JEE (Main) PHYSICS SOLVED PAPER

2023
11th April Shift 2

Section A

Q. 1. Eight equal drops of water are falling through air with a steady speed of 10 cm s^{-1}. If the drops collapse, the new velocity is:

(1) 10 cm s^{-1} **(2)** 40 cm s^{-1}
(3) 16 cm s^{-1} **(4)** 5 cm s^{-1}

Q. 2. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: A bar magnet dropped through a metallic cylindrical pipe takes more time to come down compared to a non-magnetic bar with same geometry and mass.

Reason R: For the magnetic bar, Eddy currents are produced in the metallic pipe which oppose the motion of the magnetic bar.

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

(1) A is true but R is false
(2) Both A and R are true but R is NOT the correct explanation of A
(3) A is false but R is true
(4) Both A and R are true and R is the correct explanation of A

Q. 3. A space ship of mass 2×10^4 kg is launched into a circular orbit close to the earth surface. The additional velocity to be imparted to the space ship in the orbit to overcome the gravitational pull will be (if g = 10 m s^{-2} and radius of earth = 6400 km):

(1) $7.9(\sqrt{2}-1)$ km s^{-1} **(2)** $7.4(\sqrt{2}-1)$ km s^{-1}
(3) $11.2(\sqrt{2}-1)$ km s^{-1} **(4)** $8(\sqrt{2}-1)$ km s^{-1}

Q. 4. A projectile is projected at 30° from horizontal with initial velocity 40 m s^{-1}. The velocity of the projectile at t = 2 s from the start will be (Given g = 10 m s^{-2}):

(1) Zero **(2)** $20\sqrt{3}$ m s^{-1}
(3) $40\sqrt{3}$ m s^{-1} **(4)** 20 m s^{-1}

Q. 5. A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\vec{E} = 6.6\hat{j}$ v m^{-1}. What is $\vec{B}$ at this point?

(1) $-2.2 \times 10^{-8}\hat{k}$ T **(2)** $-2.2 \times 10^{-8}\hat{i}$ T
(3) $2.2 \times 10^{-8}\hat{k}$ T **(4)** $2.2 \times 10^{-8}\hat{i}$ T

Q. 6. A car P travelling at 20 m s^{-1} sounds its horn at a frequency of 400 Hz. Another car Q is travelling behind the first car in the same direction with a velocity 40 m s^{-1}. The frequency heard by the passenger of the car Q is approximately (Take, velocity of sound = 360 m s^{-1}):

(1) 471 Hz **(2)** 514 Hz **(3)** 421 Hz **(4)** 485 Hz

Q. 7. A body of mass 500 g moves along x-axis such that it's velocity varies with displacement x according to the relation $v = 10\sqrt{x}$ m s^{-1} the force acting on the body is:

(1) 25 N **(2)** 5 N **(3)** 166 N **(4)** 125 N

Q. 8. The ratio of the de-Broglie wavelengths of proton and electron having same Kinetic energy: (Assume $m_p = m_e \times 1849$):

(1) 1 : 62 **(2)** 1 : 30 **(3)** 1 : 43 **(4)** 2 : 43

Q. 9. If force (F), velocity (V) and time (T) are considered as fundamental physical quantities, then dimensional formula of density will be:

(1) $F V^{-2} T^2$ **(2)** $F V^4 T^{-6}$
(3) $F V^{-4} T^{-2}$ **(4)** $F^2 V^{-2} T^6$

Q. 10. An electron is allowed to move with constant velocity along the axis of current carrying straight solenoid.

A. The electron will experience magnetic force along the axis of the solenoid.
B. The electron will not experience magnetic force.
C. The electron will continue to move along the axis of the solenoid.
D. The electron will be accelerated along the axis of the solenoid.
E. The electron will follow parabolic path-inside the solenoid.

