JEE Main July 2021

Question Paper With Text Solution

20 July. | Shift-1

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

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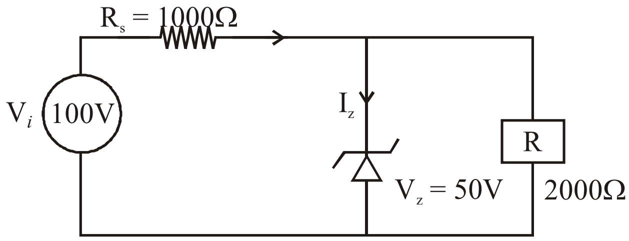
JEE MAIN JULY 2021 | 20TH JULY SHIFT-1

SECTION – A

1. For the circuit shown below, calculate the value of I_z :



(1) 0.05 A

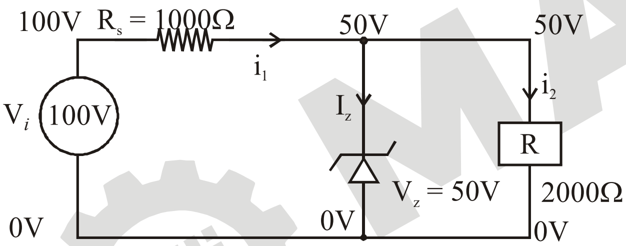
(2) 25 mA

(3) 0.1 A

(4) 0.15 A

Ans. Official Answer NTA (2)

Sol.



Potential difference across $2000\Omega = 50V$

$$i_2 = \frac{50}{2000} = 25\times10^{-3}A$$

$$i_1 = \frac{100-50}{1000} = 50\times10^{-3}A$$

From KCL :

$$I_z = i_1 - i_2 = 25mA$$

2. A current of 5 A is passing through a non-linear magnesium wire of cross-section 0.04 m^2. At every point the direction of current density is at an angle of 60° with the unit vector of area of cross-section. The magnitude of electric field at every point of the conductor is :

(Resistivity of magnesium $\rho = 44\times10^{-8}\Omega m$)

(1) 11×10^{-7} V / m

(2) 11×10^{-3} V / m

(3) 11×10^{-2} V / m

(4) 11×10^{-5} V / m

Ans. Official Answer NTA (4)

Sol. Component of J along the direction of flow o current = $J \cos 60° = \frac{5}{0.04}$

$J = 250 A / m^2$

$E = \rho J$

$= 44 \times 10^{-8} \times 250$

$E = 11 \times 10^{-5}$

3. A certain charge Q is divided into two parts q and (Q–q). How should the charges Q and q be divided so that q and (Q–q) placed at a certain distance apart experience maximum electrostic repulsion ?

(1) $Q = 4q$

(2) $Q = \frac{q}{2}$

(3) $Q = 3q$

(4) $Q = 2q$

Ans. Official Answer NTA (4)

Sol. $F = \frac{kq(Q-q)}{r^2}$

$\frac{dF}{dq} = \frac{k}{r^2}[Q-2q] = 0$

$q = \frac{Q}{2}$ for maximum force

4. A deuteron and an alpha particle having equal kinetic energy enter perpendicularly into a magnetic field. Let r_d and r_α be their respective radii of circular path. The value of $\frac{r_d}{r_\alpha}$ is equal to :

(1) 2

(2) 1

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

(4) $\sqrt{2}$

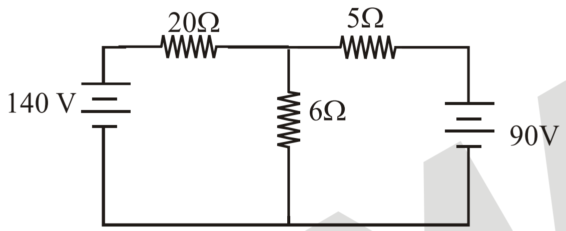
Ans. Official Answer NTA (4)

Sol. $$\frac{r_d}{r_\alpha}\frac{\left(\frac{m_d V_d}{q_d B}\right)}{\left(\frac{m_\alpha v_\alpha}{q_\alpha B}\right)}=\frac{\frac{\sqrt{2m_d k}}{e\times B}}{\frac{\sqrt{2m_\alpha k}}{2e\times B}}$$

$m_\alpha = 2m_d$

$\frac{r_d}{r_\alpha}=\sqrt{2}$

5.



