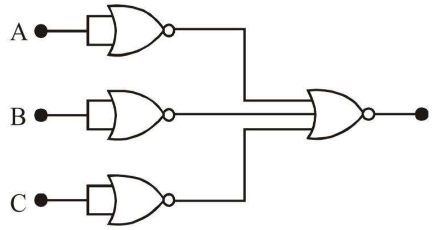
FINAL JEE–MAIN EXAMINATION – SEPTEMBER, 2020

(Held On Friday 04th SEPTEMBER, 2020) TIME : 3 PM to 6 PM

PHYSICS

TEST PAPER WITH ANSWER & SOLUTION

1. Identify the operation performed by the circuit given below :

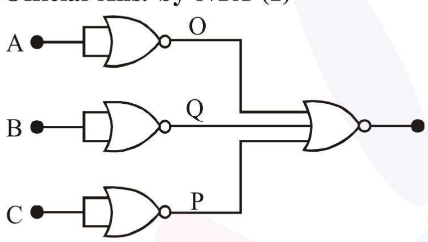


(1) AND (2) NAND

(3) OR (4) NOT

Official Ans. by NTA (1)

Sol.



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

2. Consider two uniform discs of the same thickness and different radii $R_1 = R$ and $R_2 = \alpha R$ made of the same material. If the ratio of their moments of inertia I_1 and I_2, respectively, about their axes is $I_1 : I_2 = 1 : 16$ then the value of α is :

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

Official Ans. by NTA (2)

Sol. $I_1 = \frac{MR^2}{2} = \frac{\rho(\pi R^2)t.R^2}{2}$

$I \propto R^4$

$$\frac{I_1}{I_2} = \frac{R_1^4}{R_2^4} = \frac{1}{16}$$

$$\therefore \frac{R_1}{R_2} = \frac{1}{2}$$

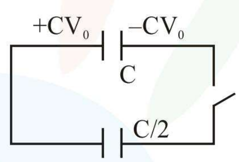
3. A capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance $\frac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitors is :

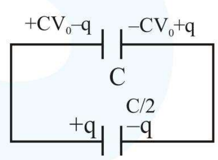
(1) $\frac{1}{6}CV_0^2$ (2) $\frac{1}{2}CV_0^2$

(3) $\frac{1}{3}CV_0^2$ (4) $\frac{1}{4}CV_0^2$

Official Ans. by NTA (4)

Sol.





$$\frac{CV_0 - q}{C} = \frac{q}{C/2} = \frac{2q}{C}$$

$$V_0 = \frac{3q}{C} \quad \Rightarrow q = \frac{CV_0}{3}$$

$$U_i = \frac{1}{2}CV_0^2$$

$$U_f = \frac{\left(\frac{2CV_0}{3}\right)^2}{2C} + \frac{\left(\frac{CV_0}{3}\right)^2}{2\left(\frac{C}{2}\right)}$$

$$= \frac{1}{2}CV_0^2\left[\frac{4}{9}+\frac{2}{9}\right] = \frac{1}{2}CV_0^2\left(\frac{2}{3}\right)$$

$$\text{Heat loss} = \frac{1}{2}CV_0^2 - \left(\frac{2}{3}\right)\left(\frac{1}{2}CV_0^2\right)$$

$$= \frac{1}{6}CV_0^2$$

4. A person pushes a box on a rough horizontal platform surface. He applies a force of 200 N over a distance of 15 m. Thereafter, he gets progressively tired and his applied force reduces linearly with distance of 100 N. The total distance through which the box has been moved is 30 m. What is the work done by the person during the total movement of the box ?

