FINAL JEE–MAIN EXAMINATION – JANUARY, 2023

(Held On Wednesday 01st February, 2023) **TIME : 3 : 00 PM to 6 : 00 PM**

PHYSICS | TEST PAPER WITH SOLUTION

SECTION-A

1. A Carnot engine operating between two reservoirs has efficiency $\frac{1}{3}$. When the temperature of cold reservoir raised by x, its efficiency decreases to $\frac{1}{6}$. The value of x, if the temperature of hot reservoir is 99° C, will be:

(1) 16.5 K (2) 33 K
(3) 66 K (4) 62 K

Official Ans. by NTA (4)

Ans. (4)

Sol. $T_H = 99°C = 99 + 273$

$= 372$ K.

$$1 - \frac{T_C}{T_H} = \frac{1}{3}$$

$$\frac{T_C}{T_H} = \frac{2}{3} \ \_\_\_(1) \Rightarrow T_C = \frac{2}{3} \times 372$$

$$= 2 \times 124 = 248 \text{ K}$$

$$1 - \frac{T_C + X}{T_H} = \frac{1}{6}$$

$$\frac{5}{6} = \frac{T_C + X}{T_H}$$

$$\frac{5}{6} = \frac{248 + X}{372}$$

$248 + X = 5 \times 62$

$X = 310 - 248 = 62$K

2. Given below are two statements : One is labelled as **Assertion A** and the other is labelled as **Reason R.**

Assertion A : Two metallic spheres are charged to the same potential. One of them is hollow and another is solid, and both have the same radii. Solid sphere will have lower charge than the hollow one.

Reason R : Capacitance of metallic spheres depend on the radii of spheres.

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

(1) **A** is false but **R** is true

(2) Both **A** and **R** are true and **R** is the correct explanation of **A**

(3) **A** is true but **R** is false

(4) Both **A** and **R** are true but **R** is not the correct explanation of **A**

Official Ans. by NTA (1)

Ans. (1)

Sol. Potential of a conducting sphere is

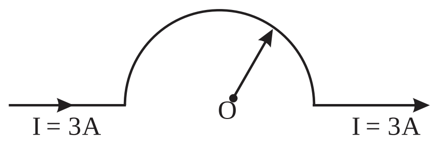
$V = \frac{KQ}{R}$ (Solid as well as hollow)

$V_1 = V_2$ and $R_1 = R_2$

$\therefore Q_1 = Q_2$

3. As shown in the figure, a long straight conductor with semicircular arc of radius $\frac{\pi}{10}$ m is carrying current I = 3A. The magnitude of the magnetic field. at the center O of the arc is:

(The permeability of the vacuum = $4\pi \times 10^{-7}$ NA^{-2})



(1) 6μT (2) 1μT
(3) 4μT (4) 3μT

Official Ans. by NTA (4)

Ans. (4)

Sol. $B_C = \frac{\mu_0 I}{4\pi R}(\pi)$ (B at centre of circular arc)

$$= \frac{\mu_0 I}{4R} = \frac{4\pi \times 10^{-7} \times 3}{4 \times \frac{\pi}{10}}$$

$= 3 \times 10^{-6}$ T $= 3\mu$T

$v_1 = 60$ cm

$$\frac{1}{v_2} + \frac{1}{(-25)} = \frac{1}{(-20)}$$

$$\frac{1}{v_2} = \frac{-1}{20} + \frac{1}{25}$$

$$= \frac{-5+4}{100} = \frac{-1}{100}$$

$v_2 = -100$ cm

$d = 60 + 100 = 160$ cm

8. The Young's modulus of a steel wire of length 6 m and cross-sectional area 3 mm^2, is 2×11^{11} N/m^2. The wire is suspended from its support on a given planet. A block of mass 4 kg is attached to the free end of the wire. The acceleration due to gravity on the planet is $\frac{1}{4}$ of its value on the earth. The elongation of wire is (Take g on the earth = 10 m/s^2):

(1) 1 cm (2) 1 mm

(3) 0.1 mm (4) 0.1 cm

Official Ans. by NTA (3)

Ans. (3)

