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JEE (Main)

PAPER-1 (B.E./B. TECH.)

2023

COMPUTER BASED TEST (CBT)

Questions & Solutions

Date: 01 February, 2023 (SHIFT-2) | TIME : (3.00 p.m. to 6.00 p.m)

Duration: 3 Hours | Max. Marks: 300

SUBJECT: PHYSICS

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PART : PHYSICS

1. If the velocity of light c, universal gravitational constant G and Planck's constant h are chosen as fundamental quantities. The dimensions of mass in the new system is :

(1) $[h^1c^1G^{-1}]$ (2) $[h^{-1/2}c^{1/2}G^{1/2}]$ (3) $[h^{1/2}c^{1/2}G^{-1/2}]$ (4) $[h^{1/2}c^{-1/2}G^1]$

Ans. **(3)**

Sol. $[M] = [G]^a [h]^b [C]^c$

$[G] = [M^{-1} L^3 T^{-2}]$; $[h] = [ML^2 T^{-1}]$

$[C] = [LT^{-1}]$

$[M] = [M^{-1}L^3 T^{-2}]^a [ML^2T^{-1}]^b [LT^{-1}]^c$

$= M^{-a+b} L^{3a+2b+c} T^{-2a-b-c}$

$-a + b = 1$

$3a + 2b + c = 0$

$-2a - b - c = 0$

$a = \frac{-1}{2}$

$b = 1/2$

$c = 1/2 \Rightarrow [M] = [h^{1/2} c^{1/2} G^{-1/2}]$

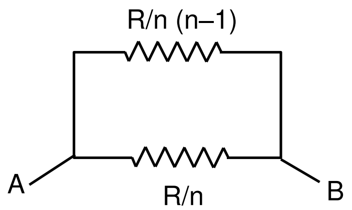
2. Equivalent resistance between the adjacent corners of a regular n–sided polygon of uniform wire of resistance R would be :

(1) $\frac{(n-1)R}{(2n-1)}$ (2) $\frac{(n-1)R}{n}$ (3) $\frac{n^2R}{n-1}$ (4) $\frac{(n-1)R}{n^2}$

Ans. **(4)**

Sol. Total resistance = R

Resistance of each edge = $\frac{R}{n}$



$$(R_{eq})_{AB} = \frac{\frac{R}{n}(n-1)\times\frac{R}{n}}{\frac{R}{n}(n-1)+\frac{R}{n}} = \frac{\frac{(n-1)}{n^2}\times R^2}{R} = \frac{(n-1)R}{n^2}$$

$$R_{eq} = \frac{(n-1)R}{n^2}$$

3. The escape velocities of two planets A and B are in the ratio 1 : 2. If the ratio of their radii respectively is 1 : 3, then the ratio of acceleration due to gravity of planet A to the acceleration of gravity of planet B will be :

(1) $\frac{3}{2}$ (2) $\frac{2}{3}$ (3) $\frac{3}{4}$ (4) $\frac{4}{3}$

Ans. **(3)**

Sol. $v_e = \sqrt{2gR_e}$

$$\frac{v_{e_1}}{v_{e_2}} = \sqrt{\frac{g_1R_1}{g_2R_2}}$$

$$\frac{1}{2} = \sqrt{\frac{g_1}{g_2}\left(\frac{1}{3}\right)}$$

$$\frac{1}{4} = \frac{g_1}{g_2} \times \frac{1}{3}$$

$$\frac{g_1}{g_2} = \frac{3}{4}$$

4. Given below are two statements : One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Two metallic spheres are charged to the same potential. One of them is hollow and another is solid, and both have the same radii. Solid sphere will have lower charge than the hollow one.

Reason R : Capacitance of metallic spheres depend on the radii of spheres.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both A and R are true and R is the correct explanation of A

(2) Both A and R are true but R is not the correct explanation of A

(3) A is true but R is false

(4) A is false but R is true

Ans. **(4)**

5. The threshold frequency of a metal is f_0. When the light of frequency $2f_0$ is incident on the metal plate, the maximum velocity of photoelectrons is v_1. When the frequency of incident radiation is increased to $5f_0$, the maximum velocity of photoelectrons emitted is v_2. The ratio of v_1 to v_2 is :

(1) $\frac{v_1}{v_2} = \frac{1}{8}$ (2) $\frac{v_1}{v_2} = \frac{1}{4}$ (3) $\frac{v_1}{v_2} = \frac{1}{16}$ (4) $\frac{v_1}{v_2} = \frac{1}{2}$

