

FINAL JEE–MAIN EXAMINATION – SEPTEMBER, 2020
(Held On Thursday 03rd SEPTEMBER, 2020) TIME : 3 PM to 6 PM

PHYSICS

TEST PAPER WITH ANSWER & SOLUTION

1. 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) Zero
(2) \vec{B}
(3) much large than $|\vec{B}|$ but opposite to \vec{B}
(4) much large than $|\vec{B}|$ and parallel to \vec{B}

Official Ans. by NTA (1)

Sol. A perfect diamagnetic substance will completely expel the magnetic field. Therefore, there will be no magnetic field inside the cavity of sphere. Hence the paramagnetic substance kept inside the cavity will experience no force.

2. The radius of R of a nucleus of mass number A can be estimated by the formula $R = (1.3 \times 10^{-15})A^{1/3}$ m. It follows that the mass density of a nucleus is of the order of:

$$(M_{\text{prot.}} \cong M_{\text{neut.}} \approx 1.67 \times 10^{-27} \text{ kg})$$

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

Official Ans. by NTA (3)

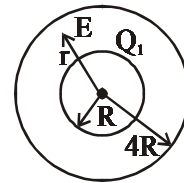
Sol.

$$\rho_{\text{nucleus}} = \frac{\text{mass}}{\text{volume}} = \frac{A}{(4/3)\pi r_0^3 A} = \frac{3}{4\pi r_0^3} = 2.3 \times 10^{17} \text{ kg / m}^3$$

3. 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 $V(R) - V(4R)$ is:

- (1) $\frac{3Q_1}{16\pi\epsilon_0 R}$ (2) $\frac{Q_2}{4\pi\epsilon_0 R}$
(3) $\frac{3Q_1}{4\pi\epsilon_0 R}$ (4) $\frac{3Q_2}{4\pi\epsilon_0 R}$

Official Ans. by NTA (1)



Sol.

$$E = \frac{KQ_1}{r^2}$$

$$\Delta V = \int_R^{4R} E \, dr = \frac{3KQ_1}{4R}$$

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

Official Ans. by NTA (4)

Sol. $q\Delta V = \frac{1}{2} mV^2 \Rightarrow v = \sqrt{\frac{2q\Delta V}{m}}$

$$\therefore \frac{V_1}{V_2} = \sqrt{\frac{e}{m} \frac{4m}{e}} = 2$$

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

(3) $r = \sqrt{\frac{3}{4}}R$ (4) $r = R$

Official Ans. by NTA (2)

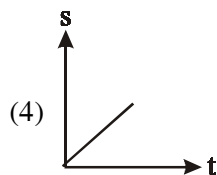
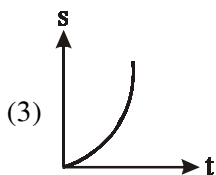
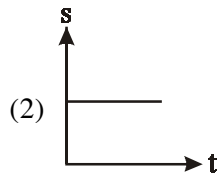
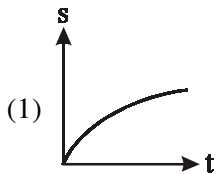
Sol. $E \cdot 4\pi r^2 = \int \rho_0 4\pi r^2 dr$

$$\Rightarrow E r^2 = 4\pi G \int_0^r \rho_0 \left(1 - \frac{r^2}{R^2}\right) r^2 dr$$

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

$$\frac{dE}{dr} = 0 \quad \therefore r = \sqrt{\frac{5}{9}} R$$

6. 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) :



Official Ans. by NTA (3)

Sol. $\frac{dK}{dE} = P = \text{const} \Rightarrow K = Pt = \frac{1}{2} mV^2$

$$\therefore V = \sqrt{\frac{2Pt}{m}} = \frac{ds}{dt} \therefore S = \sqrt{\frac{2P}{m}} \frac{2}{3} t^{\frac{3}{2}}$$

7. If a semiconductor photodiode can detect a photon with a maximum wavelength of 400 nm, then its band gap energy is:

Planck's constant $h = 6.63 \times 10^{-34}$ J.s.

