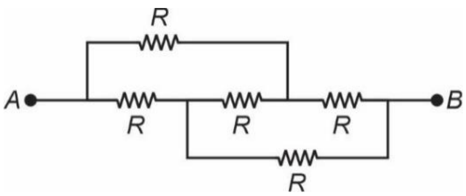
PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer:

1. In the circuit shown find the equivalent resistance between terminals *A* and *B*.

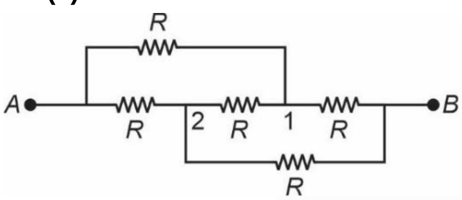


(1) $\frac{3R}{2}$ (2) $2R$

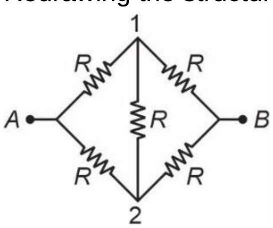
(3) $4R$ (4) R

Answer (4)

Sol.



Redrawing the structure.

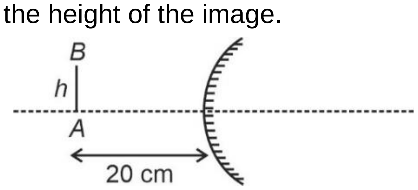


It is wheatstone bridge so

$$R_{net} = \frac{2R \times 2R}{2R + 2R} = R$$

2. An object of height *h* is placed in front of a convex mirror (radius of curvature = 20 cm).

Find the height of the image.



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

(3) $\frac{h}{6}$ (4) $\frac{h}{4}$

Answer (2)

Sol. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \frac{1}{v} + \frac{1}{-20} = \frac{1}{10}$$

$$\Rightarrow \frac{1}{v} = \frac{3}{20}$$

$$\Rightarrow v = \frac{20}{3}$$

$$\Rightarrow m = -\frac{v}{u} = \frac{1}{3}$$

3. A uniform solid cylinder of radius *R*, is released from a 600 m long ramp, inclined at 30° from the horizontal. Find the time taken to reach the bottom of ramp. (Consider sufficient friction for pure rolling)

(1) 60 sec

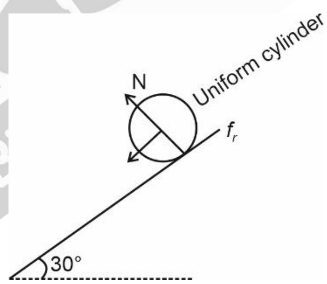
(2) $6\sqrt{10}$ sec

(3) $3\sqrt{10}$ sec

(4) 20 sec

Answer (2)

Sol.



$mg\sin\theta - f_r = ma$

Also, $\frac{3}{2}mR^2\alpha = mg\sin\theta \times R$

$$\Rightarrow \frac{3}{2}mR = mg\sin\theta$$

$$a = \frac{2}{3}g\sin\theta = \frac{2}{3} \times g \times \sin 30° = \left(\frac{g}{3}\right) = \frac{10}{3}\ \text{m/s}^2$$

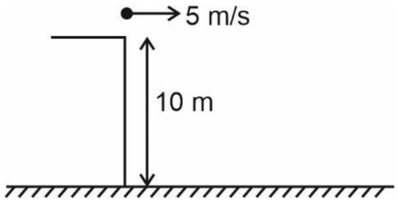
S = 600 m

$$\text{time} = \sqrt{\frac{2s}{a}} = \sqrt{\frac{1200 \times 3}{10}}$$

$$= \sqrt{360}$$

$$= 6\sqrt{10}\ \text{seconds}$$

4. A ball is thrown horizontally from a height of 10 m with a speed of 5 ms^{-1} as shown. Find the speed with which it strikes the ground.