Choose the correct answer from the options given below:

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

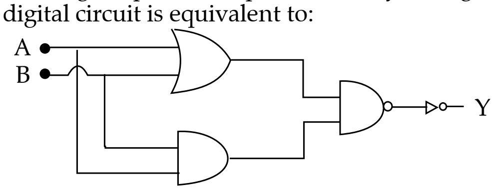
Q. 11. The Thermodynamic process, in which internal energy of the system remains constant is:

(1) Isobaric **(2)** Isochoric
(3) Adiabatic **(4)** Isothermal

Q. 12. In satellite communication, the uplink frequency band used is:

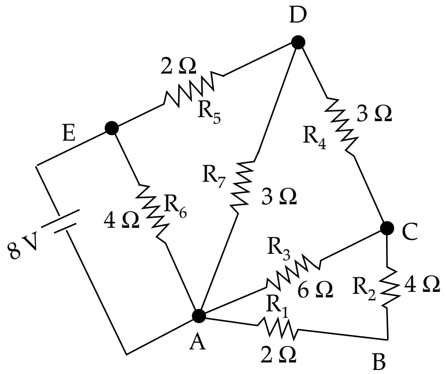
(1) 76 – 88 MHz **(2)** 420 – 890 MHz
(3) 3.7 – 4.2 GHz **(4)** 5.925 – 6.425 GHz

Q. 13. The logic operations performed by the given digital circuit is equivalent to:



(1) OR **(2)** NAND **(3)** NOR **(4)** AND

Q. 14.



The current flowing through R_2 is:

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

Q. 15. When vector $\vec{A} = 2\hat{i} + 3\hat{j} + 2\hat{k}$ is subtracted from vector $\vec{B}$, it gives a vector equal to $2\hat{j}$. Then the magnitude of vector $\vec{B}$ will be:

(1) 3 (2) $\sqrt{5}$ (3) $\sqrt{33}$ (4) $\sqrt{6}$

Q. 16. If V is the gravitational potential due to sphere of uniform density on its surface, then its value at the center of sphere will be:

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

Q. 17. The root mean square speed of molecules of nitrogen gas at 27°C is approximately: (Given mass of a nitrogen molecule = 4.6×10^{-26} kg and take Boltzmann constant $k_B = 1.4 \times 10^{-23}$ J K^{-1}):

(1) 1260 m s^{-1} (2) 91 m s^{-1}
(3) 523 m s^{-1} (4) 27.4 m s^{-1}

Q. 18. The energy of He^+ ion in its first excited state is, (The ground state energy for the Hydrogen atom is –13.6 e V):

(1) –13.6 e V (2) –54.4 e V
(3) –27.2 e V (4) –3.4 e V

Q. 19. When one light ray is reflected from a plane mirror with 30° angle of reflection, the angle of deviation of the ray after reflection is:

(1) 140° (2) 130° (3) 120° (4) 110°

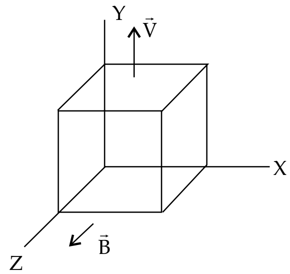
Q. 20. A capacitor of capacitance C is charge *d* to a potential V. The flux of the electric field through a closed surface enclosing the positive plate of the capacitor is:

(1) Zero (2) $\frac{CV}{\varepsilon_0}$ (3) $\frac{2CV}{\varepsilon_0}$ (4) $\frac{CV}{2\varepsilon_0}$

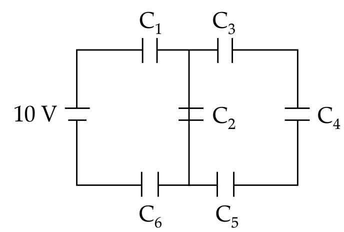
Section B

Q. 21. A coil has an inductance of 2 H and resistance of 4 Ω. A 10 V potential is applied across the coil. The energy stored in the magnetic field after the current has built up to its equilibrium value will be ________ $\times 10^{-2}$ J.

Q. 22. A metallic cube of side 15 cm moving along *y*-axis at a uniform velocity of 2 m s^{-1}. In a region of uniform magnetic field of magnitude 0.5 T directed along *z*-axis. In equilibrium the potential difference between the faces of higher and lower potential developed because of the motion through the field will be ________ mV.



Q. 23. In the given circuit:
C_1 = 2 μF, C_2 = 0.2 μF, C_3 = 2 μF, C_4 = 4 μF, C_5 = 2 μF, C_6 = 2 μF. The charge stored on capacitor C_4 is ________ μC.



Q. 24. A nucleus disintegrates into two nuclear parts, in such a way that ratio of their nuclear sizes is $1 : 2^{1/3}$. Their respective speed, have a ratio of *n* : 1. The value of *n* is ________ .

