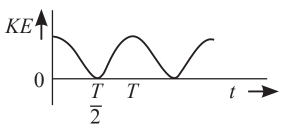
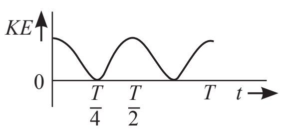
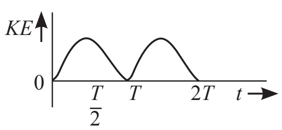
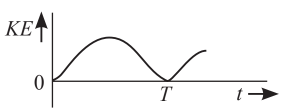
JEE (Main) 2017 Questions with Solutions Physics

1. A particle is executing simple harmonic motion with a time period T. At time $t = 0$, it is at its position of equilibrium. The kinetic energy-time graph of the particle will look like

   (a) 

   (b) 

   (c) 

   (d) 

2. The temperature of an open room of volume $30\ m^3$ increases from 17°C to 27°C due to sunshine. The atmospheric pressure in the room remains 1×10^5 Pa. If n_i and n_f are the number of molecules in the room before and after heating, then $w_f - n_i$ will be:

   (a) 2.5×10^{25} (b) -2.5×10^{25}
   (c) -1.61×10^{23} (d) 1.38×12^{23}

3. Which of the following statements is false?

   (a) A rheostat can be used as a potential divider
   (b) Kirchhoff's second law represents energy conservation
   (c) Wheatstone bridge is the most sensitive when all the four resistances are of the same order of magnitude.
   (d) In a balanced Wheatstone bridge if the cell and the galvanometer are exchanged, the null point is disturbed.

4. The following observation were taken for determining surface tension T of water by capillary method:

   Diameter of capillary $D = 1.25 \times 10^{-2}$ m
   raise of water, $h = 1.45 \times 10^{-2}$ m
   Using g = 9.80 m/s^2 and the simplified relation $T = \frac{rgh}{2} \times 10^3$ N/m, the possible error in surface tension is closest to:

   (a) 2.4% (b) 10%
   (c) 0.15% (d) 15%

5. In amplitude modulation, sinusoidal carrier frequency used is denoted by ω_c and the signle frequency is denoted by ω_m. The bandwidth ($\Delta\omega_m$) of the signal is such the $\Delta\omega_m \ll \omega_c$. Which of the following frequencies is not contained in the modulated wave?

   (a) $\omega_m + \omega_c$ (b) $\omega_c - \omega_m$
   (c) ω_m (d) ω_c

6. A diverging lens with magnitude of focal length 25 cm is placed at a distance of 15 cm from a converging lens of magnitude of focal length 20 cm. A beam of parallel light falls on the diverging lens. The final image formed is:

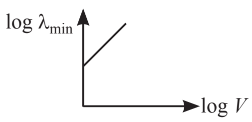
   (a) real and at a distance of 40 cm from the divergent lens
   (b) real and at a distance of 6 cm from the convergent lens
   (c) real and at a distance of 40 cm from convergent lens
   (d) virtual and at a distance of 40 cm from convergent lens

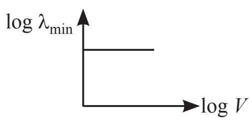
7. The moment of inertia of a uniform cylinder of length l and radius R about its perpendicular bisector is I. What is the ratio l/R such that the moment of inertia is minimum?

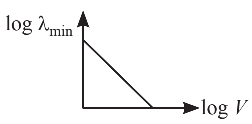
(a) 1 (b) $\frac{3}{\sqrt{2}}$

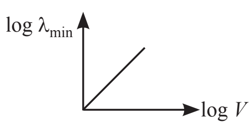
(c) $\sqrt{\frac{3}{2}}$ (d) $\frac{\sqrt{3}}{2}$

8. An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of X-ray in the spectrum, the variation of log λ_{min} with log V is correctly represented in:

(a)


(b)


(c)


(d)


9. A radioactive nucleus A with a half life T, decays into a nucleus B. At t = 0, there is no nucleus B. At sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by:

(a) $t = T\log(1.3)$ (b) $t = \frac{T}{\log(1.3)}$

(c) $t = \frac{T\log 2}{2\log 1.3}$ (d) $t = T\frac{\log 1.3}{\log 2}$

10. An electric dipole has a fixed dipole moment $\vec{p}$, which makes angle θ with respect to x-axis. When subjected to an electric field $\vec{E}_1 = E\hat{i}$, it experiences a torque $\vec{T}_1 = \tau\hat{k}$. When subjected to another electric field $\vec{E}_2 = \sqrt{3}E\hat{j}$ it experiences torque $\vec{T}_2 = \vec{T}_1$. The angle θ is:

(a) 60° (b) 90°
(c) 30° (d) 45°

11. In a common emitter amplifier circuit using an n-p-n transistor, the phase difference between the input and the output voltages will be:

(a) 135° (b) 180°
(c) 45° (d) 90°

12. C_p and C_v are specific heats at constant pressure and constant volume respectively. It is observed that

$C_p - C_v = a$ for hydrogen gas
$C_p - C_v = b$ for nitrogen gas

The correct relation between a and b is

(a) $a = 14b$ (b) $a = 28b$
(c) $a = \frac{1}{14}b$ (d) $a = b$

13. A copper ball of mass 100 gm is at a temperature T. It is dropped in a copper calorimeter of mass 100 gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by: (Given: room temperature = 30° C, specific heat of copper = 0.1cal/gm°C