The value of current in the 6Ω resistance is :

(1) 4 A

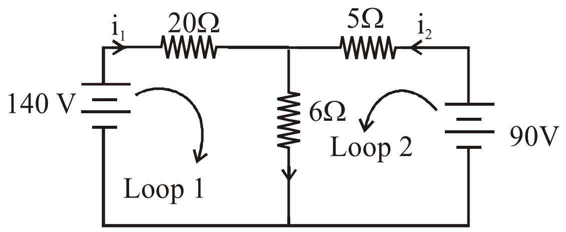
(2) 8 A

(3) 6 A

(4) 10 A

Ans. Official Answer NTA (4)

Sol.



using KVL in Loop 1 :

$140 - 20i_1 - 6(i_1 + i_2) = 0$

$13i_1 + 3i_2 = 70$ ...(1)

using KVL in Loop 2 :

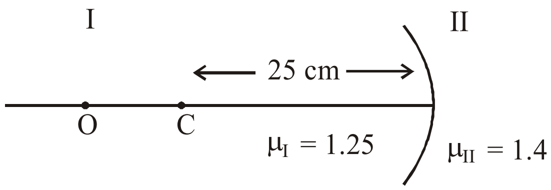
$90 - 5i_2 - 6(i_1 + i_2) = 0$

$6i_1 + 11i_2 = 90$ ....(2)

From (1) & (2) , $i_1 = 4A$ & $i_2 = 6A$

Current through $6\Omega = 10A$

6. Region I and II are separated by a spherical surface of radius 25 cm. An object is kept in region I at a distacne of 40 cm from the surface. The distance of the image from the surface is :



(1) 18.23 cm

(2) 9.52 cm

(3) 55.44 cm

(4) 37.58 cm

Ans. Official Answer NTA (4)

Sol. $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$\frac{1.4}{v} - \frac{1.25}{(-40)} = \frac{1.4 - 1.25}{(-25)}$

$v = -(37.58)\,cm$

Distance of image from surface = 37.58 cm

7. The amount of heat needed to raise the temperature of 4 moles of a rigid diatomic gas from 0°C to 50° C when no work is done is _____. (R is the universal gas constant)

(1) 175 R

(2) 500 R

(3) 250 R

(4) 750 R

Ans. Official Answer NTA (2)

Sol. $Q = \Delta u + w \quad \{w = 0\}$

$$Q = \Delta u = \frac{f}{2} nR\Delta T = \frac{5}{2} \times 4 \times R \times 50 = 500R$$

8. A nucleus of mass M emits $\gamma -$ray photon of frequency 'ν'. The loss of internal energy by the nucleus is : [Take 'c' as the speed of electromagnetic wave]

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

(2) $h\nu\left[1+\frac{h\nu}{2Mc^2}\right]$

(3) $h\nu$

(4) 0

Ans. Official Answer NTA (2)

Sol. From law of conservation of momentum :