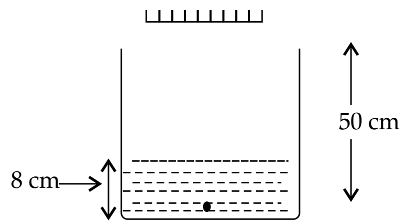
Q. 25. The surface tension of soap solution is 3.5×10^{-2} N m^{-1}. The amount of work done required to increase the radius of soap bubble from 10 cm to 20 cm is ________ $\times 10^{-4}$ J. (take $\pi = \frac{22}{7}$)

Q. 26. A circular plate is rotating in horizontal plane, about an axis passing through its center perpendicular to the plate, with an angular velocity Ω. A person sits at the center having two dumbbells in his hands. When he stretches out his hands, the moment of inertia of the system becomes triple. If E be the initial Kinetic energy of the system, then final Kinetic energy will be $\frac{E}{x}$.

The value of *x* is?

Q. 27. A block of mass 5 kg starting from rest pulled up on a smooth incline plane making an angle of 30° with horizontal with an affective acceleration of 1 m s^{-2}. The power delivered by the pulling force at *t* = 10 s from the starts is ________ W. [use *g* = 10 m s^{-2}] (Calculate the nearest integer value)

Q. 28. As shown in the figure, a plane mirror is fixed at a height of 50 cm from the bottom of tank containing water $\left(\mu = \frac{4}{3}\right)$. The height of water in the tank is 8 cm. A small bulb is placed at the bottom of the water tank. The distance of image of the bulb formed by mirror from the bottom of the tank is ___________ cm.



Q. 29. Two identical cells each of emf 1.5 V are connected in series across a 10 Ω resistance. An ideal voltmeter connected across 10 Ω resistance reads 1.5 V. The internal resistance of each cell is ___________ Ω.

Q. 30. A wire of density 8×10^3 kg m^{-3} is stretched between two clamps 0.5 m apart. The extension developed in the wire is 3.2×10^{-4} m. If $Y = 8 \times 10^{10}$ N m^{-2}, the fundamental frequency of vibration in the wire will be _________ Hz.

Answer Key

Q. No.	Answer	Topic name	Chapter name
1	(2)	Terminal velocity	Mechanical properties of fluids
2	(4)	Eddy currents	Electromagnetic induction
3	(4)	Escape velocity	Gravitation
4	(2)	Projectile motion	Motion in a plane
5	(3)	Propogation of EMW	Electromagnetic waves
6	(3)	Doppler's effect	Waves
7	(1)	Acceleration	Motion in straight line
8	(3)	de-Broglie equation	Dual nature of radiation and matter
9	(3)	Dimensions	Units and dimesnions
10	(4)	Solenoid	Moving charges and magnetism
11	(4)	First law of thermodynamics	Thermodynamics
12	(4)	Space waves	Communication systems
13	(4)	Logic gates	Semiconductors
14	(1)	Electric circuit	Current electricity
15	(3)	Vectors	Motion in a plane
16	(3)	Gravitational potential energy	Gravitation
17	(3)	RMS speed of gases	Kinetic theory of gases
18	(4)	Atomic spectrum	Atoms
19	(3)	Refraction	Ray optics
20	(2)	Gauss theorem	Electric charges and fields
21	[625]	Energy stored in an inductor	Current electricity
22	[150]	Potential	Moving charges and magnetism
23	[4]	Electric circuit	Electrostatic potential and capacitance
24	[2]	Momentum	Laws of motion
25	[264]	Surface tension	Mechanical properties of fluids
26	[3]	Angular momentum	System of particles and rotational motion
27	[300]	Motion on an inclined plane	Laws of motion
28	[98]	Refraction	Ray optics
29	[5]	Internal resistance of a cell	Current electricity
30	[80]	Fundamental frequency	Waves

SOLUTIONS

Section A

1. Option (2) is correct.

Let radius of small bubbles = r

Radius of larger bubble = R

After collapse volume will remain same, hence

$$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$$

$\Rightarrow \quad R = 2r$

Velocity of object passing though a liquid,

$$v = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$

where, ρ is the density of bubble, and σ is the density of fluid (air)

$\Rightarrow v \propto r^2$

Now $\quad \frac{v_1}{v_2} = \left(\frac{r}{R}\right)^2 = \left(\frac{r}{2r}\right)^2 = \frac{1}{4}$

$\Rightarrow \quad v_2 = 4v_1 = 4 \times 10 = 40$ cm/s

Trick: $\quad v' = vn^{2/3} = 10 \times 8^{2/3} = 40$ cm s^{-1}

2. Option (4) is correct.

When a magnet moves through a metallic pipe, eddy current get induced in the pipe.

