdot 2a^2}{r(r^2-a^2)} = \frac{1}{4\pi\varepsilon_0}\frac{p\cdot a}{r(r^2-a^2)}$$

For $\frac{r}{a} >> \text{or } r >> a$

$$V_P = \frac{1}{4\pi\varepsilon_0}\frac{pa}{r^3} \quad \text{or} \quad V_P \propto \frac{1}{r^3}.$$

However, electric potential at any point on axis of electric dipole is $V_P = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$ or $V \propto \frac{1}{r^2}$ and due to point charge is

$$V_P = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \text{ or } V \propto \frac{1}{r}.$$

21. As the two plates carry equal and opposite charge, they attract each other with a force F. As a result, the spring elongates by length l. Then,

$$F = -kl \quad ...(i)$$

where k is the force constant of the spring.

The capacitance of the parallel plae capacitor with plate separation x is

$$C = \frac{\varepsilon_0 A}{x}$$

The energy stored in the capacitor is

$$U = \frac{1}{2}\cdot\frac{q^2}{C} = \frac{q^2}{2}\cdot\frac{x}{\varepsilon_0 A}$$

As the electrostatic force is a conservative force, we can write

$$F = -\frac{dU}{dx} = -\frac{d}{dx}\left(\frac{q^2 x}{2\varepsilon_0 A}\right) = -\frac{q^2}{2\varepsilon_0 A} \quad ...(ii)$$

The negative sign shows that the force is attractive. From eqs. (i) and (ii), we get

$$-kl = -\frac{q^2}{2\varepsilon_0 A} \quad \text{or} \quad l = \frac{q^2}{2\varepsilon_0 kA}$$

OR

When a capacitor is charged, an electric field is set up in the region between its two plates. We can say that the work done in the charging process has been used in creating the electric field. Thus the presence of an electric field implies stored energy or the energy is stored in the electric field.

Consider a parallel plate capacitor, having plate area A and plate separation d. Capacitance of the parallel plate capacitor is given by

$$C = \frac{\varepsilon_0 A}{d}$$

If σ is the surface charge density on the capacitor plates, then electric field between the capacitor plates will be

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{or} \quad \sigma = \varepsilon_0 E$$

Charge on either plate of capacitor is

$$Q = \sigma A = \varepsilon_0 EA$$

$\therefore$ Energy stored in the capacitor is

$$U = \frac{Q^2}{2C} = \frac{(\varepsilon_0 EA)^2}{2\cdot\frac{\varepsilon_0 A}{d}} = \frac{1}{2}\varepsilon_0 E^2 Ad$$

But Ad = volume of the capacitor between its two plates. Therefore, the energy stored per unit volume or the energy density of the electric field is given by

$$u = \frac{U}{Ad} = \frac{1}{2}\varepsilon_0 E^2$$

Although we have derived the above equation for a parallel plate capacitor, it is true for electric field due to any charge configuration. In general, we can say that an electric field E can be regarded as a seat of energy with energy density equal to $\frac{1}{2}\varepsilon_0 E^2$.

22. The charges will flow between the two spheres till their potentials become equal. Then the charges on the two spheres would be

$$\frac{Q_1}{Q_2} = \frac{C_1 V}{C_2 V} = \frac{C_1}{C_2}$$

But $\frac{C_1}{C_2} = \frac{a}{b}$

$\therefore \frac{Q_1}{Q_2} = \frac{a}{b}$

The ratio of the electric fields at the surface of the two spheres will be

$$\frac{E_1}{E_2} = \frac{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1}{a^2}}{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_2}{b^2}} = \frac{Q_1}{Q_2}\cdot\frac{b^2}{a^2} = \frac{a}{b}\cdot\frac{b^2}{a^2} = \frac{b}{a}$$

Also, $\frac{E_1}{E_2} = \frac{\sigma_1}{\sigma_2} \quad \therefore \quad \frac{\sigma_1}{\sigma_2} = \frac{b}{a}$

Thus the surface charge densities are inversely proportional to the radii of the spheres. Since the flat portion may be considered as a spherical surface of large radius and a pointed portion as that of small radius, that is why, the surface charge density on the sharp and pointed ends of a conductor is much higher than that on its flatter portion.

