FINAL JEE–MAIN EXAMINATION – JANUARY, 2023

(Held On Wednesday 1st February, 2023) TIME : 9 : 00 AM to 12 : 00 NOON

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

Q.1 Match the List I with List II

	List I		List II
A.	Intrinsic Semiconductor	I.	Fermi-level near conduction band
B.	n-type semiconductor	II.	Fermi-level at middle
C.	p-type semiconductor	III.	Fermi-level near valence band
D.	Metals	IV.	Fermi-level inside conduction band

Choose the **correct** answer from the options given below:

(1) (A) → I, (B) → II, (C) → III, (D) → IV

(2) (A) → II, (B) → I, (C) → III, (D) →IV

(3) (A) → II, (B) → III, (C) → I, (D) → IV

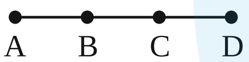
(4) (A) → III, (B) → I, (C) → II, (D) → IV

Official Ans. by NTA (3)

Ans. (3)

Sol. Based on theory.

2. An object moves with speed v_1, v_2, and v_3 along a line segment AB, BC and CD respectively as shown in figure. Where AB = BC and AD = 3 AB, then average speed of the object will be :



(1) $\frac{(v_1+v_2+v_3)}{3}$

(2) $\frac{v_1v_2v_3}{3(v_1v_2+v_2v_3+v_3v_1)}$

(3) $\frac{3v_1v_2v_3}{v_1v_2+v_2v_3+v_3v_1}$

(4) $\frac{(v_1+v_2+v_3)}{3v_1v_2v_3}$

Official Ans. by NTA (3)

Ans. (3)

Sol. AB = x

BC = x

$2x$ + CD = $3x$

CD = x

$$< v >= \frac{3x}{\frac{x}{v_1}+\frac{x}{v_2}+\frac{x}{v_3}} = \frac{3v_1v_2v_3}{v_2v_3+v_1v_3+v_1v_2}$$

3. Given below are two statements :

Statement-I: Acceleration due to gravity is different at different places on the surface of earth.

Statement-II: Acceleration due to gravity increases as we go down below the earth's surface.

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

(1) Both Statement I and Statement II are true

(2) Both Statement I and Statement II are false

(3) Statement I is true but Statement II is false

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

Official Ans. by NTA (3)

Ans. (3)

Sol. $g_{eff} = g - \omega^2 R_e \sin^2\theta$, θ → co-latitude angle

$$g_{eff} = g\left(1-\frac{d}{R_e}\right)$$, d here depth

4. Match the List-I with List-II.

	List I		List II
A.	AC generator	I.	Presence of both L and C
B.	Transformer	II.	Electromagnetic Induction
C.	Resonance phenomenon to occur	III.	Quality factor
D.	Sharpness of resonance	IV.	Mutual Inductance

Choose the **correct** answer from the options given below:

(1) A-IV, B-II, C-I, D-III

(2) A-II, B-I, C-III, D-IV

(3) A-II, B-IV, C-I, D-III

(4) A-IV, B-III, C-I, D-II

Official Ans. by NTA (3)

Ans. (3)

Sol. Based on theory.

5. Match the List-I with List-II:

	List I		List II
A.	Microwaves	I.	Radio active decay of the nucleus
B.	Gamma rays	II.	Rapid acceleration and deceleration of electron in aerials
C.	Radio waves	III.	Inner shell electrons
D.	X-rays	IV.	Klystron valve

Choose the **correct** answer from the options given below:

(1) A-I, B-II, C-III, D-IV
(2) A-IV, B-I, C-II, D-III
(3) A-I, B-III, C-IV, D-II
(4) A-IV, B-III, C-II, D-I

Official Ans. by NTA (2)

Ans. (2)

Sol. Based on theory.

