FINAL JEE–MAIN EXAMINATION – FEBRUARY, 2021

(Held On Thursday 25th February, 2021) TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS

TEST PAPER WITH ANSWER & SOLUTIONS

SECTION-A

1. For extrinsic semiconductors; when doping level is increased;

(1) Fermi-level of p-type semiconductor will go upward and Fermi-level of n-type semiconductors will go downward.

(2) Fermi-level of p-type semiconductors will go downward and Fermi-level of n-type semiconductor will go upward.

(3) Fermi-level of both p-type and n-type semiconductros will go upward for $T > T_F$ K and downward for $T < T_F$ K, where T_F is Fermi temperature.

(4) Fermi-level of p and n-type semiconductors will not be affected.

Official Ans. by NTA (2)

Sol. (2) conceptual

2. In a ferromagnetic material, below the curie temperature, a domain is defined as :

(1) a macroscopic region with zero magnetization.

(2) a macroscopic region with consecutive magnetic dipoles oriented in opposite direction.

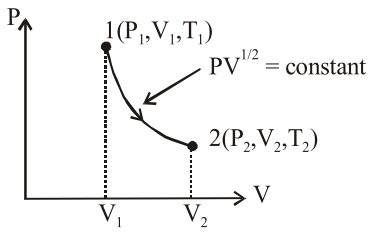
(3) a macroscopic region with randomly oriented magnetic dipoles.

(4) a macroscopic region with saturation magnetization.

Official Ans. by NTA (4)

Sol. (4) conceptual

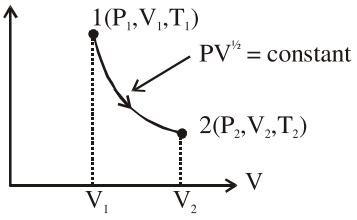
3. Thermodynamic process is shown below on a P-V diagram for one mole of an ideal gas. If $V_2 = 2V_1$ then the ratio of temperature T_2/T_1 is :



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

Official Ans. by NTA (3)

Sol.



$PV^{1/2} = c$

$\frac{nRT}{V} V^{1/2} = c$

$T = c^1 V^{1/2}$

$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1/2} = \left(\frac{2V_1}{V_1}\right)^{1/2}$

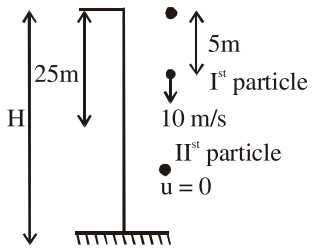
$\frac{T_2}{T_1} = \sqrt{2}$

4. A stone is dropped from the top of a building. When it crosses a point 5 m below the top, another stone starts to fall from a point 25 m below the top. Both stones reach the bottom of building simultaneously. The height of the building is :

(1) 35 m (2) 45m (3) 50 m (4) 25m

Official Ans. by NTA (2)

Sol.



Time for particle to meet = $t' = \frac{S_{rel}}{S_{rel}} = \frac{20}{10} = 2\text{sec}$

Time taken by Ist particle to reach ground = 3sec

$H = \frac{1}{2} g (3)^2 = 45$ m

5. Given below are two statements :

Statement I : In a diatomic molecule, the rotational energy at a given temperature obeys Maxwell's distribution.

Statement II : In a diatomic molecule, the rotational energy at a given temperature equals the translational kinetic energy for each molecule.

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

(1) Statement I is false but Statement II is true.

(2) Both Statement I and Statement II are false.

(3) Both Statement I and Statement II are true.

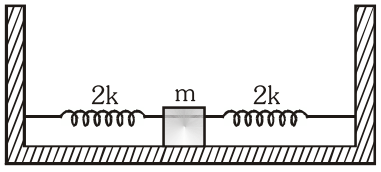
(4) Statement I is true but Statement II is false.

