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

JEE (Main) 2020

COMPUTER BASED TEST (CBT)

Questions & Solutions

Date: 03 September, 2020 (SHIFT-2) | TIME : (03.00 p.m. to 06.00 p.m)

Duration: 3 Hours | Max. Marks: 300

SUBJECT : PHYSICS

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PART : PHYSICS

Single Choice Type (एकल विकल्पीय प्रकार)

This section contains **20 Single choice questions.** Each question has 4 choices (1), (2), (3) and (4) for its answer, out of which **Only One** is correct.

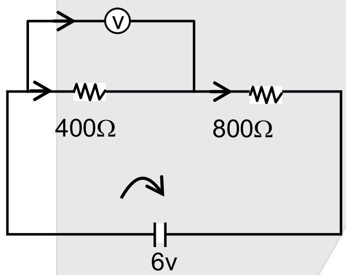
इस खण्ड में **20 एकल विकल्पी प्रश्न** हैं। प्रत्येक प्रश्न के 4 विकल्प (1), (2), (3) तथा (4) हैं, जिनमें से **सिर्फ एक सही** है।

1. Two resistors 400Ω and 800Ω are connected in series across a 6 V battery. The potential difference measured by a voltmeter of 10kΩ across 400Ω resistor is close to:

(1) 2 V (2) 1.95 V (3) 2.05 V (4) 1.8 V

Ans. **(2)**

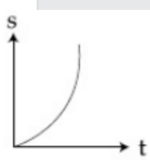
Sol.



Let voltmeter reading is v

$$\frac{v}{400}\times 400+\left(\frac{v}{10000}+\frac{v}{400}\right)800 = 6 \quad\Rightarrow\quad v+\frac{8v}{100}+2v=6\ ;\ \frac{77v}{25}=6\ ;\ v=\frac{150}{77}=1.95\text{ v}$$

2. A particle is moving unidirectionally on a horizontal plane under the action of a constant power supplying energy source. The displacement (s) – time (t) graph that describes the motion of the particle is (graphs are drawn schematically and are not to scale):

(1)


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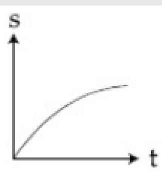

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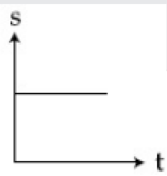
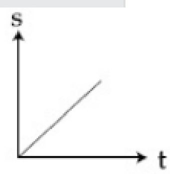


(4)


Ans. **(1)**

Sol. $P.\,t=\frac{1}{2}mv^2 \Rightarrow v=\left(\sqrt{\frac{2P}{m}}\right)t^{1/2}$

$$s=\int_0^t v\,dt=\sqrt{\frac{2P}{m}}\int_0^t t^{1/2}dt=\sqrt{\frac{2P}{m}}\cdot\frac{t^{3/2}}{3/2}\ ;\quad s=\sqrt{\frac{8P}{9m}}\cdot t^{3/2}$$

3. Two light waves having the same wavelength λ in vacuum are in phase initially. Then the first wave travels a path L_1 through a medium of refractive index n_1 while the second wave travels a path of length L_2 through a medium of refractive index n_2. After this the phase difference between the two waves is:

(1) $\frac{2\pi}{\lambda}\left(\frac{L_2}{n_1}-\frac{L_1}{n_2}\right)$ (2) $\frac{2\pi}{\lambda}\left(\frac{L_1}{n_1}-\frac{L_2}{n_2}\right)$ (3) $\frac{2\pi}{\lambda}(n_1L_1-n_2L_2)$ (4) $\frac{2\pi}{\lambda}(n_2L_1-n_1L_2)$

Ans. (3)

Sol. The optical path between any two points is proportional to the time of travel.