6. If earth has a mass nine times and radius twice to the of a planet P. Then $\frac{v_e}{3}\sqrt{x}\ ms^{-1}$ will be the minimum velocity required by a rocket to pull out of gravitational force of P, where v_e is escape velocity on earth. The value of x is

(1) 2 (2) 3
(3) 18 (4) 1

Official Ans. by NTA (1)

Ans. (1)

Sol. $v_{(\text{escape})\text{plant}} = \sqrt{\frac{2GM_P}{R_P}}$

$$= \sqrt{\frac{2G\left(\frac{M_e}{9}\right)}{\left(\frac{R_e}{2}\right)}} = \frac{v_e\sqrt{2}}{3}\ \therefore x = 2$$

7. 'n' polarizing sheets are arranged such that each makes an angle 45° with the proceeding sheet. An unpolarized light of intensity I is incident into this arrangement. The output intensity is found to be $\frac{I}{64}$. The value of n will be:

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

Official Ans. by NTA (2)

Ans. (2)

Sol. After passing through first sheet

$$I_1 = \frac{I}{2}$$

After passing through second sheet

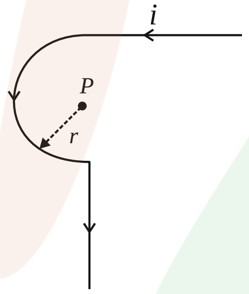
$$I_2 = I_1\cos^2(45^\circ) = \frac{I}{4}$$

After passing through n^{th} sheet

$$I_n = \frac{I}{2^n} = \frac{I}{64}$$

$$n = 6$$

8. Find the magnetic field at the point P in figure. The curved portion is a semicircle connected to two long straight wires.



(1) $\frac{\mu_0 i}{2r}\left(1+\frac{2}{\pi}\right)$ (2) $\frac{\mu_0 i}{2r}\left(1+\frac{1}{\pi}\right)$

(3) $\frac{\mu_0 i}{2r}\left(\frac{1}{2}+\frac{1}{2\pi}\right)$ (4) $\frac{\mu_0 i}{2r}\left(\frac{1}{2}+\frac{1}{\pi}\right)$

Official Ans. by NTA (3)

Ans. (3)

Sol. $B_P = \left(\frac{\mu_0 i}{4r}+\frac{\mu_0 i}{4\pi r}\right) = \frac{\mu_0 i}{2r}\left(\frac{1}{2}+\frac{1}{2\pi}\right)$

9. Which of the following frequencies does not belong to FM broadcast.

(1) 106 MHz (2) 64 MHz
(3) 99 MHz (4) 89 MHz

Official Ans. by NTA (2)

Ans. (2)

Sol. FM broadcast range is 88MHz to 108MHz

10. A steel wire with mass per unit length 7.0×10^{-3} kg m^{-1} is under tension of 70 N. The speed of transverse waves in the wire will be:

(1) 200 π m/s (2) 100 m/s
(3) 10 m/s (4) 50 m/s

Official Ans. by NTA (2)

Ans. (2)

Sol. $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{70}{70\times10^{-3}}} = 100$ m/s

11. A child stands on the edge of the cliff 10 m above the ground and throws a stone horizontally with an initial speed of 5 ms^{-1}. Neglecting the air resistance, the speed with which the stone hits the ground will be ______ ms^{-1} (given, g = 10 ms^{-2}).

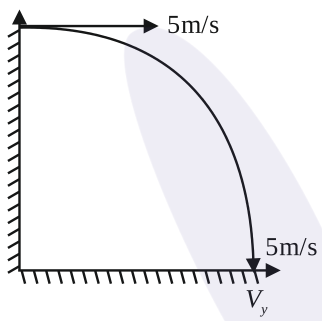
(1) 20 (2) 15

(3) 30 (4) 25

Official Ans. by NTA (2)

Ans. (2)

Sol.