Official Ans. by NTA (4)

Sol. (4) Translational degree of freedom = 3

Rotational degree of freedom = 2

6. Two identical springs of spring constant '2k' are attached to a block of mass m and to fixed support (see figure).When the mass is displaced from equilibrium position on either side, it executes simple harmonic motion. The time period of oscillations of this sytem is :



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

Official Ans. by NTA (4)

Sol. (4) For parallel combination $k_{eq} = k_1 + k_2$

$k_{eq} = 4k$

$T = 2\pi\sqrt{\frac{m}{k_{eq}}}$

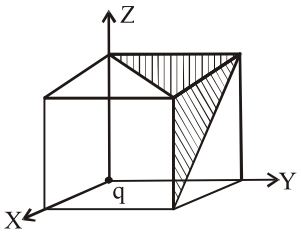
7. If a message signal of frequency 'f_m' is amplitude modulated with a carrier signal of frequency 'f_c' and radiated through an antenna, the wavelength of the corresponding signal in air is :

(1) $\frac{c}{f_c - f_m}$ (2) $\frac{c}{f_m}$ (3) $\frac{c}{f_c + f_m}$ (4) $\frac{c}{f_c}$

Official Ans. by NTA (4)

Sol. (4) $\lambda = \frac{v}{f} = \frac{c}{f_c}$

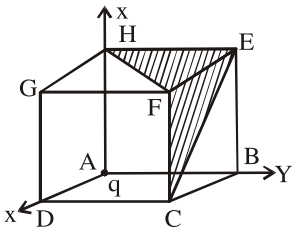
8. A charge 'q' is placed at one corner of a cube as shown in figure.The flux of electrostatic field $\vec{E}$ through the shaded area is :



(1) $\frac{q}{4\varepsilon_0}$ (2) $\frac{q}{24\varepsilon_0}$ (3) $\frac{q}{48\varepsilon_0}$ (4) $\frac{q}{8\varepsilon_0}$

Official Ans. by NTA (2)

Sol.



flux through cube = $\frac{q}{8 \in_0}$

flux through surfaces ABEH, ADGH, ABCD will be zero

$\phi\ (EFGH) = \phi\ (DCFG) = \phi\ (EBCF) = \frac{1}{3}\left(\frac{q}{8 \in_0}\right)$

$= \frac{q}{24 \in_0}$

9. The wavelength of the photon emitted by a hydrogen atom when an electron makes a transition from n = 2 to n = 1 state is :

(1) 194.8 nm (2) 913.3 nm

(3) 490.7 nm (4) 121.8 nm

Official Ans. by NTA (4)

Sol. $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

λ = 121.8 nm.

10. An LCR circuit contains resistance of 110 Ω and a supply of 220 V at 300 rad/s angular frequency. If only capacitance is removed from the circuit, current lags behind the voltage by 45°. If on the other hand, only inductor is removed the current leads by 45° with the applied voltage. The rms current flowing in the circuit will be :

(1) 1A (2) 2.5 A

(3) 1.5 A (4) 2A

Official Ans. by NTA (4)

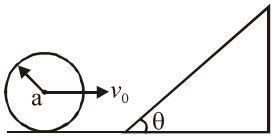
Sol. $\tan 45^\circ = \frac{1}{\omega CR} = \frac{\omega L}{R} \Rightarrow X_L = X_C$

$\Rightarrow$ resonance

$i = \frac{V}{R}$

$= \frac{220}{110} = 2A$

11. A sphere of radius 'a' and mass 'm' rolls along a horizontal plane with constant speed v_0. It encounters an inclined plane at angle θ and climbs upward. Assuming that it rolls without slipping, how far up the sphere will travel ?



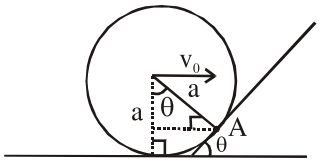
(1) $\frac{10v_0^2}{7g\sin\theta}$ (2) $\frac{v_0^2}{5g\sin\theta}$

(3) $\frac{2}{5}\frac{v_0^2}{g\sin\theta}$ (4) $\frac{v_0^2}{2g\sin\theta}$

Official Ans. by NTA (1)

Official Ans. by ALLEN (BONUS)

Sol.