Ans. **(4)**

Sol. When h is the plank's constant & f is the incident frequency f_0 threshold frequency of metal & KE is the kinetic energy of photoelectron

For $2f_0$

$h(2f_0) = hf_0 + KE_1 \Rightarrow KE_1 = hf_0$ ……(I)

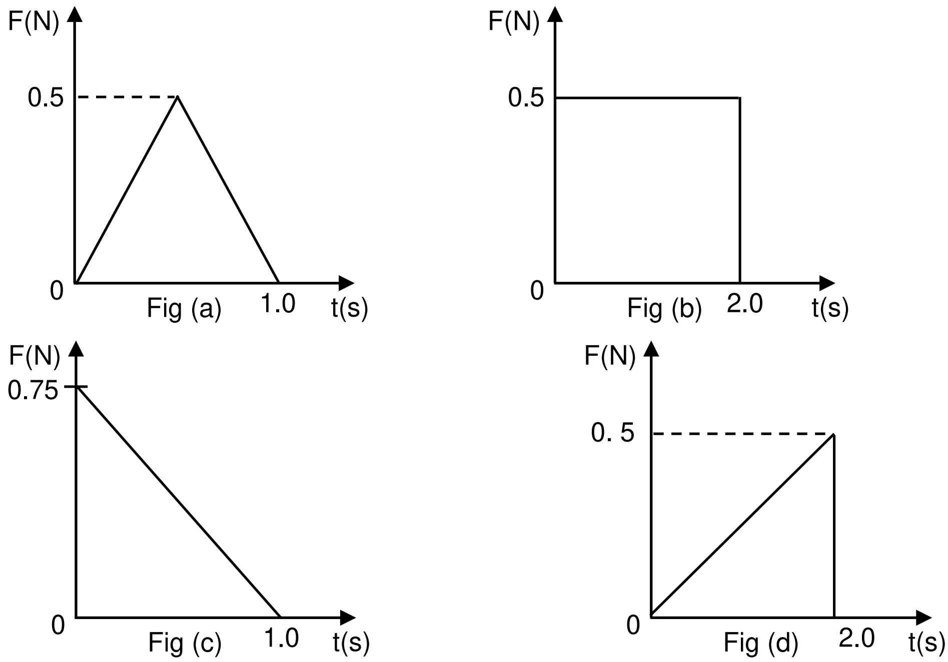
For $5f_0$

$h(5f_0) = hf_0 + KE_2 \Rightarrow KE_2 = 4hf_0$ …….(II)

divide (I) by (II)

$$\frac{KE_1}{KE_2} = \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{hf_0}{4hf_0} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{1}{4} \Rightarrow \frac{v_1}{v_2} = \frac{1}{2}$$

6. Figures (a), (b), (c) and (d) show variation of force with time.



The impulse is highest in figure.

(1) Figure (b) (2) Figure (c) (3) Figure (a) (4) Figure (d)

Ans. **(1)**

Sol. Impulse (I) = $\int F.dt$

So impulse is area under curve between F & t

For option (1)

$$\text{Area} = \frac{1}{2} \times 0.1 \times 0.5 = \frac{0.05}{2} = 0.025 \text{ N.s}$$

$I_A = 0.025$ N.s

For option (2)

Area = 0.5 × 0.1 = 0.05 N.s

$I_B = 0.05$N.s

For option (3)

Area = 1/2 × 0.5 × 0.5 = 0.0125 N.s

$I_C = 0.0125$ N.s

For option (4)

Area = 1/2 × 0.2 × 0.75 = 0.075 N.s

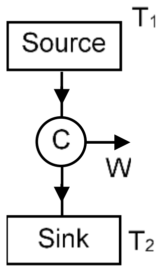
$I_D = 0.075$ N.s

7. A Carnot engine operating between two reservoirs has efficiency 1/3. When the temperature of cold reservoir raised by x, its efficiency decreases to 1/6. The value of x, if the temperature of hot reservoir is 99°C, will be

(1) 62 K (2) 16.5 K (3) 33 K (4) 66 K

Ans. **(1)**

Sol.