(1) 15 m/s

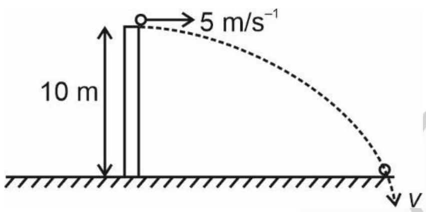
(2) 5 m/s

(3) 10 m/s

(4) 20 m/s

Answer (1)

Sol.



$v^2 = u^2 + 2gh$

$v^2 = 25 + 2 \times 10 \times 10$

$v^2 = 225$

$v = \sqrt{225}$

= 15 m/s

5. An ideal gas (adiabatic constant = 3/2) undergoes an adiabatic expansion process where change in temperature is $-T$. If there are 2 moles of the gas, find the work done by the gas.

(1) $3RT$

(2) $2RT$

(3) $4RT$

(4) $-RT$

Answer (3)

Sol. $W = \dfrac{nR\Delta T}{1-\gamma}$

$= \dfrac{2 \cdot R \cdot (-T)}{1-\dfrac{3}{2}}$

$= 4RT$

6. **Statement-1** : Value of acceleration due to gravity is same at all the point inside earth assuming it to be made up of uniform density.

Statement-2 : Value of gravitational field increases as we go towards centre in a uniform spherical shell.

(1) Both statement-1 and statement-2 are true

(2) Statement-1 is true but statement-2 is false

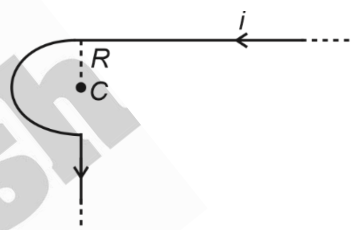
(3) Statement-1 is false but statement-1 is true

(4) Both statement-1 and statement-2 are false

Answer (4)

Sol. Value of acceleration due to gravity decreases as we go inside the earth and it does not change inside the spherical shell.

7. An infinite wire is bent in the shape as shown:



Find the magnetic field at point C.

(1) $\dfrac{\mu_0 i(1+\pi)}{4\pi R}$ (2) $\dfrac{\mu_0 i(2+\pi)}{4\pi R}$

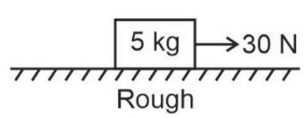
(3) $\dfrac{\mu_0 i(1+\pi)}{2\pi R}$ (4) $\dfrac{\mu_0 i}{2R}$

Answer (1)

Sol. $B = \dfrac{\mu_0 i}{4\pi R}[\sin 90^\circ + \sin 0^\circ] + \dfrac{\mu_0 i}{4R} + 0$

$= \dfrac{\mu_0 i}{4\pi R}[1+\pi]$

8. A force of 30 N is applied on a block of mass 5 kg. The block travels a distance of 50 m in 10 sec starting from rest. Find coefficient of friction

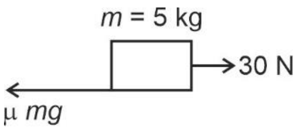


(1) 0.5 (2) 0.7

(3) 0.3 (4) 0.8

Answer (1)

Sol.



$$30 - \mu mg = ma \Rightarrow a = \left(\frac{30 - 50\mu}{5}\right)$$

$$S = \frac{1}{2}at^2$$

$$\Rightarrow \quad 50 = \frac{1}{2}a \times t^2$$

$$\Rightarrow \quad \frac{100}{100} = a$$

a = 1 m/s^2

$$\Rightarrow \quad \frac{30 - 50\mu}{5} = 1$$

$$\Rightarrow \quad \mu = \frac{25}{50} = \frac{1}{2} = 0.5$$

9. Which of the following is not the frequency of frequency modulated (FM) signal?

(1) 90 MHz

(2) 89 MHz

(3) 106 MHz

(4) 100 KHz

Answer (4)

Sol. Band of FM is in MHz

10. For a real gas, the equation of gas is given by $\left(P + \frac{an^2}{V^2}\right)(V - bn) = nRT$. If symbols have their usual meaning then the dimensions of $\frac{V^2}{an^2}$ is same as that of

(1) Compressibility (2) Bulk modulus

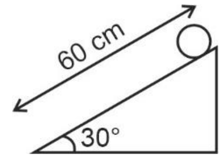
(3) Viscosity (4) Energy density

Answer (1)

Sol. $[P] = \left[\frac{an^2}{V^2}\right]$ = dimension of bulk modulus.

