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JEE Mains Paper-2022

PHYSICS

1. Dimension of mutual inductance

(1) $ML^2T^{-2}A^{-1}$ (2) $ML^2T^{-2}A^{-2}$

(3) $ML^2T^{-1}A^{-1}$ (4) $ML^2T^{-3}A^{-2}$

Sol. Answer (2)

L_{12} = Mutual inductance

U = Magnetic energy stored in coils

I = Current

$$U = \frac{1}{2}L_{12}I^2$$

$$[L_{12}] = \frac{[U]}{[I]^2}$$

$[U] = [M^1L^2T^{-2}]$

$[I] = [A^1]$

$$[L_{12}] = \frac{[M^1L^2T^{-2}]}{[A^1]^2} = [M^1L^2T^{-2}A^{-2}]$$

2. Find the ratio of rotational kinetic energy to total kinetic energy of a rolling solid sphere

(1) $\frac{7}{5}$ (2) $\frac{2}{5}$

(3) $\frac{2}{7}$ (4) $\frac{5}{7}$

Sol. Answer (3)

$$K.E_{total} = K.E_{tras} + K.E_{rotational}$$

$$K.E_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I_{com}w^2$$

In pure rolling V = Rw

$$\frac{(K.E)_{ROT}}{(K.E)_T} = \frac{\frac{1}{2}I_{com}w^2}{\frac{1}{2}Mw^2R^2 + \frac{1}{2}I_{com}w^2}$$

$$= \frac{\frac{2}{5}MR^2}{MR^2 + \frac{2}{5}MR^2}$$

$$\boxed{\frac{(K.E)_{ROT}}{(K.E)_T} = \frac{\frac{2}{5}}{\frac{7}{5}} = \frac{2}{7}}$$

3. Arrange the EM waves according to increasing order of wavelength

(1) $\lambda_{gamma} < \lambda_{x\ ray} < \lambda_{microwave} < \lambda_{visible}{}^{\infty}$

(2) $\lambda_{gamma} < \lambda_{x\ ray} < \lambda_{visible} < \lambda_{microwave}$

(3) $\lambda_{x\ ray} < \lambda_{microwave} < \lambda_{gamma} < \lambda_{visible}$

(4) $\lambda_{microwave} < \lambda_{visible} < \lambda_{x\ ray} < \lambda_{gamma}$

Sol. Answer (2)

$\lambda_{gamma} < \lambda_{x\ ray} < \lambda_{visible} < \lambda_{microwave}$

4. What is the formula for Reynold's number

(1) $\frac{\delta vd}{\eta}$ (2) $\frac{\delta v}{\eta d}$

(3) $\frac{\delta \eta}{dv}$ (4) $\frac{\delta}{\eta dv}$

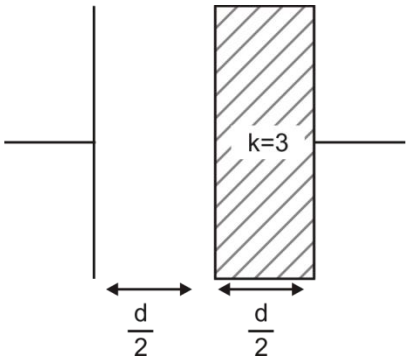
Sol. Answer (1)

Expression for Reynold's number is

$$R = \frac{\delta vd}{\eta}$$

Correct option (1)

5.



$C_{original} = 4\mu F$

$C_{new} = ?$

(1) 6 (2) 8

(3) 5 (4) 3

Sol. Answer (1)

$$C_{original} = \frac{\epsilon_0 A}{d}$$

$$C_{new} = \frac{\epsilon_0 A}{\frac{d}{2} + \frac{d}{2k}}$$

$$C_{new} = \frac{\epsilon_0 A}{\frac{d}{2}\left(1 + \frac{1}{k}\right)}$$

$$C_{new} = \frac{2}{1 + \frac{1}{k}} \frac{\epsilon_0 A}{d}$$

$$C_{new} = \frac{2}{1 + \frac{1}{k}} C_{original}$$

$$C_{new} = \frac{2}{1 + \frac{1}{3}} \times 4\mu F$$

$= 6\mu F$

Correct option (1)