(1) 5690 J (2) 5250 J

(3) 3280 J (4) 2780 J

Official Ans. by NTA (2)

Sol. F = 200 N for $0 \le x \le 15$

$= 200 - \frac{100}{15}(x-15)$ for $15 \le x < 30$

$W = \int F\,dx$

$= \int_0^{15} 200\,dx + \int_{15}^{30}\left(300 - \frac{100}{15}x\right)dx$

$= 200 \times 15 + 300 \times 15 - \frac{100}{15} \times \frac{(30^2 - 15^2)}{2}$

= 3000 + 4500 − 2250

= 5250 J

5. The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$

Its magnetic field will be given by :

(1) $\frac{E_0}{c}(\hat{x} - \hat{y})\cos(kz - \omega t)$

(2) $\frac{E_0}{c}(-\hat{x} + \hat{y})\sin(kz - \omega t)$

(3) $\frac{E_0}{c}(\hat{x} - \hat{y})\sin(kz - \omega t)$

(4) $\frac{E_0}{c}(\hat{x} + \hat{y})\sin(kz - \omega t)$

Official Ans. by NTA (2)

Sol. $\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$

direction of propagation = $+\hat{k}$

$\hat{E} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$

$\hat{k} = \hat{E} \times \hat{B}$

$\hat{k} = \left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right) \times \hat{B} \quad \Rightarrow \hat{B} = \frac{-\hat{i} + \hat{j}}{\sqrt{2}}$

$\therefore \vec{B} = \frac{E_0}{C}(-\hat{x} + \hat{y})\sin(kz - \omega t)$

6. Find the bindng energy per nucleon for ${}^{120}_{50}Sn$.

Mass of proton m_P = 1.00783 U, mass of neutron m_n = 1.00867 U and mass of tin nucleus m_{Sn} = 119.902199 U. (take 1U = 931 MeV)

(1) 8.5 MeV (2) 7.5 MeV

(3) 8.0 MeV (4) 9.0 MeV

Official Ans. by NTA (1)

Sol. B.E. = $[\Delta m].c^2$

$M_{expected} = ZM_p + (A - Z)M_n$

= 50 [1.00783] + 70 [1.00867]

M_{actual} = 119.902199

B.E. = $[50[1.00783] + 70[1.00867] - 119.902199] \times 931$

= 1020.56

$\frac{BE}{nucleon} = \frac{1020.56}{120} = 8.5$ MeV

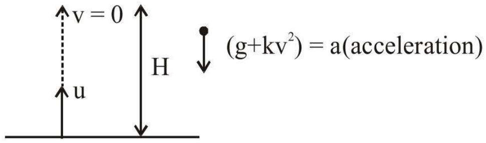
7. A small ball of mass is thrown upward with velocity u from the ground. The ball experiences a resistive force mkv^2 where v is its speed. The maximum height attained by the ball is :

(1) $\frac{1}{2k}\tan^{-1}\frac{ku^2}{g}$ (2) $\frac{1}{2k}\ln\left(1 + \frac{ku^2}{g}\right)$

(3) $\frac{1}{k}\tan^{-1}\frac{ku^2}{2g}$ (4) $\frac{1}{k}\ln\left(1 + \frac{ku^2}{2g}\right)$

Official Ans. by NTA (2)

Sol.



$\vec{F} = mkv^2 - mg$

$\vec{a} = \frac{\vec{F}}{m} = -\left[kv^2 + g\right]$

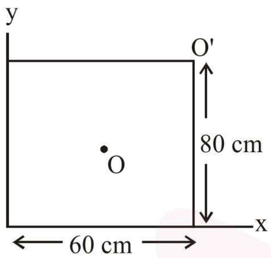
$\Rightarrow \quad v.\frac{dv}{dh} = -[kv^2 + g]$

$\Rightarrow \int_u^0 \frac{v.dv}{kv^2 + g} = -\int_0^H dh$

$\frac{1}{2K}\ln\left[kv^2 + g\right]_u^0 = -H$

$\Rightarrow \frac{1}{2K}\ln\left[\frac{ku^2 + g}{g}\right] = H$

8.

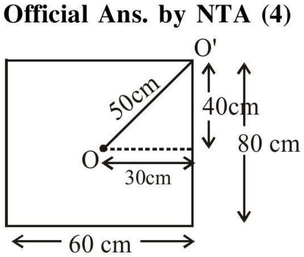


For a uniform rectangular sheet shown in the figure, the ratio of moments of inertia about the axes perpendicular to the sheet and passing through O (the centre of mass) and O' (corner point) is :

(1) 1/2 (2) 2/3 (3) 1/8 (4) 1/4

Official Ans. by NTA (4)

Sol.