Sol. Tension (F) = mg

$$= 4 \times \frac{10}{4} = 10N$$

$$\Delta L = \frac{FL}{AY}$$

$$= \frac{10 \times 6}{3 \times 10^{-6} \times 2 \times 10^{11}}$$

$= 10^{-4}$ m = 0.1 mm

9. Equivalent resistance between the adjacent corners of a regular n-sided polygon of uniform wire of resistance R would be:

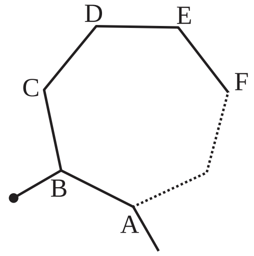
(1) $\frac{(n-1)R}{n^2}$ (2) $\frac{(n-1)R}{(2n-1)}$

(3) $\frac{n^2R}{n-1}$ (4) $\frac{(n-1)R}{n}$

Official Ans. by NTA (1)

Ans. (1)

Sol.



Suppose resistance of each arm is r, then r = R/n

$$R_{eq(AB)} = \frac{R_1R_2}{R_1 + R_2}$$

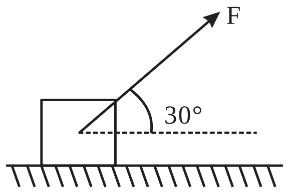
$$\frac{r(n-1)r}{r+(n-1)r}$$

$$= \frac{r(n-1)r}{nr}$$

$$= \frac{n-1}{n} r$$

$$= \frac{(n-1)R}{n^2}$$

10. As shown in the figure a block of mass 10 kg lying on a horizontal surface is pulled by a force F acting at an angle 30°, with horizontal. For $\mu_s = 0.25$, the block will just start to move for the value of F: [Given g = 10 ms^{-2}]



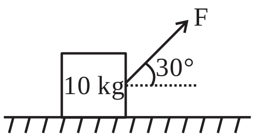
(1) 33.3 N (2) 25.2 N

(3) 20 N (4) 35.7 N

Official Ans. by NTA (2)

Ans. (2)

Sol.



N = Mg – F Sin 30°

$$= mg - \frac{F}{2} = 100 - \frac{F}{2} = \frac{200-F}{2}$$

F Cos 30° = μN

$$\sqrt{3}\frac{F}{2} = 0.25 \times \left(\frac{200-F}{2}\right)$$

$$4\sqrt{3}F = 200 - F$$

$$F = \frac{200}{4\sqrt{3}+1} = 25.22$$

11. Given below are two statements : One is labelled as **Assertion A** and the other is labelled as **Reason R**.

Assertion A : For measuring the potential difference across a resistance of 600 Ω, the voltmeter with resistance 1000 Ω will be preferred over voltmeter with resistance 4000 Ω.

Reason R : Voltmeter with higher resistance will draw smaller current than voltmeter with lower resistance.

In the light of the above statements, choose the **most appropriate** answer from the options given below.

(1) **A** is not correct but **R** is correct

(2) Both **A** and **R** are correct and **R** is the correct explanation of **A**

(3) Both **A** and **R** are correct but **R** is not the correct explanation of **A**

(4) **A** is correct but **R** is not correct

Official Ans. by NTA (1)

Allen Ans. (1)

Sol. Error of voltmeter decreases with increase in its resistance.

12. Choose the correct statement about Zener diode:

(1) It works as a voltage regulator in reverse bias and behaves like simple pn junction diode in forward bias.

(2) It works as a voltage regulator in both forward and reverse bias.

(3) It works a voltage regulator only in forward bias.

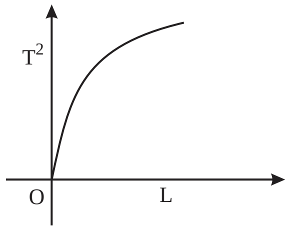
(4) It works as a voltage regulator in forward bias and behaves like simple pn junction diode in reverse bias.