6. Two objects thrown in to the air in upward direction from the same point in air. One at t = 0 & other after two seconds. Both objects were thrown with speed 50 m/s. At what time both objects will meet

(1) 6 (2) 7

(3) 8 (4) 10

Sol. Answer (1)

For the first object

$$y_1 = 50t - \frac{1}{2}gt^2$$

For the second object

$$y_2 = 50(t-2) - \frac{1}{2}g(t-2)^2$$

when they meet

$y_1 = y_2$

$$50t - \frac{1}{2}gt^2 = 50(t-2) - \frac{1}{2}g(t-2)^2$$

$$\frac{1}{2}gt^2 = 100 + \frac{1}{2}g(t-2)^2$$

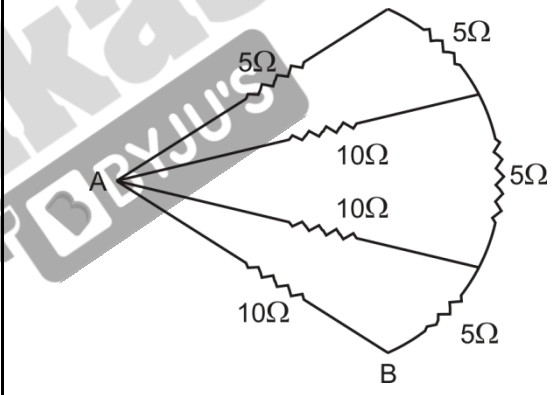
$$\frac{1}{2}g\left[t^2 - (t-2)^2\right] = 100$$

$$\frac{1}{2} \times 10\left[2(2t-2)\right] = 100$$

$$t - 1 = \frac{100}{5 \times 4} = 5$$

t = 6 sec.

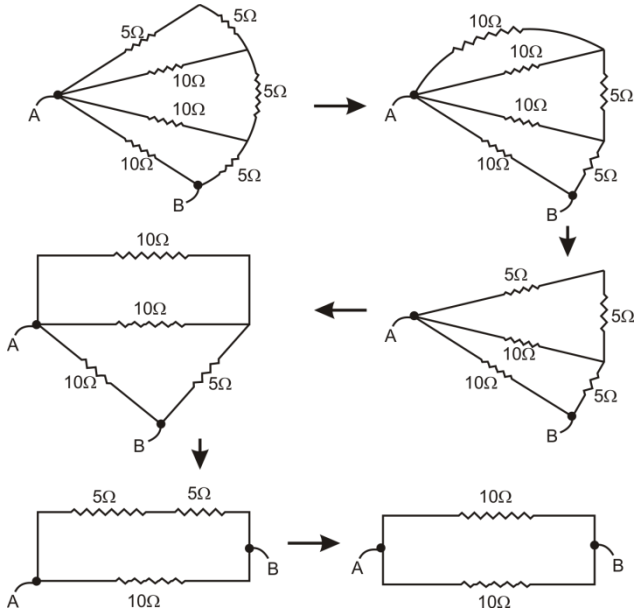
7. Calculate equivalent resistance between A & B.



(1) 10 Ω (2) 5 Ω

(3) 15 Ω (4) 2.5 Ω

Sol. Answer (2)



$\boxed{R_{eq} = 5\Omega}$

8. 64 drops of radius 0.02 mm combine to form a single drop. Each drop has charge 50 μc. Find ratio of surface charge densities of bigger to smaller drop.