(a) 1250°C (b) 825°C
(c) 800°C (d) 885°C

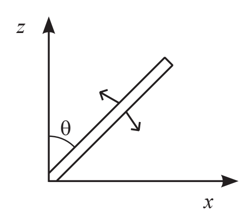
14. A body of mass $m = 10^{-2}$ kg is moving in a medium and experiences a frictional force $F = -kv^2$. Its initial speed is $v_0 =$ 10 ms^{-1}. If, after 10 s, its energy is $\frac{1}{8}mv_0^2$, the value of k will be:

(a) 10^{-4}kg m^{-1} (b) 10^{-4}kg m^{-1}s^{-1}
(c) 10^{-3}kg m^{-1} (d) 10^{-3}kg s^{-1}

15. When a current of 5 mA is passed through a galvanometer having a coil of resistance 15Ω, it shows full scale deflection. The value of the resistance to be put in series with the galvanometer to convert it into to voltmeter of range 0–10V is

(a) 2.535×10^3Ω (b) 4.005×10^3Ω
(c) 1.985×10^3Ω (d) 2.045×10^3Ω

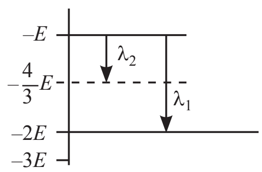
16. A slender uniform rod of mass M and length l is pivoted at one end so that it can rotate in a vertical plane (see figure). There is negligible friction at pivot. The free end is held vertically above the pivot and then released. The angular acceleration of the rod when it makes and angle θ with the vertical is:



(a) $\frac{3g}{2l}\cos\theta$ (b) $\frac{2g}{3l}\cos\theta$

(c) $\frac{3g}{2l}\sin\theta$ (d) $\frac{2g}{3l}\sin\theta$

17. Some energy levels of a molecule are shown in the figure. The ratio of the wavelengths $r = \lambda_1/\lambda_2$, is given by:

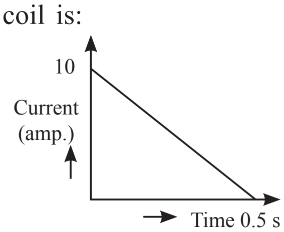


(a) $r = \frac{3}{4}$ (b) $r = \frac{1}{3}$
(c) $r = \frac{4}{3}$ (d) $r = \frac{2}{3}$

18. A man grows into a giant such that his linear dimensions increase by a factor of 9. Assuming that his density remains same, the stress in the leg will change by a factor of:

(a) 81 (b) $\frac{1}{81}$
(c) 9 (d) $\frac{1}{9}$

19. In a coil of resistance $100\,\Omega$, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is:



(a) 250 Wb (b) 275 Wb
(c) 200 Wb (d) 225 Wb

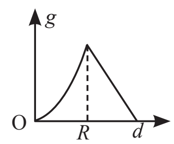
20. In a Young's double slit exper4iment, slits are separated by 0.5 mm, and the screen is placed 150 cm away. A beam of light consisting of tow wavelengths, 650 nm and 520 nm, is used to obtain interference fringes on the screen. The least distance from the common central maximum to the point where the bright fringes due to both the wavelengths coincide is

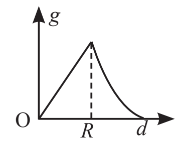
(a) 9.75 mm (b) 15.6 mm
(c) 1.56 mm (d) 7.8 mm

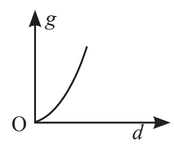
21. A magnetic needle of magnetic moment 6.7×10^{-2} Am^2 and moment of inertia 7.5×10^{-6} kg m^2 is performing simple harmonic oscillation in a magnetic field of 0.01 T. Time taken for 10 complete oscillations is:

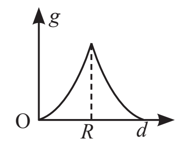
(a) 6.98 s (b) 8.76 s
(c) 6.65 s (d) 8.89 s

22. The variation of acceleration due to gravity g with distance d from centre of the earth is best represented by (R = Earth's radius)

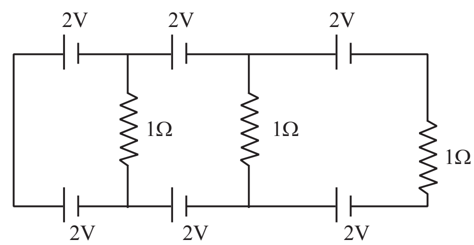
(a)


(b)


(c)


(d)


23. In the given circuit the current in each resistance is:



(a) 0.5 A (b) 0 A
(c) 1 A (d) 0.25 A

24. A particle A of mass m and initial velocity v collides with a particle B of mass $\frac{m}{2}$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is:

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

25. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modules of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by:

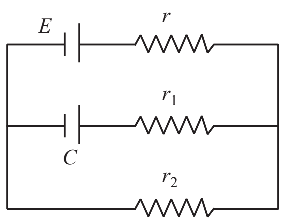
(a) $\frac{3\alpha}{PK}$ (b) $3PK\alpha$
(c) $\frac{P}{3\alpha K}$ (d) $\frac{P}{\alpha K}$

