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JEE (Main)

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

2023

COMPUTER BASED TEST (CBT)

Questions & Solutions

Date: 31 January, 2023 (SHIFT-1) | TIME : (9.00 a.m. to 12.00 p.m)

Duration: 3 Hours | Max. Marks: 300

SUBJECT: PHYSICS

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PART : PHYSICS

1. If 1000 droplets of water of surface tension 0.07 N/m, having same radius 1 mm each, combine to from a single drop. In the process the released surface energy is : $\left(\text{Take } \pi = \frac{22}{7}\right)$

(1) 8.8 x 10^{-5} J (2) 7.92 × 10^{-4} J (3) 7.92 × 10^{-6} J (4) 9.68 × 10^{-4} J

Ans. **(2)**

Sol.

Using volume conservation

$$1000 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$R = 10\ r$

$R = 10 \times 1\ mm = 10\ mm$

as surface energy $U = S(4\pi r^2)$

when S is surface energy & r is radius

$U_1 = 0.07\ (4\pi \times (1 \times 10^{-3})^2) \times 1000$ $\quad U_2 = 0.07\ (4\pi\ (10 \times 10^{-3})^2)$

$U_1 - U_2 = 0.07 \times 4\pi\ [10^{-6} \times 10^3 - 10^{-4}]$

$$0.07 \times 4\pi\ [10^{-3} - 10^{-4}] = 0.01 \times 4 \times \frac{22}{7} \times 10^{-3}\left[1 - \frac{1}{10}\right]$$

$$= 0.01 \times 4 \times 22 \times 10^{-3} \times \frac{9}{10} = 792 \times 10^{-6}\ J = 7.92 \times 10^{-4}\ J$$

2. At a certain depth "d" below surface of earth, value of acceleration due to gravity becomes four times that of its value at a height 3R above earth surface. Where R is Radius of earth (Take R = 6400 km). The depth d is equal to

(1) 4800 km (2) 640 km (3) 2560 km (4) 5260 km

Ans. **(1)**

Sol. $g_d = 4\ g_{3R}$

$$g\left(1 - \frac{d}{R}\right) = 4 \times \frac{GMe}{(R+3R)^2}$$

$$g\left(1 - \frac{d}{R}\right) = \frac{GMe}{4R^2} \qquad \therefore \frac{GM_e}{R^2} = g$$

$$1 - \frac{d}{R} = \frac{1}{4}$$

$$d = \frac{3R}{4} = 4800\ km$$

3. A rod with circular cross-section area 2 cm^2 and length 40 cm is wound uniformly with 400 turns of an insulated wire. If a current of 0.4 A flows in the wire windings, the total magnetic flux produced inside windings is $4\pi \times 10^{-6}$ Wb. The relative permeability of the rod is

(Given: Permeability of vacuum $\mu_o = 4\pi \times 10^{-7}\ NA^{-2}$)

(1) 125 (2) 12.5 (3) $\frac{5}{16}$ (4) $\frac{32}{5}$

Ans. **(1)**

Sol. $\phi = BA\cos 0°$

$\phi = \mu_r \mu_0 n i A$

$4\pi \times 10^{-6} = \mu_r \times 4\pi \times 10^{-7} \times \dfrac{400}{40 \times 10^{-2}} \times 0.4 \times 2 \times 10^{-4} \times 1$

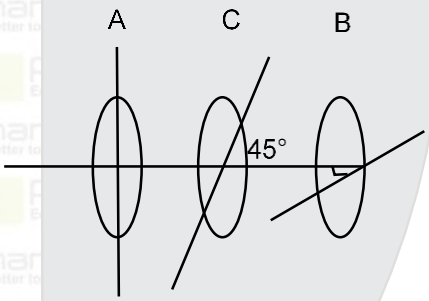
$\mu_r = 125$

4. Two polaroide A and B are placed in such a way that the pass-axis of polaroids are perpendicular to each other. Now, another polaroid C is placed between A and B bisecting angle between them. If intensity of unpolarized light is I_o then intensity of transmitted light after passing through polaroid B will be:

(1) $\dfrac{I_0}{8}$ (2) Zero (3) $\dfrac{I_0}{2}$ (4) $\dfrac{I_0}{4}$

Ans. **(1)**

Sol.



