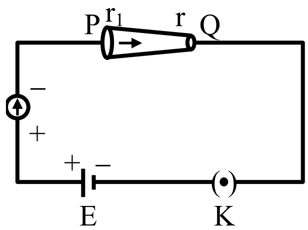
PHYSICS

SECTION-A

1. In the given figure, a battery of emf E is connected across a conductor PQ of length 'l' and different area of cross-sections having radii r_1 and r_2 ($r_2 < r_1$).



Choose the correct option as one moves from P to Q :

(1) Drift velocity of electron increases.

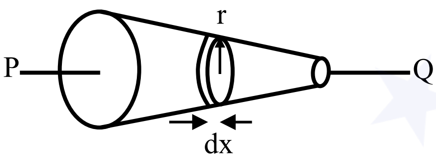
(2) Electric field decreases.

(3) Electron current decreases.

(4) All of these

Official Ans. by NTA (1)

Sol.



Current is constant in conductor

i = constant

Resistance of element $dR = \dfrac{\rho dx}{\pi r^2}$

$dV = idR = \dfrac{i\rho dx}{\pi r^2}$

$E = \dfrac{dV}{dx} = \dfrac{i\rho}{\pi r^2}$

& $V_d = \dfrac{eE\tau}{m}$

$\therefore V_d \propto E$

→ $E \propto \dfrac{1}{r^2}$

if r decreases , E will increase $\therefore$ V_d will increase

2. The number of molecules in one litre of an ideal gas at 300 K and 2 atmospheric pressure with mean kinetic energy 2×10^{-9} J per molecules is :

(1) 0.75×10^{11} (2) 3×10^{11}

(3) 1.5×10^{11} (4) 6×10^{11}

Official Ans. by NTA (3)

Sol. $KE = \dfrac{3}{2}kT$

$PV = \dfrac{N}{N_A}RT$

$N = \dfrac{PV}{kT}$

$= N = 1.5 \times 10^{11}$

3. The relative permittivity of distilled water is 81. The velocity of light in it will be :

(Given $\mu_r = 1$)

(1) 4.33×10^7 m/s (2) 2.33×10^7 m/s

(3) 3.33×10^7 m/s (4) 5.33×10^7 m/s

Official Ans. by NTA (3)

Sol. $V = \dfrac{c}{\sqrt{\mu_r \varepsilon_r}}$

$= 3.33 \times 10^7$ m/sec

4.

List-I	**List-II**
(a) MI of the rod (length L, Mass M, about an axis ⊥ to the rod passing through the midpoint)	(i) $8\ ML^2/3$
(b) MI of the rod (length L, Mass 2M, about an axis ⊥ to the rod passing through one of its end)	(ii) $ML^2/3$
(c) MI of the rod (length 2L, Mass M, about an axis ⊥ to the rod passing through its midpoint)	(iii) $ML^2/12$
(d) MI of the rod (Length 2L, Mass 2M, about an axis ⊥ to the rod passing through one of its end)	(iv) $2\ ML^2/3$

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

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

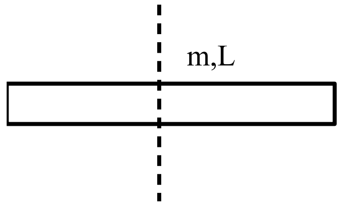
(2) (a)–(ii), (b)–(i), (c)– (iii), (d)–(iv)

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

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

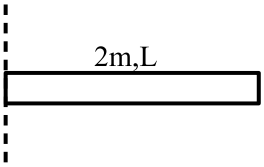
Official Ans. by NTA (3)

Sol. (a)



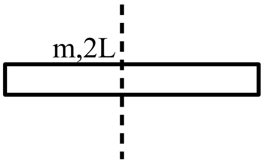
$I = \frac{mL^2}{12}$

(b)



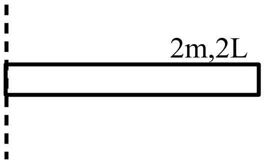
$I = \frac{(2m)(L^2)}{3}$

(c)