26. A time dependent force $F = 6t$ acts on a particle of mass 1 kg. If the particle starts from rest, the work done by the force during the first 1 sec. will be:

(a) 9 J (b) 18 J
(c) 4.5 J (d) 22 J

27. An observer is moving with half the speed of light towards a stationary microwave source emitting waves at frequency 10 GHz. What is the frequency of the microwave measured by the observer? (speed of light = 3×10^8 ms^{-1})
    (a) 17.3 GHz (b) 15.3 GHz
    (c) 10.1 GHz (d) 12.1 GHz

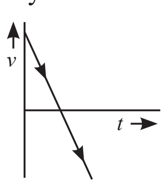
28. In the given circuit diagram when the current reaches steady state in the circuit, the charge on the capacitor of capacitance C will be:

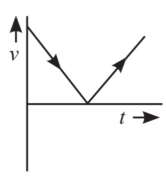


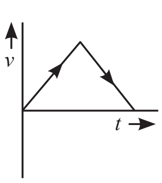
    (a) $CE\frac{r_2}{(r+r_2)}$ (b) $CE\frac{r_1}{(r_1+r)}$
    (c) CE (d) $CE\frac{r_1}{(r_2+r)}$

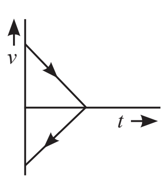
29. A capacitance of 2μF is required in an electrical circuit across a potential difference of 1.0 kV. A large number of 1μF capacitors are available which can withstand a potential difference of not more than 300V. The minimum number of capacitors required to achieve that is:
    (a) 24 (b) 32
    (c) 2 (d) 16

30. A body is thrown vertically upwards. Which one of the following graphs correctly represents the velocity vs time?

(a)


(b)


(c)


(d)


Answers

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

Solutions

1. The displacement of a particle executing simple harmonic motion is given by

$$x = A\sin(\omega t + \phi) \quad (1)$$

Since the particle is at the equilibrium position ($x = 0$) at time $t = 0$, it follows from Eq. (1) that $\phi = 0$

Hence,

$$x = A\sin(\omega t)$$

The kinetic energy of the particles is

$$\text{KE} = \frac{1}{2}mv^2$$

$$= \frac{1}{2}m\left(\frac{dx}{dt}\right)^2$$

$$= \frac{1}{2}mA^2\omega^2\cos^2(\omega t)$$

or, $\text{KE} = E_0\cos^2(\omega t)$ (2)

where $E_0 = \frac{1}{2}mA^2\omega^2$

It follows from Eq. (2) that KE is maximum = E_0

when $\cos^2(\omega t) = +1$

or, $\cos(\omega t) = \pm 1$

$\Rightarrow \omega t = 0, \pi, 2\pi, 3\pi. \ldots$ etc

or $\frac{2\pi t}{T} = 0, \pi, 2\pi, 3\pi. \ldots$ etc

or $t = 0, \frac{T}{2}, T, \frac{3T}{2}, \ldots$ etc

KE is zero when

$$\cos^2(\omega t) = 0$$

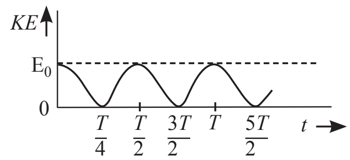
or $\cos(\omega t) = 0$

or $\cos\left(\frac{2\pi t}{T}\right) = 0$

or, $\frac{2\pi t}{T} = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots$ etc

or $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \ldots$ etc

So, the graph of KE vs t is as shown in the following figure



Hence the correct choice is (b).

2. If N is the number of moles of a gas, then the number of molecules is

n = N × Avogadro number = N × 6.023 × 10^{23}

Given T_i = 290 K and T_f = 300 K. Assuming that the gas in the room is an ideal gas, then

$$P_0V_0 = N_iRT_i \qquad (1)$$

and
$$P_0V_0 = N_fRT_f \qquad (2)$$

where $P_0 = 1\times10^5$ Pa and $V_0 = 30\,\text{m}^3$. From Eq. (1) and (2) we have

$$N_i = \frac{P_0V_0}{RT_i} \text{ and } N_f = \frac{P_0V_0}{RT_f}$$

Therefore, $N_i - N_f = \frac{P_0V_0}{R}\left(\frac{1}{T_i} - \frac{1}{T_f}\right)$

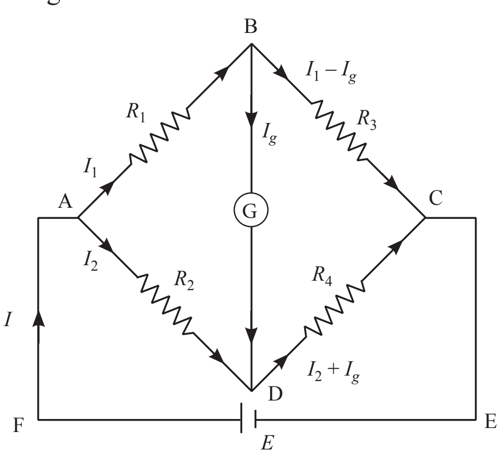
$$\therefore \quad n_f - n_i = \frac{P_0V_0}{R}\left(\frac{1}{T_f} - \frac{1}{T_i}\right)\times 6.023\times10^{23}$$

$$= \frac{(1\times10^5)\times30}{8.3}\times\left(\frac{1}{300} - \frac{1}{290}\right)\times(6.023\times10^{23})$$

$$= -2.5\times10^{25} \text{ molecules}$$

So the correct choice is (b).