$v_y = \sqrt{2gh} = \sqrt{200}$

$v_{net} = \sqrt{25+200} = 15$ m/s

12. A proton moving with one tenth of velocity of light has a certain de Broglie wavelength of λ. An alpha particle having certain kinetic energy has the same de-Brogle wavelength λ. The ratio of kinetic energy of proton and that of alpha particle is:

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

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

Official Ans. by NTA (2)

Ans. (2)

Sol. $KE = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

$\frac{KE_p}{KE_\alpha} = \frac{m_\alpha}{m_p} = 4:1$

13. A sample of gas at temperature T is adiabatically expanded to double its volume. The work done by the gas in the process is $\left(\text{given}, \gamma = \frac{3}{2}\right)$:

(1) $W = TR\,[\sqrt{2}-2]$ (2) $W = \frac{T}{R}[\sqrt{2}-2]$

(3) $W = \frac{R}{T}[2-\sqrt{2}]$ (4) $W = RT\,[2-\sqrt{2}]$

Official Ans. by NTA (4)

Ans. (4)

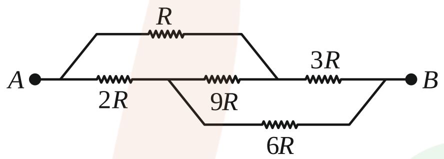
Sol. $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$TV^{1/2} = T_2(2V)^{1/2}$

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

$$W = \frac{R(T_1-T_2)}{\gamma-1} = \frac{R\left(T-\frac{T}{\sqrt{2}}\right)}{\frac{1}{2}} = RT\left(2-\sqrt{2}\right)$$

14. The equivalent resistance between A and B of the network shown in figure:



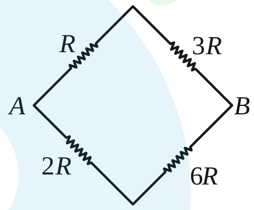
(1) $11\frac{2R}{3}$ (2) $14R$

(3) $21\,R$ (4) $\frac{8}{3}R$

Official Ans. by NTA (4)

Ans. (4)

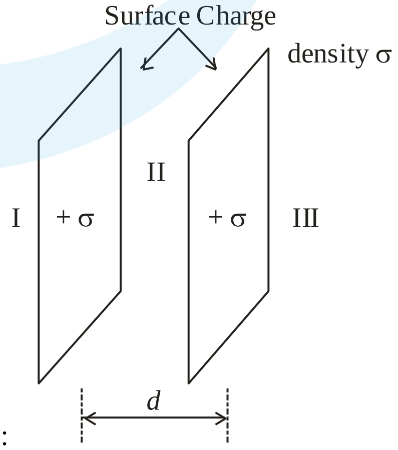
Sol. Wheat stone bridge is in balanced condition.



$\frac{1}{R_{eq}} = \frac{1}{4R} + \frac{1}{8R}$

$R_{eq} = \frac{8R}{3}$

15. Let σ be the uniform surface charge density of two infinite thin plane sheets shown in figure. Then the electric fields in three different region E_I, E_{II} and E_{III} are:



(1) $\vec{E}_{I} = \frac{2\sigma}{\epsilon_0}\hat{n}, \vec{E}_{II} = 0, \vec{E}_{III} = \frac{2\sigma}{\epsilon_0}\hat{n}$

(2) $\vec{E}_{I} = 0, \vec{E}_{II} = \frac{\sigma}{\epsilon_0}\hat{n}, \vec{E}_{III} = 0$

(3) $\vec{E}_{I} = \frac{\sigma}{2\epsilon_0}\hat{n}, \vec{E}_{II} = 0, \vec{E}_{III} = \frac{\sigma}{2\epsilon_0}\hat{n}$

(4) $\vec{E}_{I} = -\frac{\sigma}{\epsilon_0}\hat{n}, \vec{E}_{II} = 0, \vec{E}_{III} = \frac{\sigma}{\epsilon_0}\hat{n}$

Official Ans. by NTA (4)

Ans. (4)

Sol. Assuming RHS to be $\hat{n}$

$\vec{E}_I = \frac{\sigma}{2\epsilon_0}(-\hat{n}) + \frac{\sigma}{2\epsilon_0}(-\hat{n}) = -\frac{\sigma}{\epsilon_0}\hat{n}$