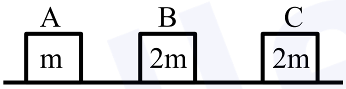
$I = \frac{m(2L)^2}{12} = \frac{mL^2}{3}$

(d)



$I = \frac{2m(2L)^2}{3} = \frac{8}{3}mL^2$

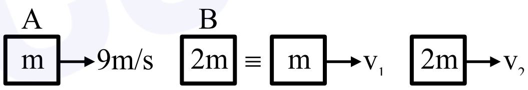
5. Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. The masses of A, B and C are m, 2 m and 2 m respectively. A moves towards B with a speed of 9 m/s and makes an elastic collision with it. Thereafter B makes a completely inelastic collision with C. All motions occur along same straight line. The final speed of C is :



(1) 6 m/s (2) 9 m/s (3) 4 m/s (4) 3 m/s

Official Ans. by NTA (4)

Sol. Collision between A and B

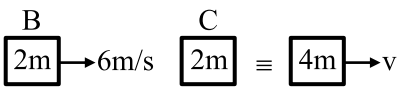


$m \times 9 = mv_1 + 2m\,v_2$ (from momentum conservation)

$e = 1 = \frac{v_2 - v_1}{9}$

$\Rightarrow v_2 = 6$ m/sec. , $v_1 = -3$ m/sec.

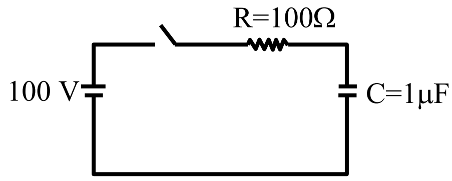
collision between B and C



$2m \times 6 = 4mv$ (from momentum conservation)

$v = 3$ m/s

6.



A capacitor of capacitance C=1 μF is suddenly connected to a battery of 100 volt through a resistance R = 100 Ω. The time taken for the capacitor to be charged to get 50 V is :

[Take ln 2 = 0.69]

(1) 1.44×10^{-4} s (2) 3.33×10^{-4} s

(3) 0.69×10^{-4} s (4) 0.30×10^{-4} s

Official Ans. by NTA (3)

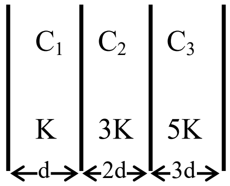
Sol. $V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$

$50 = 100\left(1 - e^{-\frac{t}{RC}}\right)$

$t = 0.69 \times 10^{-4}$ sec.

7. In the reported figure, a capacitor is formed by placing a compound dielectric between the plates of parallel plate capacitor. The expression for the capacity of the said capacitor will be :

(Given area of plate = A)



(1) $\frac{15}{34}\frac{K\varepsilon_0 A}{d}$ (2) $\frac{15}{6}\frac{K\varepsilon_0 A}{d}$

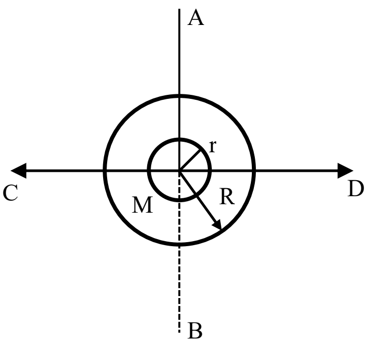
(3) $\frac{25}{6}\frac{K\varepsilon_0 A}{d}$ (4) $\frac{9}{6}\frac{K\varepsilon_0 A}{d}$

Official Ans. by NTA (1)

Sol. $\frac{1}{C_{eff}} = \frac{d}{K\epsilon_0 A} + \frac{2d}{3K\epsilon_0 A} + \frac{3d}{5K\epsilon_0 A}$

$C_{eff} = \frac{15K\epsilon_0 A}{34\,d}$

8. The figure shows two solid discs with radius R and r respectively. If mass per unit area is same for both, what is the ratio of MI of bigger disc around axis AB (Which is ⊥ to the plane of the disc and passing through its centre) of MI of smaller disc around one of its diameters lying on its plane? Given 'M' is the mass of the larger disc. (MI stands for moment of inertia)



(1) $R^2 : r^2$ (2) $2r^4 : R^4$

(3) $2R^2 : r^2$ (4) $2R^4 : r^4$

Official Ans. by NTA (4)

Sol. Ratio of moment of inertia = $\dfrac{\frac{1}{2}MR^2}{\frac{1}{4}mr^2}$

$= \dfrac{2\sigma\pi R^2R^2}{\sigma\pi r^2 r^2} = \dfrac{2R^4}{r^4}$

9. In Young's double slit experiment, if the source of light changes from orange to blue then :

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

(2) the distance between consecutive fringes will decrease.