3. The following figure shows a normal Wheatstone bridge.



Applying Kirchhoff's loop rule to loops ABDA and BCDB,

We get

$$I_1R_1 + I_gG - I_2R_2 = 0 \qquad (1)$$

and
$$(I_1 - I_g)R_3 - (I_2 + I_g)R_4 - I_gG = 0 \qquad (2)$$

When no current flow through the galvanometer (I_g = 0), the bridge is balanced. Putting I_g = 0 in Eqs. (1) and (2), we have

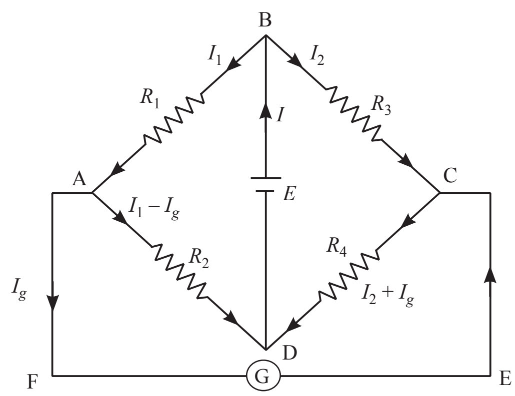
$$I_1R_1 - I_2R_2 = 0 \;\Rightarrow\; \frac{I_1}{I_2} = \frac{R_2}{R_1} \qquad (3)$$

and
$$I_1R_3 - I_2R_4 = 0 \;\Rightarrow\; \frac{I_1}{I_2} = \frac{R_4}{R_3} \qquad (4)$$

Equations (3) and (4) give

$$\frac{R_2}{R_1} = \frac{R_4}{R_3} \Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4} \qquad (5)$$

When the cell E and galvanometer G are interchanged the bridge is shown in the following figure.



Applying Kirchhoff's loop rule to loops ABCEFA and AFECDA, we get

$$-I_1R_1 + I_2R_3 - I_gG = 0 \qquad (6)$$

and
$$(I_1 - I_g)R_2 - (I_2 + I_g)R_4 - I_gG = 0 \qquad (7)$$

Putting I_g = 0 in Eqs. (6) and (7) we have

$$-I_1R_1 + I_2R_3 = 0 \;\Rightarrow\; \frac{I_1}{I_2} = \frac{R_3}{R_1} \qquad (8)$$

and
$$I_1R_2 - I_2R_4 = 0 \;\Rightarrow\; \frac{I_1}{I_2} = \frac{R_4}{R_2} \qquad (9)$$

Equation (8) and (9) give

$$\frac{R_3}{R_1} = \frac{R_4}{R_2} \Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4} \qquad (10)$$

The balance condition (5) and (10) are the same. Hence statement (d) is false. Statement (a), (b) and (c) are true.

4. $T = \frac{rhg}{2}\times 10^3 = \frac{Dhg}{4}\times 10^3$ $(\because D = 2r)$

The fractional error in T is

$$\frac{\Delta T}{T} = \frac{\Delta D}{D} + \frac{\Delta h}{h} + \frac{\Delta g}{g}$$

It is given that $g = 9.8\ \text{ms}^{-2}$ (fixed). Hence $\Delta g = 0$

Therefore,

$$\frac{\Delta T}{T} = \frac{\Delta D}{D} + \frac{\Delta h}{h}$$

It follows from the given measurements that $\Delta D = 0.01\times 10^{-2}$ m and $\Delta h = 0.01 \times 10^{-2}$m. therefore

$$\frac{\Delta T}{T} = \frac{0.01\times 10^{-2}}{1.25\times 10^{-2}} + \frac{0.01\times 10^{-2}}{1.45\times 10^{-2}}$$

$$= \frac{0.01}{1.25} + \frac{0.01}{1.45}$$

Percentage error in T is

$$\frac{\Delta T}{T}\times 100 = \frac{0.01}{1.25}\times 100 + \frac{0.01}{1.15}\times 100$$

$$= 0.8 + 0.689$$

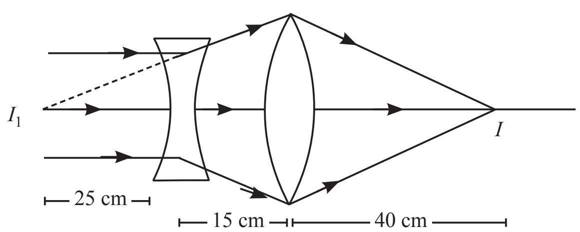
$$= 1.489$$

$$\simeq 1.5\%$$

So the correct choice is (d).

5. Refer to NCERT book page no. 526. The amplitude modulated wave contains the frequencies ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$; it does not contain the frequency ω_m. Hence the correction option is (c).

6. Refer to the following figure.



A parallel beam of light falling on a concave lens forms a virtual image I_1 at its focus which is to the left of this lens. This image I, acts as a virtual object for the convex. The object distance for the convex lens is $u = -(25 + 15) = -40$cm and $f = +20$ cm. Using these in the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we have

$$\frac{1}{v} - \frac{1}{-40} = \frac{1}{20}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{20} - \frac{1}{40} = \frac{1}{40}$$

$$\Rightarrow \quad v = +40 \text{ cm}$$

The plus sign shows that the final image I is real and is formed at a distance of 40 cm to the right of the convex lens. So the correct option is (c).