$\vec{E}_{II} = 0,$

$\vec{E}_{III} = \frac{\sigma}{2\epsilon_0}(\hat{n}) + \frac{\sigma}{2\epsilon_0}(\hat{n}) = \frac{\sigma}{\epsilon_0}(\hat{n})$

16. A mercury drop of radius 10^{-3} m is broken into 125 equal size droplets. Surface tension of mercury is 0.45 Nm^{-1}. The gain in surface energy is:

(1) 2.26×10^{-5} J (2) 28×10^{-5} J

(3) 17.5×10^{-5} J (4) 5×10^{-5} J

Official Ans. by NTA (1)

Ans. (1)

Sol. Initial surface energy = $0.45 \times 4\pi (10^{-3})^2$

$\frac{4}{3}\pi(10^{-3})^3 = 125 \times \frac{4\pi}{3}R_{new}^3$

$\therefore$ $10^{-3} = 5 R_{new}$

$\therefore$ $R_{new} = \frac{10^{-3}}{5}$ m

So, final surface energy = $0.45 \times 125 \times 4\pi\left(\frac{10^{-3}}{5}\right)^2$

Increase in energy = $0.45 \times 4\pi \times (10^{-3})^2\left[\frac{125}{25} - 1\right]$

$= 4 \times 0.45 \times 4\pi \times 10^{-6}$

$= 2.26 \times 10^{-5}$ J

17. The mass of proton, neutron and helium nucleus are respectively 1.0073 u, 1.0087 u and 4.0015u. The binding energy of helium nucleus is:

(1) 14.2 MeV (2) 28.4 MeV

(3) 56.8 MeV (4) 7.1 MeV

Official Ans. by NTA (2)

Ans. (2)

Sol. $B.E$ of Helium = $(2m_P + 2m_N - m_{He})\, c^2$

= 28.4 MeV

18. $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ represents the equation of state of some gases. Where P is the pressure, V is the volume, T is the temperature and a, b, R are the constants. The physical quantity, which has dimensional formula as that of $\frac{b^2}{a}$, will be :

(1) Bulk modulus (2) Modulus of rigidity

(3) Compressibility (4) Energy density

Official Ans. by NTA (3)

Ans. (3)

Sol. $[b] = [V]$

$\left[\frac{a}{b^2}\right] = [P]$ $\therefore$ $\left[\frac{b^2}{a}\right] = \frac{1}{[P]} = \frac{1}{[B]} = [K]$

19. The average kinetic energy of a molecule of the gas is

(1) proportional to absolute temperature

(2) proportional to volume

(3) proportional to pressure

(4) dependent on the nature of the gas

Official Ans. by NTA (1)

Ans. (1)

Sol. Basic theory

Translational $K.E$ on average of a molecule is $\frac{3}{2}$ KT which is independent of nature, pressure and volume.

20. A block of mass 5 kg is placed at rest on a table of rough surface. Now, if a force of 30N is applied in the direction parallel to surface of the table, the block slides through a distance of 50 m in an interval of time 10s. Coefficient of kinetic friction is (given, g = 10 ms^{-2}):

(1) 0.60 (2) 0.75

(3) 0.50 (4) 0.25

Official Ans. by NTA (3)

Ans. (3)

Sol. $S = ut + \frac{1}{2}at^2$

$50 = 0 + \frac{1}{2} \times a \times 100$

$a = 1$ m/s^2

$F - \mu mg = ma$

$30 - \mu \times 50 = 5 \times 1$

$50\mu = 25$

$\mu = \frac{1}{2}$

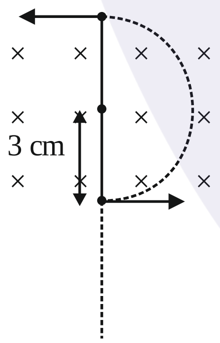
SECTION-B

21. A charge particle of 2 μC accelerated by a potential difference of 100V enters a region of uniform magnetic field of magnitude 4 mT at right angle to the direction of field. The charge particle completes semicircle of radius 3 cm inside magnetic field. The mass of the charge particle is_____ $\times 10^{-18}$ kg.