So $\left[\frac{V^2}{an^2}\right]$ has dimension of compressibility.

11. A solid cylinder starts pure rolling from top of a fixed inclined plane of slant length 60 cm as shown in the figure. Velocity of centre of mass when the cylinder reaches the bottom is equal to (g = 10 m/s^2)



(1) 1 m/sec

(2) 2 m/sec

(3) 3 m/sec

(4) 4 m/sec

Answer (2)

Sol. Using energy conservation

$$mg(0.3) = \frac{1}{2}mv_{cm}^2 + \frac{1}{2} \times \frac{mR^2}{2}\frac{v_{cm}^2}{R^2}$$

$$mg \times 0.3 = \frac{3}{4}mv_{cm}^2$$

v_{cm} = 2 m/sec

12. A stone is thrown vertically up with speed v_0 from a cliff of height H. Find the average speed of the ball till the moment it reaches ground. Given that H = 100 m, v_0 = 10 m/s, g = 10 m/s^2.

(1) $\frac{64}{1+\sqrt{21}}$ m/s (2) 55 m/s

(3) $110\left(1+\sqrt{21}\right)$ m/s (4) $\frac{110}{1+\sqrt{21}}$ m/s

Answer (4)

Sol. Total distance = $\frac{v_0^2}{2g} \times 2 + 100$

= 110 m

Total time = t_0

$\Rightarrow$ – 100 = 10t_0 – $\frac{1}{2}$ × 10 × t_0^2

$\Rightarrow t_0 = 1+\sqrt{21}$ s

$\Rightarrow$ Avg. speed = $\frac{110}{1+\sqrt{21}}$ m/s

13. A drop of mercury is divided into 125 drops of equal radius of 10^{-3} m each. If surface tension of mercury is equal to 0.45 N m^{-1}. Magnitude of change in surface energy is equal to nearly

(1) 1.41×10^{-4} J

(2) 7.06×10^{-4} J

(3) 8.47×10^{-4} J

(4) 5.65×10^{-4} J

Answer (4)

Sol. Let radius of bigger drop was R so

$$\frac{4}{3}\pi R^3 = 125 \times \frac{4}{3}\pi \times (10^{-3})^3$$

$\Rightarrow$ $R = 5 \times 10^{-3}$ m

So $U_i = 4\pi R^2\sigma = 4\pi \times (5 \times 10^{-3})^2 \times 0.45 = 1.41 \times 10^{-4}$ J

$U_f = 125 \times 4\pi r^2\sigma = 500\pi\,(10^{-3})^2 \times 0.45 = 7.06 \times 10^{-4}$ J

So $\Delta U = U_f - U_i$

$= 5.65 \times 10^{-4}$ J

14. A charged particle with charge 2×10^{-6} C, at rest, is first accelerated through a potential difference of 100 V and then it is subjected to a transverse magnetic field of 4 mT. In region of magnetic field, it undergoes a circular path of radius 3 cm. Mass of the particle is equal to

(1) 1.44×10^{-16} kg

(2) 7.2×10^{-16} kg

(3) 1.44×10^{-10} kg

(4) 7.2×10^{-10} kg

Answer (1)

Sol. $R = \dfrac{\sqrt{2mqV}}{qB}$

$$3 \times 10^{-2} = \frac{\sqrt{2m \times 100}}{\sqrt{2 \times 10^{-6}} \times 4 \times 10^{-3}}$$

$\Rightarrow$ $m = 1.44 \times 10^{-16}$ kg

15. A string of mass per unit length equal to 7×10^{-3} kg/m is subjected to a tension equal to 70 N. The speed of transverse wave on this string is equal to

