FINAL JEE–MAIN EXAMINATION – FEBRUARY, 2021

(Held On Wednesday 24th February, 2021) TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS

TEST PAPER WITH ANSWER & SOLUTIONS

SECTION-A

1. When a particle executes SHM, the nature of graphical representation of velocity as a function of displacement is :

(1) circular (2) elliptical

(3) parabolic (4) straight line

Official Ans. by NTA (2)

Sol. For a particle executing SHM,

$x = A\sin(\omega t + \phi)$

$v = \omega A\cos(\omega t + \phi)$

$\Rightarrow \frac{v^2}{\omega^2 A^2} + \frac{x^2}{A^2} = 1 \Rightarrow$ equation of ellipse between v and x

Hence option (2)

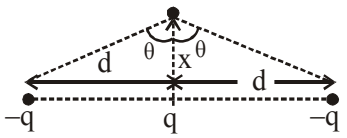
2. Two electrons each are fixed at a distance '2d'. A third charge proton placed at the midpoint is displaced slightly by a distance x (x << d) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency : (m = mass of charged particle)

(1) $\left(\frac{2q^2}{\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (2) $\left(\frac{\pi\varepsilon_0 md^3}{2q^2}\right)^{\frac{1}{2}}$

(3) $\left(\frac{q^2}{2\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (4) $\left(\frac{2\pi\varepsilon_0 md^3}{q^2}\right)^{\frac{1}{2}}$

Official Ans. by NTA (3)

Sol. From the given condition, we have



$F_{netq} = -\left[2F_{q/q}\cos\theta\right]$

$F_{netq} = -2.\frac{1}{4\pi\varepsilon_0}.\frac{q^2}{\left(\sqrt{d^2+x^2}\right)^2}.\frac{x}{\sqrt{d^2+x^2}}$

For x << d,

$F_{net\ q} = -\frac{q^2}{2\pi\varepsilon_0 d^3}x$

$\therefore\ a = -\frac{q^2}{2\pi\varepsilon_0 .md^3}x$

Comparing with equation of SHM ($a = -\omega^2 x$)

$\therefore\ \omega = \sqrt{\frac{q^2}{2\pi\varepsilon_0 md^3}}$

Hence option (3) is correct

3. On the basis of kinetic theory of gases, the gas exerts pressure because its molecules :

(1) continuously lose their energy till it reaches wall.

(2) are attracted by the walls of container.

(3) continuously stick to the walls of container.

(4) suffer change in momentum when impinge on the walls of container.

Official Ans. by NTA (4)

Sol. From the assumption of KTG, the molecules of gas collide with the walls and suffers momentum change which results in force on the wall and hence pressure.

Hence option (4) is correct

4. A soft ferromagnetic material is placed in an external magnetic field. The magnetic domains :

(1) increase in size but no change in orientation.

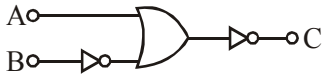
(2) have no relation with external magnetic field.

(3) decrease in size and changes orientation.

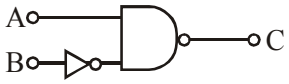
(4) may increase or decrease in size and change its orientation.

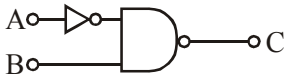
Official Ans. by NTA (4)

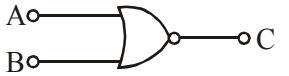
Sol. Soft ferromagnetic materials are materials which can be easily magnetised and demagnetised by external magnetic field. When external field is applied, the domains experiences a net torque hence change its

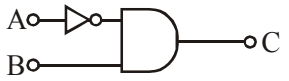
5. 

The logic circuit shown above is equivalent to :

(1) 

(2) 

(3) 

(4) 

Official Ans. by NTA (4)

Sol. Truth table of the given gate :

A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

Truth table of option (1)

A	B	C
0	0	1
0	1	1
1	0	0
1	1	1

Truth table of option (2)

A	B	C
0	0	1
0	1	0
1	0	1
1	1	1

Truth table of option (3)

A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Truth table of option (4)

A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

Alternative solution :