7. The moment of inertia of the cylinder about its perpendicular bisector is

$$I = \frac{Ml^2}{12} + \frac{MR^2}{4}$$

or $$I = \frac{M}{4}\left(\frac{l^2}{3} + R^2\right) \quad (1)$$

If ρ is the density of the cylinder, its mass is

$$M = \pi R^2 l r$$

$$\Rightarrow \quad R^2 = \frac{M}{\pi l \rho}$$

Using this in Eq. (1) we get

$$I = \frac{M}{4}\left(\frac{l^2}{3} + \frac{M}{\pi l \rho}\right)$$

I will be maximum or minimum if $\frac{dI}{dl} = 0$. Differentiating I will respect of l and setting $\frac{dI}{dl} = 0$, we have

$$0 = \frac{M}{4}\left(\frac{2l}{3} - \frac{M}{\pi l^2 \rho}\right)$$

$$\Rightarrow \quad \frac{2l}{3} - \frac{M}{\pi l^2 \rho} = 0 \quad (2)$$

Now, $\pi l^2 R\rho = M$. Putting this in Eq. (2) we get

$$\frac{2l}{3} - \frac{R^2}{l} = 0$$

$$\Rightarrow \quad \frac{l^2}{R^2} = \frac{3}{2} \Rightarrow \frac{l}{R} = \sqrt{\frac{3}{2}}$$

I is maximum if $\frac{d^2I}{dl^2} < 0$. It is easy to check that $\frac{d^2I}{dl^2}$ is negative if $\frac{l}{R} = \sqrt{\frac{3}{2}}$. So the correct option is (c).

8. X=rays are produced when a beam of fast moving electrons hits a metal target. An electron accelerated by a potential difference V acquires energy eV where e is the magnitude of the charge of the electron. It the whole of this energy is used up, a photon of maximum frequency ν_{max} is produced. The energy of this photon is $h\nu_{max}$. From $c = \nu\lambda$, the wavelength of the photon is minimum ($=\lambda_{min}$) when ν is maximum ($=\nu_{max}$) thus

$$h\nu_{\max} = eV$$

$$\Rightarrow \quad \frac{hc}{\lambda_{\min}} = eV$$

$$\Rightarrow \quad \lambda_{\min} = \left(\frac{hc}{eV}\right) = \frac{k}{V} \qquad (1)$$

where, $k = \frac{kc}{e}$. Taking logarithm of Eq. (1), we have

$$\log(\lambda_{\min}) = -\log V + \log k \qquad (2)$$

From Eq. (2) it is clear that the graph of log (λ_{min}) versus log V is a straight line with negative slope (= –1) and a positive intercept log k. So the correct choice is (c).

9. It is given that at time t, $\frac{N_B}{N_A} = 0.3 \Rightarrow N_B = 0.3N_A$.

Therefore, the total number of nuclei at time t is

$$N_A + N_B = N_A + 0.3N_A = 1.3N_A$$

We know that

$$N_A = 1.3N_A e^{-\lambda t}$$

$$\Rightarrow \quad \frac{1}{1.3} = e^{-\lambda t}$$

$$\Rightarrow \quad -\ln(1.3) = -\lambda t$$

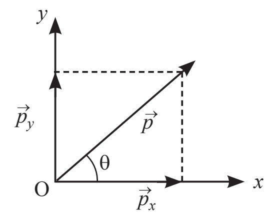
$$\Rightarrow \quad t = \frac{\ln(1.3)}{\lambda}$$

Now $\quad \lambda = \frac{\ln 2}{T}$

Therefore, $t = T\frac{\ln(1.3)}{\ln(2)}$

So the correct choice is (d).

10. Refer to the following figure.



$$\vec{p} = p_x\hat{i} + p_y\hat{j}$$

We know that torque = $\vec{p} \times \vec{E}$

$$\therefore \quad \vec{T}_1 = \left(p_x\hat{i} + p_y\hat{j}\right) \times E\hat{i} = -p_y\hat{k}E$$

$$\vec{T}_2 = \left(p_x\hat{i} + p_y\hat{j}\right) \times \sqrt{3}E\hat{j} = \sqrt{3}p_x\hat{k}E$$

It is given that

$$\vec{T}_2 = -\vec{T}_1$$

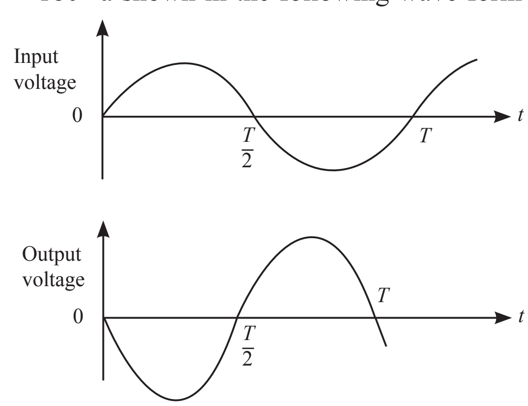
$$\therefore \quad \sqrt{3}p_x\hat{k}E = -\left(-p_y\hat{k}E\right)$$

$$\Rightarrow \quad \frac{p_y}{p_x} = \sqrt{3}$$

$$\Rightarrow \quad \tan\theta = \sqrt{3} \quad \Rightarrow \theta = 60^\circ$$

So the correct option is (a).