23. (i) Inquisitiveness and sharing.

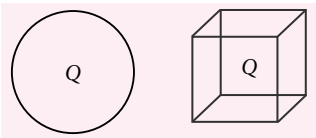
(ii) The picture on the screen is produced by striking accelerated electrons on the positively charged screen, that is why Devansh observed charging on the screen. The charged screen also attracts airborne infected particles floating

around. As many of the particles collected on the screen surface carry bacteria, the screen becomes contaminated with bacteria.

When a surgeon put his finger with gloves near the screen the bacteria may shift to the gloves. To avoid the risk, surgeons are suggested not to bring finger near a video monitor.

24. (a) According to Gauss's law, $\phi = \oint \vec{E} \cdot d\vec{s} = \frac{Q}{\varepsilon_0}$

Let us take a charge Q inside a cube or a sphere.



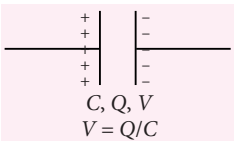
The flux through both the closed surfaces will be same, *i.e.*, $\phi_{net} = \frac{Q}{\varepsilon_0}$

(b) Refer to point 1.8 (4) page no. 13 (MTG Excel in Physics.)

OR

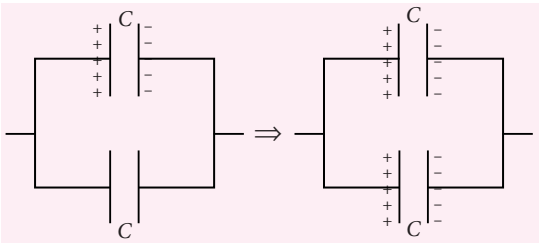
(a) Refer to point 1.11(9) page no. 16 (MTG Excel in Physics).

(b) Let fully charge capacitor C has charge Q.



Energy on the capacitor, $U = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$

Now, the charged capacitor is connected to identical uncharged capacitor.



The two capacitor will have same potential.

$$V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{Q + 0}{2C} = \frac{Q}{2C}$$

Now, total energy

$$U' = \frac{1}{2}CV^2 + \frac{1}{2}CV^2$$

$$U' = \frac{1}{2}C\left(\frac{Q}{2C}\right)^2 + \frac{1}{2}C\left(\frac{Q}{2C}\right)^2 = \frac{Q^2}{4C}$$

So, $U > U'$

Energy lost as heat during charging the another capacitor.

$$U - U' = \frac{Q^2}{2C} - \frac{Q^2}{4C} = \frac{Q^2}{4C}$$

25. Refer to point 1.4(2, 3, 4) page no. 6 (MTG Excel in Physics).

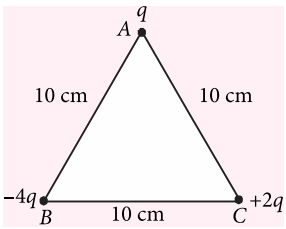
OR

(a) Refer to point 1.5(8) page no. 8 (MTG Excel in Physics)

(b) Refer to point 1.5(11) page no. 10 (MTG Excel in Physics)

26. (a) Refer to point 1.4(5) page no. 6 (MTG Excel in Physics)

(b) $W = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right]$



$$W = \frac{1}{4\pi\varepsilon_0}\left[\frac{q \times -4q}{r} + \frac{q \times 2q}{r} + \frac{-4q \times 2q}{r}\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 r}[-4 + 2 - 8] = \frac{-10q^2}{4\pi\varepsilon_0 r}$$

$$= -10 \times 9 \times 10^9 \times \frac{(1.6 \times 10^{-10})^2}{10 \times 10^{-2}} = -2.30 \times 10^{-8}\,\text{J}$$

OR

Refer to point 1.5(12) page no. 10 (MTG Excel in Physics)

MPP-2 CLASS XI ANSWER KEY

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

PHYSICS MUSING

Physics Musing was started in August 2013 issue of Physics For You. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / NEET / AIIMS / JIPMER with additional study material.