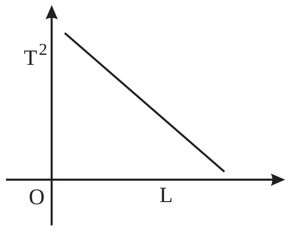
Official Ans. by NTA (1)

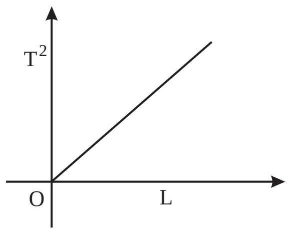
Ans. (1)

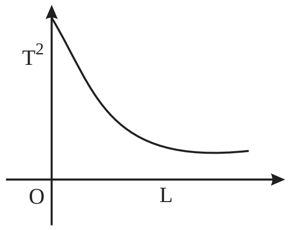
Sol. Woks as voltage regulator in reverse bias and as simple P-n junction in forward bias.

13. Choose the correct length (L) versus square of time period (T^2) graph for a simple pendulum executing simple harmonic motion.

(1)


(2)


(3)


(4)


Official Ans. by NTA (3)

Ans. (3)

Sol. $T = 2\pi\sqrt{\frac{\ell}{g}}$

$T^2 = \frac{4\pi^2}{g} \times \ell$

$T^2 \ \alpha \ \ell$

14. The escape velocities of two planets A and B are in the ratio 1 : 2. If the ratio of their radii respectively is 1 : 3, then the ratio of acceleration due to gravity of planet A to the acceleration of gravity of planet B will be:

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

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

Official Ans. by NTA (4)

Ans. (4)

Sol. $V_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G\rho\frac{4}{3}\pi R^3}{R}} = C\sqrt{\rho}.R$

$$\frac{V_{e_1}}{V_{e_2}} = \frac{R_1}{R_2}\sqrt{\frac{\rho_1}{\rho_2}} = \frac{1}{2}$$

$$\frac{R_1^2}{R_2^2} \times \frac{\rho_1}{\rho_2} = \frac{1}{4}$$

$$\frac{R_1}{R_2} = \frac{1}{3}$$

$$g = \frac{GM}{R^2} = \frac{G\frac{4}{3}\pi R^3 \times \rho}{R^2} C.\rho R$$

$$\frac{g_1}{g_2} = \frac{\rho_1 R_1}{\rho_2 R_2} = \frac{1}{4}\frac{R_2^2}{R_1^2} \times \frac{R_1}{R_2}$$

$$= \frac{1}{4} \times \frac{R_2}{R_1} = \frac{3}{4}$$

15. An electron of a hydrogen like atom, having Z = 4, jumps from 4th energy state to 2nd energy state, The energy released in this process, will be:

(Given Rch = 13.6 eV)

Where R = Rydberg constant

c = Speed of light in vacuum

h = Planck's constant

(1) 13.6 eV

(2) 10.5 eV

(3) 3.4 eV

(4) 40.8 eV

Official Ans. by NTA (4)

Ans. (4)

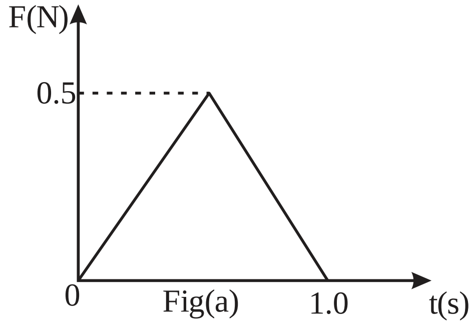
Sol. $\Delta E = 13.6 Z^2\left[\frac{1}{2^2} - \frac{1}{4^2}\right] eV$

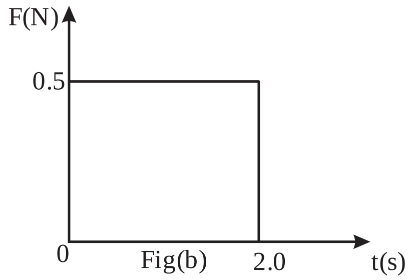
$$= 13.6 \times (4)^2\left(\frac{1}{4} - \frac{1}{16}\right) eV.$$

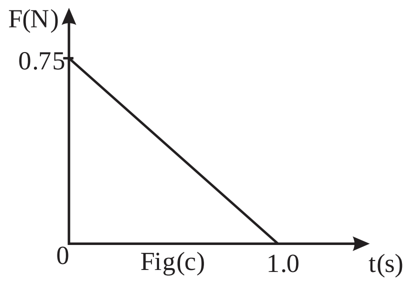
$$= 13.6[4-1] eV$$

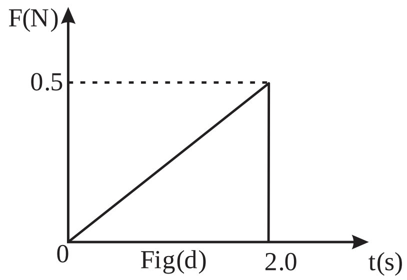
= 13.6 × 3 = 40.8 eV

16. Figures (a), (b), (c) and (d) show variation of force with time.









The impulse is highest in figure.