Let T_2 is the temperature of sink then

$$\eta_1 = 1 - \frac{T_2}{T_1} = 1 - \frac{T_2}{(372)} = 1 - \frac{T_2}{372}$$

given $\eta_1 = \frac{1}{3}$

So $\frac{1}{3} = 1 - \frac{T_2}{372} \Rightarrow \frac{T_2}{372} = 1 - \frac{1}{3} = \frac{2}{3}$

$T_2 = 248$

Now this sink temperature T_2 = 248Kn is increased by x & efficiency become $\frac{1}{6}$

$$\eta_2 = 1 - \frac{T_2 + x}{T_1} \Rightarrow \frac{1}{6} = 1 - \frac{248 + x}{372}$$

$$\frac{248 + x}{372} = 1 - \frac{1}{6} = \frac{5}{6}$$

$248 + x = 310 \Rightarrow x = 62K$

8. A coil is placed in magnetic field such that plane of coil is perpendicular to the direction of magnetic field. The magnetic flux through a coil can be changed :

(A) By changing the magnitude of the magnetic field within the coil.

(B) By changing the area of coil within the magnetic field.

(C) By changing the angle between the direction of magnetic field and the plane of the coil.

(D) By reversing the magnetic field direction abruptly without changing its magnitude.

Choose the most appropriate answer from the options given below :

(1) A and C only (2) A, B and C only (3) A, B and D only (4) A and B only

Ans. **(2)**

9. In an amplitude modulation, a modulating signal having amplitude of XV is superimposed with a carrier signal of amplitude YV in first case. Then, in second case the same modulating signal is superimposed with different carrier signal of amplitude 2YV. The ratio of modulation index in the two cases respectively will be :

(1) 2 : 1 (2) 1 : 2 (3) 1 : 1 (4) 4 : 1

Ans. **(1)**

Sol. $\mu = \frac{A_m}{A_c}$

$\frac{\mu_1}{\mu_2} = \frac{x/y}{x/2y} = \frac{2}{1}$

10. Choose the correct statement about Zener diode :

(1) It works as a voltage regulator in reverse bias and behaves like simple pn junction diode in forward bias.

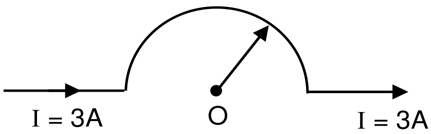
(2) It works as a voltage regulator in both forward and reverse bias.

(3) It works as a voltage regulator only in forward bias.

(4) It works as a voltage regulator in forward bias and behaves like simple pn junction diode in reverse bias.

Ans. **(1)**

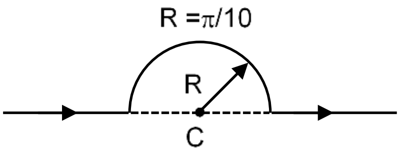
11. As shown in the figure, a long straight conductor with semi-circular arc of radius $\frac{\pi}{10}$m is carrying current I = 3A. The magnitude of the magnetic field at the center O of the arc is :
(The permeability of the vacuum = $4\pi \times 10^{-7}$ NA^{-2})



(1) 6μT (2) 4μT (3) 3μT (4) 1μT

Ans. **(3)**

Sol.



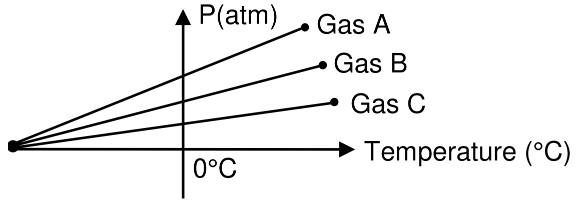
$B = \frac{\mu_0}{4}\frac{i}{R}$

$= \frac{\mu_0}{4} \times \frac{3 \times 10}{\pi}$

$B = 30 \times 10^{-7}$ T

$B = 3 \times 10^{-6}$ T = 3μT

12. For three low density gases A, B, C pressure versus temperature graphs are plotted while keeping them at constant volume, as shown in the figure.



The temperature corresponding to the point K is :

(1) –373° C (2) –40°C (3) –100°C (4) –273°C

Ans. **(4)**

Sol. When temperature goes to –273°C, all constituent particles get freeze and pressure goes to zero irrespective of the density of gas.