$I = I_0 \cos^2\theta$

$I_A = I_0/2$

$I_C = I_A \cos^2 45° = I_0/4$

$I_B = I_C \cos^2 45° = I_0/8$

5. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R**
Assertion A: The beam of electrons show wave nature and exhibit interference and diffraction.
Reason R : Davisson Germer Experimentally verified the wave nature of electrons.
In the light of the above statements, choose the most appropriate answer from the options given below:
1. A is correct but R is not correct
2.Both A and R are correct but R is Not the correct explanation of A
3. Both A and R are correct and R is the correct explanation of A
4. A is not correct but R is correct

Ans. **(3)**

Sol. interference and diffraction show wave nature and wave nature Experimentally verified by Davisson Germer

6. 100 balls each of mass m moving with speed v simultaneously strike a wall normally and reflected back with same speed, in time t s. The total force exerted by the balls on the wall is

(1) $\dfrac{100\,mv}{t}$ (2) 200mvt (3) $\dfrac{200\,mv}{t}$ (4) $\dfrac{mv}{100\,t}$

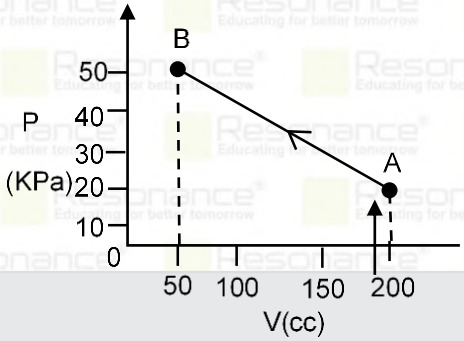
Ans. **(3)**

Sol. For each ball $F = \dfrac{\Delta P}{\Delta t}$

$F = \dfrac{mv - (-mv)}{t} = \dfrac{2mv}{t}$

For 100 balls $F_{net} = 100 \times \dfrac{2mv}{t} = \dfrac{200\,mv}{t}$

7. The pressure of a gas changes linearly with volume from A to B as shown in figure. If no heat is supplied to or extracted from the gas then change in the internal energy of the gas will be



(1) 4. 5 J (2) – 4. 5 J (3) zero (4) 6 J

Ans. **(1)**

Sol. $\Delta Q = 0$

$\Delta Q = \Delta U + W$

$\Delta U = - W$

volume decreases hence work done by system will be negative

W = Area under P - V curve

$W = -\left(\frac{1}{2} \times (10 + 50) \times 150\right) \times 10^3 \times 10^{-9} = -4.5\ J$

$\Delta U = 4.5\ J$

8. The correct relation between $\gamma = \frac{c_p}{c_v}$ and temperature T is :

(1) $\gamma \propto T^\circ$ (2) $\gamma \propto \frac{1}{T}$ (3) $\gamma \propto T$ (4) $\gamma \propto \frac{1}{\sqrt{T}}$

Ans. **(1)**

Sol. γ is dimensionless quantity it is ratio are specific heats hence it will not depend on temperature

γ for given gas remains constant

9. A free neutron decays into a proton but a free proton does not decay into neutron. This is because

1. neutron is an uncharged particle
2. neutron has larger rest mass than proton
3. neutron is a composite particle made of a proton and an electron
4. proton is a charged particle

Ans. **(2)**

Sol. In itself decay mass decreases, for mass increase decay energy required $E = (\Delta m)\, C^2$

neutron has larger rest mass than proton

10. The drift velocity of electrons for a conductor connected in an electrical circuit is V_d. The conductor in now replaced by another conductor with same material and same length but double the area of cross section. The applied voltage remains same. The new drift velocity of electrons will be

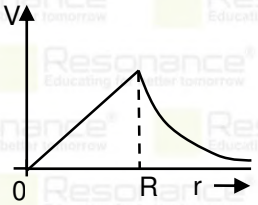
(1) $\frac{V_d}{4}$ (2) $\frac{V_d}{2}$ (3) $2V_d$ (4) V_d

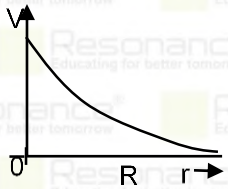
Ans. **(4)**

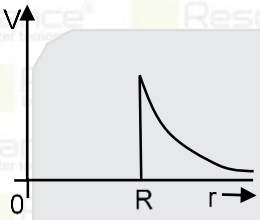
Sol. $V_d = -\frac{eE\tau}{m} = -\frac{eV\tau}{ml}$

drift velocity of electron not depends on area.