$E_1 = \frac{P^2}{2M}$ $\qquad E_2 = h\nu$

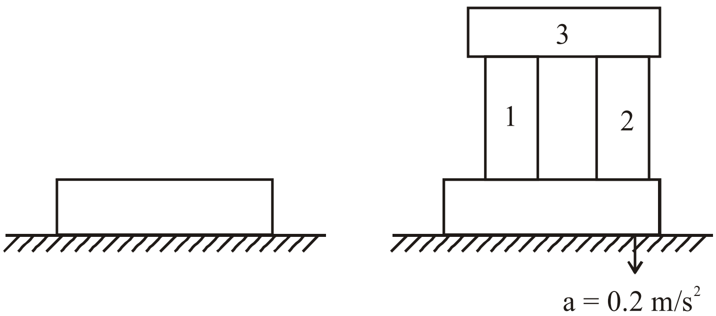
$= \frac{h^2\nu^2}{2Mc^2}$

Loss of internal energy by nucleus = $E_1 + E_2$

$= h\nu\left(1+\frac{h\nu}{2Mc^2}\right)$

9. A steel block of 10 kg rests on a horizontal floor as shown. When three iron cylinders are placed on it as shown, the block and cylinders go down with an acceleration $0.2 m/s^2$. The normal reaction R' by the floor if mass of the iron cylinders are equal and of 20 kg each, is ______N .

[Take $g = 10 m/s^2$ and $\mu_s = 0.2$]



(1) 684

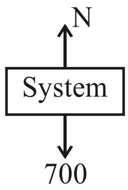
(2) 714

(3) 716

(4) 686

Ans. Official Answer NTA (4)

Sol. FBD of cylinders + Block:



$700 - N = 70 \times a$
$700 - N = 70 \times 0.2$

$N = 686\ N$

10. If $\vec{A}$ and $\vec{B}$ are two vectors satisfying the relation $\vec{A} \cdot \vec{B} = |\vec{A} \times \vec{B}|$. Then the value of $|\vec{A} - \vec{B}|$ will be :

(1) $\sqrt{A^2 + B^2 - \sqrt{2}AB}$

(2) $\sqrt{A^2 + B^2}$

(3) $\sqrt{A^2 + B^2 + 2AB}$

(4) $\sqrt{A^2 + B^2 + \sqrt{2}AB}$

Ans. Official Answer NTA (1)

Sol. $\overline{A} \cdot \overline{B} = |\overline{A} \times \overline{B}|$

$AB\cos\theta = AB\sin\theta$
$\tan\theta = 1$
$\theta = 45°$

$|\overline{A} - \overline{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

$= \sqrt{A^2 + B^2 - \sqrt{2}AB}$

11. Consider a mixture of gas molecule of types A, B and C having masses $m_A < m_B < m_C$. The ratio of their root mean square speeds at normal temperature and pressure is :

(1) $\upsilon_A = \upsilon_B \neq \upsilon_C$

(2) $\frac{1}{\upsilon_A} < \frac{1}{\upsilon_B} < \frac{1}{\upsilon_C}$

(3) $\upsilon_A = \upsilon_B = \upsilon_C = 0$

(4) $\frac{1}{\upsilon_A} > \frac{1}{\upsilon_B} > \frac{1}{\upsilon_C}$

Ans. Official Answer NTA (2)

Sol. $V_{RMS} = \sqrt{\frac{3RT}{M}}$

$$\frac{1}{V_A} < \frac{1}{V_B} < \frac{1}{V_C}$$

12. The normal reaction 'N' for a vehicle of 800 kg mass, negotiating a turn on a 30° banked road at maximum possible speed without skidding is____$\times 10^3$ kg m/s^2.

[Given cos30° = 0.87, $\mu_s = 0.2$]

(1) 6.96

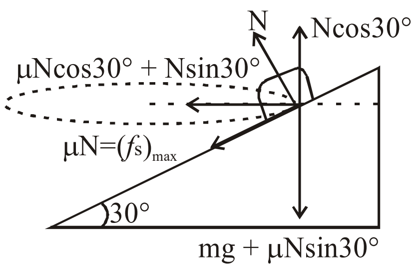
(2) 7.2

(3) 12.4

(4) 10.2

Ans. Official Answer NTA (4)

Sol.



$$N(\sin 30° + \mu \cos 30°) = \frac{mV^2}{R} \quad ....(1)$$

$$N(\cos 30° - \mu \sin 30°) = mg \quad ....(2)$$

$$N = \frac{800\times 9.8}{0.87-0.2\times 0.5} \approx 10.2\times 10^3\,N$$

13. The entropy of any system is given by $S = \alpha^2\beta \ln\left[\frac{\mu kR}{J\beta^2}+3\right]$ where α and β are the constants. μ,J, k and R are no. of moles, mechanical equivalent of heat, Boltzmann constant and gas constant respectively.[Take $S = \frac{dQ}{T}$]

Choose the incorrect option rom the following :

(1) S and α have diferent dimensions.

