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JEE Main 2023 (Memory based)

1st February 2023 - Shift 1

Answer & Solutions

PHYSICS

1. Statement 1: Value of acceleration due to gravity is same at all the points 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.

A. Both statement 1 and statement 2 are true.
B. Statement 1 is true but statement 2 is false.
C. Statement 1 is false but statement 2 is true.
D. Both statement 1 and statement 2 are false.

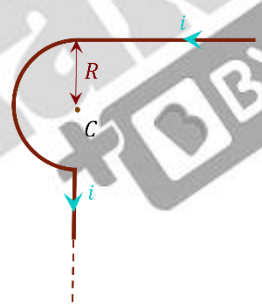
Answer (D)

Solution:

Value of acceleration due to gravity decreases as we go inside the earth.
Value of gravitational field does not change as we go towards centre in a uniform spherical shell.

2. An infinite wire is bent in the shape as shown. Find the magnetic field at point C.

A. $\frac{\mu_0 i}{4\pi r}(1+\pi)$
B. $\frac{\mu_0 i}{4\pi r}(2+\pi)$
C. $\frac{\mu_0 i}{2\pi r}(1+\pi)$
D. $\frac{\mu_0 i}{4r}$



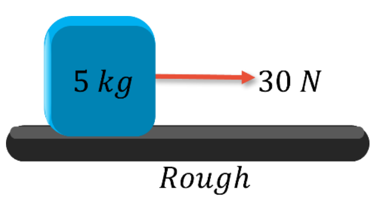
Answer (A)

Solution:

$$B_C = \frac{\mu_0 i}{4\pi R}[\sin 90° + \sin 0°] + \frac{\mu_0 i}{4R} + 0$$
$$= \frac{\mu_0 i}{4\pi R}[1+\pi]$$

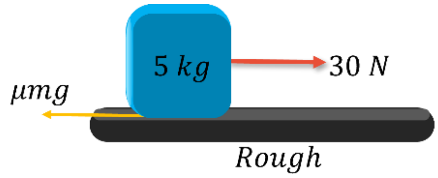
3. A force of $30\ N$ is applied on a block of mass $5\ kg$. the block travels a distance of $50\ m$ in $10\ sec$ starting from rest. Find the coefficient of friction.

A. 0.5
B. 0.7
C. 0.3
D. 0.8



Answer (A)

Solution:



Applying Newtons' second law,

$30 - \mu mg = ma$

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

As acceleration is uniform and block start from rest,

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

$\Rightarrow 50 = \frac{1}{2}\left(\frac{30 - 50\mu}{5}\right)10^2$

$\Rightarrow 5 = 30 - 50\mu$

$\Rightarrow \mu = \frac{25}{50} = 0.5$

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

A. $90\ MHz$
B. $89\ MHz$
C. $106\ MHz$
D. $100\ kHz$

Answer (D)

Solution:

Frequency of FM signal is in MHz.

5. 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

A. Compressibility
B. Bulk modulus
C. Viscosity
D. Energy Density

Answer (A)

Solution:

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

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

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

A. $\frac{64}{1+\sqrt{21}}\ m/s$

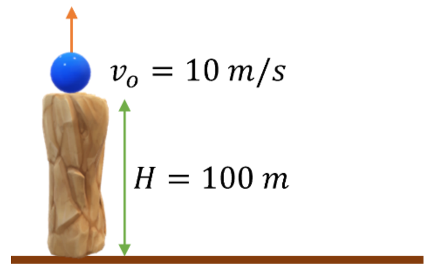
B. $55\ m/s$

C. $110(1 + \sqrt{21})\ m/s$

D. $\frac{110}{1+\sqrt{21}}\ m/s$

Answer (D)

Solution:



Total distance $= \frac{v_o^2}{2g} \times 2 + 100 = 110\ m$

Total time $= t_0$

$S = ut_0 + \frac{1}{2}at_0^2$

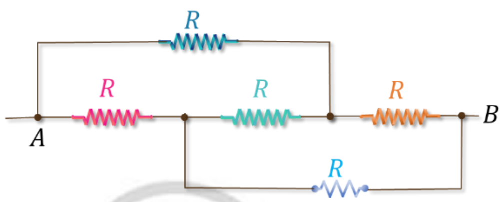
$\Rightarrow -100 = 10\ t_o - \frac{1}{2} \times 10 \times t_o^2$

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

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

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

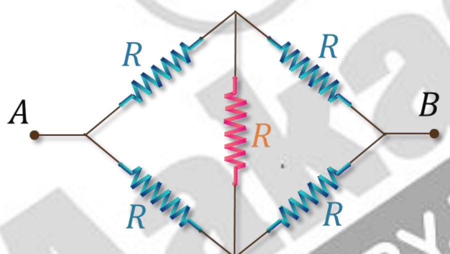
A. $3R/2$
B. $2R$
C. $4R$
D. R



Answer (D)

Solution:

Redrawing the structure, we will get the circuit as shown here:

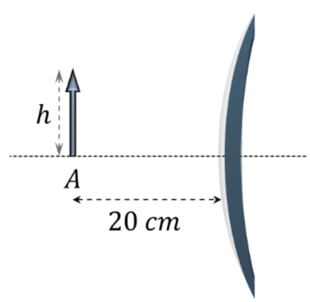


It is a balanced Wheatstone bridge.

The equivalent resistance of circuit: $R_{eq} = R$

8. An object of height h is placed in front of a convex mirror (radius of curvature $= 20\ cm$). Find the height of image.

A. $h/2$
B. $h/3$
C. $h/6$
D. $h/4$



Answer (B)

Solution:

From mirror formula:

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

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

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

Magnification of mirror:

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

$$h_i = \frac{h}{3}$$

9. 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 the ramp. (Consider sufficient friction for pure rolling)

A. $60\,sec$
B. $6\sqrt{10}\,sec$
C. $3\sqrt{10}\,sec$
D. $20\,sec$

Answer (B)

Solution:

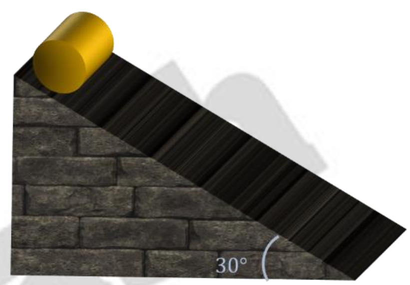
$$mg\sin\theta - f_r = ma$$

Also,

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

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

$$a = \frac{2}{3}g\sin 30° = \frac{g}{3} = \frac{10}{3}\ m/s^2$$



Ramp length, $s = 600\,m$

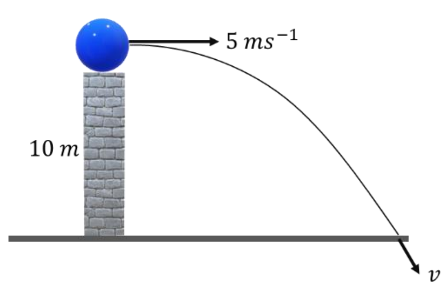
$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 600 \times 3}{10}} = 6\sqrt{10}\ seconds$$

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

A. $15\,m/s$
B. $5\,m/s$
C. $10\,m/s$
D. $20\,m/s$

Answer (A)

Solution:



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

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

$$v = 15\,m/s$$

11. 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.