(3) the distance between consecutive fringes will increase.

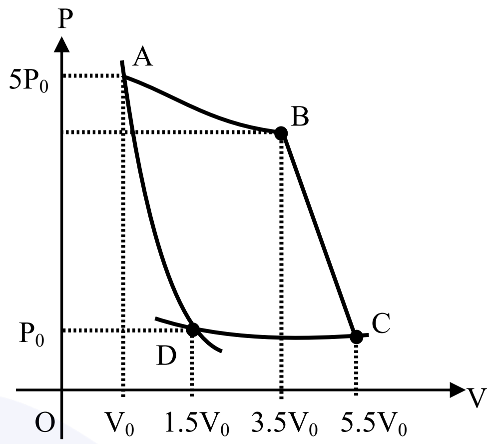
(4) the intensity of the minima will increase.

Official Ans. by NTA (2)

Sol. Fringe width = $\lambda D/d$

as λ decreases , fringe width also decreases

10. In the reported figure, there is a cyclic process ABCDA on a sample of 1 mol of a diatomic gas. The temperature of the gas during the process $A \rightarrow B$ and $C \rightarrow D$ are T_1 and T_2 ($T_1 > T_2$) respectively.



Choose the correct option out of the following for work done if processes BC and DA are adiabatic.

(1) $W_{AB} = W_{DC}$ (2) $W_{AD} = W_{BC}$

(3) $W_{BC} + W_{DA} > 0$ (4) $W_{AB} < W_{CD}$

Official Ans. by NTA (2)

Sol. Work done in adiabatic process = $\dfrac{-nR}{\gamma - 1}(T_f - T_i)$

$\therefore W_{AD} = \dfrac{-nR}{\gamma-1}(T_2 -$

and $W_{BC} = \dfrac{-nR}{\gamma-1}(T_2 - T_1)$

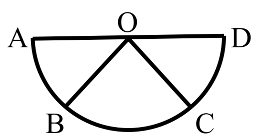
$\therefore W_{AD} = W_{BC}$

11. **Assertion A :** If A, B, C, D are four points on a semi-circular arc with centre at 'O' such that $|\overrightarrow{AB}| = |\overrightarrow{BC}| = |\overrightarrow{CD}|$, then

$\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} = 4\,\overrightarrow{AO} + \overrightarrow{OB} + \overrightarrow{OC}$

Reason R : Polygon law of vector addition yields

$\overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} + \overrightarrow{AD} = 2\,\overrightarrow{AO}$



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

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

(2) **A** is not correct but **R** is correct.

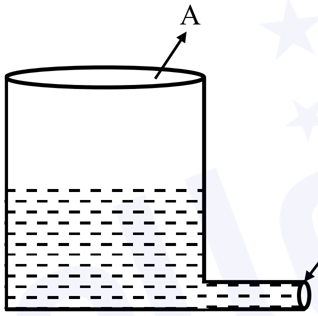
(3) Both **A** and **R** are correct and **R** is the correct explanation of **A**.

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

Official Ans. by NTA (4)

Sol. Polygon law is applicable in both but the equation given in the reason is not useful in explaining the assertion.