Rectangular sheet

$I_O = \frac{M}{12}[L^2 + B^2] = \frac{M}{12}[80^2 + 60^2]$

$I_{O'} = I_0 + Md^2$ {parallel axis theorem}

$= \frac{M}{12}\left[80^2 + 60^2\right] + M\,[50]^2$

$\frac{I_O}{I_{O'}} = \frac{M/12[80^2 + 60^2]}{\frac{M}{12}[80^2 + 60^2] + M[50]^2} = \frac{1}{4}$

9. Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW is the work done and ΔU is change in internal energy of the system :

Process	Condition
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0$, $\Delta W \neq 0$, $\Delta Q \neq 0$
(IV) Isobaric	(D) $\Delta U = 0$

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

Official Ans. by NTA (1)

Sol. (I) Adiabatic process $\Rightarrow \Delta Q = 0$

No exchange of heat takes place with surroundings

(II) Isothermal proess $\Rightarrow$ Temperature remains constant ($\Delta T = 0$)

$\Delta u = \frac{F}{2}nR\Delta T \Rightarrow \Delta u = 0$

No change in internal energy [$\Delta u = 0$]

(III) Isochoric process Volume remains constant $\Delta V = 0$

$W = \int P.dV = 0$

Hence work done is zero.

(IV) Isobaric process $\Rightarrow$ Pressure remains constant

$W = P.\ \Delta V \neq 0$

$\Delta u = \frac{F}{2}nR\Delta T = \frac{F}{2}[P\Delta V] \neq 0$

$\Delta Q = nC_P\Delta T \neq 0$

10. A paramagnetic sample shows a net magnetisation of 6 A/m when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be :

(1) 4 A/m (2) 0.75 A/m
(3) 2.25 A/m (4) 1 A/m

Official Ans. by NTA (2)

Sol. For paramagnetic material
According to curies law

$$\chi \propto \frac{1}{T}$$

$$\chi \propto \frac{1}{T} \quad \Rightarrow \quad \chi_1 T_1 = \chi_2 T_2$$

$$\Rightarrow \frac{6}{0.4} \times 4 = \frac{I}{0.3} \times 24$$

$$I = \frac{0.3}{0.4} = 0.75 \text{ A/m}$$

11. A series L-R circuit is connected to a battery of emf V. If the circuit is switched on at t = 0, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is :

(1) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$ (2) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$

(3) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$ (4) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$

Official Ans. by NTA (3)

Sol. $U_{max} = \frac{1}{2}LI_{max}^2$

$$i = I_{max}\left(1 - e^{-Rt/L}\right)$$

For U to be $\frac{U_{max}}{n}$; i has to be $\frac{I_{max}}{\sqrt{n}}$

$$\frac{I_{max}}{\sqrt{n}} = I_{max}(1 - e^{-Rt/L})$$

$$e^{-Rt/L} = 1 - \frac{1}{\sqrt{n}} = \frac{\sqrt{n}-1}{\sqrt{n}}$$

$$-\frac{Rt}{L} = \ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$$

$$t = \frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$$

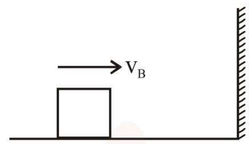
12. The driver of a bus approaching a big wall notices that the frequency of his bus's horn changes from 420 Hz to 490 Hz, when he hears it after it gets reflected from the wall. Find the speed of the bus if speed of the sound is 330 ms^{-1}.