A. $3RT$

B. $2RT$
C. $4RT$
D. $-RT$

Answer (C)

Solution:

Work done for adiabatic expansion can be given as:

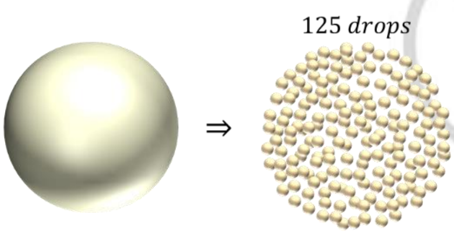
$$W = \frac{nR\Delta T}{1-\gamma} = \frac{2 \times R(-T)}{1-3/2} = 4RT$$

12. A drop of $Mercury$ is divided into 125 drops of equal radius $10^{-3}\ m$ each. If surface tension of $Mercury$ is equal to $0.45\ Nm^{-1}$. Magnitude of change in surface energy is equal to nearly:

A. $1.14 \times 10^{-4}\ J$
B. $7.06 \times 10^{-4}\ J$
C. $8.47 \times 10^{-4}\ J$
D. $5.65 \times 10^{-4}\ J$

Answer (D)

Solution:



Let radius of bigger drop was R So,

$$\frac{4}{3}\pi R^3 = 125 \times \frac{4}{3}\pi(10^{-3})^3$$
$$R = 5 \times 10^{-3}\ m$$
$$U_i = 4\pi R^2\sigma = 4\pi(5 \times 10^{-3})^2 \times 0.45 = 1.41 \times 10^{-4}\ J$$
$$U_f = 125 \times 4\pi r^2\sigma = 500 \times \pi(10^{-3})^2 \times 0.45 = 7.06 \times 10^{-4}\ J$$
So,
$$\Delta U = U_f - U_i = 5.65 \times 10^{-4}\ J$$

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

A. $1.44 \times 10^{-16}\ kg$
B. $7.2 \times 10^{-16}\ kg$
C. $1.44 \times 10^{-10}\ kg$
D. $7.2 \times 10^{-10}\ kg$

Answer (A)

Solution:

Radius of circular path can be given as:

$$R = \frac{\sqrt{2mqV}}{qB}$$

$$3 \times 10^{-2} = \frac{\sqrt{2m \times 100}}{\sqrt{2 \times 10^{-6}} \times 4 \times 10^{-3}} \Rightarrow m = 1.44 \times 10^{-16}\, kg$$

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

A. $10\, m/s$
B. $50\, m/s$
C. $100\, m/s$
D. $200\, m/s$

Answer (C)

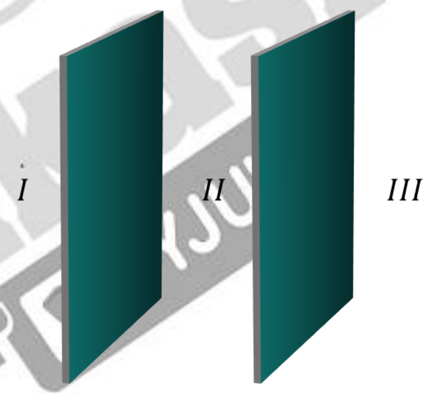
Solution:

Velocity of transverse wave can be given as:

$$v = \sqrt{\frac{T}{\mu}} == \sqrt{\frac{70}{7 \times 10^{-3}}} = 100\, m/s$$

15. Two thin insulating sheets (each having charge density $+\sigma$) are arranged as shown. Then find the net electric field magnitude in the 3 regions:

A. $E_1 = \frac{\sigma}{\epsilon_0}; E_2 = 0; E_3 = \frac{\sigma}{\epsilon_0}$
B. $E_1 = E_2 = E_3 = 0$
C. $E_1 = 0; E_2 = \frac{\sigma}{2\epsilon_0}; E_3 = \frac{\sigma}{\epsilon_0}$
D. $E_1 = \frac{\sigma}{\epsilon_0}; E_2 = 0; E_3 = \frac{\sigma}{2\epsilon_0}$



Answer (A)

Solution:

Electric field in different zones can be written as:

$$E_{I(1)} = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$
$$E_{II(2)} = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$
$$E_{III(3)} = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

16. In a series LCR circuit connected across $220\, V$, $50\, Hz$ AC supply. If the inductive reactance of the circuit is $79.6\, \Omega$. If the power delivered in the circuit is maximum, the capacitance of the circuit is $x\, \mu F$. Find x.