12. A light cylindrical vessel is kept on a horizontal surface. Area of base is A. A hole of cross-sectional area 'a' is made just at its bottom side. The minimum coefficient of friction necessary to prevent sliding the vessel due to the impact force of the emerging liquid is (a < < A) :



(1) $\frac{A}{2a}$ (2) None of these

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

Official Ans. by NTA (3)

Sol. For no sliding

$f \geq \rho a v^2$

$\mu m g \geq \rho a v^2$

$\mu \rho A h g \geq \rho a 2 g h$

$$\boxed{\mu \geq \frac{2a}{A}}$$

Option (3)

13. A particle starts executing simple harmonic motion (SHM) of amplitude 'a' and total energy E. At any instant, its kinetic energy is $\frac{3E}{4}$ then its displacement 'y' is given by :

(1) $y = a$

(2) $y = \frac{a}{\sqrt{2}}$

(3) $y = \frac{a\sqrt{3}}{2}$

(4) $y = \frac{a}{2}$

Official Ans. by NTA (4)

Sol. $E = \frac{1}{2}Ka^2$

$\frac{3E}{4} = \frac{1}{2}K(a^2 - y^2)$

$\frac{3}{4} \times \frac{1}{2}Ka^2 = \frac{1}{2}K(a^2 - y^2)$

$y^2 = a^2 - \frac{3a^2}{4}$

$y = \frac{a}{2}$

14. If '*f*' denotes the ratio of the number of nuclei decayed (N_d) to the number of nuclei at t = 0 (N_0) then for a collection of radioactive nuclei, the rate of change of '*f*' with respect to time is given as :

[λ is the radioactive decay constant]

(1) $-\lambda(1 - e^{-\lambda t})$ (2) $\lambda(1 - e^{-\lambda t})$

(3) $\lambda e^{-\lambda t}$ (4) $-\lambda e^{-\lambda t}$

Official Ans. by NTA (3)

Sol. $N = N_0 e^{-\lambda t}$

$N_d = N_0 - N$

$N_d = N_0(1 - e^{-\lambda t})$

$\frac{N_d}{N_0} = f = 1 - e^{-\lambda t}$

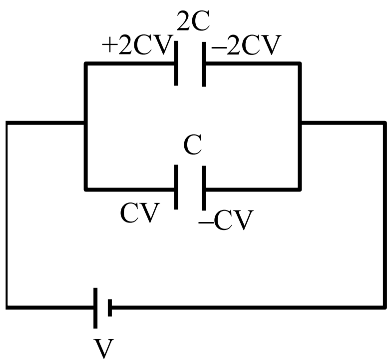
$\frac{df}{dt} = \lambda e^{-\lambda t}$

15. Two capacitors of capacities 2C and C are joined in parallel and charged up to potential V. The battery is removed and the capacitor of capacity C is filled completely with a medium of dielectric constant K. The potential difference across the capacitors will now be :

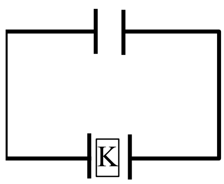
(1) $\frac{V}{K+2}$ (2) $\frac{V}{K}$ (3) $\frac{3V}{K+2}$ (4) $\frac{3V}{K}$

Official Ans. by NTA (3)

Sol.



Now,



$$V_C = \frac{2CV + CV}{KC + 2C}$$

$$= \frac{3V}{K+2}$$

16. A ball is thrown up with a certain velocity so that it reaches a height 'h'. Find the ratio of the two different times of the ball reaching $\frac{h}{3}$ in both the directions.

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

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

Official Ans. by NTA (3)

Sol. $u = \sqrt{2gh}$

Now,

$S = \frac{h}{3}$ $a = -g$

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

$$\frac{h}{3} = \sqrt{2gh}\,t + \frac{1}{2}(-g)t^2$$

$$t^2\left(\frac{g}{2}\right) - \sqrt{2gh}\,t + \frac{h}{3} = 0$$

From quadratic equation

$$t_1, t_2 = \frac{\sqrt{2gh} \pm \sqrt{2gh - \frac{4g}{2}\frac{h}{3}}}{g}$$

$$\frac{t_1}{t_2} = \frac{\sqrt{2gh} - \sqrt{\frac{4gh}{3}}}{\sqrt{2gh} + \sqrt{\frac{4gh}{3}}}$$

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

17. A 0.07 H inductor and a 12 Ω resistor are connected in series to a 220 V, 50 Hz ac source. The approximate current in the circuit and the phase angle between current and source voltage are respectively. [Take π as $\frac{22}{7}$]