Hence, Assertion A is true.

According to Lenz's law direction of this current will be such that it opposes its cause, hence eddy current will try to slow down movement of magnet.

Hence, reason R correctly explains the assertion.

3. Option (4) is correct.

Velocity of object in circular orbit,

$$v = \sqrt{\frac{GM}{R}}$$

To escape its velocity must be

$$v_{escape} = \sqrt{\frac{2GM}{r}}$$

Additional velocity needed, $v' = v_{escape} - v$

$$\Rightarrow \quad v' = \sqrt{\frac{2GM}{r}} - \sqrt{\frac{GM}{R}} \qquad \left[\frac{GM}{R^2} = g, r = R\right]$$

$$\Rightarrow \quad v' = \sqrt{2gR} - \sqrt{gR}$$

$$= \sqrt{gR}(\sqrt{2} - 1)$$

$$= \sqrt{10^{-2} \times 6400}\left(\sqrt{2} - 1\right)$$

$$= 8(\sqrt{2} - 1) \text{ km s}^{-1}$$

4. Option (2) is correct.

Given, $u = 40$ m s^{-1}, $\theta = 30°$

$u_x = u\cos\theta = 40\cos 30 = 20\sqrt{3}$ m s^{-1}

$u_y = u\sin\theta = 40\sin 30 = 20$ m s^{-1}

After $\quad t = 2$ s,

$$v_x = u_x = 20\sqrt{3}$$

$$v_y = u_y - gt = 20 - 10 \times 2 = 0$$

Since y component of velocity is zero,

hence $\quad v = v_x = 20\sqrt{3}$

5. Option (3) is correct.

Direction of $\vec{B}$ of $EMW = \vec{C} \times \vec{E} = \hat{i} \times \hat{j} = \hat{k}$

Magnitude, $|\vec{B}| = \frac{|\vec{E}|}{C} = \frac{6.6}{3 \times 10^8} = 2.2 \times 10^{-8}$ T

$\therefore \quad \vec{B} = 2.2 \times 10^{-8}\hat{k}$ T

6. Option (3) is correct.

Given, $v_P = 20$ ms^{-1}, $v_Q = 40$ ms^{-1}

$v_s = 360$ ms^{-1}, $f_{horn} = 400$ Hz

$$f_{approx.} = \left[\frac{v_S - (-v_Q)}{v_S - (-v_P)}\right]f = \left[\frac{360 + 40}{360 + 20}\right] \times 400 = 421 \text{ Hz}$$

7. Option (1) is correct.

Given, $m = 500$ g, $v = 10\sqrt{x}$

$$a = v\frac{dv}{dx} = 10\sqrt{x}\frac{d(10\sqrt{x})}{dx}$$

$$= 10\sqrt{x}\frac{10}{2\sqrt{x}} = 50 \text{ m s}^{-2}$$

Force, F = $ma = 0.5 \times 50 = 25$ N

8. Option (3) is correct.

de-Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2mKE}}$$

$\therefore \quad KE_p = KE_e \qquad \left[\therefore \lambda \propto \frac{1}{\sqrt{m}}\right]$

So, $\quad \frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e}{m_p}} = \sqrt{\frac{m_e}{1849 \times m_e}} = \frac{1}{43}$

9. Option (3) is correct.

Let $\rho \propto F^a V^b T^c$ or $\rho = k F^a V^b T^c$

Here k is a dimensionless constant.

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

$\Rightarrow M^1 L^{-3} T^0 = M^a L^{a+b} T^{-2a-b+c}$

Comparing the dimensions of both sides

$a = 1$

$a + b = -3$

$\Rightarrow \quad b = -4$

$-2a - b + c = 0$

$\Rightarrow \quad c = -2$

Hence, $\quad \rho = F^1 V^{-4} T^{-2}$

10. Option (4) is correct.

Inside a solenoid magnetic field is parallel and constant, when particle moves along, axis v and B are parallel.