11. Which of the following correctly represents the variation of electric potential (V) of a charged spherical conductor of radius (R) with radial distance (r) from the center?

(1) 

(2) 

(3) 

(4) 

Ans. **(4)**

Sol. $V = \begin{cases} V_{in} = V_{surface} = \dfrac{KQ}{R} = \text{Constant for } r \le R \\ V_{out} = \dfrac{KQ}{r} \quad r \ge R \end{cases}$

12. Spherical insulating ball and a spherical metallic ball of same size and mass are dropped from the same height. Choose the correct statement out of the following {Assume negligible air friction}

(1) Both will reach the earth's surface simultaneously.

(2) Insulating ball will reach the earth's surface earlier than the metal ball

(3) Metal ball will reach the earth's surface earlier than the insulating ball

(4) Time taken by them to reach the earth's surface will be independent of the properties of their materials

Ans. **(2)**

Sol. Magnetic field lines of earth cut in the case of conductor and develop eddy current which oppose the motion of condoctor

13. If R, X_L, and Xc represent resistance, inductive reactance and capacitive reactance. Then which of the following is dimensionless :

(1) $R X_L X_C$ (2) $\dfrac{R}{\sqrt{X_L X_C}}$ (3) $\dfrac{R}{\sqrt{X_L\ X_C}}$ (4) $v R \dfrac{X_L}{X_C}$

Ans. **(2)**

Sol. resistance, inductive reactance and capacitive reactance have same units ohm. inductive reactance and capacitive reactance are equivalent to resistance

14. The amplitude of 15 sin (1000 π t) is modulated by 10 sin (4π t) signal. The amplitude modulated signal contains frequency (ies) of

A. 500 Hz B. 2 Hz C. 250 Hz D. 498 Hz

E. 502 Hz

Choose the correct answer from the options given below:

(1) B Only (2) A and B Only (3) A, D and E Only (4) A Only

Ans. **(3)**

Sol. $f_c = 500$

$f_m = 2$

amplitude modulated signal contains frequencies $f_c + f_m$, $f_c - f_m$, f_c : 502,498,500 respectively

15. A bar magnet with a magnetic moment 5.0 Am² is placed in parallel position relative to a magnetic field of 0.4 T. The amount of required work done in turning the magnet from parallel to antiparallel position relative to the field direction is_____.

(1) 4 J (2) 1 J (3) 2 J (4) zero

Ans. **(1)**

Sol. $W = \int \tau . d\theta$

$W = \int_0^{\pi} MB \sin\theta d\theta$

$W = MB \times [-\cos]_0^{\pi}$

$W = 2\,MB = 5 \times 0.4 \times 2 = 4\ J$

16. If a source of electromagnetic radiation having power 15 kW produces 10^{16} photons per second, the radiation belongs to a part of spectrum is. (Take Planck constant h = 6 x 10^{-34} Js)

(1) Micro waves (2) Gamma rays (3) Radio waves (4) Ultraviolet rays

Ans. **(2)**

Sol. $P = \frac{E}{t} = \frac{nhc}{\lambda}$

$15 \times 10^3 = \frac{10^{16} \times 6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

$\lambda = 1.32 \times 10^{-13}$ m

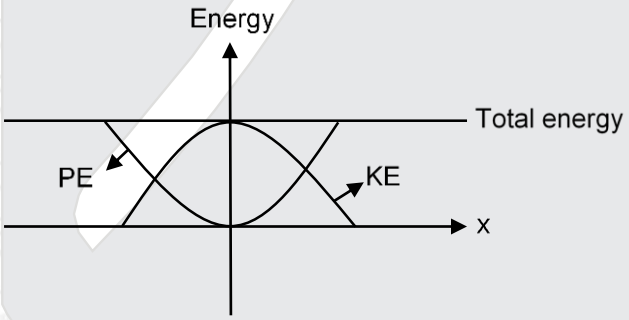
$\lambda < 10^{-12}$ comes in range of gamma rays

17. The maximum potential energy of a block executing simple harmonic motion is 25 J. A is amplitude of oscillation. At A/ 2, the kinetic energy of the block is

(1) 18.75 J (2) 37.5 J (3) 9.75 J (4) 12.5 J

Ans. **(1)**

Sol.

