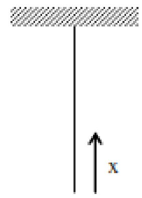
Physics (Paper A)
JEE MAIN 2016

***Questions*: 1:-** A uniform string of length 20 m is suspended from a rigid support. A short wave pulse is introduced at its lowest end. It starts moving up the string. The time taken to reach the support is: (take g = 10 ms^{-1})

(A) 2s
(B) $2\sqrt{2}$s
(C) $\sqrt{2}$s
(D) $2\pi\sqrt{2}$s

***Ans*:- (B)**



$$T(x) = \frac{Mgx}{L}$$

$$\Rightarrow v(x) = \sqrt{\frac{T}{\mu}} = \sqrt{gx}$$

$$\Rightarrow \frac{dx}{dt} = \sqrt{gx} \Rightarrow \text{time taken } = 2\sqrt{2}\,s.$$

***Questions*: 2:-** A person trying to lose weight by burning fat lifts a mass of 10 kg upto a height of 1 m 1000 times. Assume that the potential energy lost each time he lowers the mass is dissipated. How much fat will he use up considering the work done only when the weight is lifted up? Fat supplies 3.8 x 10^7 J of energy per kg which is converted to mechanical energy with a 20 % efficiency rate. Take g = 9.8 ms^{-2}:

(A) 6.45 x 10^{-3} kg
(B) 9.89 x 10^{-3} kg
(C) 12.89 x 10^{-3} kg
(D) 2.45 x 10^{-3} kg

***Ans*:- (C)**

Let fat used be 'x' kg

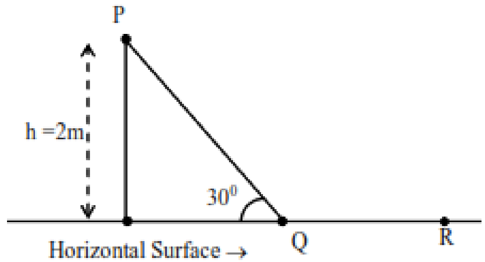
$$\Rightarrow \text{Mechanical energy available} = x \times 3.8 \times 10^7 \times \frac{20}{100}$$

$$\text{Work done in lifting up} = 10 \times 9.8 \times 1000$$

$$\Rightarrow x \times 3.8 \times 10^7 \times \frac{20}{100} = 9.8 \times 10^4$$

$$\Rightarrow x \approx 12.89 \times 10^{-3} \text{ kg.}$$

***Questions*: 3:-** A point particle of mass m, moves along the uniformly rough track PQR as shown in the figure. The coefficient of friction, between the particle and the rough track equals μ. The particle is released, from rest, from the point P and it comes to rest at a point R. The energies, lost by the ball, over the parts, PQ and QR, of the track, are equal to each other, and no energy is lost when particle changes direction from PQ to QR.



The values of the coefficient of friction μ and the distance x (=QR), are, respectively close to:

(A) 0.2 and 3.5 m
(B) 0.29 and 3.5 m
(C) 0.29 and 6.5 m
(D) 0.2 and 6.5 m

Ans:- **(B)** Since work done by friction on parts PQ and QR are equal

$$-\mu mg \times \frac{\sqrt{3}}{2} \times 4 = -\mu mgx \qquad (QR = x)$$

$$\Rightarrow x = 2\sqrt{3}\ \text{m} \approx 3.5\ \text{m}$$

Applying work energy theorem from P to R

$$mg \sin 30^0 \times 4 - \mu mg \frac{\sqrt{3}}{2} \times 4 - \mu mgx = 0$$

$$\Rightarrow \mu = \frac{1}{2\sqrt{3}} \approx 0.29.$$

Questions**: 4:-** Two identical wires A and B, each of length 'ℓ', carry the same current I. Wire A is bent into a circle of radius R and wire B is bent to form a square of side 'a'. If B_A and B_B are the values of magnetic field at the centres of the circle and square respectively, then the ratio $\frac{B_A}{B_B}$ is:

(A) $\frac{\pi^2}{16\sqrt{2}}$
(B) $\frac{\pi^2}{16}$
(C) $\frac{\pi^2}{8\sqrt{2}}$
(D) $\frac{\pi^2}{8}$