(1) Fig (c)
(2) Fig (b)
(3) Fig (a)
(4) Fig (d)

Official Ans. by NTA (2)

Ans. (2)

Sol. Impulse = Area under F = t curve

(a) $\frac{1}{2} \times 1 \times 0.5 = \frac{1}{4}$ N.s

(b) 0.5 × 2 = 1 N.s (maximum)

(c) $\frac{1}{2} \times 1 \times 0.75 = \frac{3}{8}$ N.s

(d) $\frac{1}{2} \times 2 \times 0.5 = \frac{1}{2}$ N.s

17. If the velocity of light c, universal gravitational constant G and planck's constant h are chosen as fundamental quantities. The dimensions of mass in the new system is:

(1) $\left[h^{\frac{1}{2}}c^{-\frac{1}{2}}G^{1}\right]$ (2) $\left[h^{1}c^{1}G^{-1}\right]$

(3) $\left[h^{-\frac{1}{2}}c^{\frac{1}{2}}G^{\frac{1}{2}}\right]$ (4) $\left[h^{\frac{1}{2}}c^{\frac{1}{2}}G^{-\frac{1}{2}}\right]$

Official Ans. by NTA (4)

Ans. (4)

Sol. Say dimensional formale of mass is $H^x C^y G^z$

$M^1 = (ML^2T^{-1})^x (LT^{-1}) (M^{-1}L^3T^{-2})^Z$

$M^1L^0T^0 = M^{x-z} L^{2x+y+3z} T^{-x-y-2z}$

on comparing both side

$x - z = 1$

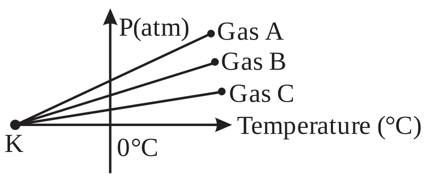
$2x + y + 3z = 0$

$-x - y - 2z = 0$

On solving above equations we get

$x = \frac{1}{2} \quad y = \frac{1}{2} \quad z = \frac{-1}{2}$

18. For three low density gases A, B, C pressure versus temperature graphs are plotted while keeping them at constant volume, as shown in the figure.



The temperature corresponding to the point 'K' is:

(1) –273°C (2) –100°C

(3) –373°C (4) –40°C

Official Ans. by NTA (1)

Ans. (1)

Sol. For isochoric process

$\frac{P}{T} = n\frac{R}{V} = \text{constant}$

$P = \frac{nR}{V}(t + 273)$

If $P = 0 \Rightarrow t = -273°C$

19. The ratio of average electric energy density and total average energy density of electromagnetic wave is:

(1) 2 (2) 1

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

Official Ans. by NTA (4)

Ans. (4)

Sol. $< u_E > = < u_B > = \frac{1}{2} < u_{total} >$

So $\frac{\langle u_E \rangle}{\langle u_{total} \rangle} = \frac{1}{2}$

20. The threshold frequency of metal is f_0. When the light of frequency $2f_0$ is incident on the metal plate, the maximum velocity of photoelectron is v_1. When the frequency of incident radiation is increased to $5f_0$. the maximum velocity of photoelectrons emitted is v_2. The ratio of v_1 to v_2 is:

(1) $\frac{v_1}{v_2} = \frac{1}{2}$ (2) $\frac{v_1}{v_2} = \frac{1}{8}$

(3) $\frac{v_1}{v_2} = \frac{1}{16}$ (4) $\frac{v_1}{v_2} = \frac{1}{4}$

Official Ans. by NTA (1)

Ans. (1)