Speed of light $c = 3 \times 10^8$ m/s

(1) 2.0 eV

(2) 1.5 eV

(3) 3.1 eV

(4) 1.1 eV

Official Ans. by NTA (3)

Sol. $\Delta E = \frac{\lambda c}{\lambda e} = 3.1 \text{ eV}$

8. 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) 5

(2) 3

(3) 6

(4) 7

Official Ans. by NTA (3)

Sol. $nC_p(50) = 160$

$$nC_v(100) = 240$$

$$\Rightarrow \frac{C_p}{2C_v} = \frac{160}{240} = \frac{\gamma}{2}$$

$$\therefore \gamma = \frac{4}{3} \text{ and } f = \frac{2}{\gamma - 1} = 6$$

9. A block of mass m attached to 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) $\sqrt{2}$ (3) 1 (4) $\frac{1}{\sqrt{2}}$

Official Ans. by NTA (4)

Sol. At equilibrium position

$$V_0 = \omega_0 A = \sqrt{\frac{K}{m}} A \quad \dots(i)$$

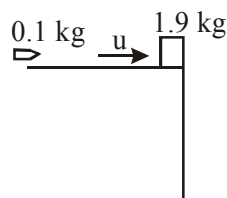
$$V = \omega A^1 = \sqrt{\frac{K}{\frac{m}{2}}} A^1 \quad \dots(ii)$$

$$\therefore A^1 = \frac{A}{\sqrt{2}}$$

10. 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 $g = 10 \text{ m/s}^2$. Assume there is no rotational motion and loss of energy after the collision is negligible.]

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

Official Ans. by NTA (1)



Sol.

$$p_i = p_f \Rightarrow 0.1 \times 20 = 2v$$

$$\therefore v = 1 \text{ m/s}$$

$$KE_f = mgh + \frac{1}{2}mv^2 = 213$$

11. 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) $\frac{2\pi}{\lambda}(n_1 L_1 - n_2 L_2)$ (2) $\frac{2\pi}{\lambda}\left(\frac{L_2}{n_1} - \frac{L_1}{n_2}\right)$

(3) $\frac{2\pi}{\lambda}\left(\frac{L_1}{n_1} - \frac{L_2}{n_2}\right)$ (4) $\frac{2\pi}{\lambda}(n_2 L_1 - n_1 L_2)$

Official Ans. by NTA (1)

Sol. $\Delta p = n_1 L_1 - n_2 L_2$

$$\Delta\phi = \frac{2\pi}{\lambda} \Delta p$$

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 :

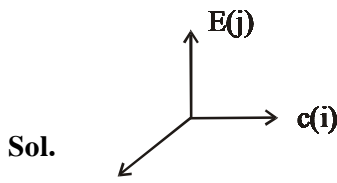
(1) $\vec{B} = E_0 \sqrt{\mu_0 \epsilon_0} \cos(kx) \hat{j}$

(2) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \epsilon_0}} \cos(kx) \hat{k}$

(3) $\vec{B} = E_0 \sqrt{\mu_0 \epsilon_0} \cos(kx) \hat{k}$

(4) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \epsilon_0}} \cos(kx) \hat{j}$

Official Ans. by NTA (3)



$$\therefore \vec{B}(\hat{k})$$

$$\Rightarrow \vec{B} = B_0 \cos(\omega t - kx) \hat{k}$$

Now put $t = 0$.