Ans:- **(C)**

$$B_A = \frac{\mu_0}{4\pi} \frac{2\pi i}{(\ell / 2\pi)}$$

$$B_B = \left[\frac{\mu_0}{4\pi} \frac{i}{\ell / 8}(\sin 45^0 + \sin 45^0)\right] \times 4$$

$$\frac{B_A}{B_B} = \frac{\pi^2}{8\sqrt{2}}$$

Questions**: 5:-** A galvanometer having a coil resistance of 100 Ω gives a full scale deflection, when a current of 1 mA is passed through it. The value of the resistance, which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 A is:

(A) 2Ω
(B) 0.1Ω
(C) 3Ω
(D) 0.01Ω

Ans:- **(D)**

For full scale deflection

$100 \times i_g = (i - i_g)S$

where 'S' is the required resistance

$$S = \frac{100 \times 1 \times 10^{-3}}{(10 - 10^{-3})}$$

$S \approx 0.01\ \Omega$

***Questions*: 6:-** An observer looks at a distant tree of height 10 m with a telescope of magnifying power of 20. To the observer the tree appears:

(A) 10 times nearer.
(B) 20 times taller.
(C) 20 times nearer.
(D) 10 times taller.

***Ans*:- (C)** 20 times nearer.

***Questions*: 7:-** The temperature dependence of resistances of Cu and undoped Si in the temperature range 300 – 400 K, is best described by:

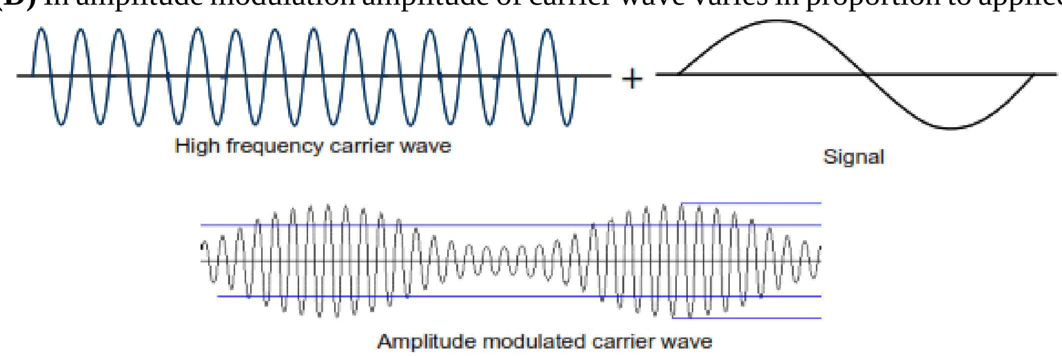
(A) Linear increase for Cu, exponential increase for Si.
(B) Linear increase for Cu, exponential decrease for Si.
(C) Linear decrease for Cu, linear decrease for Si.
(D) Linear increase for Cu, linear increase for Si.

***Ans*:- (B)** The electric resistance of a typical intrinsic (undoped) semiconductor decreases exponentially with temperature $\rho = \rho_0 e^{-aT}$where a is a constant.

***Questions*: 8:-** Choose the correct statement:

(A) In amplitude modulation the frequency of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(B) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(C) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the frequency of the audio signal.
(D) In amplitude modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.

***Ans*:- (D)** In amplitude modulation amplitude of carrier wave varies in proportion to applied signal.



***Questions*: 9:-** Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed numbers of A and B nuclei will be:

(A) 4 : 1
(B) 1 : 4

(C) 5 : 4 (D) 1 : 16

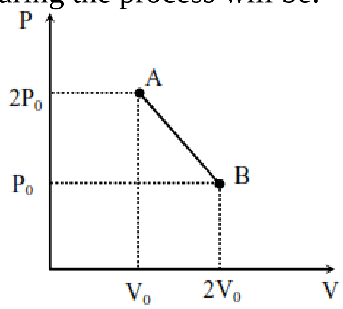
Ans:- **(C)**

for A : $N_0 - \frac{N_0}{2^4} = \frac{15N_0}{16}$

for B : $N_0 - \frac{N_0}{2^2} = \frac{3N_0}{4}$

The required ratio is $\frac{5}{4}$

***Questions*: 10:-** 'n' moles of an ideal gas undergoes a process A → B as shown in the figure. The maximum temperature of the gas during the process will be:



(A) $\frac{3P_0V_0}{2nR}$ (B) $\frac{9P_0V_0}{2nR}$

(C) $\frac{9P_0V_0}{nR}$ (D) $\frac{9P_0V_0}{4nR}$

Ans:- **(D)**

Equation of line is

$PV_0 + P_0V = 3P_0V_0$ …(i)

Also $PV = nRT$ …(ii)

for T_{max}, $\frac{dT}{dV} = 0$

$\Rightarrow V = \frac{3V_0}{2}$, $P = \frac{3P_0}{2}$

$\Rightarrow T_{max} = \frac{9P_0V_0}{4nR}$

***Questions*: 11:-** An arc lamp requires a direct current of 10 A and 80 V to function. If it is connected to a 220 V (rms), 50 Hz AC supply, the series inductor needed for it to work is close to:

(A) 0.08 H (B) 0.044 H

(C) 0.065 H (D) 80 H

Ans:- **(C)**

For the lamp with direct current,

$V = IR$

$\Rightarrow R = 8\Omega$ and $P = 80 \times 10 = 800$ W

For ac supply

$$P = I_{rms}^2 R = \frac{\varepsilon_{rms}^2}{Z^2} R$$

$$\Rightarrow Z^2 = \frac{(220)^2 \times 8}{800}$$

$$\Rightarrow Z = 22\Omega$$

$$\Rightarrow R^2 + \omega^2 L^2 = (22)^2$$

$$\Rightarrow \omega L = \sqrt{420}$$

$$\Rightarrow L = 0.065 \text{ H}$$

***Questions*: 12:-** A pipe open at both ends has a fundamental frequency f in air. The pipe is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column is now:

(A) $\frac{3f}{4}$

(B) 2f

(C) f

(D) $\frac{f}{2}$

***Ans*:- (C)**

For open pipe in air, fundamental frequency:

$$f = \frac{V}{2\ell}$$

For the pipe closed at one end (dipped in water), fundamental frequency:

$$f' = \frac{V}{4\ell'} = \frac{V}{4 \times \frac{\ell}{2}} = \frac{V}{2\ell}$$

$$\therefore \quad f' = f$$

***Questions*: 13:-** The box of pin hole camera, of length L, has a hole of radius a. It is assumed that when the hole is illuminated by a parallel beam of light of wavelength λ the spread of the spot (obtained on the opposite wall of the camera) is the sum of its geometrical spread and the spread due to diffraction. The spot would then have its minimum size (say b_{min}) when:

(A) $a = \sqrt{\lambda L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

(B) $a = \sqrt{\lambda L}$ and $b_{min} = \sqrt{4\lambda L}$

(C) $a = \frac{\lambda^2}{L}$ and $b_{min} = \sqrt{4\lambda L}$

(D) $a = \frac{\lambda^2}{L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

***Ans*:- (B)**

We know that

Geometrical spread = a

and diffraction spread = $\frac{\lambda L}{a}$

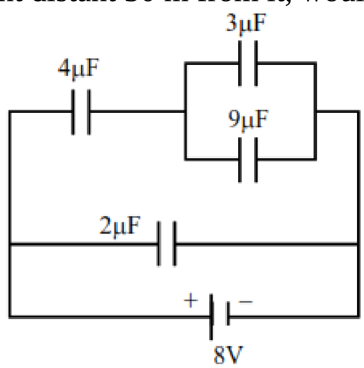
so spot size(b) = $a + \frac{\lambda L}{a}$

for minimum spot size $a = \frac{\lambda L}{a}$

$\Rightarrow \quad a = \sqrt{\lambda L}$

and $b_{min} = \sqrt{\lambda L} + \sqrt{\lambda L} = \sqrt{4\lambda L}$

***Questions*: 14:-** A combination of capacitors is set up as shown in the figure. The magnitude of the electric field, due to a point charge Q (having a charge equal to the sum of the charges on the 4 μF and 9 μF capacitors), at a point distant 30 m from it, would equal:



(A) 360 N/C
(B) 420 N/C
(C) 480 N/C
(D) 240 N/C

***Ans*:- (B)**

Charge on 9 μF capacitor = 18 μC

Charge on 4 μF capacitor = 24 μC

$\therefore \quad Q = 24 + 18 = 42\ \mu C$

$\therefore \quad \frac{KQ}{r^2} = \frac{9 \times 10^9 \times 42 \times 10^{-6}}{(30)^2} = 420\ N/C$

***Questions*: 15:-** Arrange the following electromagnetic radiations per quantum in the order of increasing energy:

A: Blue light
B: Yellow light
C: X-ray
D: Radiowave

(A) A, B, D, C
(B) C, A, B, D
(C) B, A, D, C
(D) D, B, A, C

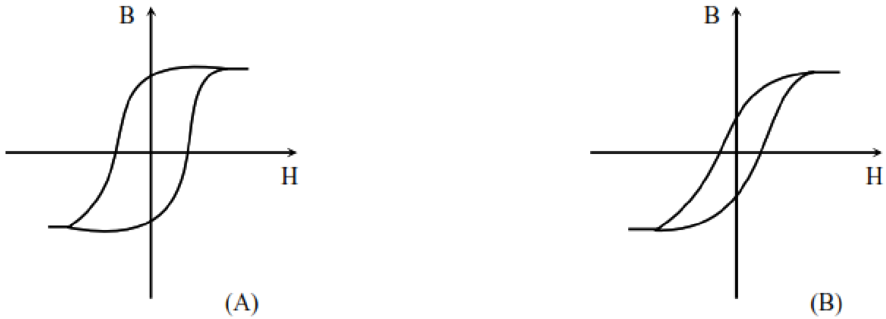
***Ans*:- (D)** Radiation energy per quantum is

E = h*v*

As per EM spectrum, the increasing order of frequency and hence energy is

Radio wave < Yellow light < Blue light < X Ray

***Questions*: 16:-** Hysteresis loops for two magnetic materials A and B are given below:



(A) (B)

These materials are used to make magnets for electric generators, transformer core and electromagnet core.
Then it is proper to use:
(A) A for electromagnets and B for electric generators
(B) A for transformers and B for electric generators
(C) B for electromagnets and transformers
(D) A for electric generators and transformers
Ans:- **(C)** For electromagnet and transformer, the coercivity should be low to reduce energy loss

***Questions*: 17:-** A pendulum clock loses 12 s a day if the temperature is 40°C and gains 4 s a day if the temperature is 20°C. The temperature at which the clock will show correct time, and the co-efficient of linear expansion (α) of the metal of the pendulum shaft are respectively:
(A) 60°C; $\alpha = 1.85 \times 10^{-4}/^{o}C$ (B) 30°C; $\alpha = 1.85 \times 10^{-3}/^{o}C$
(C) 55°C; $\alpha = 1.85 \times 10^{-2}/^{o}C$ (D) 25°C; $\alpha = 1.85 \times 10^{-5}/^{o}C$
Ans:- **(D)**

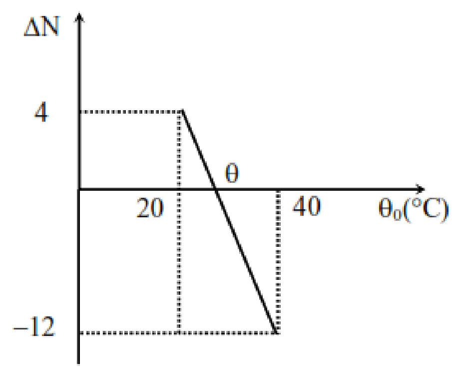
First Method

Time period $T = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{\ell_0}{g}(1+\alpha\Delta\theta)}$

$T = T_0\left[1+\frac{1}{2}\alpha\Delta\theta\right]$

$N = \frac{2\times 86400}{T} = \left(\frac{2\times 86400}{T_0}\right)\left(1+\frac{1}{2}\alpha\Delta\theta\right) = N\left(1+\frac{\alpha\Delta\theta}{2}\right)$