13. The ratio of average electric energy density and total average energy density of electromagnetic wave is:

(1) 2 (2) 3 (3) $\frac{1}{2}$ (4) 1

Ans. **(3)**

Sol. Average electric energy density = $\frac{1}{2}\varepsilon_0 E^2$

Total average energy density = $\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$

$\Rightarrow \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$

Total average energy density = $\varepsilon_0 E^2$

$\Rightarrow \frac{\text{Average electric energy density}}{\text{Total average energy density}} \Rightarrow \frac{\frac{1}{2}\varepsilon_0 E^2}{\varepsilon_0 E^2} = \frac{1}{2}$

14. Two objects A and B are placed at 15 cm and 25 cm from the pole in front of a concave mirror having radius of curvature 40 cm. The distance between images formed by the mirror is :

(1) 40 cm (2) 160 cm (3) 60 cm (4) 100 cm

Ans. **(2)**

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

From O_1

u = – 15 cm, f = – 20 cm

$\frac{1}{V_1} - \frac{1}{15} = -\frac{1}{20} \Rightarrow \frac{1}{V_1} = \frac{1}{15} - \frac{1}{20} = \frac{4-3}{60} = \frac{1}{60}$

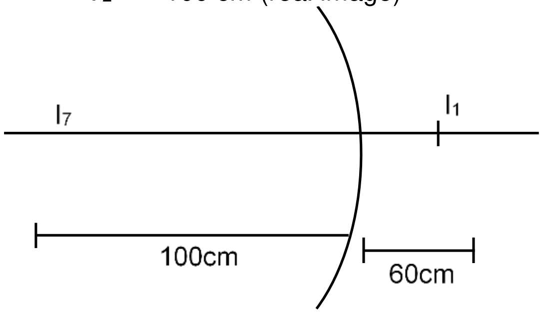
V_1 = 60 cm (virtual image)

For O_2

u = – 25 cm, f = –20cm

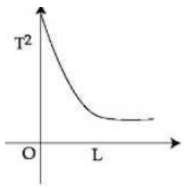
$\frac{1}{V_2} - \frac{1}{25} = -\frac{-1}{20} \Rightarrow \frac{1}{V_2} = \frac{1}{25} - \frac{1}{20} = \frac{4-5}{100} = \frac{1}{100}$

$V_2 = -100$ cm (real image)

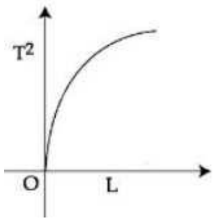


Separation = 160

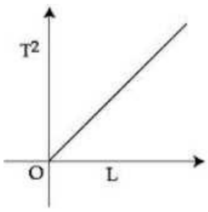
15. Choose the correct length (L) versus square of time period (T^2) graph for a simple pendulum executing simple harmonic motion.



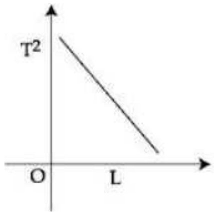
(1)



(2)



(3)



(4)

Ans. **(3)**

Sol. $T = 2\pi\sqrt{\frac{\ell}{g}}$

$T^2 = 4\pi^2 \frac{\ell}{g} \Rightarrow T^2 \propto \ell \quad \Rightarrow \quad T^2 = k\ell$

16. An electron of a hydrogen like atom, having Z= 4, jumps from 4th energy state to 2nd energy state. The energy released in this process, will be (Given Rch = 13.6 eV)
Where R = Rydberg constant, c = speed of light in vacuum, h = Planck's constant.
(1) 40.8 eV (2) 3.4 eV (3) 10.5 eV (4) 13.6 eV

Ans. **(1)**

Sol. Given :
$Z = 4, n_1 = 4, n_2 = 2$
Rch = 13.6 eV

$E = -13.6\frac{z^2}{n^2}$

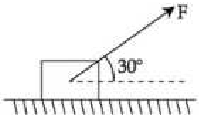
$E_1 = -13.6\frac{(4)^2}{(4)^2} = -13.6 \times 1$ eV

$E_2 = -13.6\frac{(4)^2}{(2)^2} = -13.6 \times 4$ eV

$\Rightarrow \Delta E = E_1 - E_2 = [-13.6 - (-13.6 \times 4)]$

$\Rightarrow \Delta E = 40.8$ eV

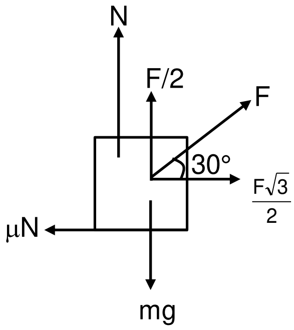
17. As shown in the figure a block of mass 10 kg lying on a horizontal surface is pulled by a force F acting at an angle 30°, with horizontal. For μ_s = 0.25, the block will just start to move for the value of F : [Given g = 10 ms^{-2}]