(1) 10 m/sec

(2) 50 m/sec

(3) 100 m/sec

(4) 200 m/sec

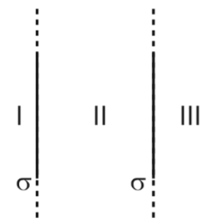
Answer (3)

Sol. $v = \sqrt{\dfrac{T}{\mu}}$

$= \sqrt{\dfrac{70}{7 \times 10^{-3}}}$

= 100 m/sec

16. Two thin insulating sheets (each having charge density +σ) are arranged as shown:



Then find the net electric field (magnitude) in the 3 regions:

(1) $E_1 = \dfrac{\sigma}{\varepsilon_0}$

$E_2 = 0$

$E_3 = \dfrac{\sigma}{\varepsilon_0}$

(2) $E_1 = E_2 = E_3 = 0$

(3) $E_1 = 0$

$E_2 = \dfrac{\sigma}{2\varepsilon_0}$

$E_3 = \dfrac{\sigma}{\varepsilon_0}$

(4) $E_1 = \dfrac{\sigma}{\varepsilon_0}$

$E_2 = 0$

$E_3 = \dfrac{\sigma}{2\varepsilon_0}$

Answer (1)

Sol. $E_1 = \dfrac{\sigma}{2\varepsilon_0} + \dfrac{\sigma}{2\varepsilon_0} = \dfrac{\sigma}{\varepsilon_0}$

$E_2 = \dfrac{\sigma}{2\varepsilon_0} - \dfrac{\sigma}{2\varepsilon_0} = 0$

$E_3 = \dfrac{\sigma}{2\varepsilon_0} + \dfrac{\sigma}{2\varepsilon_0} = \dfrac{\sigma}{\varepsilon_0}$

17. Match the two columns:

	Column I		Column II
a.	Intrinsic semiconductor	1.	Fermi level is closer to conduction band
b.	p-type semiconductor	2.	Fermi level is closer to valence band
c.	n-type semiconductor	3.	Fermi level is inside conduction band
d.	Metal	4.	Fermi level is in between the two bands

(1) a – 4, b – 2, c – 1, d – 3

(2) a – 1, b – 3, c – 2, d – 4

(3) a – 3, b – 2, c – 1, d – 4

(4) a – 2, b – 1, c – 3, d – 4

Answer (1)

Sol. In intrinsic, fermi level is between the two bands.

In p-type, fermi level is closer to valence band.

In n-type, fermi level is closer to conduction band.

In metal, fermi level is inside conduction band.

18.

19.

20.

SECTION - B

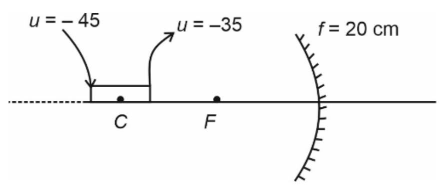
Numerical Value Type Questions: This section contains 10 questions. In Section B, attempt any five questions out of 10. The answer to each question is a **NUMERICAL VALUE.** For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g., 06.25, 07.00, –00.33, –00.30, 30.27, –27.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.

21. A cylindrical rod of length 10 cm is placed along the principal axis of concave mirror (f = 20 cm) in such a way that the COM of the rod is at 40 cm from the pole of mirror. The length of image of rod is $\frac{x}{3}$ cm.

Find x.

Answer (32.00)

Sol.



For u = – 45 cm

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v}-\frac{1}{45}=\frac{-1}{20}$$

$$\frac{1}{v}=\frac{-1}{20}+\frac{1}{45}=\frac{-9+4}{180}=\frac{-5}{180}$$

v = – 36 cm

For u = – 35 cm

$$\frac{1}{v}=-\frac{1}{20}+\frac{1}{35}$$

$$=\frac{-7+4}{140}=\left(\frac{-3}{140}\right)$$

$$u_2=-\left(\frac{140}{3}\right)$$

$$|v_1-v_2|=\left|\frac{140}{3}-36\right|$$

Length of image $=\left(\frac{32}{3}\right)$ cm

22. In an series LCR circuit connected across 220 V, 50 Hz A.C supply. If the inductive reactance of the circuit is 79.6 Ω. If the power delivered in the circuit is maximum, the capacitance of the circuit is x μF. Find x.