The distance traversed by light in a medium of refractive index μ in time t is given by

$d=vt$ .....(i)

where v is velocity of light in the medium. The distance traversed by light in a vacuum in this time,

$\Delta = ct$

$= c\times\frac{d}{v}$ [from equation (i)]

$= d\frac{c}{v} = \mu d$ ....(ii) (Since, $\mu=\frac{c}{v}$)

This distance is the equivalent distance in vacuum and is called optical path.

Here, optical path for first ray $=n_1L_1$

Optical path for second ray $=n_2L_2$

Path difference $=n_1L_1-n_2L_2$

Now, phase difference

$=\frac{2\pi}{\lambda}\times$ path difference

$=\frac{2\pi}{\lambda}\times(n_1L_1-n_2L_1)$

4. A block of mass 1.9 kg is at rest at the edge of a table, of height 1 m. A bullet of mass 0.1 kg collides with the block and sticks to it. If the velocity of the bullet is 20 m/s in the horizontal direction just before the collision then the kinetic energy just before the combined system strikes the floor, is [Take g = 10 m/s^2. Assume there is no rotational motion and loss of energy after the collision is negligible.]

(1) 21J (2) 23 J (3) 20 J (4) 19 J

Ans. (1)

Sol. Conservation of linear momentum

$0.1 \times 20 = (0.1 + 1.9) \times v$

$v = 1$ m/s

Using work energy theorem

$W_g = \Delta k$

$2 \times g \times 1 = k - \frac{1}{2}\times 2 \times 1^2$

$\therefore k = 21$ J

5. A calorimeter of water equivalent 20 g contains 180 g of water at 25°C. 'm' grams of steam at 100°C is mixed in it till the temperature of the mixture is 31°C. The value of 'm' is close to (Latent heat of water = 540 cal g^{-1}, specific heat of water = 1 cal $g^{-1}{}^{\circ}C^{-1}$)

(1) 2 (2) 4 (3) 3.2 (4) 2.6

Ans. **(1)**

Sol. (200) (31 – 25) = m × 540 + m(1) (69)

1200 = m(609)

m ≈ 2

6. A perfectly diamagnetic sphere has a small spherical cavity at its centre, which is filled with a paramagnetic substance. The whole system is placed in a uniform magnetic field $\vec{B}$. Then the field inside the paramagnetic substance is:

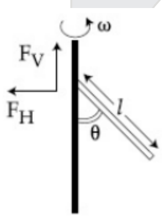
(1) much large than $|\vec{B}|$ but opposite to $\vec{B}$ (2) Zero

(3) much large than $|\vec{B}|$ but parallel to $\vec{B}$ (4) $\vec{B}$

Ans. **(2)**

Sol. When magnetic field is applied diamagnetic substance produces magnetic field in opposite direction so net magnetic field will be zero.

7.



A uniform rod of length 'ℓ' is pivoted at one of its ends on a vertical shaft of negligible radius. When the shaft rotates at angular speed ω the rod makes an angle θ with it (see figure). To find θ equate the rate of change of angular momentum (direction going into the paper) $\frac{m\ell^2}{12}\omega^2 \sin\theta$ about the centre of mass (CM) to the torque provided by the horizontal and vertical forces F_H and F_V about the CM. The value of θ is then such that:

(1) $\cos\theta = \frac{2g}{3\ell\omega^2}$ (2) $\cos\theta = \frac{3g}{2\ell\omega^2}$ (3) $\cos\theta = \frac{g}{2\ell\omega^2}$ (4) $\cos\theta = \frac{g}{\ell\omega^2}$

Ans. **(2)**

Sol. Torque of centrifugal force τ_{cf} = $dm.x\sin\theta\omega^2 x\cos\theta = \frac{m}{\ell}\omega^2 \sin\theta\cos\theta\int_0^{\ell} x^2 dx$

$$\tau_{ef} = \frac{m\ell^2\omega^2 \sin\theta\cos\theta}{3}$$

$$\tau_{mg} = \tau_{cf}$$

$$mg.\frac{\ell}{2}\sin\theta = \frac{m\ell^2\omega^2 \sin\theta\cos\theta}{3}$$

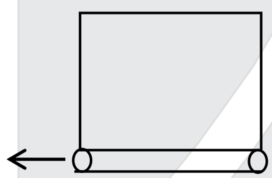
$$\cos\theta = \frac{3g}{2\ell\omega^2}$$