Official Ans. by NTA (144)

Ans. (144)

Sol. $r = \frac{mv}{qB} = \frac{\sqrt{2km}}{qB}, m = \frac{r^2 q^2 B^2}{2k}$



$$m = \frac{\frac{1}{100} \times \frac{3}{100} \times 2 \times 2 \times 4 \times 10^{-3} \times 4 \times 10^{-3} \times 10^{-12}}{2 \times (100) \times 10^{-6}}$$

$= 144 \times 10^{-18}$ kg

22. In an experiment to find emf of a cell using potentiometer, the length of null point for a cell of emf 1.5 V is found to be 60 cm. If this cell is replaced by another cell of emf E. the length-of null point increases by 40 cm. The value of E is $\frac{x}{10}$ V. The value of x is __________.

Official Ans. by NTA (25)

Ans. (25)

Sol. $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

$\frac{1.5}{E_2} = \frac{60}{60+40} = \frac{6}{10} = \frac{3}{5}$

$E_2 = \frac{5}{2} = \frac{x}{10}$

$x = 25$

23. A small particle moves to position $5\hat{i} - 2\hat{j} + \hat{k}$ from its initial position $2\hat{i} + 3\hat{j} - 4\hat{k}$ under the action of force $5\hat{i} + 2\hat{j} + 7\hat{k}$ N. The value of work done will be ___________ J.

Official Ans. by NTA (40)

Ans. (40)

Sol. $W = \vec{F} \cdot (\vec{r}_f - \vec{r}_i)$

$= (5\hat{i} + 2\hat{j} + 7\hat{k}) \cdot ((5\hat{i} - 2\hat{j} + \hat{k}) - (2\hat{i} + 3\hat{j} - 4\hat{k}))$

$W = 40$ J

24. A light of energy 12.75 eV is incident on a hydrogen atom in its ground state. The atom absorbs the radiation and reaches to one of its excited states. The angular momentum of the atom in the excited state is $\frac{x}{\pi} \times 10^{-17}$ eVs. The value of x is ________ (use $h = 4.14 \times 10^{-15}$eVs, $c = 3 \times 10^8$ ms^{-1}).

Official Ans. by NTA (828)

Ans. (828)

Sol. In the ground state energy = –13.6 eV

So energy

$\frac{-13.6\text{eV}}{n^2} = -13.6 + 12.75$

$\frac{-13.6\text{eV}}{n^2} = -0.85$

$n = \sqrt{16}$

$\boxed{n = 4}$

Angular momentum $= \frac{nh}{2\pi} = \frac{4h}{2\pi} = \frac{2h}{\pi}$

Angular momentum $= \frac{2}{\pi} \times 4.14 \times 10^{-15}$

$= \frac{828 \times 10^{-17}}{\pi}$eVs

25. A certain pressure 'P' is applied to 1 litre of water and 2 litre of a liquid separately. Water gets compressed to 0.01% whereas the liquid gets compressed to 0.03%. The ratio of Bulk modulus of water to that of the liquid is $\frac{3}{x}$. The value of x is __________.

Official Ans. by NTA (1)

Ans. (1)

Sol. $B_{water} = \frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)} = \frac{-\Delta P}{\frac{0.01}{100}}$

$B_{liquid} = \frac{-\Delta P}{\frac{0.03}{100}}$

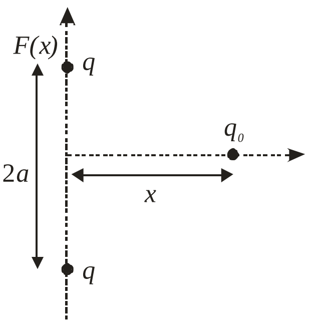
$\frac{B_{water}}{B_{liquid}} = 3$

$x = 1$

26. Two equal positive point charges are separated by a distance $2a$. The distance of a point from the centre of the line joining two charges on the equatorial line (perpendicular bisector) at which force experienced by a test charge q_0 becomes maximum is $\frac{a}{\sqrt{x}}$. The value of x is __________.