Sol. $K_{max} = hf - hf_0$

For $f = 2f_0$

$\frac{1}{2} m V_1^2 = 2hf_0 - hf_0 = hf_0$

For $f = 5f_0$

$\frac{1}{2} m V_2^2 = 5hf_0 - hf_0 = 4hf_0$

$\frac{V_1}{V_2} = \frac{1}{2}$

SECTION-B

21. For a train engine moving with speed of 20 ms^{-1}. the driver must apply brakes at a distance of 500 m before the station for the train to come to rest at the station. If the brakes were applied at half of this distance, the train engine would cross the station with speed $\sqrt{x}$ ms^{-1}. The value of x is ______ (Assuming same retardation is produced by brakes)

Official Ans. by NTA (200)

Ans. (200)

Sol. u = 20 m/s, S_1 = 500 m, v = 0

By third equation of mation

$0 = (20)^2 - 2a.\ 500 \Rightarrow a = \frac{4}{10} m/s^2$

u = 20 m/s, S_2 = 250 m, v = ?

$v^2 = (20)^2 - 2a.\ 250$

$= v = \sqrt{200} m/s$

x = 200

22. A force F = (5 + $3y^2$) acts on a particle in the y-direction, where F is newton and y is in meter. The work done by the force during a displacement from y = 2m to y = 5m is ______j.

Official Ans. by NTA (132)

Ans. (132)

Sol. $F = 5 + 3y^2$

$$W = \int_2^5 (5+3y^2)dy$$

$$= \left[5y + \frac{3y^3}{3}\right]_2^5$$

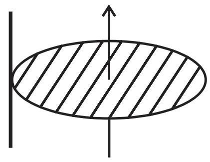
= 132 J

23. Moment of inertia of a dise of mass M and radius 'R' about any of its diameter is $\frac{MR^2}{4}$. The moment of inertia of this disc about an axis normal to the disc and passing through a point on its edge will be, $\frac{x}{2}MR^2$. The value of x is _____.

Official Ans. by NTA (3)

Ans. (3)

Sol.



$I = I_{cm} + Md^2$

$= \frac{MR^2}{2} + MR^2$

$= \frac{3}{2}MR^2$

x = 3

24. Nucleus a having Z = 17 and equal number of protons and neutrons has 1.2 MeV binding energy per nucleon.

Another nucleus B of Z = 12 has total 26 nucleons and 1.8 MeV binding energy per nucleons.

The difference of binding energy of B and A will be ____MeV.

Official Ans. by NTA (6)

Ans. (6)

Sol. For A mass number = 34

Total binding energy = 1.2 × 34 = 40.8 MeV

For B mass number = 26

total binding energy = 1.8 × 26 MeV

= 46.8 MeV

Difference of BE = 6 MeV

25. A square shaped coil of area 70 cm^2 having 600 turns rotates in a magnetic field of 0.4 wbm^{-2}, about an axis which is parallel to one of the side of the coil and perpendicular to the direction of field. If the coil completes 500 revolution in a minute, the instantaneous emf when the plane of the coil is inclined at 60° with the field, will be ____ V. (Take $\pi = \frac{22}{7}$)

Official Ans. by NTA (44)

Ans. (44)

Sol. N = 600, A = 70 × 10^{-4} m^2, B = 0.4T

$\omega = \frac{500 \times 2\pi}{60} = \frac{100\pi}{6} rad/s$

E= NABω sinωt   ωt is angle b/w $\vec{A}$ & $\vec{B}$

$= 600 \times 70 \times 10^{-4} \times 0.4 \times \frac{100\pi}{6} \times \frac{1}{2}$

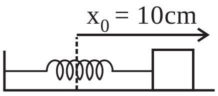
= 44 V

26. A block is fastened to a horizontal spring. The block is pulled to a distance x = 10 cm from its equilibrium position (at x = 0) on a frictionless surface from rest. The energy of the block at x = 5 cm is 0.25 J. The spring constant of the spring is ____Nm^{-1}.