(1) 1 : 4 (2) 8 : 1

(3) 1 : 8 (4) 4 : 1

Sol. Answer (4)

Let as assume that radius of each drop is r and radius of combined drop is R

As volume is same, we can write

$$64\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

R = 4r

If not charge on each drop is q, then net charge on the combination is 64q

$$\sigma = \frac{q}{4\pi r^2}$$

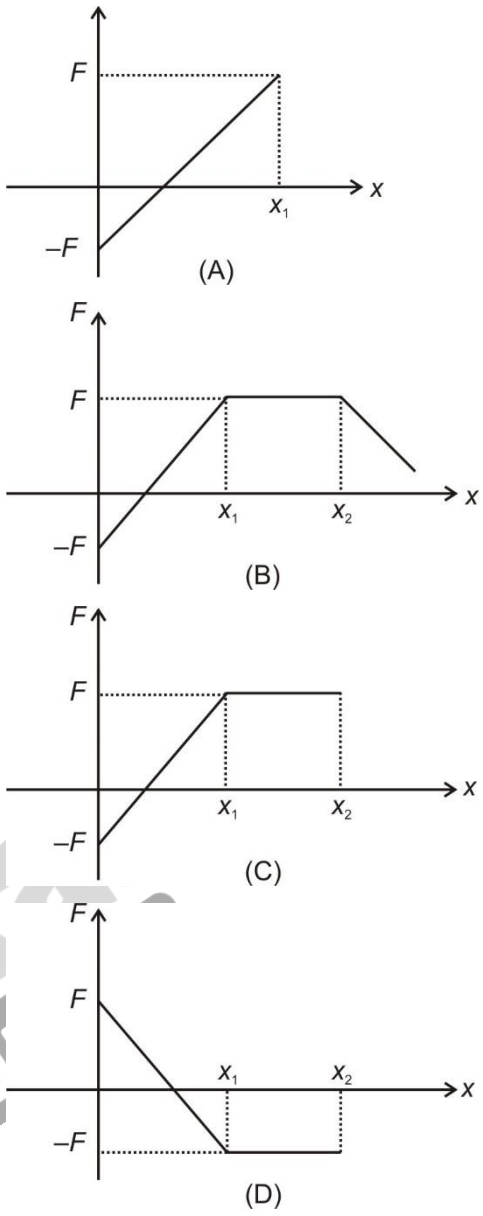
$$\sigma' = \frac{64q}{4\pi R^2}$$

$$\frac{\sigma'}{\sigma} = \frac{\frac{64q}{4\pi R^2}}{\frac{q}{4\pi r^2}} = 64\frac{r^2}{R^2}$$

$$\frac{\sigma'}{\sigma} = \frac{64}{16} = 4:1$$

Correct option (4)

9. Find the decending order of work done



(1) B > C > A > D

(2) B > C > D > A

(3) C > B > A > D

(4) C > A > B > D

Sol. Answer (1)

Work done is given by area under *F-x* curve

$W_B > W_C > W_A > W_D$

10. Work done in rotating a magnetic dipole of dipole moment $M = 14\times10^{-5}\,Am^2$ in a uniform magnetic field $B = 2\times10^5$ Tesla by an angle of $\theta = 60^o$ (initially dipole is aligned in the direction of field) is

(1) 7 J (2) 14 J

(3) 28 J (4) 21 J

Sol. Answer (2)

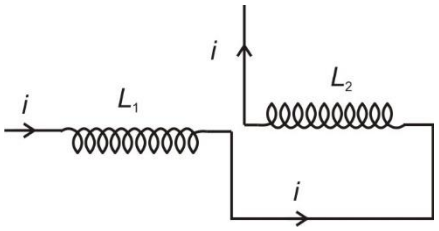
Given $\theta_1 = 0^o$ and $\theta_2 = 60^o$

We know, $w_{ex} = MB[\cos\theta_1 - \cos\theta_2]$

$w_{ex} = 14\times10^{-5}\times2\times10^5(\cos0^o - \cos60^o)$

$w_{ex} = 28\times\frac{1}{2} = 14$ J

11. If mutual inductance of the circuit is *M* then total inductance is



(1) $L_1 - L_2 + M$

(2) $L_1 + L_2 + M$

(3) $L_1 + L_2 - 2M$

(4) $L_2 - L_1 - 2M$

Sol. Answer (3)

Both the inductors has current in opposite sense w.r.t. each other

$L_{eff} = L_1 + L_2 - 2M$

12. Assertion (A) : As we move from pole to equator, magnitude of gravitational acceleration is same and always pointed towards centre of earth.