In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / NEET. The detailed solutions of these problems will be published in next issue of Physics For You.

The readers who have solved five or more problems may send their detailed solutions with their names and complete address. The names of those who send atleast five correct solutions will be published in the next issue.

We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

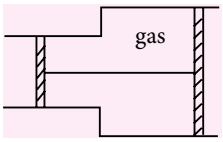
PROBLEM Set 47

SINGLE OPTION CORRECT TYPE

1. 10 g of ice at –20 °C is dropped into a calorimeter containing 10 g of water at 10 °C, the specific heat of water is twice that of ice. When equilibrium is reached the calorimeter will contain

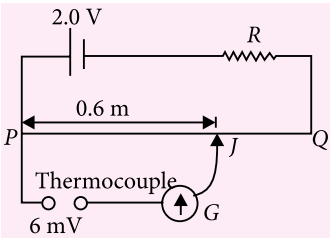
(a) 20 g of water at 0 °C
(b) 15 g of water at 0 °C
(c) 10 g ice and 10 g of water at 0 °C
(d) 5 g ice and 15 g of water at 0 °C

2. A gas is filled in the cylinder shown in the figure. The two pistons are joined by an inextensible string. If the gas is heated, the pistons will



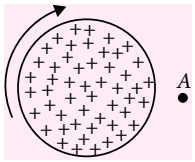
(a) move towards left
(b) move towards right
(c) remain stationary
(d) move away from each other

3. Figure shows a simple potentiometer circuit for measuring a small emf produced by a thermocouple. The meter wire PQ has a resistance of 5 Ω. If a balance point is obtained 0.6 m along PQ when measuring an emf of 6 mV, what is the value of resistance R?



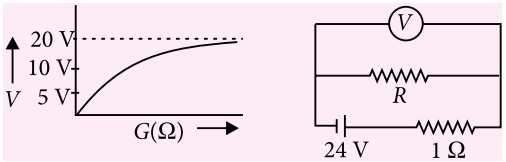
(a) 95 Ω (b) 995 Ω
(c) 195 Ω (d) 1995 Ω

4. A positively charged disc is rotated clockwise (in its plane) as shown in figure. The direction of the magnetic field at point A in the plane of the disc is



(a) perpendicular to the plane and into the plane of paper
(b) makes an angle 30° to the plane
(c) makes an angle 60° to the plane
(d) perpendicular to the plane and out of the plane of paper

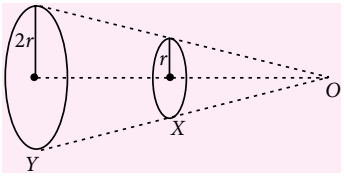
5. A cell of internal resistance 1 Ω is connected across a resistor. A voltmeter having variable resistance G is used to measure potential difference across resistor. The plot of voltmeter reading V against G is shown. What is value of external resistor R?



(a) 5 Ω (b) 4 Ω (c) 3 Ω (d) 1 Ω

MULTIPLE OPTIONS CORRECT TYPE

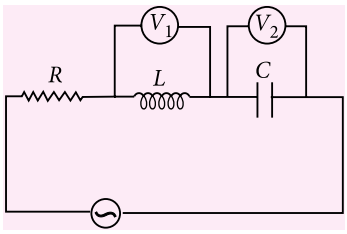
6. Two circular coils X and Y having equal number of turns and carrying equal currents in same sense are placed co-axially, such that they subtend the same solid angle at O. Let B be the magnetic field at O due to smaller coil X, then



By Akhil Tewari, Author Foundation of Physics for JEE Main & Advanced, Professor, IITians PACE, Mumbai.