13. 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 next 5 minutes will be close to :

- (1) 33°C
 (2) 35°C
 (3) 31°C
 (4) 28°C

Official Ans. by NTA (1)

Sol.
$$\frac{50 - 40}{300} = \beta \left(\frac{50 + 40}{2} - 20 \right)$$

$$\frac{40 - T}{300} = \beta \left(\frac{40 + T}{2} - 20 \right)$$

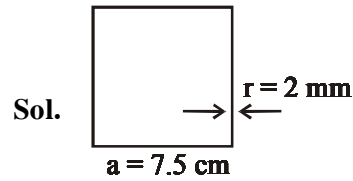
$$\therefore T = \frac{100}{3}$$

14. 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 $\frac{dB}{dt} = 0.032 \text{ Ts}^{-1}$. The induced current in the loop is close to

(Resistivity of the metal wire is $1.23 \times 10^{-8} \Omega\text{m}$)

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

Official Ans. by NTA (1)



$$q_i = \frac{d(Ba^2)}{dt} = a^2 \frac{dB}{dt}$$

$$i = \frac{q}{R} = \frac{a^2 \frac{dB}{dt}}{\frac{\rho(40)}{\pi r^2}}$$

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

Official Ans. by NTA (4)

Sol.
$$S = \frac{P}{A} = \frac{\text{ML}^2\text{T}^{-3}}{\text{L}^2} = \text{MT}^{-3}$$

16. 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 NO deflection in both cases i.e. before and after reversing the probes if the chosen component is capacitor.
 (2) 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.
 (3) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes if the chosen component is metal wire.
 (4) Multimeter shows an equal deflection in both cases i.e. before and after reversing the probes if the chosen component is resistor.

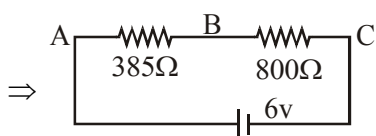
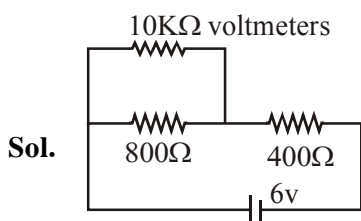
Official Ans. by NTA (1)

- Sol.** (1) Multimeter shows deflection when it connects with capacitor
 (2) If we assume that LED has negligible resistance then multimeter shows no deflection for the forward bias but when it connects in reverse direction, it break down occurs so splash of light out.
 (3) The resistance of metal wire may be taken zero, so no deflection in multimeter
 (4) No matter, how we connect the resistance across multimeter It shows same deflection.

17. Two resistors 400Ω and 800Ω are connected in series across a 6 V battery. The potential difference measured by a voltmeter of $10\text{ k}\Omega$ across 400Ω resistor is close to:

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

Official Ans. by NTA (2)



So the potential difference in voltmeter across

the points A and B is $\frac{6}{1185} \times 385 = 1.949\text{ V}$

18. 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 X-rays to the number density of photons of the visible light of the given wavelengths is :

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

Official Ans. by NTA (1)

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

$$\therefore \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{5}$$

19. 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 = $1\text{ cal g}^{-1} \text{ }^\circ\text{C}^{-1}$)

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

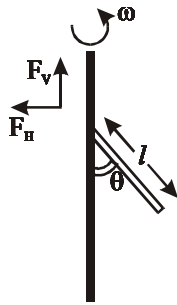
Official Ans. by NTA (2)

Sol.

Cal	H_2O	Stem
20gm	180gm	m
25°C	25°C	100°C

$$200 \times 1 \times (31 - 25) = m \times 540 + m \times 1 \times (100 - 31)$$

20.



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)

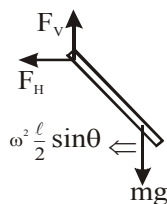
$\frac{m\ell^2}{12}\omega^2 \sin\theta \cos\theta$ about the centre of mass

(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:

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

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

Official Ans. by NTA (2)



Sol.

$$F_V = mg$$

$$F_H = m\omega^2 \frac{\ell}{2} \sin\theta$$

$$mg \frac{\ell}{2} \sin\theta - m\omega^2 \frac{\ell}{2} \sin\theta \frac{\ell}{2} \cos\theta = \frac{m\ell^2}{12} \omega^2 \sin\theta \cos\theta$$

$$\cos\theta = \frac{3}{2} \frac{g}{\omega^2 \ell} \quad \dots(ii)$$

21. When an object is kept at a distance of 30 cm from a concave mirror, the image is formed at a distance of 10 cm 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 _____.