Reason (R): At the equator, the acceleration due to gravity is pointed towards centre of earth.

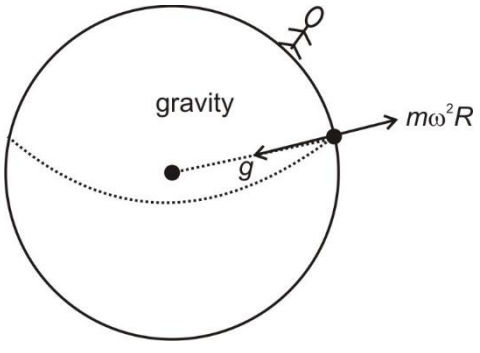
(1) Assertion and reason both are correct and reason is correct explanation of assertion.

(2) Assertion and reason both are correct but reason is not the correct explanation of assertion.

(3) Assertion is true, reason is false.

(4) Assertion is false, reason is true.

Sol. Answer (4)



Assertion is false

We know, acceleration due to gravity at a latitude λ

$g' = g - R\omega^2\cos^2\lambda$

Reason is true

At equator, effective acceleration due to gravity points towards centre

13. A light source is placed at the bottom of container filled with a liquid upto height H. If refractive index of liquid is μ then find the maximum radius of circle on the surface of liquid from which light will not emerged out.

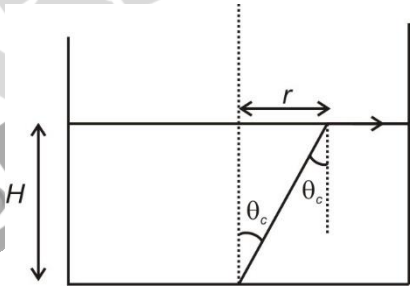
(1) $\frac{H}{\sqrt{\mu^2-1}}$

(2) $\frac{H}{(\mu^2-1)}$

(3) $\frac{H}{2\sqrt{\mu^2-1}}$

(4) $\frac{H}{2(\mu^2-1)}$

Sol. Answer (1)



$\sin\theta_c = \frac{1}{\mu}$

$\tan\theta_c = \frac{1}{\sqrt{\mu^2-1}}$

$\frac{r}{H} = \frac{1}{\sqrt{\mu^2-1}}$

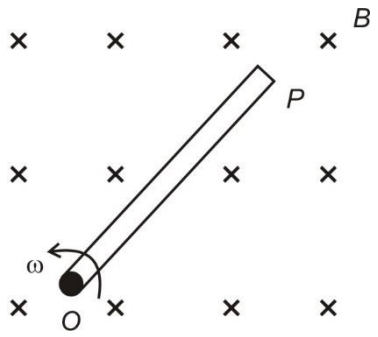
$r = \frac{H}{\sqrt{\mu^2-1}}$

14. A conducting rod of length *l* = 1 m is rotating with angular velocity $\omega = 5$ rad/sec in a uniform magnetic field $B = 0.2$ Tesla about its one end. If field is perpendicular to plane of rotation then emf induced across the ends is

(1) 5 v (2) 1.25 v

(3) 0.5 v (4) 2.5 v

Sol. Answer (3)



$L = 1$ m

$\omega = 5$ rad/sec

$B = 0.2$ T

$\in_{op} = \frac{1}{2}B\omega L^2$

$= \frac{1}{2}(0.2)\times(5)\times(1)^2$

$\in_{op} = 0.5$ v

15. A source of light (wavelength = 670 nm) is moving away from earth. An observer on earth observes wavelength of 670.4 nm. Find the speed of the source with respect to earth.