(a) magnetic field at O due to larger coil = $2B$
(b) magnetic field at O due to larger coil = $B/2$
(c) total magnetic field at O is $3B/2$
(d) total magnetic field at O is $\frac{\sqrt{5}B}{2}$

7. In the given figure, R = 100 Ω, $L = \frac{2}{\pi}$ H and $C = \frac{8}{\pi}$ μF are connected in series with an ac source of 200 V and frequency υ. V_1 and V_2 are two hot-wire voltmeters. If the readings of V_1 and V_2 are same, then



(a) υ = 125 Hz (b) υ = 250π Hz
(c) current through R is 2 A
(d) $V_1 = V_2$ = 1000 V

INTEGER ANSWER TYPE

8. 2 litre of liquid at 10 °C is mixed with 7 litre of same liquid at 20 °C. Consider the linear increase in volume of liquid with increase in temperature and neglect all kinds of heat losses from liquid to surroundings. After thermal equilibrium is reached, if change in volume of liquid is V ml then find V. (volume expansion coefficient of liquid $\gamma = 0.000035\ °C^{-1}$)

9. A certain amount of monatomic gas undergoes a process for which $U^{\beta} \propto V$, where U is internal energy and V is volume of gas. It is found that the ratio $\frac{\Delta U}{\Delta Q}$ for the process is $\frac{1}{3}$. What is the value of β?

10. A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12 V, $\frac{50}{\pi}$ Hz ac source a current 2.4 A flows in the circuit. If the inductance of the coil is $x \times 10^{-2}$ H. Find the value of x.

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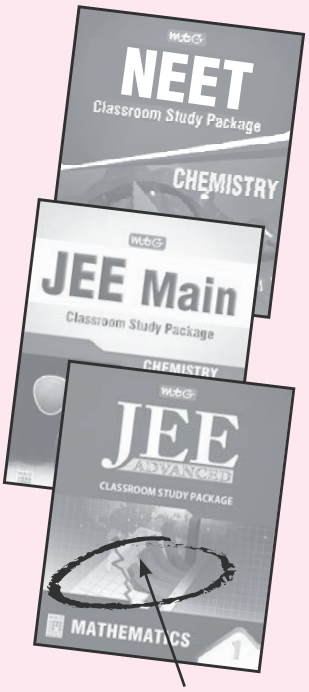

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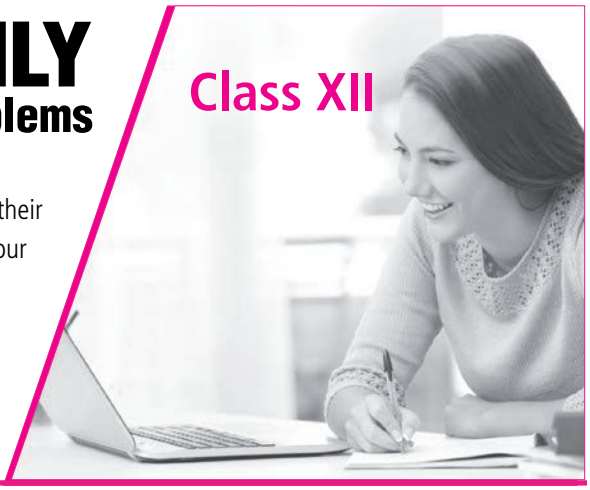
MPP-2 MONTHLY Practice Problems

Class XII



This specially designed column enables students to self analyse their extent of understanding of specified chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Electrostatic Potential and Capacitance

Total Marks : 120 **Time Taken : 60 min**

NEET / AIIMS

Only One Option Correct Type

1. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at a distance of 2 cm from the centre of the sphere is

(a) zero (b) 10 V (c) 4 V (d) 10/3 V

2. The electric field strength at a distance r from the centre of a charged sphere of radius R is E. If $r > R$, how much work will be done in bringing a test charge q_0 from infinity to that point?