So, F = qvBsin 0 = 0

In the absence of magnetic force, particle will continue moving along the axis with constant velocity.

11. Option (4) is correct.

Internal energy is given by,

$$\Delta U = nC_v\Delta T$$

For isothermal processes,

$$\Delta T = 0$$

Hence, $\Delta U = nC_v \times 0 = 0$

or U = constant

12. Option (4) is correct.

Uplink frequency is the frequency of signals going from ground station to satellites ~ 5.8 − 6.2 GHz.

13. Option (4) is correct.

Inputs		$Y_1 = \overline{A+B}$	$Y_2 = A.B$	$Y_3 = \overline{Y_1.Y_2}$	$Y = \overline{Y_3}$
A	B				
0	0	1	0	1	0
0	1	1	0	1	0
1	0	1	0	1	0
1	1	0	1	0	1

Hence, final output is similar to that of AND gate.

14. Option (1) is correct.

Equivalent resistance is given by,

$R = (((((R_1 + R_2) \,||\, R_3) + R_4) \,||\, R_7) + R_5) \,||\, R_6$

$R = (((((2 + 4)||6) + 3)||3) + 2)||4$

$R = 2\,\Omega$

Net current, $i = \frac{V}{R} = \frac{8}{2} = 4$ A

From the concept of symmetry, current in R_2, $i_2 = \frac{1}{4}$ A

15. Option (3) is correct.

Given, $\vec{B} - \vec{A} = 2\hat{j}$

Or, $\vec{B} - (2\hat{i} + 3\hat{j} + 2\hat{k}) = 0\hat{i} + 2\hat{j} + 0\hat{k}$

Or, $\vec{B} = 2\hat{i} + 5\hat{j} + 2\hat{k}$

Or, $|\vec{B}| = \sqrt{2^2 + 5^2 + 2^2} = \sqrt{33}$

16. Option (3) is correct.

Gravitational potential at a point inside a sphere is given by $-\frac{GM}{2R^3}(3R^2 - x^2)$.

At surface, $x = R$, hence

$$V = -\frac{GM}{R}$$

At center, $x = 0$, hence

$$V_{centre} = -\frac{GM}{2R^3}(3R^2) = -\frac{3GM}{2R} = 1.5V$$

17. Option (3) is correct.

Given, Temperature of gas, $T = 27 + 273 = 300$ K

Mass of nitrogen molecule, $m = 4.6 \times 10^{-26}$ kg

r.m.s. speed of gas is given by, $v_{rms} = \sqrt{\frac{3kT}{m}}$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

$$= \sqrt{\frac{3 \times 1.4 \times 10^{-23} \times 300}{4.6 \times 10^{-26}}}$$

$= 522.4$ m s^{-1} or ≈ 523 m s^{-1}

18. Option (4) is correct.

Energy of atom in n^{th} orbit,

$$E_n = -\frac{13.6Z^2}{n^2}\text{ e V}$$

Here, $n = 2$, $Z = 2$

$$E_n = -\frac{13.6 \times 2^2}{2^2}\text{e V}$$

$$= -13.6\text{ e V}$$

19. Option (3) is correct.

Angle of deviation,

$\delta = 180 - (\angle i + \angle r)$

$\delta = 180^o - (30^o + 30^o)$ $[\angle i = \angle r]$

$\delta = 180° - 60^o = 120^o$

20. Option (2) is correct.

As per Gauss law, $\phi = \frac{q_{in}}{\varepsilon_0} = \frac{CV}{\varepsilon_0}$

Section B

21. The correct answer is (625).

Given, Applied voltage = 10 V,

$L = 2$ H, $R = 4\,\Omega$

At steady state, inductor behaves like short circuit.

Hence, $i = \frac{V}{R} = \frac{10}{4} = 2.5$ A

$$E_{inductor} = \frac{1}{2}Li^2 = \frac{1}{2} \times 2 \times 2.5^2 = 6.25\text{ J}$$

or $E_{inductor} = 625 \times 10^{-2}$ J

22. The correct answer is (150).

Potential of surface passing through origin,

$$V = 0$$

Potential of other surface,

$$V' = vBl$$

$$V' = 2 \times 0.5 \times 0.15$$

$= 0.15$ volt or 150 mV

23. The correct answer is (4).

$$\frac{1}{C'} = \frac{1}{C_3} + \frac{1}{C_4} + \frac{1}{C_5} = \frac{1}{2} + \frac{1}{4} + \frac{1}{2}$$

$$C' = \frac{5}{4}\ \mu F$$

$$C'' = C' + C_2 = \frac{5}{4} + 0.2 = 1.45\ \mu F$$

$$\frac{1}{C_{eq}} = \frac{1}{C''} + \frac{1}{C_1} + \frac{1}{C_6} = \frac{1}{C''} + \frac{1}{2} + \frac{1}{2}$$