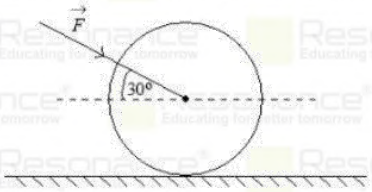


$U_{max} = \frac{1}{2} KA^2$

$KE = \frac{1}{2} K (A^2 - x^2)$

$At\ x = A/2\ KE = \frac{1}{2} K(A^2 - \frac{A^2}{4}) = \frac{3}{4} \times \frac{1}{2} KA^2 = \frac{3}{4} \times 25 = 18.75\ J$

18. As shown in figure, a 70 kg garden roller is pushed with a force of $\vec{F}$ = 200 N at an angle of 30° with horizontal. The normal reaction on the roller is (Given g = 10 ms^{-2})

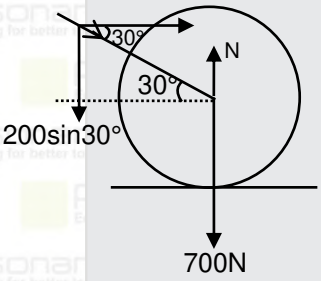


(1) 800 N (2) 600 N (3) 200 $\sqrt{3}$ N (4) 800 $\sqrt{2}$ N

Ans. **(1)**

Sol. N = 200sin30° + 700

N = 800 Newton

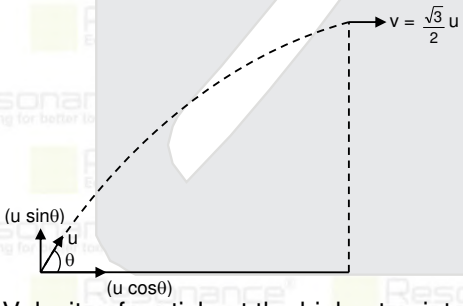


19. The initial speed of a projectile fired from ground is u. At the highest point during its motion, the speed of projectile is $\frac{\sqrt{3}}{2}\upsilon$ The time of flight of the projectile is :

(1) $\frac{2u}{g}$ (2) $\frac{u}{2g}$ (3) $\frac{u}{g}$ (4) $\frac{\sqrt{3u}}{g}$

Ans. **(3)**

Sol.



Velocity of particle at the highest point

$u\cos\theta = \frac{\sqrt{3}}{2}u$

$\cos\theta = \frac{\sqrt{3}}{2}$

$\theta = 30°$

$T = \frac{2u\sin\theta}{g} \Rightarrow T = \frac{2u\sin 30}{g} \Rightarrow T = \frac{u}{g}$

20. The effect of increase in temperature on the number of electrons in conduction band (n_e) and resistance of a semiconductor will be as:

(1) n_e decreases, resistance increases (2) Both n_e and resistance increase

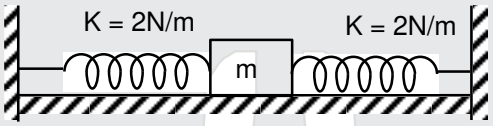
(3) n_e increases, resistance decreases (4) Both n_e and resistance decrease

Ans. **(3)**

Sol. Thermal coefficient of resistance α for semiconductor negative hence on increasing temperature resistance decreases.

On increasing temperature electrons of valance band get energy and jumps into conduction band

21. In the figure given below, a block of mass M = 490 g placed on a frictionless table is connected with two springs having same spring constant (K = 2 Nm^{-1}). If the block is horizontally displaced through 'X' m then the number of complete oscillations it will make in 14π seconds will be



Ans. **20**

Sol. $T = 2\pi\sqrt{\frac{M}{K_{eq}}}$

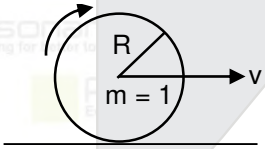
$= 2\pi\sqrt{\frac{0.49}{4}} = \frac{22}{7}\times 0.7 = 0.7\,\pi$

No. of oscillations = $\frac{14\pi}{0.7\pi} = 20$

22. A solid sphere of mass 1 kg rolls without slipping on a plane surface. Its kinetic energy is 7×10^{-3} J. The speed of the centre of mass of the sphere is_____ cm s^{-1}

Ans. **10**

Sol.