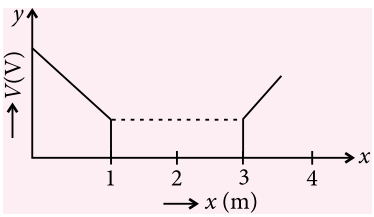
(a) q_0RE (b) $\frac{1}{2}q_0RE$

(c) q_0rE (d) $\frac{1}{2}q_0rE$

3. The plates of a parallel plate capacitor are charged to 100 V, and the battery is removed. A 2 mm thick dielectric slab is inserted between the plates. Then to maintain the same potential difference the distance between the plates is increased by 1.6 mm. The dielectric constant of the slab is

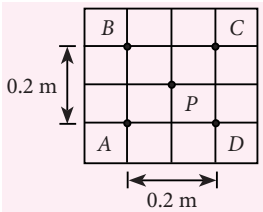
(a) 4 (b) 5 (c) 6 (d) 8

4. The variation of electric potential with distance from a fixed point is shown in the figure. What is the value of electric field at $x = 2$ m ?



(a) zero (b) 6/2 (c) 6/1 (d) 6/3

5. A, B, C, D and P are points in a uniform electric field. The potentials at these points are $V(A) = 2$ V, $V(P) = V(B) = V(D) = 5$ V and $V(C) = 8$ V. The electric field at P is



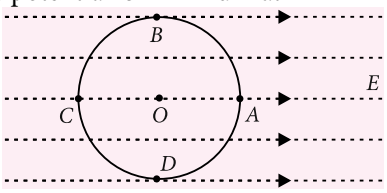
(a) 10 V m^{-1} along PB

(b) 5 V m^{-1} along PC

(c) $15\sqrt{2}$ V m^{-1} along PA

(d) 5 V m^{-1} along PA

6. The electric field in a region surrounding the origin and along the x-axis is uniform. A small circle is drawn with the center at the origin cutting the axes at points A, B, C and D having coordinates $(a, 0)$, $(0, a)$, $(-a, 0)$, and $(0,-a)$ respectively, as shown in figure then the potential is minimum at



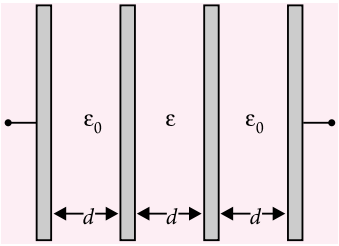
(a) A

(b) B

(c) C

(d) D

7. For the configuration of media of permittivities ε_0, ε, and ε_0 between parallel plates each of area A, as shown in figure, the equivalent capacitance is



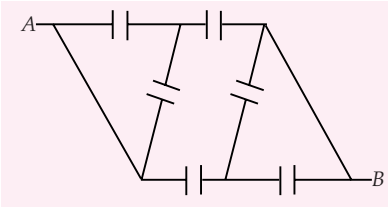
(a) $\varepsilon_0 A/d$

(b) $\varepsilon\varepsilon_0 A/d$

(c) $\dfrac{\varepsilon\varepsilon_0 A}{d(\varepsilon + \varepsilon_0)}$

(d) $\dfrac{\varepsilon\varepsilon_0 A}{(2\varepsilon + \varepsilon_0)d}$

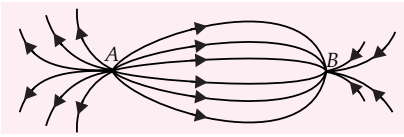
8. A network of six identical capacitors, each of value C is made as shown in the figure. Equivalent capacitance between points A and B is



(a) $\frac{C}{4}$
(b) $\frac{3C}{4}$
(c) $\frac{4C}{3}$
(d) $3C$

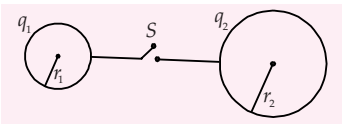
9. The capacities of three capacitors are in the ratio 1 : 2 : 3. Their equivalent capacitance when connected in parallel is $\frac{60}{11}$ μF more than that when they are connected in series. The capacitance of individual capacitors in μF are
(a) 4, 6, 7 (b) 1, 2, 3 (c) 2, 3, 4 (d) 1, 3, 6

10. The spatial distribution of the electric field due to charges (A, B) is shown in figure. Which one of the following statements is correct?