8. A uniform magnetic field B exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate $dB/dt = 0.032\ Ts^{-1}$. The induced current in the loop is close to (Resistivity of the metal wire is $1.23 \times 10^{-8}\ \Omega m$)

(1) 0.61 A (2) 0.34 A (3) 0.43 A (4) 0.53 A

Ans. **(1)**

Sol.



Radius = d/2 = 2 mm

$$R_{wire} = \frac{\rho\ell}{A}$$

$$\phi = BA\ ;\ |e| = \frac{d\phi}{dt} = \frac{dB}{dt}(A)$$

$$i = \frac{e}{R} = \left|\frac{dB}{dt}\right|\frac{(A)^2}{\rho\ell} = \frac{0.032 \times \{\pi \times 2 \times 10^{-3}\}^2}{1.23 \times 10^{-8} \times 4 \times 0.3}$$

= 0.61 A

9. A block of mass m attached to a massless spring is performing oscillatory motion of amplitude 'A' on a frictionless horizontal plane. If half of the mass of the block breaks off when it is passing through its equilibrium point, the amplitude of oscillation for the remaining system become fA. The value of f is:

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

Ans. **(2)**

Sol. Remaining energy $\frac{1}{2}\left(\frac{1}{2}KA^2\right) = \frac{1}{2}KA'^2$

$A' = \frac{A}{\sqrt{2}}$

10. The radius R of a nucleus of mass number A can be estimated by the formula R = (1.3 × 10^{-15}) $A^{1/3}$ m. It follows that the mass density of n nucleus is of the order of: ($M_{prot.} \cong M_{neut.} \approx 1.67 \times 10^{-27}$ kg)

(1) 10^{10} kg m^{-3} (2) 10^{24} kg m^{-3} (3) 10^{3} kg m^{-3} (4) 10^{17} kg m^{-3}

Ans. **(4)**

Sol. Theory Based

11. Concentric metallic hollow spheres of radii R and 4R hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference V9R) – V(4R) is:

(1) $\frac{Q_2}{4\pi\varepsilon_0 R}$ (2) $\frac{3Q_2}{4\pi\varepsilon_0 R}$ (3) $\frac{3Q_1}{16\pi\varepsilon_0 R}$ (4) $\frac{3Q_1}{4\pi\varepsilon_0 R}$

Ans. **(3)**

Sol. $V_{inner} = \frac{KQ_1}{R} + \frac{KQ_2}{4R}$

$V_{outer} = \frac{KQ_1}{4R} + \frac{KQ_2}{4R}$

Potential difference

$\Delta V = V_{inner} - V_{outer}$

$= \frac{3}{4}.\frac{KQ_1}{R} = \frac{3}{16\pi \in_0}.\frac{Q_1}{R}$

12. The electric field of a plane electromagnetic wave propagating along the x direction in vacuum is $\vec{E} = E_0\,\hat{j}\cos(\omega t - kx)$. The magnetic field $\vec{B}$, at the moment t = 0 is:

(1) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \in_0}}\cos(kx)\,\hat{k}$ (2) $\vec{B} = E_0\sqrt{\mu_0 \in_0}\cos(kx)\,\hat{k}$

(3) $\vec{B} = E_0\sqrt{\mu_0 \in_0}\cos(kx)\,\hat{j}$ (4) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \in_0}}\cos(kx)\,\hat{j}$

Ans. **(2)**

Sol. $B_0 = \frac{E_0}{C} = \frac{E_0}{1/\sqrt{\mu_0 \in_0}} = E_0\sqrt{\mu_0 \in_0}$