$\Delta N = N - N_0 = \frac{1}{2}\alpha\Delta\theta N_0 \Rightarrow \Delta N \propto \Delta\theta$



$\Rightarrow \theta_0 = 25°C$

Putting θ_0, we get $\alpha = 1.85 \times 10^{-5}/°C$

Second Method

According to given conditions

$86412 = 2\pi\sqrt{\frac{\ell_{40}}{g}}$ ...(i)

$86396 = 2\pi\sqrt{\frac{\ell_{20}}{g}}$ ...(ii)

$86400 = 2\pi\sqrt{\frac{\ell}{g}}$ ...(iii)

From equation (i) and (iii)

$$12 = \frac{2\pi}{\sqrt{g}}\left[\sqrt{\ell_{40}} - \sqrt{\ell}\right] \quad \ldots(iv)$$

$$\text{and } 4 = \frac{2\pi}{\sqrt{g}}\left[\sqrt{\ell} - \sqrt{\ell_{20}}\right] \quad \ldots(v)$$

on dividing (iv) and (v)

$$3 = \frac{\sqrt{1+\alpha(40-\theta)} - 1}{1 - \sqrt{1+\alpha(20-\theta)}}$$

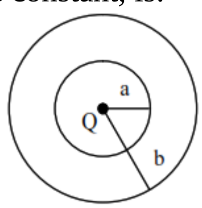
$$\Rightarrow 3 = \frac{40-\theta}{\theta-20} \text{ (by Binomial theorem)}$$

$$\Rightarrow \theta = 25°$$

on using θ in (i) and (iii)

$$\frac{86412}{86400} = \sqrt{1+\alpha 15} \Rightarrow \alpha = 1.85 \times 10^{-5}/°C$$

***Questions*: 18:-** The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is:



(A) $\frac{Q}{2\pi(b^2-a^2)}$

(B) $\frac{2Q}{\pi(a^2-b^2)}$

(C) $\frac{2Q}{\pi a^2}$

(D) $\frac{Q}{2\pi a^2}$

***Ans*:- (D)** According Gauss's law, we can write,

$$E \times 4\pi r^2 = \frac{1}{\varepsilon_0}\left[Q + \int_a^r \left(\frac{A}{r}\right)\left(4\pi r^2 dr\right)\right] = \frac{1}{\varepsilon_0}\left[Q + 2\pi A(r^2 - a^2)\right]$$

For E to be independent of r,

$$Q - 2\pi A a^2 = 0 \Rightarrow a = \frac{Q}{2\pi a^2}$$

***Questions*: 19:- I**n an experiment for determination of refractive index of glass of a prism by i – δ, plot, it was found that a ray incident at angle 35°, suffers a deviation of 40° and that it emerges at angle 79°. In that case which of the following is closest to the maximum possible value of the refractive index?

(A) 1.6

(B) 1.7

(C) 1.8

(D) 1.5

***Ans*:- (D)**

$\delta = i + e - A \Rightarrow A = 74°$

$$\mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{5}{3}\sin\left(37° + \frac{\delta_{min}}{2}\right)$$

μ_{max} can be $\frac{5}{3}$, so μ will be less than $\frac{5}{3}$

Since δ_{min} will be less than 40°, so

$\mu < \frac{5}{3}\sin 57° < \frac{5}{3}\sin 60° \Rightarrow \mu < 1.446$

So the nearest possible value of μ should be 1.5

***Questions*: 20:-** A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90s, 91s, 95s and 92s. If the minimum division in the measuring clock is 1s, then the reported mean time should be:

(A) 92 ± 5.0s
(B) 92 ± 1.8s
(C) 92 ± 3s
(D) 92 ± 2s

***Ans*:- (D)**

$$t = \frac{t_1 + t_2 + t_3 + t_4}{4} = \frac{90 + 91 + 95 + 92}{4} = 92$$

Now mean deviation is equal to $\left(\frac{2+1+3+0}{4}\right) = 1.5$

Since least count of clock is one second, so $\Delta t = 2\,\text{sec}$