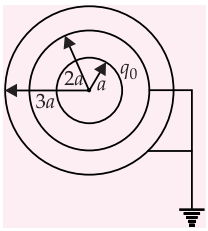
(a) A is +ve and B –ve and $|A| > |B|$
(b) A is –ve and B + ve and $|A| = |B|$
(c) Both are +ve but $A > B$
(d) Both are –ve but $A > B$

11. A system consists of two metallic spheres of radii r_1 and r_2 connected by a thin wire and a switch S as shown in figure. Initially S is open and spheres carry charges q_1 and q_2 respectively. If the switch is closed, the potential of the system is ($k = 1/4\pi\varepsilon_0$)



(a) $k\frac{q_1q_2}{r_1r_2}$ (b) $k\frac{q_1+q_2}{r_1+r_2}$
(c) $k\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}\right)$ (d) $k\frac{q_1+q_2}{(r_1r_2)^{1/2}}$

12. Three concentric conducting spherical shells are arranged as shown in figure. The middle and outermost shells are earthed. The innermost sphere is given a charge q_0, what are the charges in the middle and the outermost sphere respectively?



(a) q_0 and $-q_0$ (b) $-q_0$ and zero
(c) zero and q_0 (d) $-q_0$ and q_0

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** Electron has a negative charge.
Reason : Electrons move always from a region of higher potential to a region of lower potential.

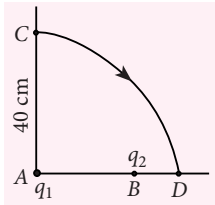
14. **Assertion :** In the absence of an externally applied electric field, the displacement per unit volume of a polar dielectric material is always zero.
Reason : In polar dielectrics, each molecule has a permanent dipole moment but these are randomly oriented in the absence of an externally applied electric field.

15. **Assertion :** A capacitor can be broken by placing large amount of charge on it.
Reason : After breakage potential, capacitor is destroyed.

JEE MAIN / JEE ADVANCED

Only One Option Correct Type

16. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\frac{q_3}{4\pi\varepsilon_0}k$, where k is

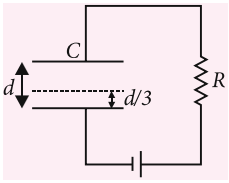


(a) $8q_2$ (b) $6q_1$ (c) $8q_1$ (d) $6q_2$

17. Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are $+q$ and $-q$. The potential difference between the centres of the two rings is ($k = 1/4\pi\varepsilon_0$)

(a) Zero (b) $kq\left(\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right)$
(c) $2kq\left(\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right)$ (d) $k\frac{qR}{d^2}$

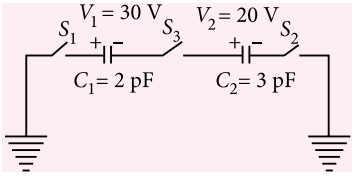
18. A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant $K = 2$.
The level of liquid is $d/3$ initially. Suppose the liquid level decreases at a constant speed v, the time constant as a function of time t is



(a) $\dfrac{6\varepsilon_0 R}{5d+3vt}$ (b) $\dfrac{(15d+9vt)\varepsilon_0 R}{2d^2-3dvt-9v^2t^2}$

(c) $\dfrac{6\varepsilon_0 R}{5d-3vt}$ (d) $\dfrac{(15d-9vt)\varepsilon_0 R}{2d^2+3dvt-9v^2t^2}$

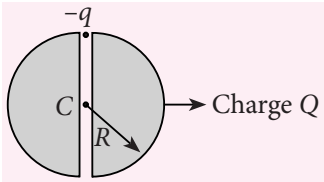
19. For the circuit shown in figure, which of the following statements is true?