Answer (40.00)

Sol. For maximum power, LCR should be resonance condition,

$X_L = X_C$

$\Rightarrow 79.6=\frac{1}{\omega_c}$ as $\omega = 2\pi f$

$= 2\pi \times 50 = 100\pi$ rad/sec

$$C = \frac{1}{(79.6 \times 100\pi)}$$

$= 4 \times 10^{-5}$

$= 40 \times 10^{-6}$ F

$= 40\ \mu$F

23. An alpha particle and a proton having same de-broglie wavelengths will have kinetic energies in the ratio _______

Answer (00.25)

Sol. Charge on α particle = $2e$

Mass of proton = m

Mass of α particle = $4m$

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{(P_\alpha)}{(P_p)} = \frac{\sqrt{2K_\alpha m_\alpha}}{\sqrt{2K_p m_p}} = 1$$

$$\frac{K_\alpha}{K_p} \times \left(\frac{m_\alpha}{m_p}\right) = 1$$

$$\frac{K_\alpha}{K_p} \times 4 = 1$$

$$\frac{K_\alpha}{K_p} = \frac{1}{4}$$

24. If mass of a planet is 9 times that of earth and radius is 2 times that of earth, then escape speed from this planet is $\frac{xv_e}{\sqrt{2}}$. Find x. v_e is escape speed from earth.

Answer (03)

Sol. $v_e' = \sqrt{\frac{2GM'}{R'}}$

$$v_e = \sqrt{\frac{2GM}{R}}$$

$$\Rightarrow \frac{v_e'}{v_e} = \sqrt{\frac{9}{2}}$$

$$\Rightarrow v_e' = \frac{3v_e}{\sqrt{2}}$$

25. There are n number of polarizers arranged one after the other. Each polarizer pass axis is inclined at 45° with respect to the previous polarizer. Unpolarized light of intensity I_0 is incident on this setup. Final transmitted light has intensity $\frac{I_0}{64}$. Find n.

Answer (06.00)

Sol. $I = \frac{I_0}{2} \times \underbrace{\cos^2 45° \times \cos^2 45° \times ...}_{(n-1)\text{ times}}$

$$\Rightarrow \frac{I_0}{64} = \frac{I_0}{2} \times \left(\frac{1}{2}\right)^{n-1}$$

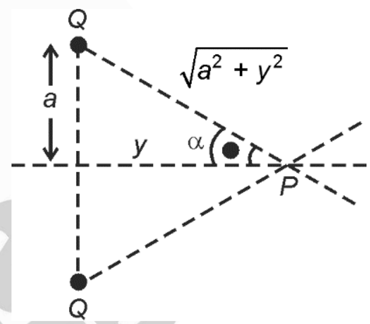
$\Rightarrow n - 1 = 5$

$\Rightarrow n = 6$

26. Two point charges each of magnitude Q is kept at a separation of $2a$. The distance from mid point on perpendicular bisector where a point charge will experience maximum force is $\frac{a}{\sqrt{x}}$. Find the value of x.

Answer (02.00)

Sol.



E due to one charge = $\frac{KQ}{(a^2 + y^2)}$

E_{net} at point P = $2E\cos\alpha$

$$= \frac{2KQy}{(y^2 + a^2)^{\frac{3}{2}}}$$

Force = $q\,E_{net}$

$\frac{dF}{dy} = 0$, for maximum force, on solving $\frac{dF}{dy} = 0$,

we get, $y = \left(\frac{a}{\sqrt{2}}\right)$

$\therefore\quad x = 2$

27.

28.

29.

30.