Angular momentum conservation about A

$mv_0\, a\cos\theta + \frac{2}{5}ma^2\omega$

$= mva + \frac{2}{5}ma^2\omega^1$

$^{mv}{}_0 a\left[\frac{2}{5} + \cos\theta\right] = \frac{7}{5}mva$

$v = \frac{5}{7} = v_0\left[\frac{2}{5} + \cos\theta\right]$

$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{7}{10}mv^2 = mgh$

No option Maching

12. An electron of mass m_e and a proton of mass m_p = 1836 m_e are moving with the same speed.

The ratio of their de Broglie wavelength $\frac{\lambda_{electron}}{\lambda_{proton}}$

will be :

(1) 1836 (2) 1

(3) 918 (4) $\frac{1}{1836}$

Official Ans. by NTA (1)

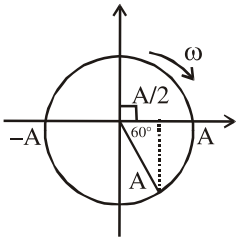
Sol. $\frac{\lambda_e}{\lambda_p} = \frac{\frac{h}{m_e v}}{\frac{h}{m_p v}} = 1836$

13. $Y = A\sin(\omega t + \phi_0)$ is the time-displacement equation of a SHM. At t = 0 the displacement of the particle is $Y = \frac{A}{2}$ and it is moving along negative *x*-direction. Then the initial phase angle ϕ_0 will be :

(1) $\frac{\pi}{6}$ (2) $\frac{\pi}{3}$ (3) $\frac{5\pi}{6}$ (4) $\frac{2\pi}{3}$

Official Ans. by NTA (3)

Sol.



initial phase $\frac{\pi}{2}+\frac{\pi}{3}=\frac{5\pi}{6}$

14. If e is the electronic charge, c is the speed of light in free space and h is Planck's constant, the quantity $\frac{1}{4\pi\varepsilon_0}\frac{|e|^2}{hc}$ has dimensions of :

(1) $[M^0 L^0 T^0]$ (2) $[L\ C^{-1}]$
(3) $[M\ L\ T^{-1}]$ (4) $[M\ L\ T^0]$

Official Ans. by NTA (1)

Sol. $F = \frac{1}{4\pi\ \epsilon_0}\frac{e^2}{r^2}$

$E = \frac{hc}{\lambda}$

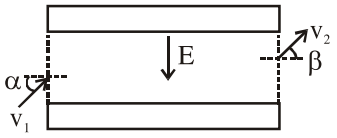
$\left[\frac{e^2}{4\pi\varepsilon_0}\times\frac{1}{hc}\right]=\frac{Fr^2}{E\lambda}=\left(M^0L^0T^0\right)$

15. An electron with kinetic energy K_1 enters between parallel plates of a capacitor at an angle 'α' with the plates. It leaves the plates at angle 'β' with kinetic energy K_2. Then the ratio of kinetic energies $K_1 : K_2$ will be :

(1) $\frac{\sin^2\beta}{\cos^2\alpha}$ (2) $\frac{\cos^2\beta}{\cos^2\alpha}$ (3) $\frac{\cos\beta}{\cos\alpha}$ (4) $\frac{\cos\beta}{\sin\alpha}$

Official Ans. by NTA (2)

Sol.

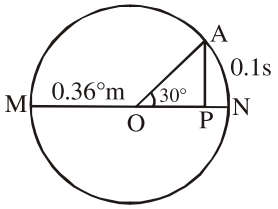


velocity along the plate will not change.

$\therefore v_1\cos\alpha = v_2\cos\beta$

$\frac{K_1}{K_2}\Rightarrow\frac{v_1^2}{v_2^2}=\frac{\cos^2\beta}{\cos^2\alpha}$

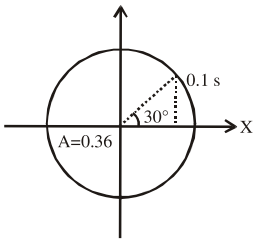
16. The point A moves with a uniform speed along the circumference of a circle of radius 0.36 m and covers 30° in 0.1 s. The perpendicular projection 'P' from 'A' on the diameter MN represents the simple harmonic motion of 'P'. The restoration force per unit mass when P touches M will be :



(1) 100 N (2) 0.49 N
(3) 50 N (4) 9.87 N

Official Ans. by NTA (4)

Sol.



