PART –A (PHYSICS)

Questions: **1:-** The value of numerical aperature of the objective lens of a microscope is 1.25. If light of wavelength 5000 Å is used, the minimum separation between two points, to be seen as distinct, will be :

(A) 0.48 μm   (B) 0.38 μm
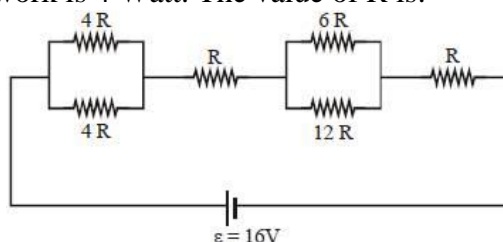(C) 0.24 μm   (D) 0.12 μm

Ans:- **C**

Numerical aperature of the microscope is given as

$$NA = \frac{0.61\lambda}{d}$$

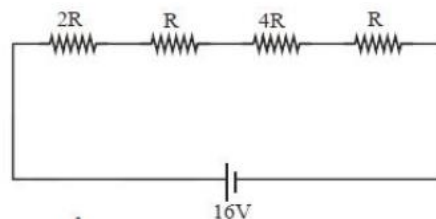Where d = minimum sparaton between two points to be seen as distinct

$$d = \frac{0.61\lambda}{NA} = \frac{(0.61) \times (5000 \times 10 \, m^{-10})}{1.25} = 2.4 \times 10^{-7} \, m$$

$$= 0.24 \, \mu m$$

Questions: **2:-** The resistive network shown below is connected to a D.C. source of 16 V. The power consumed by the network is 4 Watt. The value of R is:


(A) 8 Ω   (B) 6 Ω
(C) 16 Ω   (D) 1 Ω

Ans:- **A**

$$P = \frac{16^2}{8R} = 4$$

$$\therefore \quad R = 8\Omega$$

Questions: **3:-** The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole set up is moving towards right with a constant speed of 1 cms⁻¹. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7 Ω, the current in the loop at that instant will be close to :

v=1cm/sec
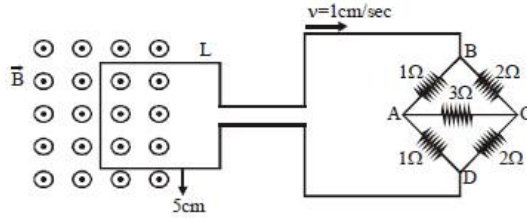
(A) 115 μA   (B) 170 μA
(C) 60 μA   (D) 150 μA

Ans:- **B**

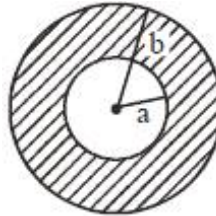Since it is a balanced wheatstone bridge, its equivalent resistance = $\dfrac{4}{3}\Omega$

$\varepsilon = B\ell v = 5 \times 10^{-4}$ V

So total resistance

$R = \dfrac{4}{3} + 1.7 \approx 3\Omega$

$\therefore \quad i = \dfrac{\varepsilon}{R} \approx 166\ \mu A \approx 170\ \mu A$

Questions: **4**:- A circular disc of radius b has a hole of radius a at its centre (see figure). If the mass per unit area of the disc varies as $\left(\dfrac{\sigma_0}{r}\right)$, then the radius of gyration of the disc about its axis passing through the centre is :

(A) $\dfrac{a+b}{3}$

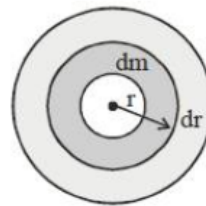(B) $\sqrt{\dfrac{a^2 + b^2 + ab}{3}}$

(C) $\dfrac{a+b}{2}$

(D) $\sqrt{\dfrac{a^2 + b^2 + ab}{2}}$

Ans:- **B**

$dI = (dm)r^2$

$= (\sigma\, dA)r^2$

$= \left(\dfrac{\sigma_0}{r}\, 2\pi dr\right)r^2 = (\sigma_0\, 2\pi_0 r^2 dr$

$I = \int DI = \int\limits_a^b \sigma_0 2\pi r^2 dr$

$= \sigma_0 2\pi \left(\dfrac{b^3 - a^3}{3}\right)$

$m = \int dm = \int \sigma dA$

$= \sigma_0 2\pi \int\limits_a^b dr$

Questions: 5:- A man (mass = 50 kg) and his son (mass = 20 kg) are standing on a frictionless surface facing each other. The man pushes his son so that he starts moving at a speed of 0.70 ms^{-1} with respect to the man. The speed of the man with respect to the surface is:
(A) 0.47 m^{s-1}
(B) 0.28 ms^{-1}
(C) 0.14 ms^{-1}
(D) 0.20 ms^{-1}