11. In a common emitter amplifier circuit the input and output voltages are out of phase by a angle of 180° a shown in the following wave form graphs.



During the positive half cycle of the input voltage, the output voltage is negative and vice versa. So the correct choice is (b).

12. For an ideal gas,

$$C'_p - C'_v = R$$

where C'_p and C'_v are the molar specific heats at constant pressure and constant volume respectively. Now, the specific heart C of a gas $= \frac{\text{molar specific heat}}{\text{molar mass}}$. For hydrogen gas molar mass = 2 and for nitrogen molar mass = 28. So

For hydrogen $C_p - C_v = \frac{R}{2}$

For nitrogen $C_p - C_v = \frac{R}{28}$

Comparing with given relation in the question, we have $a = \frac{R}{2}$ and $b = \frac{R}{28}$. So $\frac{a}{b} = 14$ or $a = 14b$.

Thus the correct option is (a).

13. Heat is ained by the calorimeter and the water filled in it and heat is lost by the copper ball. Specific heat of water = 1 cal/g°C

Heat gained

= 100 × 0.1 × (75 – 30) + 170 × 1 × (75 – 30)

= 450 + 7650 = 8100 cal

Heat lost

= 100 ×0.1 × (T – 75)

= (10T – 750) cal

Now, heat gained = heat lost. Therefore,

8100 = 10T –750

⇒ T = 885°C, which is choice (d)

14. Let v be the speed of the ball at t = 10s. Its kinetic energy at t = 10s is $\frac{1}{2}mv^2$. It is given that

$$\frac{1}{2}mv^2 = \frac{1}{8}mv_0^2$$

$$\Rightarrow \quad v^2 = \frac{v_0^2}{4} \Rightarrow v = \frac{v_0}{2} = \frac{10\ \text{ms}^{-1}}{2} = 5\ \text{ms}^{-1}$$

Frictional force $F = -kv^2$. Now $F = ma = m\frac{dv}{dt}$. Hence

$$m\frac{dv}{dt} = -kv^2$$

$$\Rightarrow \quad \frac{dv}{v^2} = -\frac{kdt}{m}$$

$$\Rightarrow \quad \int_{v_0}^{v} \frac{dv}{v^2} = -\frac{k}{m}\int_0^t dt$$

$$\Rightarrow \quad \left| -\frac{1}{v} \right|_{v_0}^{v} = -\frac{k}{m}|t|_0^t = -\frac{kt}{m}$$

$$\Rightarrow \quad \frac{1}{v} - \frac{1}{v_0} = \frac{kt}{m}$$

$$\Rightarrow \quad \frac{1}{5} - \frac{1}{10} = \frac{k \times 10}{10^{-2}}$$

$$\Rightarrow \quad \frac{1}{10} = k \times 10^3$$

⇒ $k = 10^{-4}$ kg m^{-1}

The SI unit of $k = \frac{\text{SI unit of } F}{\text{SI unit of } v^2}$

$$= \frac{\text{kg m s}^{-2}}{\text{m}^2\text{s}^{-2}} = \text{kg m}^{-1}$$

So the correct option is (a).

15. Current for full scale deflection (I_g) = 5 mA = 5 × 10^{-3}A. Galvanometer resistance (G) = 15Ω. The required resistance is

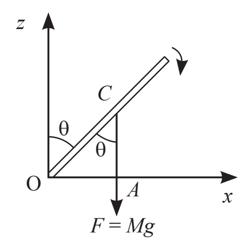
$$R = \frac{V}{I_g} - G$$

$$= \frac{10}{5 \times 10^{-3}} - 15$$

= 2000 – 15 = 1985 W

So, the correct option is (c)

16. The entire mass of the rod can be assumed to be at its centre of mass. For a uniform rod the centre of mass is its centre C (see the following figure) so that $OC = \frac{l}{2}$



The axis of rotation passes through O and is perpendicular to the x-z plane. Now torque about O is

τ = force × perpendicular distance of the line of application of force from the axis of rotation

$= F \times OA = F \times OC \sin\theta$

or $\quad \tau = Mg \times \frac{l}{2}\sin\theta$

The moment of inertia of the rod about the axis of rotation is

$$I = \frac{Ml^2}{3}$$

Now, $\tau = I\alpha$

$$\Rightarrow \quad \frac{Mgl\sin\theta}{2} = \frac{ml^2}{3}\times\alpha$$

$$\Rightarrow \quad \alpha = \frac{3}{2}\frac{g\sin\theta}{l}$$, which is choice (c).

17. Change in energy $= h\nu = \frac{hc}{\lambda}$ or $\Delta E = \frac{hc}{\lambda}$

For transition $\lambda_1, \Delta E = -E-(-2E) = E$. Hence

$$E = \frac{hc}{\lambda_1} \Rightarrow \lambda_1 = \frac{hc}{E} \quad (1)$$

For transition $\lambda_2, \Delta E = -E - \left(-\frac{4E}{3}\right) = \frac{E}{3}$. Hence

$$\frac{E}{3} = \frac{hc}{\lambda_2} \Rightarrow \lambda_2 = \frac{3hc}{E} \quad (2)$$

From Eqs. (1) and (2) we find that

$$\frac{\lambda_1}{\lambda_2} = \frac{1}{3} \text{ or } r = \frac{1}{3}$$

So the correct choice is (b).