Given Boolean expression can be written as

$\overline{A+\overline{B}}=C$

$\therefore\ C=\overline{A}\cdot\overline{\overline{B}}=\overline{A}\cdot B$

Hence option (4) is correct

6. The period of oscillation of a simple pendulum is $T=2\pi\sqrt{\frac{L}{g}}$. Measured value of 'L' is 1.0 m from meter scale having a minimum division of 1 mm and time of one complete oscillation is 1.95 s measured from stopwatch of 0.01 s resolution. The percentage error in the determination of 'g' will be :

(1) 1.13% (2) 1.03%

(3) 1.33% (4) 1.30%

Official Ans. by NTA (1)

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

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

$\frac{\Delta g}{g}=\frac{\Delta\ell}{\ell}+\frac{2\Delta T}{T}$

$\frac{\Delta g}{g}=\frac{1\times10^{-3}}{1}+2\times\frac{0.01}{1.95}$

$\frac{\Delta g}{g}=0.0113$ or 1.13%

option (1) is correct

7. Given below are two statements :

Statement I : PN junction diodes can be used to function as transistor, simply by connecting two diodes, back to back, which acts as the base terminal.

Statement II : In the study of transistor, the amplification factor β indicates ratio of the collector current to the base current.

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 true

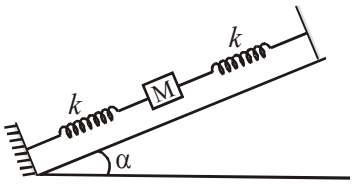
(3) Both Statement I and Statement II are false

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

Official Ans. by NTA (1)

Sol. Back to back diode will not the make a transistor

8. In the given figure, a body of mass M is held between two massless springs, on a smooth inclined plane. The free ends of the springs are attached to firm supports. If each spring has spring constant *k*, the frequency of oscillation of given body is :

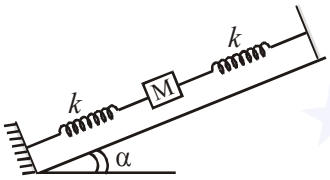


(1) $\frac{1}{2\pi}\sqrt{\frac{k}{2M}}$ (2) $\frac{1}{2\pi}\sqrt{\frac{2k}{Mg\sin\alpha}}$

(3) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (4) $\frac{1}{2\pi}\sqrt{\frac{k}{Mg\sin\alpha}}$

Official Ans. by NTA (3)

Sol.

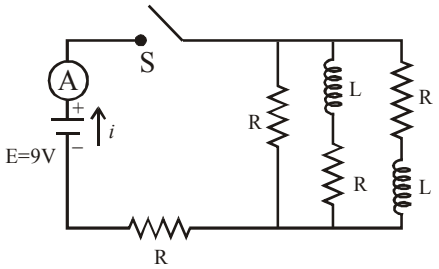


$K_{eq} = K_1 + K_2 = K + K = 2K$

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

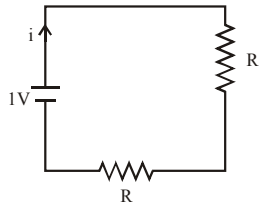
$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{2K}{m}}$ (Option 3) is correct

9. Figure shows a circuit that contains four identical resistors with resistance R = 2.0 Ω, two identical inductors with inductance L = 2.0 mH and an ideal battery with *emf* E = 9 V. The current '*i*' just after the switch 'S' is closed will be :



(1) 2.25 A (2) 3.0 A

Sol. Just after the switch is closed, inductor will behave like infinite resistance (open circuit) so the circuit will look like



$i = \frac{9}{R+R} = \frac{9}{4} = 2.25$

Option (1) is correct.

10. The de Broglie wavelength of a proton and α-particle are equal. The ratio of their velocities is :

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

Official Ans. by NTA (2)

Sol. $\lambda = \frac{h}{mv}$

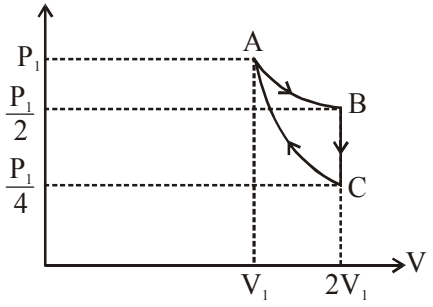
$\lambda_P = \lambda_\alpha$

$m_P v_P = m_\alpha v_\alpha$

$m_P v_P = 4m_p v_\alpha$ $(m_\alpha = 4m_P)$

$\frac{v_P}{v_\alpha} = 4$ (Option 2) is correct

11. If one mole of an ideal gas at (P_1, V_1) is allowed to expand reversibly and isothermally (A to B) its pressure is reduced to one-half of the original pressure (see figure). This is followed by a constant volume cooling till its pressure is reduced to one-fourth of the initial value (B→C). Then it is restored to its initial state by a reversible adiabatic compression (C to A). The net workdone by the gas is equal to :