(1) 91 kmh^{-1} (2) 71 kmh^{-1}

(3) 81 kmh^{-1} (4) 61 kmh^{-1}

Official Ans. by NTA (1)

Sol.



$$f_1 = \left(\frac{330}{330 - v_B}\right)420$$

$$f_2 = \left(\frac{330 + v_0}{330}\right)\left(\frac{330}{330 - v_B}\right)420$$

$$490 = \left(\frac{330 + v_B}{330 - v_B}\right)420$$

$$\frac{7}{6} = \frac{330 + v_B}{330 - v_B}$$

$$v_B = \frac{330}{13} \text{ m/s}$$

$$= \frac{330}{13} \times \frac{18}{5} \approx 91 \text{ km/hr}$$

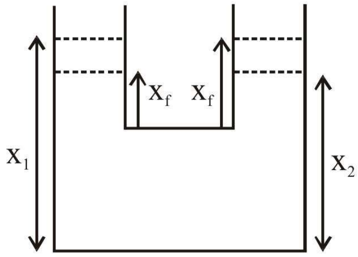
13. Two identical cylindrical vessels are kept on the ground and each contain the same liquid of density d. The area of the base of both vessels is S but the height of liquid in one vessel is x_1 and in the other, x_2. When both cylinders are connected through a pipe of negligible volume very close to the bottom, the liquid flows from one vessel to the other until it comes to equilibrium at a new height. The change in energy of the system in the process is :

(1) $gdS\,(x_2 + x_1)^2$ (2) $\frac{3}{4}gdS(x_2 - x_1)^2$

(3) $\frac{1}{4}gdS(x_2 - x_1)^2$ (4) $gdS(x_2^2 + x_1^2)$

Official Ans. by NTA (3)

Sol.



$U_i = (\rho S x_1)g \cdot \frac{x_1}{2} + (\rho S x_2)g \cdot \frac{x_2}{2}$

$U_f = (\rho S x_f)g \cdot \frac{x_f}{2} \times 2$

By volume conservation

$Sx_1 + Sx_2 = S(2x_f)$

$x_f = \frac{x_1 + x_2}{2}$

$\Delta U = \rho S g\left[\left(\frac{x_1^2}{2} + \frac{x_2^2}{2}\right) - x_f^2\right]$

$= \rho S g\left[\frac{x_1^2}{2} + \frac{x_2^2}{2} - \left(\frac{x_1 + x_2}{2}\right)^2\right]$

$= \frac{\rho S g}{2}\left[\frac{x_1^2}{2} + \frac{x_2^2}{2} - x_1 x_2\right]$

$= \frac{\rho S g}{4}(x_1 - x_2)^2$

14. A circular coil has moment of inertia 0.8 kg m^2 around any diameter and is carrying current to produce a magnetic moment of 20 Am^2. The coil is kept initially in a vertical position and it can rotate freely around a horizontal diameter. When a uniform magnetic field of 4T is applied along the vertical, it starts rotating around its horizontal diameter. The angular speed the coil acquires after rotating by 60° will be :

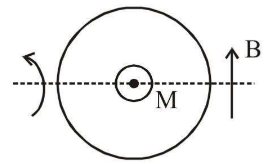
(1) 10 rad s^{-1} (2) 20 π rad s^{-1}

(3) 10 π rad s^{-1} (4) 20 rad s^{-1}

Official Ans. by NTA (1)

Sol. $I_{dia} = 0.8$ kg/m^2

$M = 20$ Am^2



$U_i + K_i = U_f + K_f$

$0 + 0 = -MB \cos 30° + \frac{1}{2} I\omega^2$

$20 \times 4 \times \frac{\sqrt{3}}{2} = \frac{1}{2}(0.8)\,\omega^2$

$\omega = \sqrt{100\sqrt{3}} = 10(3)^{1/4}$

15. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at x = 0. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is :

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

Official Ans. by NTA (4)

Sol. $E = E_0(1 - ax^2)$

$W = \int qE\,dx = qE_0 \int_0^{x_0} (1 - ax^2)\,dx$

$= qE_0\left[x_0 - \frac{ax_0^3}{3}\right]$

For $\Delta KE = 0$, $W = 0$

Hence $x_0 = \sqrt{\frac{3}{a}}$

16. A cube of metal is subjected to a hydrostatic pressure of 4 GPa. The percentage change in the length of the side of the cube is close to : (Given bulk modulus of metal, $B = 8 \times 10^{10}$ Pa)