(1) 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$

(2) 88 A and $\tan^{-1}\left(\frac{11}{6}\right)$

(3) 0.88 A and $\tan^{-1}\left(\frac{11}{6}\right)$

(4) 8.8 A and $\tan^{-1}\left(\frac{6}{11}\right)$

Official Ans. by NTA (1)

Sol. $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

$X_L = \omega L$

$X_L = 2 \times \frac{22}{7} \times 50 \times 0.07 = 22\,\Omega$

$\phi = \tan^{-1}\left(\frac{22}{12}\right)$ $R = 12\,\Omega$

$$\phi = \tan^{-1}\left(\frac{11}{6}\right)$$

$$Z = \sqrt{X_L^2 + R^2} = 25.059$$

$$I = \frac{V}{Z} = \frac{220}{25.059} = 8.77\,A$$

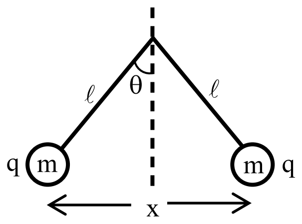
18. Two identical tennis balls each having mass 'm' and charge 'q' are suspended from a fixed point by threads of length 'l'. What is the equilibrium separation when each thread makes a small angle 'θ' with the vertical ?

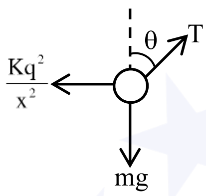
(1) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$ (2) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$

(3) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{\frac{1}{3}}$ (4) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{\frac{1}{3}}$

Official Ans. by NTA (2)

Sol.





$T\cos\theta = mg$

$T\sin\theta = \frac{kq^2}{x^2}$

$\tan\theta = \frac{kq^2}{x^2 mg}$

as $\tan\theta \approx \sin\theta \approx$

$\frac{x}{2L} = \frac{Kq^2}{x^2 mg}$

$x = \left(\frac{q^2 L}{2\pi\varepsilon_0 mg}\right)^{1/3}$

19. **Assertion A :** If in five complete rotations of the circular scale, the distance travelled on main scale of the screw gauge is 5 mm and there are 50 total divisions on circular scale, then least count is 0.001 cm.

Reason R :

$\text{Least Count} = \frac{\text{Pitch}}{\text{Total divisions on circular scale}}$

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) **A** is correct but **R** is not correct.

(4) Both **A** and **R** are correct and **R** is NOT the correct explanation of **A**.

Official Ans. by NTA (1)

Sol. $\text{Least count} = \frac{\text{Pitch}}{\text{total division on circular scale}}$

In 5 revolution, distance travel, 5 mm

In 1 revolution, it will travel 1 mm.

So least count $= \frac{1}{50} = 0.02$

20. A body takes 4 min. to cool from 61° C to 59°C. If the temperature of the surroundings is 30°C, the time taken by the body to cool from 51°C to 49° C is :

(1) 4 min. (2) 3 min.

(3) 8 min. (4) 6 min.

Official Ans. by NTA (4)

Sol. $\frac{\Delta T}{\Delta t} = K(T_t - T_S)$ T_t = average temp.

T_S = surrounding temp.

$\frac{61-59}{4} = K\left(\frac{61+59}{2} - 30\right)$ ....(1)

$\frac{51-49}{t} = K\left(\frac{51+49}{2} - 30\right)$ ....(2)

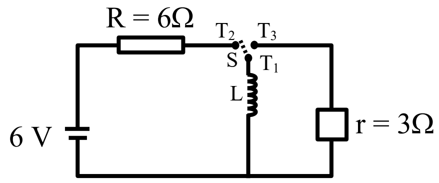
Divide (1) & (2)

$\frac{t}{4} = \frac{60-30}{50-30} = \frac{30}{20}$

so, $t = 6$ minutes

SECTION-B

1. Consider an electrical circuit containing a two way switch 'S'. Initially S is open and then T_1 is connected to T_2. As the current in R = 6 Ω attains a maximum value of steady state level, T_1 is disconnected from T_2 and immediately connected to T_3. Potential drop across r = 3 Ω resistor immediately after T_1 is connected to T_3 is______V. (Round off to the Nearest Integer)