(1) $RT\left(\ln 2 - \frac{1}{2(\gamma-1)}\right)$ (2) $-\frac{RT}{2(\gamma-1)}$

(3) 0 (4) RT ln 2

Sol. A – B = isothermal process

$$W_{AB} = P_1V_1 \ln\left[\frac{2V_1}{V_1}\right] = P_1V_1\ln(2)$$

B – C $\rightarrow$ Isochoric process

$W_{BC} = 0$

C – A $\rightarrow$ Adiabatic process

$$W_{CA} = \frac{P_1V_1 - \frac{P_1}{4}\times 2V_1}{1-\gamma} = \frac{P_1V_1\left[1-\frac{1}{2}\right]}{1-\gamma} = \frac{P_1V_1}{2(1-\gamma)}$$

$$W_{net} = W_{AB} + W_{BC} + W_{CA} \qquad \{P_1V_1 = RT\}$$

$$= P_1V_1\ln(2) + 0 + \frac{P_1V_1}{2(1-\gamma)}$$

$$W_{net} = RT\left[\ln(2) - \frac{1}{2(\gamma-1)}\right]$$

Option (1) is correct.

12. An X-ray tube is operated at 1.24 million volt. The shortest wavelength of the produced photon will be :

(1) 10^{-3} nm (2) 10^{-1} nm

(3) 10^{-2} nm (4) 10^{-4} nm

Official Ans. by NTA (1)

Sol. $\lambda_{min} = \frac{1240}{\Delta V}(\text{nm})$

$$= \frac{1240}{1.24\times 10^6} = 10^{-3}\text{ nm}$$

Option (1) is correct.

13. Which of the following equations represents a travelling wave ?

(1) $y = A\sin(15x - 2t)$

(2) $y = Ae^{-x^2}(vt+\theta)$

(3) $y = Ae^{x}\cos(\omega t - \theta)$

(4) $y = A\sin x\cos\omega t$

Official Ans. by NTA (1)

Sol. y = F(x, t)

For travelling wave y should be linear function of x and t and they must exist as (x ± vt)

14. According to Bohr atom model, in which of the following transitions will the frequency be maximum ?

(1) n = 4 to n = 3 (2) n = 2 to n = 1

(3) n = 5 to n = 4 (4) n = 3 to n = 2

Official Ans. by NTA (2)

Sol. $\Delta E = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = h\nu$

It is maximum if $n_1 = 1$ and $n_2 = 2$

n = 5 ..... –0.544 eV

n = 4 ..... –0.850 eV

n = 3 ..... –1.511 eV

n = 2 ..... –3.4 eV

n = 1 ..... –13.6 eV

Option (2) is correct.

15. If the source of light used in a Young's double slit experiment is changed from red to violet :

(1) consecutive fringe lines will come closer.

(2) the central bright fringe will become a dark fringe.

(3) the fringes will become brighter.

(4) the intensity of minima will increase.

Official Ans. by NTA (1)

Sol. $\beta = \frac{\lambda.D}{d}$

$\lambda_R > \lambda_V$

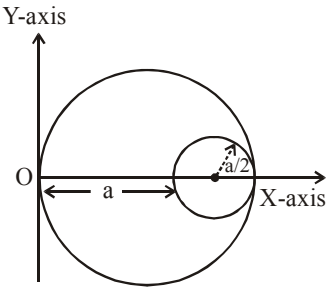
$\beta_R = \frac{\lambda_R D}{d}$ and $\beta_V = \frac{\lambda_V D}{d}$

$\beta_R > \beta_V$

Fringe pattern will shrink.

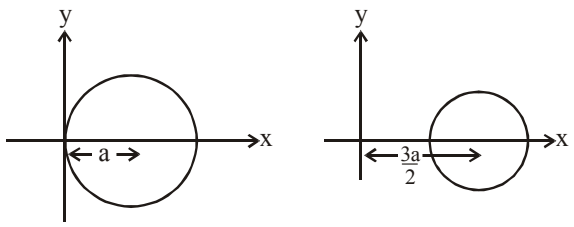
Option (1) is correct.