(1) 20 N (2) 35.7 N (3) 33.3 N (4) 25.2 N

Ans. **(4)**

Sol. FBD of the block



N = mg – F/2

$f = \mu N = 0.25\left[100 - \frac{F}{2}\right]$

Condition so that block can slide

F cos 30° ≥ f

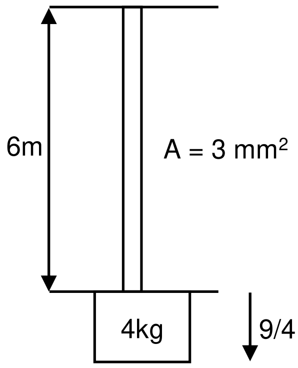
$\frac{\sqrt{3}F}{2} \geq 0.25\left[100 - \frac{F}{2}\right] \Rightarrow F = \frac{200}{4\sqrt{3}+1} \Rightarrow F = 25.2\text{ N}$

18. The Young's modulus of a steel wire of length 6m and cross–sectional area 3mm^2, is 2 × 10^{11} N/m^2. the wire is suspended from its support on a given planet. A block of mass 4 kg is attached to the free end of the wire. The acceleration due to gravity on the planet is 1/4 of its value on the earth. The elongation of wire is (Take g on the earth = 10 m/s^2) :

(1) 0.1 cm (2) 1mm (3) 1 cm (4) 0.1 mm

Ans. **(4)**

Sol. $\text{Stress} = \frac{F}{A} = \frac{4 \times \frac{10}{4}}{3 \times 10^{-6}} = \frac{10}{3} \times 10^6\ \text{N/m}^2$



$\frac{\text{Stress}}{\text{strain}} = y$

$\frac{\text{stress}}{y} = \frac{\Delta\ell}{\ell} \Rightarrow \Delta\ell = \frac{\ell \times \sigma}{y}$

$\Delta\ell = \frac{6 \times \frac{10}{3} \times 10^6}{2 \times 10^{11}} = \frac{10^7}{10^{11}}$

$\Delta\lambda = 10^{-4}\text{ m} \Rightarrow \Delta\lambda = 0.1\text{ mm}$

19. For a body projected at an angle with the horizontal from the ground, choose the correct statement :

(1) The kinetic energy (K.E.) is zero at the highest point of projectile motion.

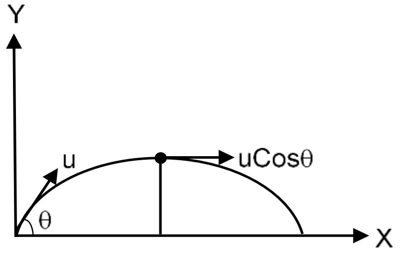
(2) The horizontal component of velocity is zero at the highest point

(3) The vertical component of momentum is maximum at the highest point.

(4) Gravitational potential energy is maximum at the highest point.

Ans. **(4)**

Sol.



At maximum height

$V_y = 0$

$V_X = u\cos\theta$

potential energy = mgH_{max}

$K.E. = \frac{1}{2}m\,(u\cos\theta)^2$

$K.E. = \frac{1}{2}mu^2\cos^2\theta$

20. Given below are two statements : One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : For measuring the potential difference across a resistance of 600 Ω, the voltmeter with resistance 1000 Ω. will be preferred over voltmeter with resistance 4000 Ω.

Reason R : Voltmeter with higher resistance will draw smaller current than voltmeter with lower resistance.

In the light of the above statements, choose the most appropriate answer from the options given below.

(1) Both A and R are correct but R is not the correct explanation of A

(2) Both A and R are correct and R is the correct explanation of A

(3) A is not correct but R is correct

(4) A is correct but R is not correct.

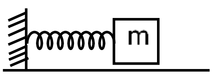
Ans. **(3)**

Sol. Voltmeter of higher voltage is preferred so assertion is incorrect

21. A block is fastened to a horizontal spring. The block is pulled to a distance x = 10 cm from its equilibrium position (at x = 0) on a frictionless surface from rest. The energy of the block at x = 5cm is 0.25 J. The spring constant of the spring is ————Nm^{-1}.

Ans. **NTA Ans is 50 & Reso Ans. is 67 or 200.**

Sol.