(a) With S_1 closed, $V_1 = 15$ V, $V_2 = 20$ V
(b) With S_3 closed, $V_1 = V_2 = 25$ V
(c) With S_1 and S_2 closed, $V_1 = V_2 = 0$
(d) With S_1 and S_3 closed, $V_1 = 30$ V, $V_2 = 20$ V.

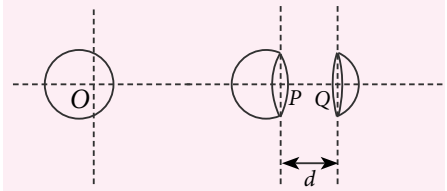
More than One Option Correct Type

20. In a uniformly charged dielectric sphere, a very thin tunnel has been made along the diameter as shown in figure. A charge particle $-q$ having mass m is released from rest at one end of the tunnel. For the situation described, mark the correct statement(s). (Neglect gravity.)



(a) Charge particle will perform SHM about centre of the sphere as mean position
(b) Time period of the particle is
$2\pi\sqrt{4\pi\varepsilon_0 mR^3/qQ}$
(c) Particle will perform oscillation but not SHM.
(d) Speed of the particle while crossing the mean position is $\sqrt{qQ/4\pi\varepsilon_0 mR}$

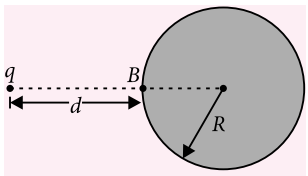
21. An insulating spherical shell of uniform surface charge density is cut into two parts and placed at a distance d apart as shown in figure. $|\vec{E_P}|$ and $|\vec{E_Q}|$ denote the electric fields at P and Q, respectively. As $d \to \infty$



(a) $|\vec{E_P}| > |\vec{E_Q}|$ (b) $|\vec{E_P}| = |\vec{E_Q}|$
(c) $|\vec{E_P}| < |\vec{E_Q}|$ (d) $|\vec{E_P}| + |\vec{E_Q}| = 0$

22. The electric potential at a point of a certain distance from a point charge is 600 V and the electric field is 200 N C^{-1}. Which of the following statements will be true?
(a) The magnitude of the charge is 20×10^{-3} C.
(b) The distance of the given point from the charge is 3 m.
(c) The potential at a distance of 9 m will be 200 V.
(d) The work done by an external agent in moving a point charge of 1 mC from the given point to a point at a distance of 9 m will be 4×10^{-4} J

23. For the situation shown in figure, mark the correct statement(s).



Hollow neutral conductor

(a) Potential of the conductor is $q/[4\pi\varepsilon_0(d + R)]$.
(b) Potential of the conductor is $q/4\pi\varepsilon_0 d$.
(c) Potential of the conductor cannot be determined as the nature of distribution of induced charges is not known.
(d) Potential at point B due to the induced charges is $-qR/[4\pi\varepsilon_0(d + R)d]$.

Integer Answer Type

24. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = \kappa r^a$, where κ and a are constants and r is the distance from its centre. If the electric field at $r = R/2$ is 1/8 times that at $r = R$, find the value of a.

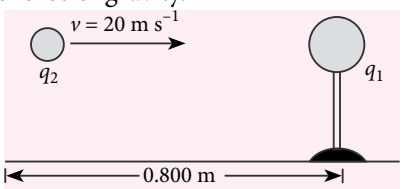
25. A parallel plate capacitor of capacity C_0 is charged to a potential V_0. E_1 is the energy stored in the capacitor when the battery is disconnected and the plate separation is doubled, and E_2 is the energy stored in the capacitor when the charging battery

is kept connected and the separation between the capacitor plates is doubled. Find the ratio E_1/E_2.

26. The capacitance of a capacitor becomes 4/3 times its original value if a dielectric slab of thickness $t = d/2$ is inserted between the plates (d is the separation between the plates). What is the dielectric constant of the slab?