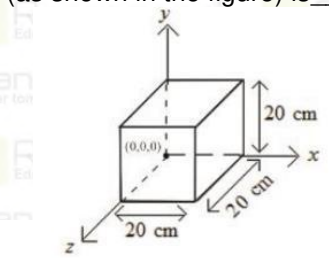


$$\text{K.E.} = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{2}{5}\right)MR^2\omega^2 + \frac{1}{2}mv^2$$

$$\text{K.E.} = \frac{1}{5}mv^2 + \frac{1}{2}mv^2 \quad (\because v = R\omega)$$

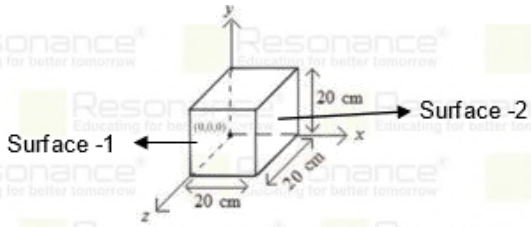
$$\frac{(2+5)mv^2}{10} = \text{KE} \Rightarrow \frac{7}{10}\times 1\times v^2 = 7\times 10^{-3} \Rightarrow v^2 = \sqrt{10^{-2}} \Rightarrow v = \frac{1}{10}\ \text{m/s} \Rightarrow v = 10\ \text{cm/s}$$

23. Expression for an electric field is given by $\vec{E} = 4000\,x^2\,\hat{i}\ \frac{V}{m}$. The electric flux through the cube of side 20 cm when placed in electric field (as shown in the figure) is_____ V cm.



Ans. **640**

Sol.



Flux through all surfaces except surface 1 & 2 will be 0 hence net flux will be due to only surface 1& 2

$\phi = \phi_1 + \phi_2$

$\phi_1 = EA\cos0^\circ = 0 \times A \times 1 = 0 \quad \{\because x = 0 \Rightarrow E = 0\}$

$\phi_2 = EA\cos0^\circ = 4000 \times (0.2)^2 \times (0.2)^2 \times 1 = 6.4Vm$

$\phi = \phi_1 + \phi_2 = 0 + 6.4Vm = 640\ Vcm$

24. In a medium the speed of light wave decreases to 0.2 times to its speed in free space The ratio of relative permittivity to the refractive index of the medium is x:1. The value of x is_____. (Given speed of light in free space = $3 \times 10^8\ ms^{-1}$ and for the given medium $\mu_r = 1$)

Ans. **5**

Sol. $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}, v = \dfrac{1}{\sqrt{\mu\varepsilon}}$

$n = \dfrac{c}{v} = \dfrac{c}{0.2c} = 5 \Rightarrow \quad n = \dfrac{c}{v} = \sqrt{\dfrac{\mu.\varepsilon}{\mu_0.\varepsilon_0}} = \sqrt{\mu_r\varepsilon_r}$

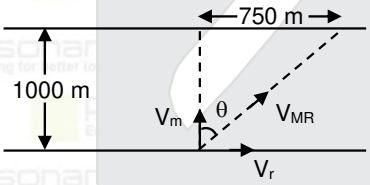
$n = \sqrt{\mu_r.\varepsilon_r} \quad \Rightarrow \quad 5 = \sqrt{1.\varepsilon_r} \quad (\mu_r = 1)$

$\varepsilon_r = 25 \quad \Rightarrow \quad \dfrac{\varepsilon_r}{n} = \dfrac{25}{5} = 5 \quad \Rightarrow \quad X = 5$

25. The speed of a swimmer is 4 km h^{-1} in still water. If the swimmer makes his strokes normal to the flow of river of width 1 km, he reaches a point 750 m down the stream on the opposite bank.
The speed of the river water is _____km h^{-1}

Ans. **3**

Sol.



$\tan\theta = \dfrac{V_r}{V_m} = \dfrac{750}{1000} \Rightarrow \quad V_r = \dfrac{75}{100} \times 4 \Rightarrow \quad V_r = 3\ km/hr$

26. A lift of mass M = 500 kg is descending with speed of 2 ms^{-1}. Its supporting cable begins to slip thus allowing it to fall with a constant acceleration of 2 ms^{-2}. The kinetic energy of the lift at the end of fall through to a distance of 6 m will be_____ kJ.