(2) S, β, k and μR have the same dimensions.

(3) α and k have the same dimensions.

(4) α and J have the same dimensions.

Ans. Official Answer NTA (3)

Sol. $[\mu] =$ mol

[J] = Dimension less = 1

$[k] = ML^2T^{-2}K^{-1}$

$[R] = ML^2T^{-2}\,mol^{-1}K^{-1}$

$$\left[\frac{\mu kR}{J\beta^2}\right] = 1$$

$$[\beta^2] = \frac{mol\times ML^2T^{-2}K^{-1}ML^2T^{-2}mol^{-1}K^{-1}}{1}$$

$[\beta] = ML^2T^{-2}K^{-1}$

$[S] = [\alpha^2\beta]$

$ML^2T^{-2}K^{-1} = [\alpha^2]\times ML^2\,T^{-2}K^{-1}$

$[\alpha] = 1$

14. A butterfly is flying with a velocity $4\sqrt{2}$ m/s in North-East direction. Wind is slowly blowing at 1m/s from North to South. The resultant displacement of the butterfly in 3 seconds is :

(1) $12\sqrt{2}$ m

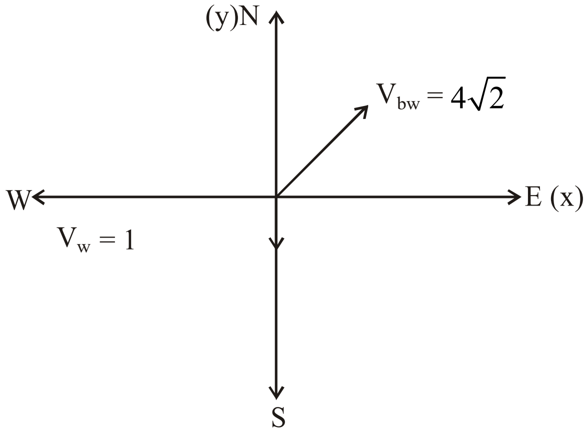
(2) 15 m

(3) 3 m

(4) 20 m

Ans. Official Answer NTA (2)

Sol.



$\overline{V}_b = \overline{V}_{bw} + \overline{V}_w = 4\hat{i} + 4\hat{j} - 1\hat{j}$

$\overline{V}_b = 4\hat{i} + 3\hat{j}$

$\overline{S} = \overline{V}_b \times t = 12\hat{i} + 9\hat{j}$ & $|\overline{s}| = 15$ m

15. The value of tension in a long thin metal wire been changed from T_1 to T_2. The lengths of the metal wire at two different values of tension T_1 and T_2 are l_1 and l_2 respectively. The actual length of the metal wire is :

(1) $\frac{T_1 l_1 - T_2 l_2}{T_1 - T_2}$

(2) $\frac{l_1 + l_2}{2}$

(3) $\sqrt{T_1 T_2 l_1 l_2}$

(4) $\frac{T_1 l_2 - T_2 l_1}{T_1 - T_2}$

Ans. Official Answer NTA (4)

Sol. From Hooke's Law: $\frac{T_1}{A} = \frac{y(l_1 - L)}{L}$ ....(1)