18. Stress $= \frac{\text{Force}}{\text{area}} = \frac{mg}{A} = \frac{V\rho g}{A}$

Where V is the volume and ρ is the density. If the linear dimension of a body is L. Then its volume $V \propto L^3$ and its area $A \propto L^2$. Hence

$$\text{Stress} \propto \frac{L^3\rho g}{L^2} \propto L\rho g$$

Since ρ remains unchanged, stress $\propto L$. Hence, if L increases by a factor of 9, the stress will also increases by a factor of 9. So the correct choice is (c).

19. From the given $I - t$ graph, it is clear that the slope is $m = -\frac{10}{0.5} = -20\,\text{As}^{-1}$ and intercept c = 10A. Therefore, the equation of the straight line graph is

$$I = (-20t + 10) \text{ ampere}$$

Induced charge is

$$q = \int I dt$$

$$= \int_{t=0}^{t=0.5s} (-20t+10)dt$$

$$= \left|-10t^2\right|_0^{0.5} + \left|10t\right|_0^{0.5}$$

$$= -2.5 + 5 = 2.5 \text{ coulomb}$$

Now change in magnetic flux is given by

$$\Delta\phi = qR$$

$$= 2.5 \times 100 = 250 \text{ Wb},$$

which is choice (a).

Note: The value of q can also be obtained as follows.

$$q = \int I dt$$

= Area under the I – t graph

$$= \frac{1}{2}\times 10 \times 0.5 = 2.5 \text{ coulomb}$$

20. Let m th bright fringe of wavelength λ_m and nth bright fringe of wavelength λ_n coincide at a distance y from the central maximum, then

$$y = \frac{m\lambda_m D}{d} = \frac{n\lambda_n D}{d}$$

$$\Rightarrow \quad \frac{m}{n} = \frac{\lambda_n}{\lambda_m} = \frac{520}{650} = \frac{4}{5}$$

The least integral values of m and n which satisfy this condition are $n = 4$ and $m = 5$, i.e. 4^{th} bright fringe of 650 nm coincides with 5^{th} bright fringe of 520 nm. The smallest value of y at which this happens is

$$y_{\min} = \frac{n\lambda_m D}{d}$$

$$= \frac{4\times(650\times10^{-9})\times1.5}{0.5\times10^{-3}}$$

$$= 7.8 \times 10^{-3} \text{ m} = 7.8 \text{ mm},$$

which is choice (d).

21. Given $I = 7.5 \times 10^{-6}$ kgm^2, $M = 6.7 \times 10^{-2}$ Am^2 and $B = 0.01$ T.

The time period of oscillations (i.e. time for one oscillation) is

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

$$= 2\times3.14\times\sqrt{\frac{7.5\times10^{-6}}{6.7\times10^{-2}\times0.01}}$$

$$= 0.665 \text{ s}$$

$\therefore$ Time for 10 oscillations = $10T$ = 6.65s. so, the correct choice is (c).

22. At a point at a distance d inside the earth from the centre of the earth, g is given by

$$g = \frac{GMd}{R^3}$$

where M is the mass of the earth. So g varies linearly with d for ($d < R$)

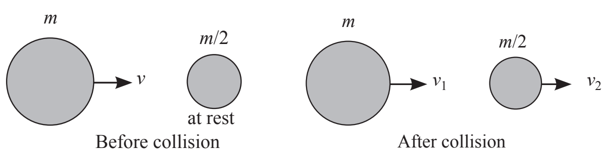
For a point at a distance d outside the earth from the centre of the earth, g is given by

$$g = \frac{GM}{d^2}$$

So $g \propto \frac{1}{d^2}$ for ($d > R$). Hence the correct option is (b).

23. From the given circuit, it is clear that the potential difference across each resistance = $2V - 2V =$ zero. Hence the current in each resistance is zero. So the correct option is (b).

24. Refer to the following figure.



Conservation of linear momentum gives

$$mv + \frac{m}{2}\times 0 = mv_1 + \frac{m}{2}v_2$$

$$\Rightarrow \quad 2v = 2v_1 + v_2 \Rightarrow v_2 = 2(v - v_1) \qquad (1)$$

Since the collision is elastic, kinetic energy is also conserved.

$$\frac{1}{2}mv^2 + 0 = \frac{1}{2}mv_1^2 + \frac{1}{2}\left(\frac{m}{2}v_2\right)^2$$

$$\Rightarrow \quad 2v^2 = 2v_1^2 + v_2^2 \qquad (2)$$

Using (1) and (2), we have

$$2v^2 = 2v_1^2 + 4(v - v_1)^2$$

$$\Rightarrow \quad v^2 - 4vv_1 + 3v_1^2 = 0$$

$$\Rightarrow \quad v^2 - 3vv_1 - vv_1 + 3v_1^2 = 0$$

$$\Rightarrow \quad v(v - 3v_1) - v_1(v - 3v_1) = 0$$

$$\Rightarrow \quad v = v_1 \text{ and } v = 3v_1$$

Since $v = v_1$ is not possible, $v = 3v_1$ or $v_1 = \frac{v}{3}$

Using this in Eq. (2) we get $v_2 = \frac{4v}{3}$

de-Broglie wavelengths of the particle are $\lambda_1 = \frac{h}{p_1}$ and $\lambda_2 = \frac{h}{p_2}$ i.e.

$$\lambda_1 = \frac{h}{mv_1} \text{ and } \lambda_2 = \frac{h}{\frac{m}{2}v_2} = \frac{2h}{mv_2}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{v_2}{2v_1} = \frac{4v}{3}\times\frac{1}{2}\times\frac{3}{v} = 2$$

So the correct option is (d).