Official Ans. by NTA (50)

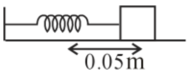
Ans. (67)

Sol.



$$U_i = \frac{1}{2}kx_0^2$$

$K_i = 0$



$$U_f = \frac{1}{2}k\left(\frac{x_0}{2}\right)^2$$

$K_f = 0.25$ J

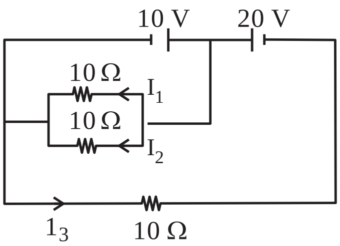
$$\frac{1}{2}kx_0^2 + 0 = \frac{1}{2}k\frac{x_0^2}{4} + 0.25$$

$$\frac{1}{2}kx_0^2\frac{3}{4} = \frac{1}{4}$$

$$\frac{1}{2}k\frac{3}{100} = 1 \Rightarrow k = \frac{200}{3}\text{N/m}$$

= 67 N/m

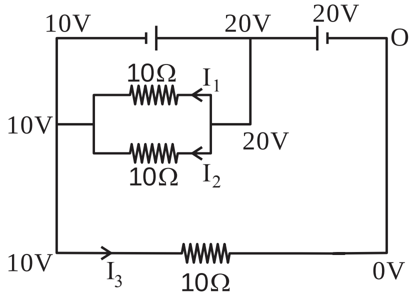
27. In the given circuit the value of $\left|\frac{I_1 + I_3}{I_2}\right|$ is:



Official Ans. by NTA (2)

Ans. (2)

Sol.

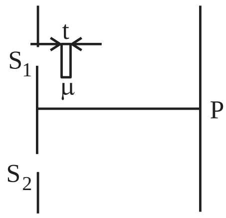


$$I_1 = I_2 = \frac{20-10}{10} = 1\text{A}$$

$I_3 = 1$A

$$\left|\frac{I_1 + I_3}{I_2}\right| = 2$$

28. As shown in the figure, in Young's double slit experiment, a thin plate of thickness t = 10 μm and refractive index μ = 1.2 is inserted infront of slit S_1. The experiment is conducted in air (μ = 1) and uses a monochromatic light of wavelength λ = 500 nm. Due to the insertion of the plate, central maxima is shifted by a distance of $x\beta_0$. β_0 is the fringe-width before the insertion of the plate. The value of the x is_____.



Official Ans. by NTA (4)

Ans. (4)

Sol. Fringe shift $= \frac{t(\mu-1)}{\lambda}B$

$$= \frac{10\times10^{-6}(1.2-1)}{5\times10^{-7}}B$$

$$= \frac{10^{-5}\times0.2}{5\times10^{-7}} = 4$$

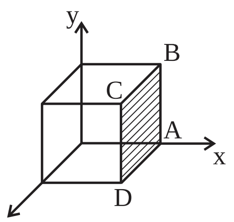
29. A cubical volume is bounded by the surfaces $x = 0, x = a, y = 0, y = a, z = 0, z = a$. The electric field in the region is given by $\vec{E} = E_0 x \hat{i}$. Where $E_0 = 4 \times 10^4$ NC^{-1} m^{-1}. If $a = 2$ cm, the charge contained in the cubical volume is $Q \times 10^{-14}$C. The value of Q is____.

Take $\in_0 = 9 \times 10^{-12}$ C^2/Nm^2)

Official Ans. by NTA (288)

Ans. (288)

Sol.



$\vec{E} = E_0 x\hat{i}$

$\phi_{net} = \phi_{ABCD} = E_0 a.a^2$

$\frac{q_{en}}{\in_0} = E_0 a^3$

$q_{en} = E_0 \in_0 a^3$

$= 4 \times 10^4 \times 9 \times 10^{-12} \times 8 \times 10^{-6}$

$= 288 \times 10^{-14}$ C

Q = 288

Ans. 288

30. The surface of water in a water tank of cross section area 750 cm^2 on the top of a house is *h* m. above the tap level. The speed of water coming out through the tap of cross section area 500 mm^2 is 30 cm/s. At that instant, $\frac{dh}{dt}$ is $x \times 10^{-3}$ m/s. The value of x will be_____.

Official Ans. by NTA (2)

Ans. (2)

Sol. $A_1V_1 = A_2 V_2$

$750 \times 10^{-4} V_1 = 500 \times 10^{-6} \times 0.3$

$V_1 = \frac{500 \times 3 \times 10^{-3}}{750}$ m / s

$= 2 \times 10^{-3}$ m/s

$\frac{dh}{dt} = -2 \times 10^{-3}$ m / s