Comprehension Type

A small metal sphere, carrying a net charge $q_1 = -2\mu C$, is held in a stationary position by insulating supports. A second small metal sphere, with a net charge of $q_2 = -8\,\mu C$ and mass 1.50 g is projected toward q_1. When the two spheres are 0.800 m apart, q_2 is moving toward q_1 with speed 20 m s^{-1} as shown in figure. Assume that the two spheres can be treated as point charges. You can ignore the force of gravity.

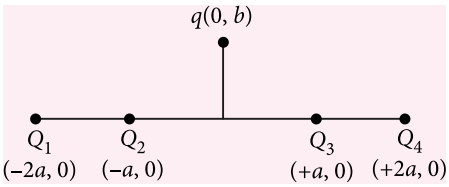


27. The speed of q_2 when the spheres are 0.400 m apart is
(a) $2\sqrt{10}$ m s^{-1} (b) $2\sqrt{6}$ m s^{-1}
(c) $4\sqrt{10}$ m s^{-1} (d) $4\sqrt{6}$ m s^{-1}

28. How close does q_2 get to q_1 ?
(a) 0.20 m (b) 0.30 m (c) 0.10 m (d) 0.15 m

Matrix Match Type

29. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x-axis at $x = -2a$, $-a$, $+a$ and $+2a$ respectively. A positive charge q is placed on the positive y-axis at a distance $b > 0$. The signs of these charges are given in column I. The direction of the forces on the charge q is given in column II. Match column I with column II

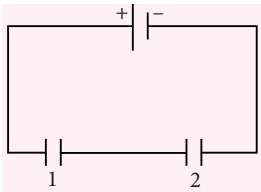


	Column-I		Column-II
A.	Q_1, Q_2, Q_3, Q_4 all positive	P.	$+x$
B.	Q_1, Q_2 positive; Q_3, Q_4 negative	Q.	$-x$
C.	Q_1, Q_4 positive; Q_2, Q_3 negative	R.	$+y$
D.	Q_1, Q_3 positive; Q_2, Q_4 negative	S.	$-y$

	A	B	C	D
(a)	R	P	S	Q
(b)	S	Q	R	P
(c)	R	P	Q	S
(d)	S	Q	P	R

30. Two identical capacitors are connected in series, and the combination is connected with a battery, as shown. Some changes in capacitor 1 are now made independently after the steady state is achieved as listed in column I. Some effects that may occur in the new steady state due to these changes on capacitor 2 are listed in column II.

Match the changes on capacitor 1 in column I with the corresponding effect on capacitor 2 in column II.



	Column-I		Column-II
A.	A dielectric slab is inserted	P.	Charge on the capacitor increases
B.	Separation between plates is increased	Q.	Charge on the capacitor decreases
C.	A metal plate is inserted connecting both plates	R.	Energy stored in the capacitor increases
D.	The left plate is grounded	S.	No change occurs

	A	B	C	D
(a)	P, R	Q	P, R	S
(b)	P	Q, R	P	S
(c)	Q, R	P	S	P
(d)	P	Q, R	S	R

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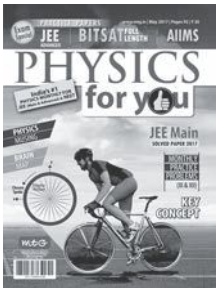

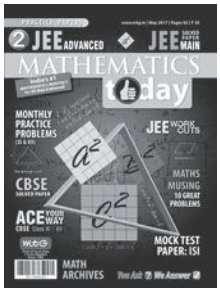

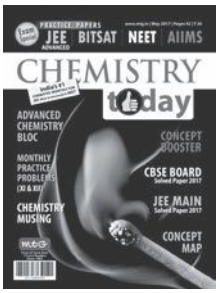

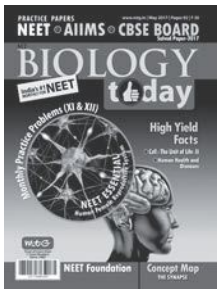

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