As the light is propagating in x direction

& $\hat{E} \times \hat{B} \,||\, \hat{C}$

∴ $\vec{B}$ should be in $\hat{k}$ direction

13. Hydrogen ion and singly ionized helium atom are accelerated, from rest, through the same potential difference. The ratio of final speeds of hydrogen and helium ions is close to:

(1) 1 : 2 (2) 2 : 1 (3) 5 : 7 (4) 10 : 7

Ans. **(2)**

Sol. $qV = \frac{1}{2}mv^2$

Hence $v \propto \frac{1}{\sqrt{m}}$

$$\frac{v_H}{v_{He}} = \sqrt{\frac{4}{1}} = 2:1$$

14. If a semiconductor photodiode can detect a photon with a maximum wavelength of 400 nm, then its band gap energy is: Planck's constant h = 6.63×10^{-34} J.s.

Speed of light c = 3×10^8 m/s

(1) 1.1 eV (2) 1.5 eV (3) 2.0 eV (4) 3.1 eV

Ans. **(4)**

Sol. λ = 400 nm

Band gap $E_g = \frac{hc}{\lambda} = \frac{1237.5}{400} = 3.09\,\text{eV}$

15. Amount of solar energy received on the earth's surface per unit area per unit time is defined a solar constant. Dimension of solar constant is:

(1) ML^2T^{-2} (2) ML^0T^{-3} (3) $M^2L^0T^{-1}$ (4) MLT^{-2}

Ans. **(2)**

Sol. Solar constant = $\frac{\text{Energy}}{\text{Time Area}}$

$$= \frac{M^1L^2T^{-2}}{TL^2} = M^1L^0T^{-3}$$

16. Two sources of light emit X-rays of wavelength 1 nm and visible light of wavelength 500 nm, respectively. Both the sources emit light of the same power 200 W. The ratio of the number density of photons of the visible light of the given wavelengths is:

(1) 250 (2) $\frac{1}{500}$ (3) 500 (4) $\frac{1}{250}$

Ans. **(2)**

Sol. P_s – Power of source

$P_s = n\frac{hc}{\lambda}$; n = no. of photons emitted /s

$\Rightarrow \quad n \propto \lambda \quad \Rightarrow \quad \frac{n_2}{n_1} = \frac{\lambda_2}{\lambda_1} = 1/500$

17. Which of the following will NOT be observed when a multimeter (operating in resistance measuring mode) probes connected across a component, are just reversed?

(1) Multimeter shows a deflection, accompanied by a splash of light out of connected component in one direction and NO deflection on reversing the probes if the chosen component is LED

(2) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes is the chsosen component is metal wire.

(3) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes if the chosen component is capacitor.

(4) Multimeter shows an equal deflection in both cases i.e., before and after reversing the probes if the chosen component is resistor.

Ans. **(3)**

Sol. Based on Theory

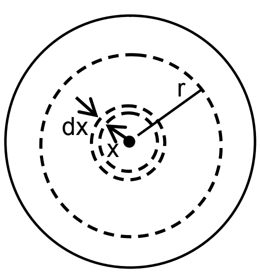
18. The mass density of a planet of radius R varies with the distance r from its centre as $\rho(r) = \rho_0\left(1-\frac{r^2}{R^2}\right)$.

Then the gravitational field is maximum at:

(1) r = R (2) r = $\frac{1}{\sqrt{3}}$ (3) r = $\sqrt{\frac{5}{9}}$ R (4) $\sqrt{\frac{3}{4}}$ R

Ans. **(3)**

Sol.