16. A circular hole of radius $\left(\frac{a}{2}\right)$ is cut out of a circular disc of radius 'a' as shown in figure. The centroid of the remaining circular portion with respect to point 'O' will be :



(1) $\frac{1}{-}$a (2) $\frac{10}{-}$a (3) $\frac{5}{-}$a (4) $\frac{2}{-}$a

Sol.



Let σ be the uniform mass density of disc then

$$x_{COM} = \frac{(\sigma\pi a^2)a - \sigma\pi\left(\frac{a^2}{4}\right)\times\frac{3a}{2}}{\sigma\pi a^2 - \frac{\sigma\pi a^2}{4}}$$

$$= \frac{a - \frac{3a}{8}}{1 - \frac{1}{4}} = \frac{5a}{6}$$

Option (2) is correct.

17. Zener breakdown occurs in a *p-n* junction having p and n both :

(1) lightly doped and have wide depletion layer.

(2) heavily doped and have narrow depletion layer.

(3) lightly doped and have narrow depletion layer.

(4) heavily doped and have wide depletion layer.

Official Ans. by NTA (2)

Sol. Zener diode is heavily doped and have narrow depletion layer.

Option (2) is correct.

18. Match List - I with List - II.

List - I	List - II
(a) Source of microwave frequency	(i) Radioactive decay on nucleus
(b) Source of infrared frequency	(ii) Magnetron
(c) Source of Gamma Rays	(iii) Inner shell electrons
(d) Source of X-rays	(iv) Vibration of atoms and molecules
	(v) LASER

Choose the correct answer from the options given below :

(1) (a)-(vi), (b)-(iv), (c)-(i), (d)-(v)

(2) (a)-(vi), (b)-(v), (c)-(i), (d)-(iv)

(3) (a)-(ii), (b)-(iv), (c)-(vi), (d)-(iii)

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

Official Ans. by NTA (4)

Sol. (a) Source of microwave frequency is magnetron.

(b) Source of infrared frequency is vibration of atoms and molecules.

(c) Source of Gamma rays is radioactive decay of nucleus

(d) Source of X-rays inner shell electron transition.

Option (4) is correct.

19. A particle is projected with velocity v_0 along *x*-axis. A damping force is acting on the particle which is proportional to the square of the distance from the origin i.e., $ma = -\alpha x^2$.. The distance at which the particle stops :

(1) $\left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{2}}$ (2) $\left(\frac{2v_0}{3\alpha}\right)^{\frac{1}{3}}$

(3) $\left(\frac{2v_0^2}{3\alpha}\right)^{\frac{1}{2}}$ (4) $\left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{3}}$

Official Ans. by NTA (4)

Sol. $F = -\alpha x^2$

$ma = -\alpha x^2$

$$a = \frac{-\alpha x^2}{m}$$

$$\frac{v\,dv}{dx} = -\frac{\alpha}{m}x^2$$

$$\int_{v_0}^{0} v\,dv = \int_0^x -\frac{\alpha}{m}x^2 dx$$

$$\left(\frac{v^2}{2}\right)_{v_0}^{0} = -\frac{\alpha}{m}\left(\frac{x^3}{3}\right)_0^x$$

$$\frac{-v_0^2}{2} = -\frac{\alpha}{m}\frac{x^3}{3}$$

$x = \left(3mv_0^2\right)^{\frac{1}{3}}$

Option(4) is most suitable option as (m) is not given

20. A body weighs 49 N on a spring balance at the north pole. What will be its weight recorded on the same weighing machine, if it is shifted to the equator ?

(Use $g = \frac{GM}{R^2} = 9.8\ ms^{-2}$ and radius of earth, R = 6400 km.]

(1) 49 N (2) 48.83 N

(3) 49.83 N (4) 49.17 N

Official Ans. by NTA (2)

Sol. Weight of pole = mg = 49 N

At equator due to rotation = $g_e = g - R\omega^2$

so $W = mg_e = m(g - R\omega^{2)}$

$\therefore W_P > W_e$ $W_P = 49$ N

So, $W_e = 48.83$ N. $W_e < 49$ N

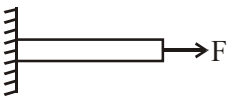
Option (2) is correct.