Official Ans. by NTA (2)

Ans. (2)



Sol.

$$F = \frac{2Kqq_0x}{(x^2 + a^2)^{3/2}}$$

For F to be maximum

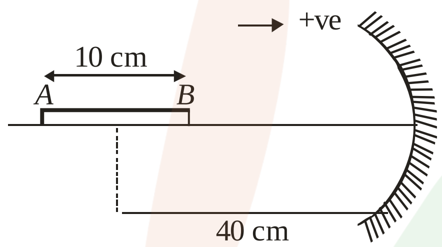
$$\frac{dF}{dx} = 0$$

$$x = \frac{a}{\sqrt{2}}$$

27. A thin cylindrical rod of length 10 cm is placed horizontally on the principle axis of a concave mirror of focal length 20 cm. The rod is placed in a such a way that mid point of the rod is at 40 cm from the pole of mirror. The length of the image formed by the mirror will be $\frac{x}{3}$ cm. The value of x is __________.

Official Ans. by NTA (32)

Ans. (32)



Sol.

$U_A = -45$ cm, f = –20 cm

$$V_A = \frac{-45 \times (-20)}{-45 - (-20)} = \frac{-900}{25} = -36 \text{ cm}$$

And $U_B = -35$cm

$$\therefore V_B = \frac{-35 \times (-20)}{-35 - (-20)} = \frac{700}{-15}$$

$\therefore V_A - V_B$ = length of image

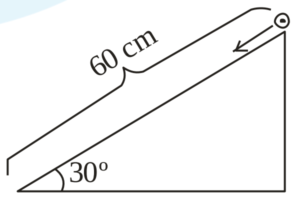
$$= \left(-36 + \frac{140}{3}\right) \text{cm}$$

$$= \frac{-108 + 140}{3} \text{cm}$$

$$= \frac{32}{3} \text{cm}$$

$\therefore x = 32$

28. A solid cylinder is released from rest from the top of an inclined plane of inclination 30° and length 60 cm. If the cylinder rolls without slipping, its speed upon reaching the bottom of the inclined plane is __________ ms^{-1}. (Given g = 10 ms^{-2})



Official Ans. by NTA (2)

Ans. (2)

Sol. $v = \sqrt{\dfrac{2gh}{1+\dfrac{k^2}{R^2}}}$

Where $h = 60 \sin 30^\circ = 30$ cm

$$k^2 = \frac{R^2}{2}$$

$v = 2\ ms^{-1}$

29. The amplitude of a particle executing SHM is 3 cm. The displacement at which its kinetic energy will be 25% more than the potential energy is: ________ cm.

Official Ans. by NTA (2)

Ans. (2)

Sol. $KE = PE + \dfrac{PE}{4}$

$KE = \dfrac{5}{4} PE$

$\dfrac{1}{2} m\omega^2 (A^2 - x^2) = \dfrac{5}{4} \times \dfrac{1}{2} m\omega^2 x^2$

$[v = \omega\sqrt{A^2 - x^2}]$

$A^2 - x^2 = \dfrac{5}{4} x^2$

$\dfrac{9x^2}{4} = A^2$

$\boxed{x = \dfrac{2}{3} A}$

$\therefore x = \dfrac{2}{3} \times 3\text{cm}$

$x = 2$ cm

30. A series LCR circuit is connected to an ac source of 220V, 50Hz. The circuit contain a resistance $R = 100\Omega$ and an inductor of inductive reactance $X_L = 79.6\ \Omega$. The capacitance of the capacitor needed to maximize the average rate at which energy is supplied will be _________ μF.

Official Ans. by NTA (40)

Ans. (40)

Sol. To maximize the average rate at which energy supplied i.e. power will be maximum.

So in LCR circuit power will be maximum at the condition of resonance and in resonance condition

$X_L = X_C$

$79.6 = \dfrac{1}{\omega C}$

$\therefore C = \dfrac{1}{2\pi \times 50 \times 79.6}$

$\therefore \boxed{C = 40\mu F}$