$dm = \rho \times 4\pi x^2 dx \quad = \rho_0\left(1-\frac{x^2}{r^2}\right)\times 4\pi x^2 dx$

$m = 4\pi\rho_0\int_0^r\left(x^2-\frac{x^4}{R^2}\right)dx$ s

$m = 4\pi\rho_0\left|\frac{r^3}{3}-\frac{r^5}{5R^2}\right|$

$E = \frac{Gm}{r^2} = \frac{G}{r^2}\times 4\pi\rho_0\left(\frac{r^3}{3}-\frac{r^5}{5R^2}\right)$

$E = 4\pi G\rho_0\left(\frac{r}{3}-\frac{r^3}{5R^2}\right)$

E is maximum when $\frac{dE}{dr}=0 \Rightarrow \frac{dE}{dr}=4\pi G\rho_0\left(\frac{1}{3}-\frac{3r^2}{5R^2}\right)=0$

$\Rightarrow r=\frac{\sqrt{5}}{3}R$

$E_{max} = 4\pi G\rho_0\times\frac{\sqrt{5}R}{3}\left[\frac{1}{3}-\frac{1}{5}\times\frac{5}{9}\right]$

$E_{max} = \frac{8\sqrt{5}}{27}\pi G\rho_0.R$

19. To raise the temperature of a certain mass of gas by 50°C at a constant pressure, 160 calories of heat is required. When the same mass of gas is cooled by 100°C at constant volume, 240 calories of heat is released. How many degrees of freedom does each molecule of this gas have (assume gas to be ideal)?

(1) 7 (2) 6 (3) 5 (4) 3

Ans. **(2)**

Sol. At constant pressure:

$\Delta Q = nC_P\Delta T \quad \Rightarrow \quad 160 = nC_P.50 \quad \ldots(1)$

At constant volume

$\Delta Q = nC_V\Delta T \quad \Rightarrow \quad 240 = nC_V.100 \quad \ldots(2)$

Equation (1) divided by (2)

$\frac{160}{240}=\frac{C_P}{C_V}.\frac{50}{100}$

$\frac{C_P}{C_V}=\frac{4}{3}=1+\frac{2}{f}$

$f = 6$

20. A metallic sphere cools from 50°C to 40°C in 300 s. If atmospheric temperature around is 20°C, then the sphere's temperature after the nest 5 minutes will be close to:

(1) 33°C (2) 31°C (3) 35°C (4) 28°C

Ans. **(1)**

Sol. Using Newton's Law of cooling

$$\frac{50-40}{5\text{Min}} = K\left(\frac{50+40}{2}-20\right) \qquad \text{......(i)}$$

Next 5 Min.

$$\frac{40-\theta}{5} = K\left(\frac{40+\theta}{2}-20\right) \qquad \text{......(ii)}$$

Dividing (ii) / (i)

$$\frac{40-\theta}{10} = \frac{40+\theta-40}{50+40-40} = \frac{\theta}{50}$$

$$40 - \theta = \frac{\theta}{5}$$

$$200 - 5\theta = \theta$$

$$\therefore \theta = \frac{200}{6} = 33.3^\circ C$$

Numerical Value Type (संख्यात्मक प्रकार)

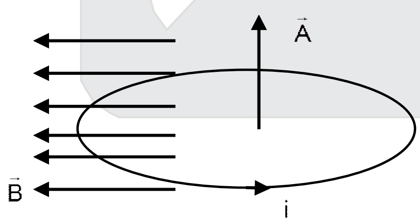
This section contains **5 Numerical value type questions.**

इस खण्ड में **5 सख्यात्मक प्रकार के प्रश्न** हैं।

21. A galvanometer coil has 500 turns and each turn has an average area of 3 × 10^{-4} m^2. If a torque of 1.5 Nm is required to keep this coil parallel to a magnetic field when a current of 0.5 A is flowing through it, the strength of the field (in T) is

Ans. **20**

Sol.