Official Ans. by NTA (1)

$$\text{Sol.} \quad \left| \left(\frac{dv}{dt} \right) \right| = \left| \frac{v^2}{u^2} \right| \left| \frac{du}{dt} \right|$$

$$= \left(\frac{10}{30} \right)^2 \times 9 = 1 \text{ m/s}$$

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

Official Ans. by NTA (20)

$$\text{Sol.} \quad \vec{\tau} = \vec{m} \times \vec{B}$$

$$\tau = NI \times A \times B$$

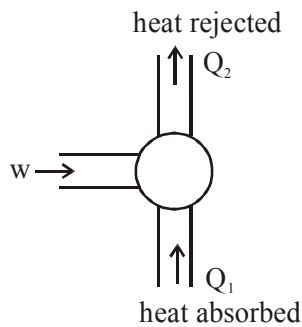
$$1.05 = 500 \times 3 \times 10^{-4} \times \frac{1}{2} \times B$$

$$B = 20$$

23. 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 surrounding at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer?

Official Ans. by NTA (8791)

Sol.



$$w + Q_1 = Q_2$$

$$w = Q_2 - Q_1$$

$$\text{C.O.P.} = \frac{Q_1}{w} = \frac{Q_1}{Q_2 - Q_1} = \frac{273}{300 - 273} = \frac{Q_1}{W}$$

$$w = \frac{27}{273} \times 80 \times 100 \times 4.2$$

$$Q_2 = w + Q_1$$

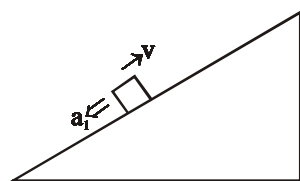
$$Q_2 = \frac{27}{273} \times 80 \times 100 \times 4.2 + 80 \times 100 \times 4.2$$

$$Q_2 = \frac{300}{273} \times 80 \times 100 = 8791.2 \text{ cal}$$

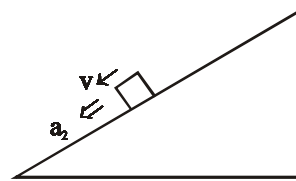
- 24.** A block starts moving up an inclined plane of inclination 30° with an initial velocity of v_0 . It comes back to its initial position with velocity $\frac{v_0}{2}$. The value of the coefficient of kinetic friction between the block and the inclined plane is close to $\frac{I}{1000}$, The nearest integer to I is _____.

Official Ans. by NTA (346)

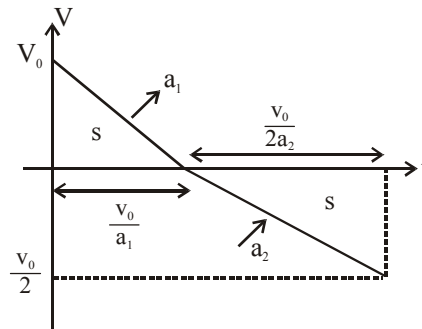
Sol.



$$a_1 = g(\sin\theta + \mu \cos\theta)$$



$$a_2 = g(\sin\theta + \mu \cos\theta)$$

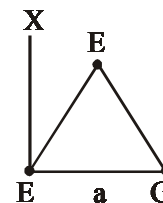


$$\therefore \frac{1}{2}v_0 \frac{v_0}{a_1} = \frac{1}{2} \left(\frac{v_0}{2} \right) \left(\frac{v_0}{2a_1} \right)$$

$$\Rightarrow 3 \sin \theta = 5 \mu \cos \theta$$

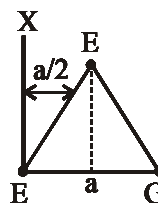
$$\therefore \mu = \sqrt{3}/5$$

- 25.** 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 _____.



Official Ans. by NTA (25)

25.



$$I = 0 + m \left(\frac{a}{2} \right)^2 + ma^2$$

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