Official Ans. by NTA (3)

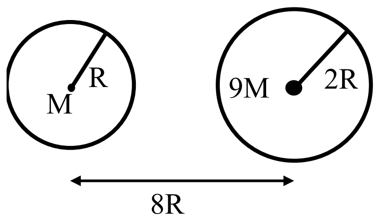
Sol. When T_1 and T_2 are connected, then the steady state current in the inductor $I = \frac{6}{6} = 1A$

When T_1 and T_3 are connected then current through inductor remains same. So potential difference across 3Ω

$V = Ir = 1 \times 3 = 3$ volt

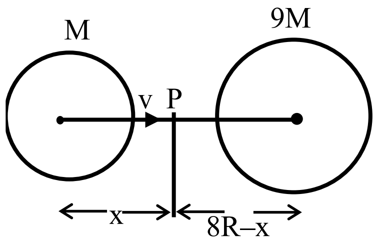
2. Suppose two planets (spherical in shape) of radii R and 2R, but mass M and 9 M respectively have a centre to centre separation 8 R as shown in the figure. A satellite of mass 'm' is projected from the surface of the planet of mass 'M' directly towards the centre of the second planet. The minimum speed 'v' required for the satellite to reach the surface of the second planet is $\sqrt{\frac{a}{7}\frac{GM}{R}}$ then the value of 'a' is ________.

[Given : The two planets are fixed in their position]



Official Ans. by NTA (4)

Sol.



Acceleration due to gravity will be zero at P therefore,

$$\frac{GM}{x^2} = \frac{G9M}{(8R-x)^2}$$

$8R - x = 3x$

$x = 2R$

Apply conservation of energy and consider velocity at P is zero.

$$\frac{1}{2}mv^2 - \frac{GMm}{R} - \frac{G9Mm}{7R} = 0 - \frac{GMm}{2R} - \frac{G9Mm}{6R}$$

$$\therefore V = \sqrt{\frac{4}{7}\frac{GM}{R}}$$

3. In Bohr's atomic model, the electron is assumed to revolve in a circular orbit of radius 0.5 Å. If the speed of electron is 2.2×16^6 m/s, then the current associated with the electron will be ___________ $\times 10^{-2}$ mA. [Take π as $\frac{22}{7}$]

Official Ans. by NTA (112)

Sol. $I = \frac{e}{T} = \frac{e\omega}{2\pi} = \frac{eV}{2\pi r}$

$$I = \frac{1.6 \times 10^{-19} \times 2.2 \times 10^6 \times 7}{2 \times 22 \times 0.5 \times 10^{-10}}$$

$= 1.12$ mA

112×10^{-2} mA

4. A radioactive sample has an average life of 30 ms and is decaying. A capacitor of capacitance 200 μF is first charged and later connected with resistor 'R'. If the ratio of charge on capacitor to the activity of radioactive sample is fixed with respect to time then the value of 'R' should be ______Ω.

Official Ans. by NTA (150)

Sol. $T_m = 30$ ms

$C = 200\ \mu F$

$$\frac{q}{N} = \frac{Q_0 e^{-t/RC}}{N_0 e^{-\lambda t}} = \frac{Q_0}{N_0} e^{t\left(\lambda - \frac{1}{RC}\right)}$$

Since q/N is constant hence

$$\lambda = \frac{1}{RC}$$

$$R = \frac{1}{\lambda C} = \frac{T_m}{C} = \frac{30\times10^{-3}}{200\times10^{-6}} = 150\ \Omega$$

5. A particle of mass 9.1×10^{-31} kg travels in a medium with a speed of 10^6 m/s and a photon of a radiation of linear momentum 10^{-27} kg m/s travels in vacuum. The wavelength of photon is _______ times the wavelength of the particle.