Ans:- **D**
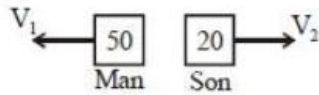
$\Rightarrow$ 0 = 50V$_1$ – 20V$_2$ and V$_1$ + V$_2$ = 0.7
$\Rightarrow$ V$_1$ = 0.2

Questions: 6:- Two identical parallel plate capacitors, of capacitance C each, have plates of area A, separated by a distance d. The space between the plates of the two capacitors, is filled with three dielectrics, of equal thickness and dielectric constants 1K , 2K and 3K . The first capacitor is filled as shown in fig. I, and the second one is filled as shown in fig. II. If these two modified capacitors are charged by the same potential V, the ratio of the energy stored in the two, would be (1E refers to capacitor (I) and 2E to capacitor (II)) :
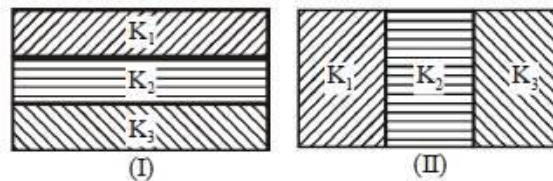
(A) $\dfrac{E_1}{E_2} = \dfrac{K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

(B) $\dfrac{E_1}{E_2} = \dfrac{9K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

(C) $\dfrac{E_1}{E_2} = \dfrac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{9K_1K_2K_3}$

(D) $\dfrac{E_1}{E_2} = \dfrac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{K_1K_2K_3}$
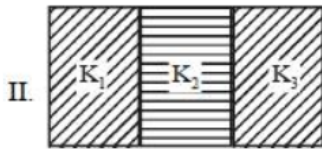
Ans:- **B**

I.
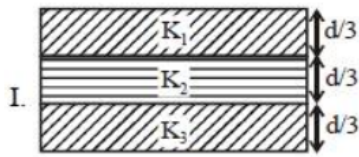
$$C_1 = \frac{3\varepsilon_0 A K_1}{d}$$

$$C_2 = \frac{3\varepsilon_0 A K_2}{d}$$

$$C_3 = \frac{3\varepsilon_0 A K_3}{d}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow \quad C_{eq} = \frac{3\varepsilon_0 A K_1 K_2 K_3}{d(K_1 K_2 + K_2 K_3 + K_3 K_1)} \qquad \ldots(i)$$

II.

$$C_1 = \frac{\varepsilon_0 K_1 A}{3d}$$

$$C_2 = \frac{\varepsilon_0 K_2 A}{3d}$$

$$C_3 = \frac{\varepsilon_0 K_3 A}{3d}$$

$$C'_{eq} = C_1 + C_2 + C_3$$

$$= \frac{\varepsilon_0 A}{3d}(K_1 + K_2 + K_3) \qquad \ldots(ii)$$

Now,

$$\frac{E_1}{E_2} = \frac{\frac{1}{2}C_{eq}\cdot V^2}{\frac{1}{2}C'_{eq}V^2} = \frac{9 K_1 K_2 K_3}{(K_1 + K_2 + K_3)(K_1 K_2 + K_2 K_3 + K_3 K_1)}$$

Questions: **7**:- Two moles of helium gas is mixed with three moles of hydrogen molecules (taken to be rigid). What is the molar specific heat of mixture at constant volume? (R = 8.3 J/mol K)

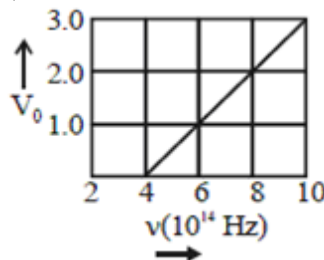(A) 17.4 J/mol K (B) 15.7 J/mol K
(C) 19.7 J/mol K (D) 21.6 J/mol K

Ans:- **A**

$$f_{mix} = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2} = \frac{2\times 3 + 3\times 5}{5} = \frac{21}{5}$$

$$C_v = \frac{fR}{5} = \frac{21}{5}\times\frac{R}{2} = 17.4 \text{ J/mol K}$$

Questions: **8**:- The stopping potential V_0 (in volt) as a function of frequency (ν) for a sodium emitter, is shown in the figure. The work function of sodium, from the data plotted in the figure, will be: (Given: Planck's constant (h) = 6.63×10^{-34} Js, electron charge e = 1.6×10^{-19} C)