As block have kinetic energy at x = 5 cm & block is pulled upto 10 cm and force is removed then mean position will be at x = 0, so that amplitude will be a = 10 cm

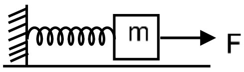
Kinetic energy of block = $\frac{1}{2}K(A^2 - x^2) = 0.25$

$\Rightarrow \frac{1}{2}K\left(A^2 - \frac{A^2}{4}\right) = 0.25 \qquad \Rightarrow \frac{1}{2}K\left(\frac{3}{4}A^2\right) = 0.25$

A = 10 cm = 0.1

$k = \frac{0.25 \times 8}{3 \times (0.01)} = \frac{200}{3} = 67 N/m$

Second solution



If forces not removed F = kx at equilibrium, as velocity is zero at x = 0 and block is pulled upto x = 10 so x = 5 will be mean position and amplitude of motion A = 5 cm.

So at x = 5

Potential energy of spring is zero

Kinetic energy of block = Total energy of SHM

$\frac{1}{2}KA^2 = 0.25$

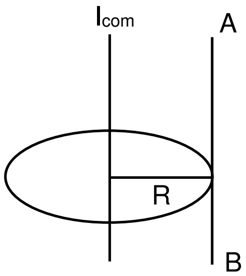
A = 0.05 m

$\therefore$ K = 200 N/m

22. Moment of inertia of a disc of mass M and radius 'R' about any of its diameter is $\frac{MR^2}{4}$. The moment of inertia of this disc about an axis normal to the disc and passing through a point on its edge will be, $\frac{x}{2}$ MR^2. The value of x is ————.

Ans. **3**

Sol. using parallel axis theorem



$I_{AB} = I_{com} + MR^2$

$I_{AB} = \frac{MR^2}{2} + MR^2 = \frac{3}{2}MR^2$

23. A cubical volume is bounded by the surfaces x = 0, x = a, y = 0, y = a, z = 0, z = a. The electric field in the region is given by $\vec{E} = E_0 x\hat{i}$. Where $E_0 = 4 \times 10^4$ $NC^{-1}m^{-1}$. If a = 2cm, the charge contained in the cubical volume is $Q \times 10^{-14}$ C. The value of Q is ————

Ans. **288**

Sol. $E_{at\ x=a} = E_0\ a$

$\Rightarrow \quad \int \vec{E}.d\vec{A} = \dfrac{Q}{\varepsilon_0}$

$\Rightarrow \quad E_0\, a \times a^2 = \dfrac{Q}{\varepsilon_0}$

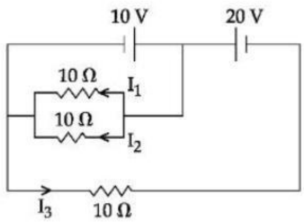
$Q = E_0\, a^3\, \varepsilon_0$

$Q = 4 \times 10^4 \left(\dfrac{2}{100}\right)^3 \times 9 \times 10^{-12}$

$Q = 288 \times 10^{-14}$ C

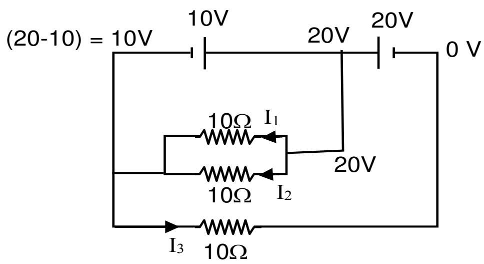
x = 288

24. In the given circuit, the value of $\left|\dfrac{I_1 + I_3}{I_2}\right|$ is ———



Ans. 2

Sol.



$I_3 = \dfrac{10V}{10\Omega} = 1A$

$I_1 = \dfrac{(20-10)V}{10\Omega} = 1A$

$I_2 = \dfrac{(20-10)V}{10\Omega} = 1A$

$\left|\dfrac{I_1 + I_3}{I_2}\right| = \dfrac{1+1}{1} = 2$

25. The surface of water in a water tank of cross section area 750 cm² on the top of a house is h m above the tap level. The speed of water coming out through the tap of cross section area 500 mm² is 30 cm/s. At that instant, $\dfrac{dh}{dt}$ is x × 10^{-3} m/s. the value of x will be ———