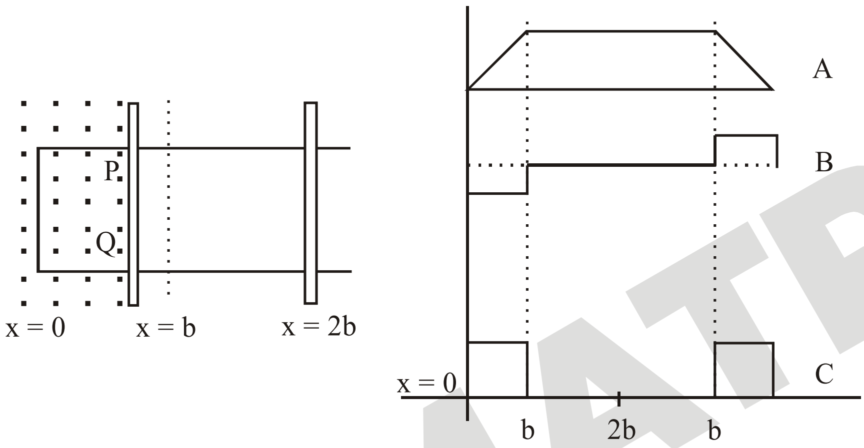
$\frac{T_2}{A} = \frac{y(l_2 - L)}{L}$ ......(2)

From (1)/(2)

$\frac{T_1}{T_2} = \frac{l_1 - L}{l_2 - L}$

$$L = \frac{T_1 l_2 - T_2 l_1}{T_1 - T_2}$$

16. The arm PQ of a rectangular conductor is moving from x = 0 to x = 2b outwards and then inwards from x = 2b to x = 0 as shown in the figure. A uniform magnetic field perpendicular to the plane is acting from x = 0 to x = b. Identify the graph showing the variation of different quantities with distance.



(1) A-Flux, B-Power dissipated, C-EMF

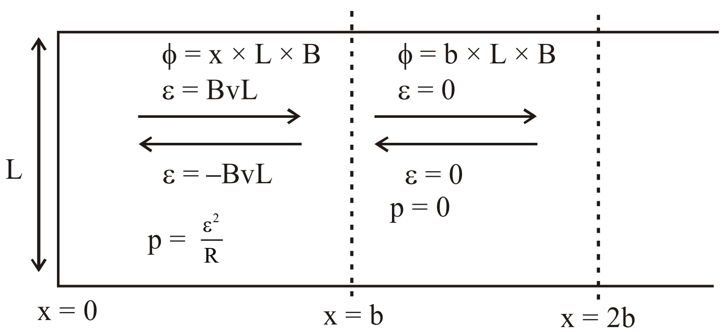
(2) A-EMF, B-Power dissipated, C-Flux

(3) A-Flux, B-EMF, C-Power dissipated

(4) A-Power dissipated, B-Flux, C-EMF

Ans. Official Answer NTA (3)

Sol.



17. A radioactive material decays by simultaneous emissions of two particles with half lives of 1400 years and 700 years respectively. What will be the time after which one third of the material remains ? (Take ln 3 = 1.1)

(1) 700 years

(2) 340 years

(3) 740 years

(4) 1110 years

Ans. Official Answer NTA (3)

Sol. $\lambda_{eq} = \lambda_1 + \lambda_2$ (for simultaneous decay)