(1) 0.6 (2) 1.67 (3) 5 (4) 20

Official Ans. by NTA (2)

Sol. $B = \dfrac{-\frac{\Delta P}{\Delta V}}{V}$

$\left|\dfrac{\Delta V}{V}\right| = \dfrac{\Delta P}{B}$

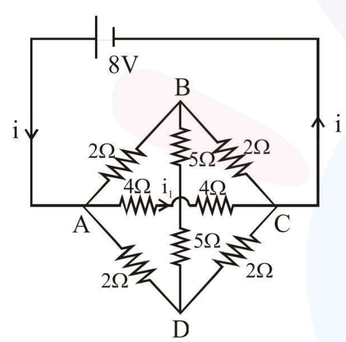
$= \dfrac{4\times10^{9}}{8\times10^{10}} = \dfrac{1}{20}$

$\dfrac{\Delta \ell}{\ell} = \dfrac{1}{3} \times \dfrac{\Delta V}{V} = \dfrac{1}{60}$

Percentage change $= \dfrac{\Delta \ell}{\ell}\times100\%$

$= \dfrac{100}{60}\% = 1.67\%$

17. The value of current i_1 flowing from A to C in the circuit diagram is :



(1) 5A (2) 2A (3) 4A (4) 1A

Official Ans. by NTA (4)

Sol. Voltage across AC = 8V

$R_{AC} = 4 + 4 = 8\Omega$

$i_1 = \dfrac{V}{R_{AC}} = \dfrac{8}{8} = 1\text{ A}$

18. A body is moving in a low circular orbit about a planet of mass M and radius R. The radius of the orbit can be taken to be R itself. Then the ratio of the speed of this body in the orbit to the escape velocity from the planet is :

(1) 1 (2) 2 (3) $\dfrac{1}{\sqrt{2}}$ (4) $\sqrt{2}$

Official Ans. by NTA (3)

Sol. $V_{orbit} = \sqrt{\dfrac{GM}{R}}$

$V_{escape} = \sqrt{\dfrac{2GM}{R}}$

$\dfrac{V_{orbit}}{V_{escape}} = \dfrac{1}{\sqrt{2}}$

19. A quantity x is given by (IFv^2/WL^4) in terms of moment of inertia I, force F, velocity v, work W and Length L. The dimensional formula for x is same as that of :

(1) Planck's constant

(2) Force constant

(3) Energy density

(4) Coefficient of viscosity

Official Ans. by NTA (3)

Sol. $x = \dfrac{IFV^2}{WL^4}$

$[x] = \dfrac{[ML^2][MLT^{-2}][LT^{-1}]^2}{[ML^2T^{-2}][L]^4}$

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

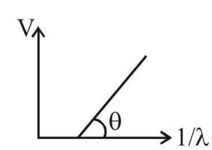
$[\text{Energy density}] = \left[\dfrac{E}{V}\right]$

$= \left[\dfrac{ML^2T^{-2}}{L^3}\right]$

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

Same as x

20. In a photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength obtained is shown in the figure. As the intensity of incident radiation is increased :



(1) Slope of the straight line get more steep

(2) Straight line shifts to left

(3) Graph does not change

(4) Straight line shifts to right

Official Ans. by NTA (3)

Sol. $eV = \frac{hc}{\lambda} - \phi$

$$V = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \phi$$

Slope of the line in above equation and all other terms are independent of intensity.

The graph does not change.

21. Orange light of wavelength 6000×10^{-10} m in illuminates a single slit of width 0.6×10^{-4} m. The maximum possible number of diffraction minima produced on both sides of the central maximum is ______.