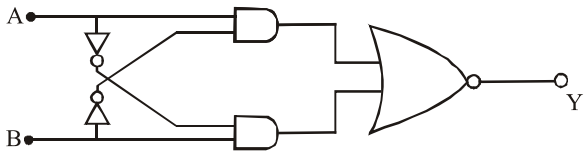
$30°\rightarrow 0.1$ s

$360°\rightarrow 1.2$ s = T

$\omega = \frac{2\pi}{T} = \frac{5\pi}{3}$

At M, $F = m\omega^2A \Rightarrow \frac{F}{m} = \omega^2A$

17. The truth table for the followng logic circuit is :



(1)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(2)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(3)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

(4)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

Official Ans. by NTA (2)

Sol. $y = \overline{(A\bar{B} + \bar{A}B)}$

$y = \overline{A\bar{B}} \cdot \overline{\bar{A}B}$

$y = (\bar{A} + B).(A + \bar{B})$

$y = \bar{A}.A + \bar{A}\bar{B} + A.B + B\bar{B}$

$y = AB + \bar{A}\bar{B}$

A	B	$Y = AB + \bar{A}\bar{B}$
0	0	1
0	1	0
1	0	0
1	1	1

18. The stopping potential for electrons emitted from a photosensitive surface illuminated by light of wavelength 491 nm is 0.710 V. When the incident wavelength is changed to a new value, the stopping potential is 1.43 V. The new wavelength is :

(1) 329 nm (2) 309 nm

(3) 382 nm (4) 400 nm

Official Ans. by NTA (3)

Sol. $\frac{hc}{\lambda} = \phi + eV_s$

$\frac{1240}{491} = \phi + 0.71.$ .....(1)

$\frac{1240}{\lambda} = \phi + 1.43$ .....(2)

$\therefore \lambda = 382$ nm Ans.

19. Match List I with List II.

List I	List II
(a) Rectifier	(i) Used either for stepping up or stepping down the a.c. voltage
(b) Stabilizer	(ii) Used to convert a.c. voltage into d.c. voltage
(c) Transformer	(iii) Used to remove any ripple in the rectified output voltage
(d) Filter	(iv) Used for constant output voltage even when the input voltage or load current change

Choose the correct answer from the options given below :

(1) (a)–(ii), (b)–(iv), (c)–(i), (d)–(iii)

(2) (a)–(iii), (b)–(iv), (c)–(i), (d)–(ii)

(3) (a)–(ii), (b)–(i), (c)–(iv), (d)–(iii)

(4) (a)–(ii), (b)–(i), (c)–(iii), (d)–(iv)

Official Ans. by NTA (1)

Sol. (a) Rectifier → AC to DC

(b) Stabilizer → used for constant output voltage even when input voltage or current change.

(c) Transformer → Step - up or step - down ac voltage.

(d) Filter → used to remove any ripple in the rectified output voltage.

20. Consider the diffraction pattern obtained from the sunlight incident on a pinhole of diameter 0.1μm. If the diameter of the pinhole is slightly increased, it will affect the diffraction pattern such thtat :

(1) its size decreases, and intensity decreases

(2) its size increases, and intensity increases

(3) its size increases, but intensity decreases

(4) its size decreases, but intensity increases

Official Ans. by NTA (4)

Sol. $\sin\theta = \frac{m\lambda}{a}$

when a increases, θ decreases,

width decreases

width decreases so intensity will increases

SECTION-B

1. The peak electric field produced by the radiation coming from the 8 W bulb at a distance of 10 m is $\frac{x}{10}\sqrt{\frac{\mu_0 c}{\pi}}\frac{V}{m}$. The efficiency of the bulb is 10% and it is a point source. The value of x is_____.

Official Ans. by NTA (2)

Sol. $I = \frac{1}{2} c \in_0 E_0^2$

$$\frac{8}{4\pi\times10^2}\times\frac{1}{2} = \frac{1}{4}\times c\times\frac{1}{\mu_0 c^2}\times E_0^2$$

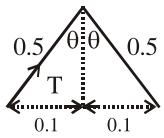
$$E_0 = \frac{2}{10}\times\sqrt{\frac{\mu_0 c}{\pi}} \Rightarrow x = 2$$

2. Two small spheres each of mass 10 mg are suspended from a point by threads 0.5 m long. They are equally charged and repel each other to a distance of 0.20 m. The charge on each of the sphere is $\frac{a}{21}\times10^{-8}$ C. The value of 'a' will be _____.