$\lambda_{eq} = \frac{\ln 2}{1400} + \frac{\ln 2}{700} = \frac{3\ln 2}{1400}$

$N = N_o e^{-\lambda t}$

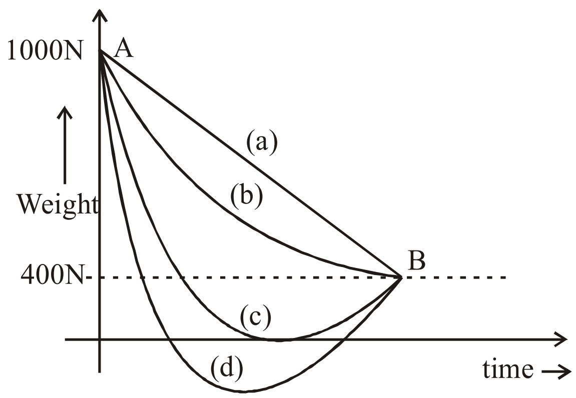
$\frac{N_o}{3} = N_o e^{-\lambda t}$

$\lambda t = \ln 3$

$\frac{3}{1400}\ln 2 \times t = \ln 3$

$t \approx 740 \text{years}$

18. A person whose mass is 100 kg travels from Earth to Mars in a spaceship. Neglect all other objects in sky and take acceleration due to gravity on the surface of the Earth and Mars as $10m/s^2$ and $4m/s^2$ respectively. Identify from the below figures, the curve that fits best for the weight of the passenger as a function of time.



(1) (a)

(2) (c)

(3) (d)

(4) (b)

Ans. Official Answer NTA (2)

Sol. Net gravitational force on person due to Earth & mass will be zero only once during the motion :

19. AC voltage V(t) = 20 $\sin \omega t$ of frequency 50 Hz is applied to a parallel plate capacitor. The separation between the plates is 2mm and the area is $1 m^2$. The amplitude of the oscillating displacement current for the applied AC voltage is _____.[Take $\varepsilon_0 = 8.85 \times 10^{-12} F/m$]

(1) 83.37 μA

(2) 27.79 μA

(3) 21.14 μA

(4) 55.58 μA

Ans. Official Answer NTA (2)

Sol. $i_d = \epsilon_o \frac{d\phi_E}{dt}$

$i_d = \epsilon_o \frac{d}{dt}\left(\frac{V \times 1}{2 \times 10^{-3}}\right)$

$= \frac{\epsilon_o}{2 \times 10^{-3}} \times 20 \cos(\omega t) \times \omega$

$i_d = \frac{8.85 \times 10^{-12} \times 20 \cos(\omega t) \times 2\pi \times 50}{2 \times 10^{-3}}$

$i_d = 27.79 \mu A$

20. The radiation corresponding to $3 \rightarrow 2$ transition of a hydrogen atom falls on a gold surface to generate photoelectrons. These electrons are passed through a magnetic field of 5×10^{-4}T. Assume that the radius of the largest circular path followed by these electrons is 7mm, the work function of the metal is :

(Mass of electron = 9.1×10^{-31}kg)

(1) 1.36 eV

(2) 0.82 eV

(3) 1.88 eV

(4) 0.16 eV

Ans. Official Answer NTA (2)

Sol. Energy of radiation emitted from hydrogen atom = $13.6\text{eV}\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$

$=\frac{3.4}{9}\times 5$

= 1.9 eV

$k_{max}=(1.9-\phi)\text{eV}$

$R_{max}=\frac{mV_{max}}{qB}=\frac{\sqrt{2mk_{max}}}{eB}$

$7\times10^{-3}=\frac{\sqrt{2\times9.1\times10^{-31}\times(1.9-\phi)\times e}}{1.6\times10^{-19}\times5\times10^{-4}}$

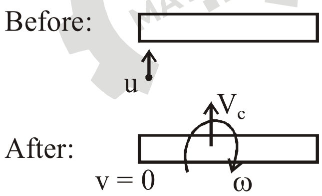
$\phi\approx 0.82\text{eV}$

SECTION - B

1. A rod of mass M and length L is lying on a horizontal frictionless surface. A particle of mass 'm' travelling along the surface hits at one end of the rod with a velocity 'u' in a direction perpendicular to the rod. The collision is completely elastic. After collision, particle comes to rest. The ratio of masses $\left(\frac{m}{M}\right)$ is $\frac{1}{x}$. The value of 'x' will be _____.

Ans. Official Answer NTA (4)

Sol.