Ans. **10**

Sol. V = 2 m/s $\quad a = 2m/s^2$

at d = 6

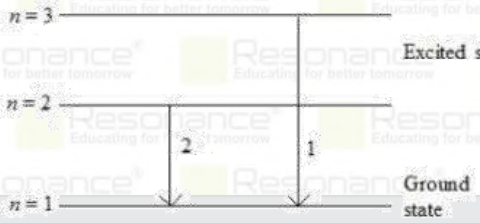
Velocity $\quad V^2 = u^2 + 2as$

$V = \sqrt{4 + 2\times2\times6}$

$V = \sqrt{28}$

Then KE $= \dfrac{1}{2}mv^2 = \dfrac{1}{2} \times 500 \times \sqrt{(28)}^2 = \dfrac{1}{2} \times 500 \times 28 = 500 \times 14 = 7000\ J$; K.E. = 7 kJ

27. For hydrogen atom, λ_1 and λ_2 are the wavelengths corresponding to the transitions x 1 and 2 respectively as shown in figure. The ratio of λ_1 and λ_2 is $\frac{x}{32}$. The value of x is_____



Ans. **27**

Sol. $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\frac{1}{\lambda_1} = R\left[1 - \frac{1}{9}\right] = \frac{8}{9}R$

$\frac{1}{\lambda_2} = R\left[1 - \frac{1}{4}\right] = \frac{3}{4}R$

$\frac{\lambda_1}{\lambda_2} = \frac{\frac{3}{4}}{\frac{8}{9}} = \frac{27}{32}$

X = 27

28. An inductor of 0.5 mH, a capacitor of 20 μF and resistance of 20Ω are connected in series with a 220 V ac source. If the current is in phase with the emf, the amplitude of current of the circuit is $\sqrt{x}$ A. The value of x is

Ans. **242**

Sol. Current and emf are in same phase

It will be either pure resistive circuit or case of resonance

$x_L = x_c \Rightarrow z = \sqrt{R^2 + (x_L - X_c)^2} = R$

$I_0 = \frac{V_0}{z} = \frac{V_{rms}\sqrt{2}}{z}$

$I_0 = \frac{220 \times \sqrt{2}}{20}$

$I_0 = \sqrt{242} = \sqrt{x}$

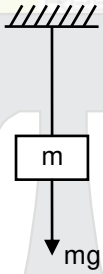
X = 242

29. A thin rod having a length of 1 m and area of cross-section 3×10^{-6} m^2 is suspended vertically from one end. The rod is cooled from 210°C to 160°C. After cooling, a mass M is attached at the lower end of the rod such that the length of rod again becomes 1 m. Young's modulus and coefficient of linear expansion of the rod are 2×10^{11} N m^2 and 2×10^{-5} K-1 respectively. The value of M is_____kg. (Take g = 10 ms^{-2})

Ans. **60**

Sol. As $\frac{\Delta\ell}{\ell} = \alpha\Delta T \Rightarrow \frac{\Delta\ell}{\ell} = 2 \times 10^{-5} \times (210 - 160)$

$$\frac{\Delta\ell}{\ell} = 2 \times 10^{-5} \times 50 = 10^{-3}$$



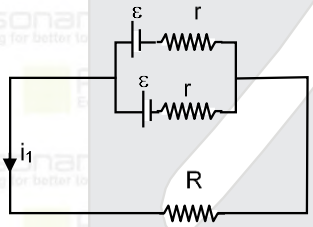
As young modulus $y = \frac{F}{A} \times \frac{\ell}{\Delta\ell}$

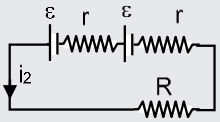
So, $2 \times 10^{11} = \frac{mg}{3\times10^{-6}} \times 10^3 \Rightarrow \frac{2\times10^{11}\times3\times10^{-6}\times10^{-3}}{10} = m \Rightarrow m = 60\ kg$

30. Two identical cells, when connected either in parallel or in series gives same current in an external resistance 5 Ω. The internal resistance of each cell will be_____Ω.

Ans. **5**

Sol.





In case of parallel connection

$\varepsilon_{net} = \frac{\varepsilon r + \varepsilon r}{r + r} = \varepsilon$

$r_{net} = \frac{r}{2}$

$i_1 = \frac{\varepsilon}{R + \frac{r}{2}} = \frac{2\varepsilon}{2R + r}$

In case of series connection

$\varepsilon_{net} = 2\varepsilon \qquad r_{net} = 2r$

$i_2 = \frac{2\varepsilon}{R + 2r}$

$i_1 = i_2 \Rightarrow \frac{2\varepsilon}{2R + r} = \frac{2\varepsilon}{R + 2r}$

$2R + r = R + 2r$

$R = r = 5\Omega$

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