(A) 1.82 eV   (B) 1.66 eV
(C) 2.12 eV   (D) 1.95 eV

Ans:- **B**

$$hv = \phi + ev_0$$

$$v_0 = \frac{hv}{e} - \frac{\phi}{e}$$

v_0 is zero for $v = 4 \times 10^{14}$ Hz

$$0 = \frac{hv}{e} - \frac{\phi}{e}$$

$$\Rightarrow \phi = hv$$

$$= \frac{6.63 \times 10^{-34} \times 4 \times 10^{14}}{1.6 \times 10^{-19}} = 1.66 \text{ eV}$$

Questions: **9**:- At 40°C, a brass wire of 1 mm is hung from the ceiling. A small mass, M is hung from the free end of the wire. When the wire is cooled down from 40 ° C to 20 ° C, it regains its original length of 0.2 m. The value of M is close to:
(Coefficient of linear expansion and Young's modulus of brass are 10^{-5}/°C and 10^{11} respectively; $g = 10\text{ms}^{-2}$)
(A) 0.5 kg   (B) 9 kg
(C) 0.9 kg   (D) 1.5 kg
Ans: - **B**

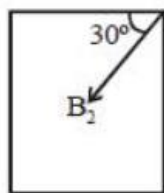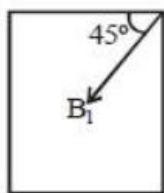$$Mg = \left(\frac{Ay}{\ell}\right)\Delta\ell$$

$$Mg = (Ay)\alpha\Delta T = 2\pi$$
It is closest to 9.

Questions: **10**:- A magnetic compass needle oscillates 30 times per minute at a place where the dip is 45°, and 40 times per minute where the dip is 30°. If B_1 and B_2 are respectively the total magnetic field due to the earth at the two places, then the ratio B_1/B_2 is best given by:
(A) 3.6   (B) 1.8
(C) 2.2   (D) 0.7
Ans:- **D**

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{\mu B_1 \cos 45°}{I}} \qquad f_2 = \frac{1}{2\pi}\sqrt{\frac{\mu B_2 \cos 30°}{I}}$$

$$\frac{f_1}{f_2} = \frac{B_1 \cos 45°}{B_2 \cos 30°}$$

$$\therefore \quad \frac{B_1}{B_2} \times 0.7$$

Questions: **11**:- An excited He ion emits two photons in succession, with wavelengths 108.5 nm and 30.4 nm, in making a transition to ground state. The quantum number n, corresponding to its initial excited state is (for photon of wavelengthλ, energy $E = \frac{1240 \; eV}{\lambda \;(in \; nm)}$:)
(A) n = 4   (B) n = 6
(C) n = 5   (D) n = 7

Ans:- **C**

$$\frac{1}{\lambda} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)z^2$$

$$\frac{1}{1085} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)2^2$$

$\therefore$ m = 2

$\therefore$ n = 5

Questions: 12:-
When M_1 gram of ice at $-10°C$ (specific heat = 0.5 cal $g^{-1}°C^{-1}$) is added to M_2 gram of water
at 50°C, finally no ice is left and the water is at 0°C. The value of latent heat of ice, in cal g^{-1} is:

(A) $\dfrac{50M_2}{M_1} - 5$

(B) $\dfrac{5M_2}{M_1} - 5$

(C) $\dfrac{50M_2}{M_1}$

(D) $\dfrac{5M_1}{M_2} - 50$

Ans:- **A**

Heat lost = Heat gain

$\Rightarrow \quad M_2 \times 1 \times 50 = M_1 \times 0.5 \times 10 + M_1.L_f$

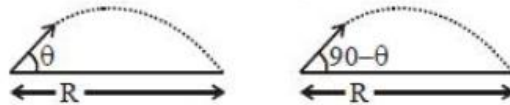$\Rightarrow \quad L_f = \dfrac{50M_2 - 5M_1}{M_1}$

$\qquad = \dfrac{50M_2}{M_1} - 5$

Questions: 13:- A shell is fired from a fixed artillery gun with an initial speed u such that it hits the target on the ground at a distance R from it. If t_1 and t_2 are the values of the time taken by it to hit the target in two possible ways, the product $t_1 t_2$ is:
(A) 2R / g
(B) R / 4g
(C) R / g
(D) R/2g

Ans:- **A**

Range will be same for time t_1 and t_2, so angles of projection will be 'θ' & '$90° - \theta$'
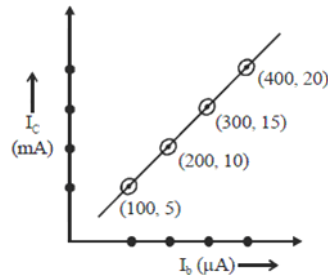