Conservation of angular momentum : $mu\times\frac{L}{2}=\frac{ML^2}{12}\times\omega$ .....(1)

about centre of rod

Conservation of linear momentum: $mu = MV_c$ ....(2)

$e = 1 = \frac{V_c + \omega L/2}{u} \Rightarrow V_c + \omega\frac{L}{2} = u$ ....(3)

(1)/(2)

$\frac{L}{2} = \frac{\omega L^2}{12V_c} \Rightarrow \omega L = 6V_c$

Putting this in (3) : $V_c = \frac{u}{4}$

Putting this in (2) : $\frac{m}{M} = \frac{1}{4}$

2. A circular disc reaches from top to bottom of an inclined plane of length 'L'. When it slips down the plane, it takes time 't_1'. When it rolls down the plane, it takes time t_2. The value of $\frac{t_2}{t_1}$ is $\sqrt{\frac{3}{x}}$. The value of x will be ______.

Ans. Official Answer NTA (2)

Sol. When it slips: $a = g\sin\theta$

$L = \frac{1}{2}at^2$

$t_1 = \sqrt{\frac{2L}{g\sin\theta}}$

When it rolls :

$a = \frac{g\sin\theta}{1 + I/mR^2} = \frac{2}{3}g\sin\theta$

$t_2 = \sqrt{\frac{2L}{\frac{2}{3}g\sin\theta}}$

$\frac{t_2}{t_1} = \sqrt{\frac{3}{2}}$

3. A carrier wave $V_c(t) = 160\sin(2\pi\times10^6\ t)$ volts is made to vary between V_{max} = 200 V and V_{min} = 120 V by a message signal $V_m(t) = A_m\sin(2\pi\times10^3\ t)$ volts. The peak voltage A_m of the modulating signal is____.

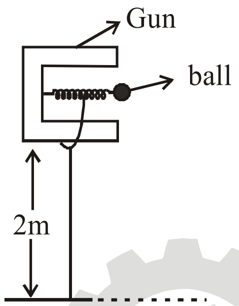
Ans. Official Answer NTA (40)

Sol. $V_{max} = 160 + A_m = 200$

$V_{min} = 160 - A_m = 120$

$A_m = 40V$

4. In a spring gun having spring constant 100N/m a small ball 'B' of mass 100g is put in its barrel (as shown in figure) by compressing the spring through 0.05m. There should be a box placed at a distance 'd' on the ground so that the ball falls in it. If the ball leaves the gun horizontally at a height of 2m above the ground. The value of d is _____m. (g = 10 m/s²).



Ans. Official Answer NTA (1)

Sol. Time of flight = $t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{4}{g}}$

Velocity of ball when if leaves the barrel = V_x

$$\frac{1}{2}\times kx^2 = \frac{1}{2}mv_x^2$$

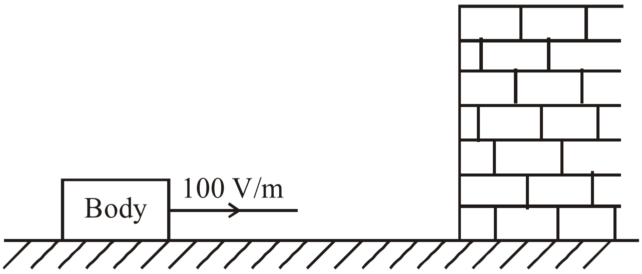
$$\frac{1}{2}\times100\times(0.05)^2 = \frac{1}{2}\times(0.1)\times v_x^2$$

$$v_x = \sqrt{2.5}$$

$$d = v_x\times t = \sqrt{2.5}\times\sqrt{\frac{4}{g}}$$

d = 1m

5. A body having specific charge $8\mu C/g$ is resting on a frictionless plane at a distance 10 cm from the wall (as shown in the figure). It starts moving towards the wall when a uniform electric field of 100 V/m is applied horizontally towards the wall. If the collision of the body with the wall is perfectly elastic, then the time period of the motion will be ______s.