$\Rightarrow \quad C_{eq} = 0.5\ \mu F$

Now, $Q = C_{eq} \times V = 0.5 \times 10 = 5\ \mu C$

$$Q' = \frac{5\ \mu C \times 0.8}{0.8 + 0.2} = 4\ \mu C$$

24. The correct answer is (2).

As per conservation of linear momentum,

$$\Rightarrow \quad m_1 v_1 = m_2 v_2$$

$$\Rightarrow \quad \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{\rho \times \frac{4}{3} \times \pi \times r_2^3}{\rho \times \frac{4}{3} \times \pi \times r_1^3}$$

$$\Rightarrow \quad \frac{v_1}{v_2} = \frac{r_2^3}{r_1^3} = \left(\frac{2^{1/3}}{1}\right)^3 = \frac{2}{1}$$

Comparing with $n : 1$, we get $n = 2$.

25. The correct answer is (264).

Here, initial radius, $r = 10$ cm or 0.1 m

Final radius, $r' = 20$ cm or 0.2 m

Work done, $W = \sigma \times \Delta SA$

$$\Rightarrow \quad W = \sigma \times 2 \times 4\pi\,(r'^2 - r^2)$$

$$\Rightarrow \quad W = 3.5 \times 10^{-2} \times 8 \times \frac{22}{7}(0.2^2 - 0.1^2)$$

$$= 264 \times 10^{-4}\ \text{J}$$

26. The correct answer is (3).

Applying conservation of angular momentum

$$I_1\omega_1 = I_2\omega_2$$

$$\Rightarrow \quad I\omega = 3I\omega_2$$

$$\Rightarrow \quad \omega_2 = \frac{\omega}{3}$$

Kinetic energy of system,

$$E = \frac{1}{2} I\omega^2$$

New kinetic energy,

$$E' = \frac{1}{2} \times 3I\left(\frac{\omega}{3}\right)^2 = \frac{1}{3}\left(\frac{1}{2} I\omega^2\right)$$

$$\Rightarrow \quad E' = \frac{E}{3}$$

Comparing with $\frac{E}{x}$ we get $x = 3$

27. The correct answer is (300).

From FBD on the block

$$F - mg\sin 30 = ma$$

$$F = mg\sin 30 + ma$$

$$\Rightarrow \quad F = 5 \times 10 \times \frac{1}{2} + 5 \times 1 = 30\ \text{N}$$

Now, $u = 0\ \text{m s}^{-1}$, $a = 1\ \text{m s}^{-2}$, $t = 10$ s

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

Power, $P = Fv = 30 \times 10 = 300$ watt

28. The correct answer is (98).

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$d_a = \frac{8}{\frac{4}{3}} = 6\ \text{cm}$$

Apparent distance between object and mirror is 50 – (8 – 6) = 48 cm, since object and image are at same distance so image will also be at 48 cm. Hence, total distance between image and actual position of object is 48 + 50 = 98 cm.

29. The correct answer is (5).

Given, $E_1 = E_2 = 1.5$ V

$r_1 = r_2 = r$, $R = 10\ \Omega$

$$I = \frac{E_1 + E_2}{R + r_1 + r_2} = \frac{1.5 + 1.5}{10 + 2r} = \frac{1.5}{10}$$

$$\Rightarrow \quad 30 = 15 + 3r$$

$$\Rightarrow \quad r = 5\ \Omega$$

30. The correct answer is (80).

Fundamental frequency,

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

$$f = \frac{1}{2l}\sqrt{\frac{YA\Delta l}{\rho l}}$$

$$f = \frac{1}{2 \times 0.5}\sqrt{\frac{8 \times 10^{10} \times 3.2 \times 10^{-4}}{8 \times 10^3 \times 0.5}}$$

$$f = \sqrt{6400}$$

$$= 80\ \text{Hz}$$

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