[Given g = 10 ms^{-2}]

Official Ans. by NTA (20)

Sol.



$T\cos\theta = mg = 10\times10^{-6}\times10 = 10^{-4}$

$$T\sin\theta = \frac{9\times10^9\times q^2}{0.04} = F$$

$$\tan\theta = \frac{0.1}{\sqrt{0.24}} = \frac{F}{mg}$$

$$q = \frac{2\sqrt{10}}{3\sqrt{\sqrt{24}}}\times10^{-8}$$

$$0.95\times10^{-8} = \frac{a}{21}\times10^{-8}$$

a = 20

3. The initial velocity v_i required to project a body vertically upward from the surface of the earth to reach a height of 10R, where R is the radius of the earth, may be described in terms of escape velocity v_e such that $v_i = \sqrt{\frac{x}{y}}\times v_e$. The value of x will be _____.

Official Ans. by NTA (10)

Sol. $$\frac{-GMm}{11R} = \frac{-GMm}{R} + \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{20GM}{11R}}$$

4. The wavelength of an X-ray beam is 10Å. The mass of a fictitious particle having the same energy as that of the X-ray photons is $\frac{x}{3}$ h kg.

The value of x is_____.

(h = Planck's constant)

Official Ans. by NTA (10)

Sol. $\frac{hc}{\lambda} = mc^2$

$m = \frac{h}{c\lambda}$

5. A reversible heat engine converts one-fourth of the heat input into work. When the temperature of the sink is reduced by 52 K, its efficiency is doubled. The temperature in Kelvin of the source will be _____.

Official Ans. by NTA (208)

Sol. $\eta = \frac{1}{4} = 1 - \frac{T_2}{T_1}$

$\frac{T_2}{T_1} = \frac{3}{4}$

$\frac{T_2 - 52}{T_1} = \frac{1}{2}$

6. The percentage increase in the speed of transverse waves produced in a stretched string if the tension is increased by 4%, will be _____%.

Official Ans. by NTA (2)

Sol. $v = \sqrt{\frac{T}{\mu}}$

$\frac{\Delta V}{V} = \frac{1}{2}\frac{\Delta T}{T}$

7. If $\vec{P} \times \vec{Q} = \vec{Q} \times \vec{P}$, the angle between $\vec{P}$ and $\vec{Q}$ is θ ($0° < \theta < 360°$). The value of 'θ' will be _____°.

Official Ans. by NTA (180)

Sol. $-PQ \sin\theta$

$= PQ \sin\theta$

$\Rightarrow \theta = 180°$

8. Two identical conducting spheres with negligible volume have 2.1 nC and –0.1 nC charges, respectively. They are brought into contact and then separated by a distance of 0.5 m. The electrostatic force acting between the spheres is_____$\times 10^{-9}$ N.

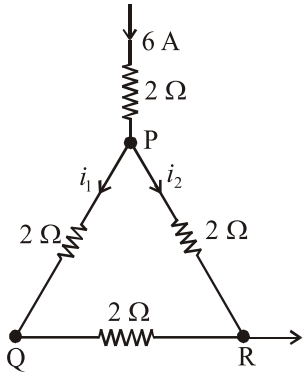
[Given : $4\pi\varepsilon_0 = \frac{1}{9\times10^9}$ SI unit]

Official Ans. by NTA (36)

Sol. $q = \frac{(2.1-0.1)}{2}$ nC = 1nC

$f = \frac{9\times10^9\times10^{-18}}{(0.5)^2} = 36 \times 10^{-9}$

9. A current of 6 A enters one corner P of an equilateral triangle PQR having 3 wires of resistance 2Ω each and leaves by the corner R. The currents i_1 in ampere is _____.



Official Ans. by NTA (2)

Sol. For parallel combination current devides in the inverse ratio of resistance.

$i_{PQ} = \frac{2}{6} \times 6$ A

10. Two particles having masses 4 g and 16 g respectively are moving with equal kinetic energies. The ratio of the magnitudes of their linear momentum is n : 2. The value of n will be _____.

Official Ans. by NTA (1)

Sol. $\frac{p_1^2}{2\times4} = \frac{p_2^2}{2\times16}$

$\frac{p_1}{p_2} = \frac{1}{2}$