Official Ans. by NTA (200)

Sol. Condition for minimum,

$d\sin\theta = n\lambda$

$$\therefore \sin\theta = \frac{n\lambda}{d} < 1$$

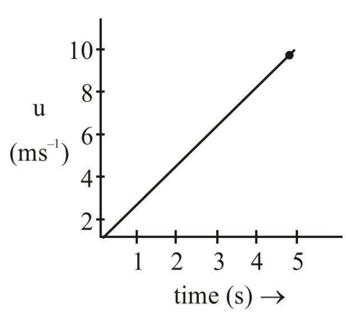
$$n < \frac{d}{\lambda} = \frac{6 \times 10^{-5}}{6 \times 10^{-7}} = 100$$

$\therefore$ Total number of minima on one side = 99

Total number of minima = 198

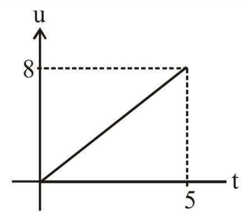
Correct Answer is 198

22. The speed verses time graph for a particle is shown in the figure. The distance travelled (in m) by the particle during the time interval t = 0 to t = 5s will be ______ :



Official Ans. by NTA (20)

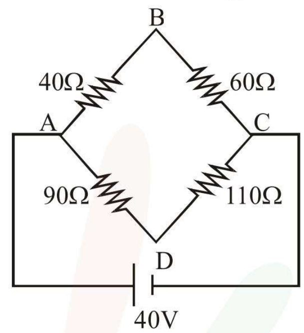
Sol.



Distance = $\int v\, dt$

Area under graph = $\frac{1}{2} \times 5 \times 8 = 20$

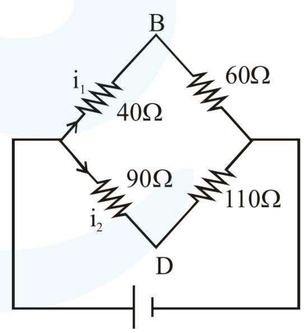
23.



Four resistances 40Ω, 60Ω, 90Ω and 110Ω make the arms of a quadrilateral ABCD. Across AC is a battery of emf 40V and internal resistance negligible. The potential difference across BD is V is _______.

Official Ans. by NTA (2)

Sol.



$$i_1 = \frac{40}{40+60} = 0.4$$

$$i_2 = \frac{40}{90+110} = \frac{1}{5}$$

$v_B + i_1(40) - i_2(90) = v_D$

$$v_B - v_D = \frac{1}{5}(90) - \frac{4}{10} \times 40$$

$v_B - v_D = 18 - 16 = 2$

24. The distance between an object and a screen is 100 cm. A lens can produce real image of the object on the screen for two different positions between the screen and the object. The distance between these two positions is 40 cm. If the power of the lens is close to $\left(\frac{N}{100}\right)$D where N is an integer, the value of N is ______.

Official Ans. by NTA (5)

Sol. Using displacement method

$$f = \frac{D^2 - d^2}{4D}$$

Here, D = 100 cm

d = 40 cm

$$f = \frac{100^2 - 40^2}{4(100)} = 21 \text{ cm}$$

$$P = \frac{1}{f} = \frac{100}{21} \text{ D} \qquad \frac{N}{100} = \frac{100}{21} \quad N = 476$$

25. The change in the magnitude of the volume of an ideal gas when a small additional pressure ΔP is applied at a constant temperature, is the same as the change when the temperature is reduced by a small quantity ΔT at constant pressure. The initial temperature and pressure of the gas were 300 K and 2 atm respectively. If |ΔT| = C|ΔP| then value of C in (K/atm) is ______:

Official Ans. by NTA (150)

Sol. $PV = nRT$

$P\Delta V + V\Delta P = 0$ (for constant temp.)

$P\Delta V = nR\Delta T$ (for constant pressure)

$$\Delta T = \frac{P\Delta V}{nR}$$

$$\Delta P = -\frac{P\Delta V}{V} \qquad (\Delta V \text{ is same in both cases})$$

$$\frac{\Delta T}{\Delta P} = \frac{P\Delta V}{nR}\frac{V}{-P\Delta V} = \frac{-V}{nR} = -\frac{T}{P}$$

(PV = nRT)

$$\left(\frac{V}{nR} = \frac{T}{P}\right) \qquad \left|\frac{\Delta T}{\Delta P}\right| = \left|\frac{-300}{2}\right| = 150$$