$t_1 = \dfrac{2u\sin\theta}{g}$, $t_2 = \dfrac{2u\sin(90° - \theta)}{g}$ and $R = \dfrac{u^2\sin2\theta}{g}$

$t_1t_2 = \dfrac{4u^2\sin\theta\cos\theta}{g^2} = \dfrac{2}{g}\left[\dfrac{2u^2\sin\theta\cos\theta}{g}\right]$

$\qquad = \dfrac{2R}{g}$

Questions: **14**:- The transfer characteristic curve of a transistor, having input and output resistance 100Ω and $100\ k\Omega$ respectively, is shown in the figure. The Voltage and Power gain, are respectively :

(A) $5\times10^4, 2.5\times10^6$

(B) $5\times10^4, 5\times10^6$

(C) $5\times10^4, 5\times10^5$

(D) $2.5\times10^4, 2.5\times10^6$

Ans:- **A**

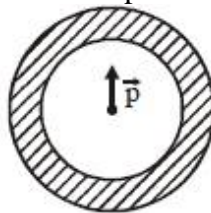$$V_{gain} = \left(\frac{\Delta I_C}{\Delta I_B}\right)\frac{R_{out}}{R_{in}} = \left(\frac{5\times10^{-3}}{100\times10^{-6}}\right)\times10^3$$

$$= \frac{1}{20}\times10^8 = 5\times10^4$$

$$P_{gain} = \left(\frac{\Delta I_C}{\Delta I_b}\right)(V_{gain})$$

$$= \left(\frac{5\times10^{-3}}{100\times10^{-6}}\right)(5\times10^4)$$

$$= 2.5\times10^6$$

Questions: **15**:- Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{P}$ as shown. In this case:


(A) Surface charge density on the inner surface of the shell is zero everywhere.

(B) Electric field outside the shell is the same as that of a point charge at the centre of the shell.

(C) Surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$

(D) Surface charge density on the outer surface depends on $|\vec{P}|$

Ans:- **B**

Total charge of dipole = 0, so charge induced on outside surface = 0.

But due to non uniform electric field of dipole, the charge induced on inner surface is non zero and non uniform.

So, for any observer outside the shell, the resultant electric field is due to Q uniformly distributed on outer surface only and it is equal to.
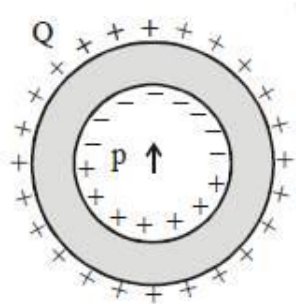
$$E = \frac{KQ}{r^2}$$

Questions: **16:-** Which of the following combinations has the dimension of electrical resistance ($\in_0$ is the permittivity of vacuum and μ_0 is the permeability of vacuum)?

(A) $\sqrt{\dfrac{\epsilon_0}{\mu_0}}$

(B) $\dfrac{\mu_0}{\epsilon_0}$

(C) $\dfrac{\epsilon_0}{\mu_0}$
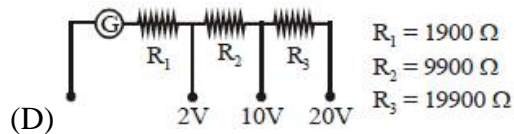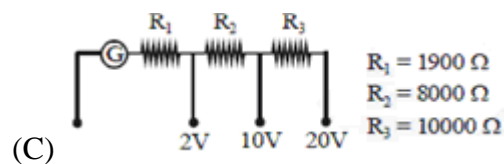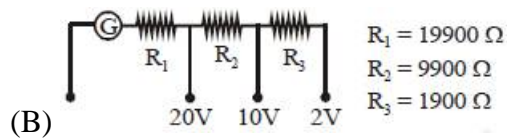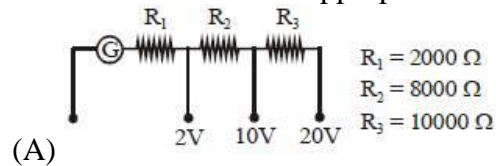
(D) $\sqrt{\dfrac{\mu_0}{\epsilon_0}}$

Ans:- **D**

$[\epsilon_0] = M^{-1} L^{-3} T^4 A^2$

$[\mu_0] = M L T^{-2} A^{-2}$

$[R] = M L^2 T^{-3} A^{-2}$

$$[R] = \left[\sqrt{\frac{\mu_0}{\epsilon_0}} \right]$$

Questions: **17:-** A galvanometer of resistance 100 Ω has 50 divisions on its scale and has sensitivity of 20 μA / division. It is to be converted to a voltmeter with three ranges, of 0–2 V, 0–10 V and 0–20 V. The appropriate circuit to do so is:

(A)

$R_1 = 2000\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

(B)

$R_1 = 19900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 1900\ \Omega$

(C)

$R_1 = 1900\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

(D)

$R_1 = 1900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 19900\ \Omega$

Ans:- **C**

$20 \times 50 \times 10^{-6} = 10^{-3}$ Amp.