Official Ans. by NTA (910)

Sol. For photon $\lambda_1 = \frac{h}{P} = \frac{6.6\times10^{-34}}{10^{-27}}$

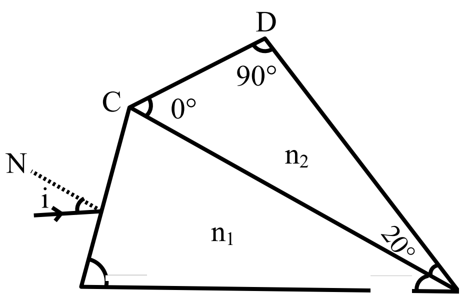
For particle $\lambda_2 = \frac{h}{mv} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^6}$

$$\therefore \frac{\lambda_1}{\lambda_2} = 910$$

6. A prism of refractive index n_1 and another prism of refractive index n_2 are stuck together (as shown in the figure). n_1 and n_2 depend on λ, the wavelength of light, according to the relation

$n_1 = 1.2 + \frac{10.8\times10^{-14}}{\lambda^2}$ and $n_2 = 1.45 + \frac{1.8\times10^{-14}}{\lambda^2}$

The wavelength for which rays incident at any angle on the interface BC pass through without bending at that interface will be _________ nm.



Official Ans. by NTA (600)

Sol. For no bending, $n_1 = n_2$

$$1.2 + \frac{10.8\times10^{-14}}{\lambda^2} = 1.45 + \frac{1.8\times10^{-4}}{\lambda^2}$$

On solving,

$9 \times 10^{-14} = 25\ \lambda^2$

$\lambda = 6 \times 10^{-7}$

$\lambda = 600$ nm

7. A stone of mass 20 g is projected from a rubber catapult of length 0.1 m and area of cross section 10^{-6} m^2 stretched by an amount 0.04 m. The velocity of the projected stone is __________ m/s.

(Young's modulus of rubber = 0.5×10^9 N/m^2)

Official Ans. by NTA (20)

Sol. By energy conservation

$$\frac{1}{2}.\frac{YA}{L}.x^2 = \frac{1}{2}mv^2$$

$$\frac{0.5\times10^9\times10^{-6}\times(0.04)^2}{0.1} = \frac{20}{1000}v^2$$

$\therefore\ v^2 = 400$

$\boxed{v = 20\ m/s}$

8. A transistor is connected in common emitter circuit configuration, the collector supply voltage is 10 V and the voltage drop across a resistor of 1000 Ω in the collector circuit is 0.6 V. If the current gain factor (β) is 24, then the base current is _______ μA. (Round off to the Nearest Integer)

Official Ans. by NTA (25)

Sol. $\beta = \frac{I_C}{I_B} = 24$; $R_C = 1000$

$\Delta V = 0.6$

$$I_C = \frac{0.6}{1000}$$

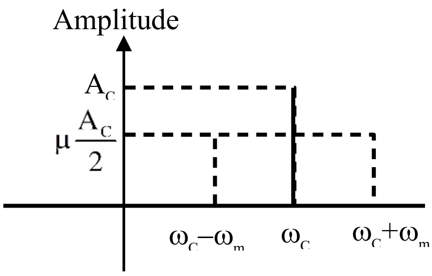
$I_C = 6 \times 10^{-4}$

$$I_B = \frac{I_C}{\beta} = \frac{6\times10^{-4}}{24} = 25\mu A$$

9. The amplitude of upper and lower side bands of A.M. wave where a carrier signal with frequency 11.21 MHz, peak voltage 15 V is amplitude modulated by a 7.7 kHz sine wave of 5V amplitude are $\frac{a}{10}$ V and $\frac{b}{10}$ V respectively. Then the value of $\frac{a}{b}$ is ____________.

Official Ans. by NTA (1)

Sol.



$$\frac{a}{10}=\frac{b}{10}=\frac{\mu A_C}{2}$$

$$\Rightarrow \frac{a}{b}=1$$

10. In a uniform magnetic field, the magnetic needle has a magnetic moment 9.85×10^{-2} A/m^2 and moment of inertia 5×10^{-6} kg m^2. If it performs 10 complete oscillations in 5 seconds then the magnitude of the magnetic field is ________ mT. [Take π^2 as 9.85]

Official Ans. by NTA (8)

Sol. $T = 2\pi\sqrt{\frac{I}{MB}}$

$B = 80 \times 10^{-4} = 8mT$