(1) 1.8×10^5 m/s

(2) 3.6×10^5 m/s

(3) 0.6×10^5 m/s

(4) 10^5 m/s

Sol. Answer (1)

Red shift

$\lambda_{emitted} = 670$ nm

$\lambda_{obs} = 670.4$ nm

$V = ?$

$c = 3\times10^8$ m/s

If $v << c$

$\frac{\lambda_{obs} - \lambda_{emitted}}{\lambda_{emitted}} = \frac{v}{c}$

$\frac{670.4 - 670}{670} = \frac{v}{c}$

$v = 1.8\times10^5$m/s

16. A light of wavelength 4000Å is incident on a metal surface, due to which electron ejected which are left in a uniform magnetic field B = 2 mT perpendicularly. If maximum radius created by the electrons are r = 2 mm. Then work function of metal will be.

(1) 2.8 eV

(2) 1.7 eV

(3) 2.1 eV

(4) 1.3 eV

Sol. Answer (2)

$k_{max} = \frac{hc}{\lambda} - \phi$

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

$\phi = \frac{hc}{\lambda} - \frac{1}{2}mv^2$ .....(*i*)

$R = \frac{mv}{eB}$

$v = \frac{eBR}{m}$ .....(*ii*)

From (i) and (ii)

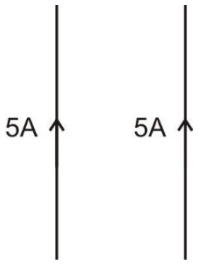
$\phi = \frac{hc}{\lambda} - \frac{1}{2}m\frac{e^2B^2R^2}{m^2}$

$\phi = \frac{12400}{4000} - \frac{1.6\times10^{-19}\times4\times10^{-6}\times4\times10^{-6}}{2\times9.1\times10^{-31}}$

$\phi = 3.1 - 1.4$

$\phi = 1.7$ eV

17. Force between two straight parallel wires kept in air is 10^{-6} N and length of each wire is 10 cm. Find distance between them.



(1) 1 m

(2) 0.5 m

(3) 2 m

(4) 0.25 m

Sol. Answer (2)

$F = 10^{-6}$ N

$L = 10$ cm

$d = ?$

$I_1 = I_2 = 5$

$$\frac{F}{L}=\frac{\mu_0 I_1 I_2}{2\pi d}\ \text{(attractive)}$$

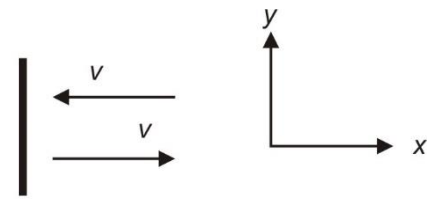
$$\frac{10^{-6}}{10\times10^{-2}}=\frac{4\pi\times10^{-7}}{2\pi}\times\frac{5\times5}{d}$$

$$d=50\times10^{-2}$$

$$d=0.5\ \text{m}$$

18. Mass of ball is 0.4 kg and its initial speed is 15 m/s. It is hit with a bat and returned with same speed, find impulse.

Sol. Answer (12.00)



bat

According to impulse momentum theorem

$$\int F dt=\vec{P_F}-\vec{P_I}$$

$$\text{Impulse}=(mv)-(-mv)$$

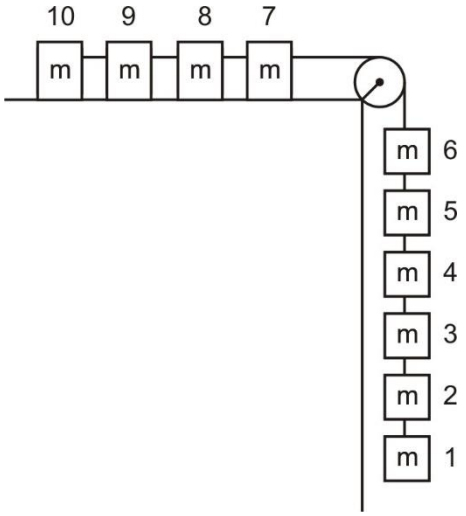
$$=2mv$$

$$=2\times\frac{4}{10}\times15$$

$$\text{Impulse}=12\ \text{kg m/s}$$

19. Find the tension between 7th & 8th blocks connected by strings as shown in figure below:

(m = 2 kg)