$V_1 = \dfrac{2}{10^{-3}} = 100 + R_1$

$1900 = R_1$

$V_2 = \dfrac{10}{10^{-3}} = (2000 + R_2)$

$R_2 = 8000$

$V_3 = \dfrac{20}{10^{-3}} = 10 \times 10^3 + R_3 = 10 \times 10^3 \, R_3$

Questions: 18:- In a double slit experiment, when a thin film of thickness t having refractive index µ is introduced in front of one of the slits, the maximum at the centre of the fringe pattern shifts by one fringe width. The value of t is (λ is the wavelength of the light used):

(A) $\dfrac{\lambda}{2(\mu - 1)}$

(B) $\dfrac{\lambda}{(\mu - 1)}$

(C) $\dfrac{\lambda}{(2\mu - 1)}$

(D) $\dfrac{2\lambda}{(\mu - 1)}$
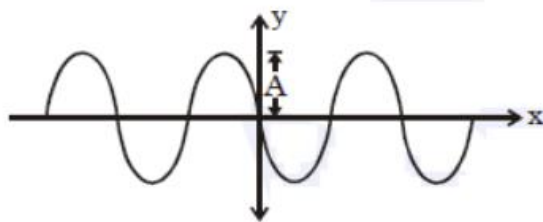
Ans: - **B**

$\Delta x = (\mu - 1)t = 1\lambda$
for one maximum shift
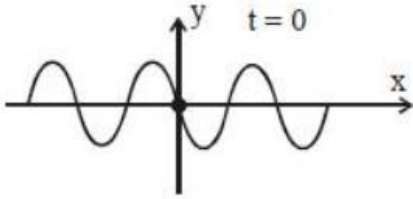
$t = \dfrac{\lambda}{\mu - 1}$

Questions: 19:-

A progressive wave travelling along the positive x-direction is represented by $y(x, t) = A$ sin
$(kx - \omega t + \phi)$. Its snapshot at t = 0 is given in the figure:
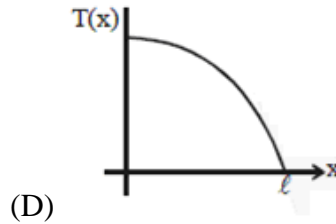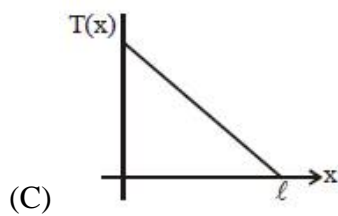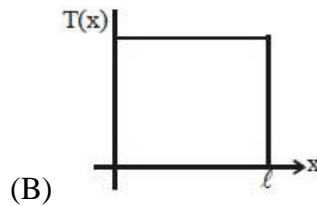

For this wave, the phase ϕ is :
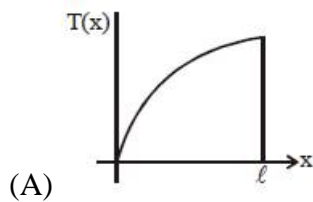
(A) π

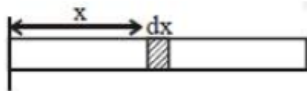(B) $\dfrac{\pi}{2}$

(C) $-\dfrac{\pi}{2}$

(D) 0

Ans: - **A**

$$y = A \sin (kx - wt + \phi)$$

at $x = 0$, $t = 0$ and slope is negative

$\Rightarrow \phi = \pi$

Questions: 20:- A uniform rod of length ℓ is being rotated in a horizontal plane with a constant angular speed about an axis passing through one of its ends. If the tension generated in the rod due to rotation is $T(x)$ at a distance x from the axis, then which of the following graphs depicts it most closely?

(A)

(B)

(C)

(D)

Ans: - D

$$T = \int_{x=x}^{x=\ell} dm\omega^2 x = \int_{x=x}^{x=\ell} \frac{m}{\ell} dx\omega^2 x \ T$$

$$= \frac{m\omega^2}{2\ell}(\ell^2 - x^2)$$

$$T = \frac{m\omega^2}{2\ell}(\ell^2 - x^2)$$