Answer (40)

Solution:

For maximum power, LCR should be in resonance condition,
$X_L = X_C$

$$\Rightarrow 79.6 = \frac{1}{\omega c} = \frac{1}{2\pi f c} = \frac{1}{2\pi \times 50 \times c}$$
$$\Rightarrow c = \frac{1}{79.6 \times 100\pi} = 40 \times 10^{-6}\ F = 40\ \mu F$$

17. An $alpha$ particle and a $proton$ having same $de - Broglie$ wavelengths will have $kinetic\ energies$ in the ratio ___________.

Answer (0.25)

Solution:

charge on α particle = 2e
mass of proton = m
mass ofα particle = 4m

$$\frac{\lambda_P}{\lambda_\alpha} = \frac{(P_\alpha)}{(P_P)} = \frac{\sqrt{2K_\alpha m_\alpha}}{\sqrt{2K_P m_P}} = 1$$
$$\frac{K_\alpha}{K_P} \times \left(\frac{m_\alpha}{m_P}\right) = 1$$
$$\frac{K_\alpha}{K_P} \times (4) = 1$$
$$\frac{K_\alpha}{K_P} = \frac{1}{4} = 0.25$$

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

Answer (3)

Solution:

$$\text{Escape speed from earth, } v_e = \sqrt{\frac{2GM_e}{R_e}}$$
$$\text{Escape speed from planet, } v_e' = \sqrt{\frac{2GM'}{R'}} = \sqrt{\frac{2G \times 9M_e}{2R_e}} = v_e \times \frac{3}{\sqrt{2}}$$

19. There are n number of polarizers arranged one after the other. Each polarizer pass axis is inclined at 45^0 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 (6)

Solution:

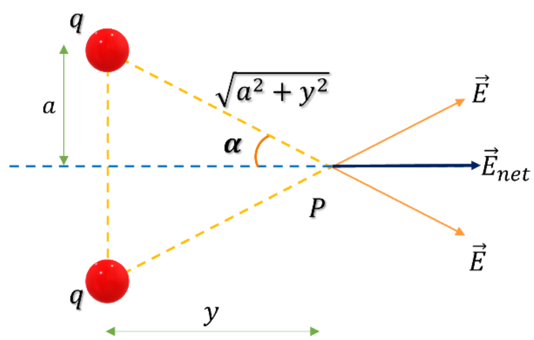
Intensity of light passing through 1^{st} polarizer will be $I_0/2$
Intensity of light passing through 2^{nd} polarizer will be $\frac{I_0}{2} \times \cos^2 45°$
Intensity of light passing through 3^{rd} polarizer will be $\frac{I_0}{2} \times (\cos^2 45°)^2$
Similarly, for n polarizers:
$$I = \frac{I_0}{2} \times \cos^2 45° \times \cos^2 45° \times \ldots\ldots\ldots\ldots \quad (\text{upto } n-1 \text{ times})$$

$$\Rightarrow \frac{I_0}{64} = \frac{I_0}{2} \times \left(\frac{1}{2}\right)^{n-1}$$
$$\Rightarrow n - 1 = 5 \text{ or } n = 6$$

20. 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 (2)

Solution:



$$E \text{ due to one charge} = \frac{kq}{a^2 + y^2}$$
$$E_{net} \text{ at point } P = 2E \cos\alpha$$
$$= \frac{2Kq}{a^2 + y^2} \times \frac{y}{(a^2 + y^2)^{\frac{1}{2}}}$$
$$= \frac{2Kqy}{(a^2 + y^2)^{\frac{3}{2}}}$$

$$Force = qE_{net}$$

$$\frac{dF}{dy} = 0, \text{ for maximum force}$$
$$\text{On solving, } \frac{dF}{dy} = 0$$
$$\Rightarrow y = \left(\frac{a}{\sqrt{2}}\right)$$
$$\text{So, } x = 2$$