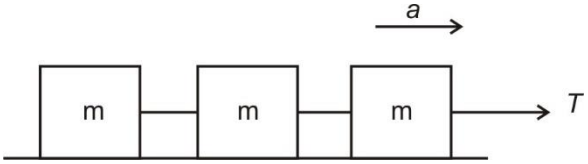


Sol. Answer (36.00)

Net pulling force on the system = F = 6 mg

$$a=\frac{F}{M}=\frac{6mg}{10m}=\frac{3g}{5}$$

Let the tension in string connecting 7th and 8th block is T.



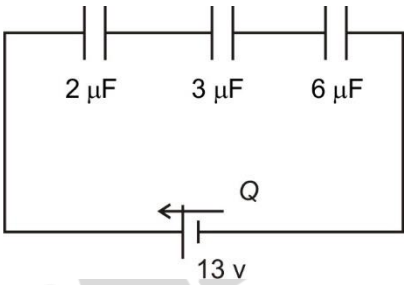
T = 3 ma

$$T=3m\times\frac{3g}{5}$$

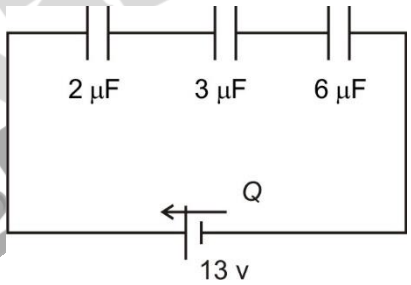
$$m=2\ \text{kg}$$

T = 36 N

20. Find the value of charge flows through battery in the given circuit in (μC)



Sol. Answer (13.00)



Since capacitors are connected in series, they carry same charge

$$\frac{1}{C_{eq}}=\frac{1}{2}+\frac{1}{3}+\frac{1}{6}$$

$$\frac{1}{C_{eq}}=\frac{3+2+1}{6}$$

$$C_{eq}=1\,\mu\text{F}$$

$$Q=C_{eq}V$$

$$Q=1\,\mu\text{F}\times13\,V=13\,\mu\text{C}$$

21. The energy of emitted photoelectrons from a metal is 0.9 eV and energy of incident photon is 3.1 eV then the work function of a metal in eV is

Sol. Answer (2.20)

$$k_{\max}=E_{photon}-\phi$$

$0.9\text{ eV} = 3.1\text{ eV} - \phi$

$\phi = (3.1 - 0.9)\text{ eV}$

$\phi = 2.2\text{ eV}$

22. 20 tuning forks are arranged in increasing order of frequency such that every tuning fork produces 4 beats with previous one. If frequency of last tuning fork is double the first, then the frequency of last tuning fork is?

Sol. Answer (152 Hz)

Let frequencies of tuning fork are

$x, x+4, x+2(4), ..., x+19(4)$

$x+19(4) = 2x$ [*given*]

$19 \times 4 = x$

$x = 76$

Frequency of last tuning fork =
$2x = 2 \times 76 = 152\text{ Hz}$

23. $y(m) = 20 \sin(\omega_m t)$ $\omega_c = 10^7 \pi$

$y(c) = 40 \sin(\omega_c t)$ $\omega_m = 10^3 \pi$

Amplitude of wave with lowest frequency $(\omega_c - \omega_m)$

(1) 10

(2) 20

(3) 0.5

(4) 0.025

Sol. Answer (1)

Equation of AM modulated wave

$= A_c \sin\omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)t$

$\mu = \frac{A_m}{A_c} = \text{modulation index}$

Amplitude of LSF is $\frac{\mu A_c}{2}$

$\frac{A_m}{A_c} \times \frac{A_c}{2}$

$= \frac{A_m}{2} = \frac{20}{2} = 10$