25. Let V be the original volume of the cube at 0°C. The decrease in volume under external pressure P is

$$\Delta V = \frac{VP}{K} \qquad (1)$$

Let ΔT be the increase in its temperature to compensate for this increase in volume, then

$$\Delta V = \gamma V \Delta T = 3\alpha V \Delta T \qquad (2)$$

where γ is the coefficient of cubical expansion which is equal to 3α. Equating (1) and (2)

$$\frac{VP}{K} = 3\alpha V \Delta T$$

$\Rightarrow \quad \Delta T = \frac{P}{3\alpha K}$, which is option (c).

26. Given $F = 6t$ also $F = ma = m\frac{dv}{dt}$. Therefore

$$m\frac{dv}{dt} = 6t$$

$$\Rightarrow \quad \frac{dv}{dt} = \frac{6t}{m}$$

$$\Rightarrow \quad dv = \frac{6tdt}{m}$$

$$\Rightarrow \quad \int_0^v dv = \frac{6}{m}\int_0^{1s} tdt$$

$$\Rightarrow \quad |v|_0^v = \frac{6}{m}\left|\frac{t^2}{2}\right|_0^{1s}$$

$$\Rightarrow \quad v = \frac{6}{m}\frac{(1)^2}{2} = \frac{3}{m} = \frac{3}{1} = 3\text{ ms}^{-1} \qquad (\because m = 2kg)$$

From work energy theorem

Work done = change in kinetic energy

$$= \frac{1}{2}mv^2 - 0$$

$$= \frac{1}{2}\times 1\times 3^2$$

$$= 4.5 \text{ J}$$

So the correct choice is (c).

27. The apparent frequency measured by the observer is

$$\nu_a = \nu \times \sqrt{\frac{1+\frac{v}{c}}{1-\frac{v}{c}}}$$

where c = speed of microwaves = speed of light

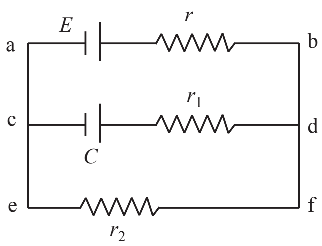
v = speed of the source = $\frac{c}{2}$ (given)

ν = actual frequency of microwaves = 10 GHz (given)

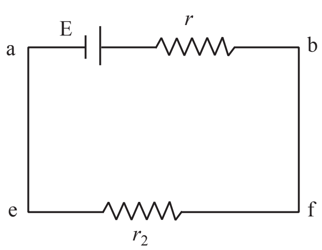
$$\therefore \quad \nu_a = 10\ \text{GHz} \times \sqrt{\frac{1+\frac{1}{2}}{1-\frac{1}{2}}} = 17.3\ \text{GHz}$$

So the correct option is (a).

28. Refer to the following figure



In the steady state (i.e. when the capacitor is fully charged) no current flows through the branch cd of the circuit. Hence the potential difference between ef = potential difference between cd. The circuit reduces to



Current flowing in the circuit in the steady state is

$$I = \frac{E}{r + r_2}$$

Potential difference between ef is

$$V_{ef} = Ir_2 = \frac{Er_2}{r + r_2}$$

Now potential difference across the capacitor = $V_{\text{ef.}}$. The charge on the capacitor is

$$Q = CV_{ef} = \frac{CEr_2}{r + r_2}, \text{ which is choice (a).}$$

29. Capacitance of each capacitor is C = 1μF. Some of these capacitors are connected in series and some of these series combinations are connected in parallel. Since each capacitor has the same capacitance, and since each capacitor can withstand a maximum potential difference of 300V the minimum number of capacitors that are connected in series is 4. Each capacitor then will have a voltage of $\frac{1000\text{V}}{4} = 250\text{V}$ which is safe. The equivalent capacitance of these 4 capacitors connected in series is

$$C_1 = \frac{C}{4} = \frac{1\mu F}{4} = \frac{1}{4}\mu F$$

Let n such series combination be connected in parallel. The total capacitance of the network is $\frac{n}{4}\mu F$. This capacitance is required to be $2\mu F$. Thus

$$\frac{n}{4}\mu F = 2\mu F \quad \Rightarrow n = 2 \times 4 = 8$$

Thus 8 parallel combinations of 4 series capacitors are required. Therefore, minimum number of capacitors required = 8 × 4 = 32. So the correct option is (b).

30. Velocity v at any instant of time t is given by

$$v = u + at$$

where u is the initial velocity. For body thrown vertically upwards, u and v are positive but a = $-g$. So

$$v = -gt + u$$

Hence the graph of v versus t is a straight line with a negative slope (= $-g$) and a positive intercept ($+u$). so the correct option is (a). as shown in the following figure.