Ans. 2

Sol. Using continuity equation

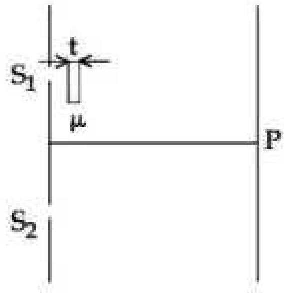
$A_1V_1 = A_2 V_2$

$750\text{ cm}^2 \times \dfrac{dh}{dt} = 500 \times 10^{-2}\text{ cm}^2 \times 30\text{cm/s}$

$\frac{dh}{dt} = \frac{150}{750} cm/s = \frac{1}{5} cm/s = 0.2 \ cm/s$

$\frac{dh}{dt} = 2 \times 10^{-3}$ m/s   so x = 2

26. As shown in the figure, in Young's double slit experiment, a thin plate of thickness t = 10 μm and refractive index μ = 1.2 is inserted infront of slit S_1. The experiment is conducted in air (μ = 1) and uses a monochromatic light of wavelength λ = 500 nm. Due to the insertion of the plate, central maxima is shifted by a distance of $x\beta_0$. β_0 is the fringe–width before the insertion of the plate. The value of the x is ———



Ans. 4

Sol. $(\mu - 1)\ t = \frac{dy}{D}$

$(\mu - 1)\ t = \frac{d}{D}(x)\frac{\lambda D}{d}$

$(\mu - 1)\ t = x\lambda$

$x = \frac{(\mu - 1)t}{\lambda}$

$\frac{0.2 \times 10 \times 10^{-6}}{5 \times 10^{-7}} = \frac{2}{5} \times 10 = 4$

27. Nucleus A having Z =17 and equal number of protons and neutrons has 1.2 MeV binding energy per nucleon. Another nucleus B of Z = 12 has total 26 nucleons and 1.8 MeV binding energy per nucleons. The difference of binding energy of B and A will be ———— MeV.

Ans. 6

Sol. In A, Z = 17 and have equal no. of protons and Neutrons i.e. nucleons = 2(17) = 34
Total binding energy of A = 34 × 1.2 = 40.8 MeV
Total binding energy of B = 26 × 1.8 = 46.8 MeV
ΔB.E. = 46.8 – 40.8 = 6 MeV

28. A square shaped coil of area 70 cm^2 having 600 turns rotates in a magnetic field of 0.4 wbm^{-2}, about an axis which is parallel to one of the side of the coil and perpendicular to the direction of field. If the coil completes 500 revolution in a minute, the instantaneous emf when the plane of the coil is inclined at 60° with the field, will be ———V. (Take $\pi = \frac{22}{7}$)

Ans. 44

Sol. $V = BA\sin\theta \frac{d\theta}{dt} = (BA\sin\theta)\ \omega$

$\omega = \frac{500}{60} \times 2\pi = \frac{50\pi}{3}$ and $\theta = 30°$ (angle between area and magnetic field)

$V = (0.4)(70 \times 10^{-4})(\sin 30°)\ \frac{50}{3} \times \frac{22}{7} = 44$

29. For a train engine moving with speed of 20 ms^{-1}, the driver must apply brakes at a distance of 500m before the station for the train to come to rest at the station. If the brakes were applied at half of this distance, the train engine would cross the station with speed $\sqrt{x}$ ms^{-1}. The value of x is ——— .
(Assuming same retardation is produced by brakes)

Ans. **200**

Sol. $V^2 - u^2 = 2as$

$0 - (20)^2 = 2 \times a \times 500$

$-\frac{400}{1000} = a \Rightarrow a = -0.4 m/s^2$

(–ve sing tells that direction of acceleration is opposite to direction of velocity)

For train -2

$V^2 - u^2 = 2as$

$v^2 - (20)^2 = 2 \times (-0.4) \times 250$

$v^2 = 400 - 200 = 200$

$v = \sqrt{200}\ m/s$

$x = 200$

30. A force $F = (5 + 3y^2)$ acts on a particle in the y–direction, where F is in newton and y is in meter. The work done by the force during a displacement from y = 2m to y = 5m is ————J.

Ans. 132

Sol. $\vec{F} = (5 + 3y^2)$

$\int dw = \int_2^5 (5 + 3y^2).dy$

$w = [5y + y^3]_2^5 = (5(5) + (5)^3) - (5(2) + (2)^3)$

$w = (25 + 125) - (10 + 8) = 150 - 18 = 132$ J

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