SECTION-B

1. A uniform metallic wire is elongated by 0.04 m when subjected to a linear force F. The elongation, if its length and diameter is doubled and subjected to the same force will be _____ cm.

Official Ans. by NTA (2)

Sol.



$F = Y.A.\ \frac{\Delta\ell}{\ell}$

$\Delta\ell = \frac{F}{Y.A.}.\ell$

$\Delta\ell = \frac{F.\ell}{Y.\pi r^2}$

$\Delta\ell \propto \frac{\ell}{r^2}$

$\frac{\Delta\ell_2}{\Delta\ell_1} = \left(\frac{\ell_2}{\ell_1}\right)\left(\frac{r_1}{r_2}\right)^2$

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

$\frac{\Delta\ell_2}{\Delta\ell_1} = \frac{1}{2}$

$\Delta\ell_2 = \frac{\Delta\ell_1}{2}$

$= \frac{0.04}{2}$

$= 0.02$ m

$\boxed{\Delta\ell_2 = 2cm}$

$\boxed{Ans. = 2}$

2. A cylindrical wire of radius 0.5 mm and conductivity 5×10^7 S/m is subjected to an electric field of 10 mV/m. The expected value of current in the wire will be $x^3\pi$ mA. The value of x is ____.

Official Ans. by NTA (5)

Sol. Conductivity $\sigma = 5 \times 10^7$ S/m

Radius r = 0.5 mm = 5×10^{-4} m

$E = 10 \times 10^{-3}\ \frac{V}{m}$

$J = \sigma E = 10 \times 10^{-3} \times 5 \times 10^7$

$J = 5 \times 10^5$

$\frac{i}{A} = 5 \times 10^5$

$i = 5 \times 10^5 \times \pi r^2$

$= 5 \times 10^5 \times \pi \times (5 \times 10^{-4})^2$

$= 125\pi \times 10^{-3}$ Amp

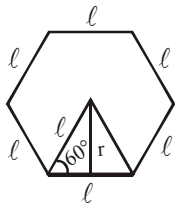
$i = 125\ \pi$ mA

$\boxed{x = 5}$

$\boxed{Ans.\ 5}$

3. A uniform thin bar of mass 6 kg and length 2.4 meter is bent to make an equilateral hexagon. The moment of inertia about an axis passing through the centre of mass and perpendicular to the plane of hexagon is ____ $\times 10^{-1}$ kg m^2.

Sol.



m = mass of one side of hexagon = 1 kg

$6\ell = 2.4 \quad \boxed{\ell = 0.4\,m}$

$\sin 60° = \frac{r}{\ell}$

$r = \ell \sin 60° = \frac{\ell\sqrt{3}}{2}$

$MOI, \quad I = \left[\frac{m\ell^2}{12} + mr^2\right]6$

$= \left[\frac{m\ell^2}{12} + m\left(\frac{\ell\sqrt{3}}{2}\right)^2\right]6$

$= 5\ m\ \ell^2$

$= 5 \times 1 \times 0.16$

$= 0.8$

$I = 8 \times 10^{-1}\ kg\ m^2$

Ans. 8

4. Two solids A and B of mass 1 kg and 2 kg respectively are moving with equal linear momentum. The ratio of their kinetic energies $(K.E.)_A : (K.E.)_B$ will be $\frac{A}{1}$, so the value of A will be ___.

Official Ans. by NTA (2)

Sol. Kinetic energy $K = \frac{P^2}{2m}$, $(P_A = P_B)$

$K \propto \frac{1}{m}$

$\frac{K_A}{K_B} = \frac{m_B}{m_A}$

$= \frac{2}{1}$

5. The root mean square speed of molecules of a given mass of a gas at 27°C and 1 atmosphere pressure is 200 ms^{-1}. The root mean square speed of molecules of the gas at 127°C and 2 atmosphere pressure is $\frac{x}{\sqrt{3}} ms^{-1}$. The value of x will be _____.