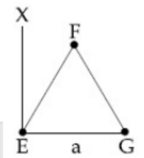


$$\tau = |\vec{M}\times\vec{B}| = NiAB\sin(90^\circ)$$

$$= NiAB = Ni\,S\,B$$

$$\Rightarrow \quad B = \frac{\tau}{NiS} = \frac{1.5}{500\times0.5\times3\times10^{-4}} = 20$$

22. An massless equilateral triangle EFG of side 'a' (As shown in figure) has three particles of mass m situated at its vertices. The moment of inertia of the system about the line EX perpendicular to EG in the plane of EFG is $\frac{N}{20}$ ma^2 where N is an integer. The value of N is



Ans. **25**

Sol. $I = m \times O^2 + ma^2 + m\left(\frac{a}{2}\right)^2$

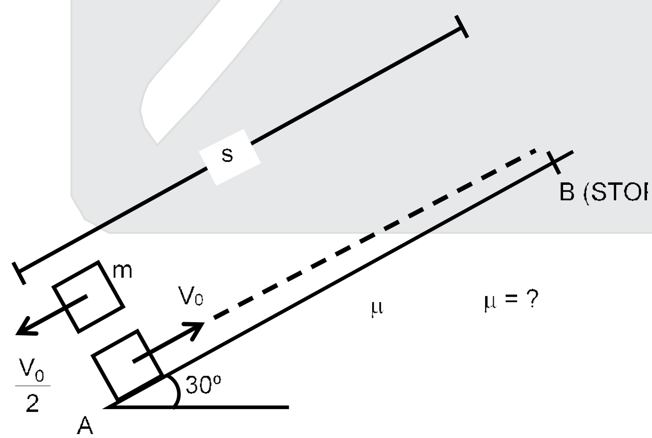
$= \frac{5}{4} ma^2 = \frac{25}{20} ma^2$

N = 25

23. A block starts moving up an inclined plane of inclination 30° with an initial velocity of υ_0. It comes back to its initial position with velocity $\frac{\upsilon_0}{2}$. The value of the coefficient of kinetic friction between the block and the inclined plane is close to $\frac{I}{1000}$, The nearest integer to I is :

Ans. **346**

Sol.



A to B

$a_1 = g \sin 30^\circ + \mu g \cos 30^\circ$

$= \frac{g}{2} + \frac{\mu g\sqrt{3}}{2}$; $g = 10 \text{ m/s}^2$

$V_0^2 - 2a_1(s) = 0$

$s = \frac{V_0^2}{a_1}$ ....(i)

B to A

$a_2 = \frac{g}{2} - \frac{\mu\sqrt{3}}{2}g$

$\left(\frac{V_0}{2}\right)^2 = 2a_2\ (s)$

$s = \frac{V_0^2}{4a_2}$ ....(ii)

From equation (i) and (ii)

$\frac{V_0^2}{a_1} = \frac{V_0^2}{4a_2}$

$\Rightarrow a_1 = 4a_2$

$\Rightarrow 5 + 5\sqrt{3}\mu = 4\{5 - 5\sqrt{3}\mu\}$

$\Rightarrow 5 + 5\sqrt{3}\mu = 20 - 20\sqrt{3}\mu \Rightarrow 25\sqrt{3}\mu = 15 \Rightarrow \mu = \frac{\sqrt{3}}{5} = 0.346 = \frac{346}{1000}$

So, $\frac{I}{1000} = \frac{346}{1000}$

24. When an object is kept at a distance of 30 cm from a concave mirror, the image is formed at a distance of 10cm from the mirror. If the object is moved with a speed of 9 cms^{-1}, the speed (in cms^{-1}) with which image moves at that instant is

Ans. 1

Sol. Velocity of image

$v_i = -\frac{v^2}{u^2} \times v_0$

$= -\frac{10^2}{30^2}(9)$

$= -1$ cm/sec

25. If minimum possible work is done by a refrigerator in converting 100 grams of water at 0°C to ice, how much heat (in calories) is released to the surroundings at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer?

Ans. **8791**

Sol. $Q_2 = mL = 8000$

$$\frac{w}{Q_2} = \frac{Q_1 - Q_2}{Q_2} = \frac{T_1 - T_2}{T_2}$$

$$\frac{Q_1 - 8000}{8000} = \frac{27}{273}$$

$Q_1 = 8791$