Ans. Official Answer NTA (1)

$$a = \frac{qE}{m} = \frac{8\times10^{-6}}{10^{-3}}\times100 = 0.8$$

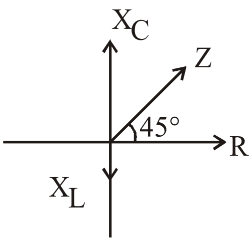
Time taken to reach wall $= \sqrt{\frac{2L}{a}} = \sqrt{\frac{2\times0.1}{0.8}} = \frac{1}{2}s$

Time period $= 2\times\frac{1}{2} = 1s$

6. In an LCR series circuit, an inductor 30mH and a resistor 1 Ω are connected to an AC source of angular frequency 300 rad/s. The value of capacitance for which, the current leads the voltage by 45° is $\frac{1}{x}\times10^{-3}F$. Then the value of x is ______.

Ans. Official Answer NTA (3)

Sol.



$$\tan 45° = \frac{X_C - X_L}{R}$$

$$\frac{1}{\omega C} - \omega L = R$$

$\frac{1}{\omega C} = 1+9$

$C = \frac{1}{3} \times 10^{-3}\,F$

x = 3

7. An object viewed from a near point distance of 25 cm, using a microscopic lens with magnification '6', gives an unresolved image. A resolved image is observed at infinite distance with a total magnification double the earlier using an eyepiece along with the given lens and a tube of length 0.6m, if the focal length of the eyepiece is equal to _______cm.

Ans. Official Answer NTA (25)

Sol. magnification of simple microscope in near point adjustment

$1 + \frac{D}{f_o} = 6$

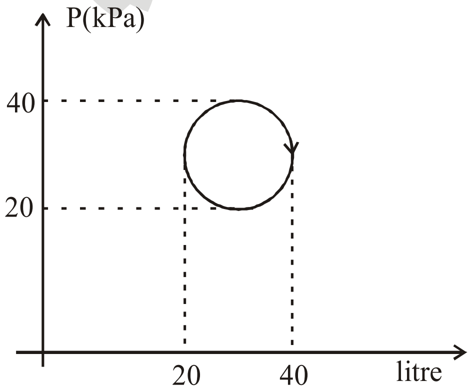
$f_o = 5cm$

magnification of compound microscope in normal adjustment

$\left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right) = 12$

$f_e = 25cm$

8. In the reported figure, heat energy absorbed by a system in going through a cyclic process is _____ πJ.



Ans. Official Answer NTA (100)

Sol. $Q = \Delta u + w$ $\{\Delta u = 0$ in cyclic process$\}$

Q = w = Area enclosed

$= \pi R^2$

$= \pi \times 10^2 \times 10^3 \times 10^{-3}$

$= 100\pi J$

9. The frequency of a car horn encountered a change from 400 Hz to 500 Hz, when the car approaches a vertical wall. If the speed of sound is 330 m/s. Then the speed of car is _____ km/h.

Ans. Official Answer NTA (132)

Sol. $f' = f_0\left(\frac{v}{v - v_c}\right) \times \left(\frac{v + v_c}{v}\right) = f_0\left(\frac{v + v_c}{v - v_c}\right)$

$500 = 400\left(\frac{330 + v_c}{330 - v_c}\right)$

$v_c = \frac{330}{9} \times \frac{3600}{1000} = 132 km/h$

10. The amplitude of wave disturbance propagating in the positive x-direction is given by $y = \frac{1}{(1+x)^2}$ at time t = 0 and $y = \frac{1}{1+(x-2)^2}$ at t = 1s, where x and y are in metres. The shape of wave doesnot change during the propagation . The velocity of the wave will be _____m/s.

Ans. Official Answer NTA (2)

Sol. at t = 0 $y = f(x) = \frac{1}{1+x^2}$

at t = 1 $y = f(x - vt) = \frac{1}{1+(x - v \times 1)^2}$

v = 2m/s