Official Ans. by NTA (400)

Sol. $v_{rms} = \sqrt{\frac{3RT}{M}}$

$v_{rms} \propto \sqrt{T}$

$\frac{(v_{rms})_2}{(v_{rms})_1} = \sqrt{\frac{T_2}{T_1}}$

$= \sqrt{\frac{400}{300}}$

$= \frac{2}{\sqrt{3}}$

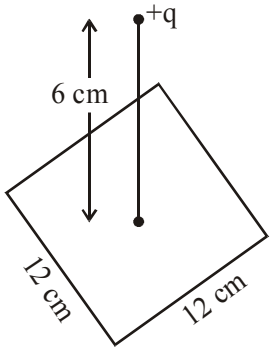
$(v_{rms})_2 = \frac{2}{\sqrt{3}}(v_{rms})_1$

$= \frac{2}{\sqrt{3}} \times 200$

$(v_{rms})_2 = \frac{400}{\sqrt{3}} m/s$

Ans. 400

6. A point charge of +12 μC is at a distance 6 cm vertically above the centre of a square of side 12 cm as shown in figure. The magnitude of the electric flux through the square will be _____ × 10^3 Nm^2/C.



Sol. From symmetry $\phi = \frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$

$$= \frac{12\times10^{-6}}{6\times8.85\times10^{-12}}$$

$$= 225.98 \times 10^3 \ \frac{Nm^2}{s}$$

$$\simeq 226\times10^3 \frac{Nm^2}{C}$$

7. A signal of 0.1 kW is transmitted in a cable. The attenuation of cable is –5 dB per km and cable length is 20 km. The power received at receiver is 10^{-x} W. The value of x is _____.

[Gain in dB = $10\log_{10}\left(\frac{P_0}{P_i}\right)$]

Official Ans. by NTA (8)

Sol. Sound level decreases by 5dB every km so sound level decreased in 20 km = 100 dB

$$\beta_2 - \beta_1 = 10\log_{10}\frac{I_2}{I_1}$$

$$-100 = 10\log_{10}\frac{I_2}{I_1} \Rightarrow \frac{I_1}{I_2} = 10^{10}$$

$$I_2 = 10^{-10}\, I_1 \Rightarrow P_2 = 10^{-10}\, P_1 = 10^{-8}\ W$$

$x = 8$ Ans. 8

8. A series LCR circuit is designed to resonate at an angular frequency $\omega_0 = 10^5$ rad/s. The circuit draws 16 W power from 120 V source at resonance. The value of resistance 'R' in the circuit is ___Ω.

Official Ans. by NTA (900)

Sol. At resonance

$$P = \frac{V^2}{R}$$

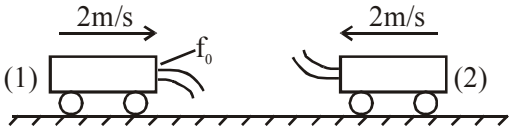
$$R = \frac{V^2}{P} = \frac{(120)^2}{16}$$

$$= 900\Omega$$

9. Two cars are approaching each other at an equal speed of 7.2 km/hr. When they see each other, both blow horns having frequency of 676 Hz. The beat frequency heard by each driver will be _____ Hz. [Velocity of sound in air is 340 m/s.]

Official Ans. by NTA (8)

Sol.



Frequency of sound heard by car-1, which comes by reflection from car-2

$$f_1 = f_0\left(\frac{340+2}{340-2}\right)\left(\frac{340+2}{340-2}\right)$$

$$= f_0\left(\frac{342}{338}\right)^2$$

Frequency of sound coming directly from car-2

$$f_2 = f_0\left(\frac{340+2}{340-2}\right)$$

$$\therefore\ f_1 - f_2 = f_0\left(\frac{342}{338}\right)\left(\frac{342}{338}-1\right) = 8.09 \simeq 8$$

10. An electromagnetic wave of frequency 3 GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be ____ × 10^{-2} cm.

Official Ans. by NTA (667)

Sol. λ in vacuum = $\frac{c}{f} = \frac{3\times10^8}{3\times10^9} = 0.1m$

$\therefore\ \lambda$ in medium = $\frac{0.1}{\mu}$

Where refractive index

$$\mu = \sqrt{\mu_r\varepsilon_r}$$

Assuming non-magnetic material $\mu_r = 1$

$$\therefore\quad \mu = \sqrt{2.25} = 1.5$$

$$\lambda_m = \frac{0.1}{1.5} = \frac{1}{15}m = 6.67cm$$

$$= 667 \times 10^{-2}\ cm$$

Ans. 667