PAPER : IIT-JAM 2019

PHYSICS-PH

1. **Section-A contains 30 Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which ONLY ONE is correct. From Q.1 to Q.10 carries 1 Marks and Q.11 to Q.30 carries 2 Marks each.**
2. **Section-B contains 10 Multiple Select Questions(MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE or MORE than ONE is/are correct. For each correct answer you will be awarded 2 marks.**
3. **Section-C contains 20 Numerical Answer Type (NAT) questions. From Q.01 to Q.10 carries 1 Mark each and Q.11 to Q.20 carries 2 Marks each. For each NAT type question, the value of answer in between 0 to 9.**
4. **In all sections, questions not attempted will result in zero mark. In Section–A (MCQ), wrong answer will result in negative marks. For all 1 mark questions, 1/3 marks will be deducted for each wrong answer. For all 2 marks questions, 2/3 marks will be deducted for each wrong answer. In Section–B (MSQ),there is no negative and no partial marking provisions. There is no negative marking in Section–C (NAT) as well.**

SECTION-A

Multiple Choice Questions (MCQ)

Q.1 – Q.10 carry one mark each.

1. In a heat engine based on the Carnot cycle, heat is added to the working substance at constant

   (a) Entropy (b) Pressure (c) Temperature (d) Volume

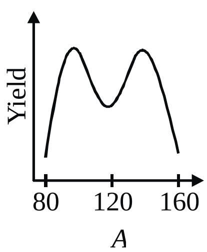
2. If $\phi(x, y, z)$ is a scalar function which satisfies the Laplace equation, then the gradient of ϕ is

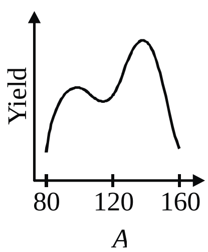
   (a) solenoidal and irrotational (b) solenoidal but not irrotational
   (c) irrotational but not solenoidal (d) neither solenoidal nor irrotational

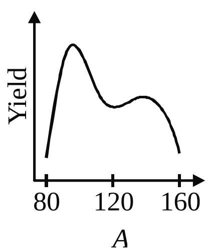
3. The function $f(x)=\dfrac{8x}{x^2+9}$ is continuous everywhere except at

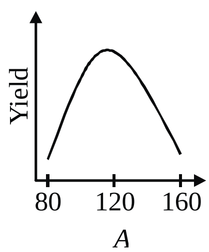
   (a) $x=0$ (b) $x=\pm 9$ (c) $x=\pm 9i$ (d) $x=\pm 3i$

4. In the thermal neutron induced fission of ^{235}U, the distribution of relative number of the observed fission fragments (Yield) versus mass number (A) is given by

   (a) 

   (b) 

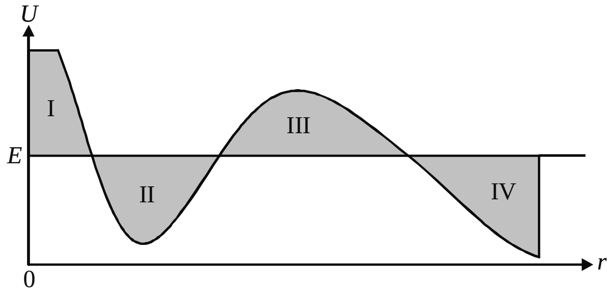
   (c) 

   (d) 

5. Isothermal compressibility is given by

   (a) $\dfrac{1}{V}\left(\dfrac{\partial V}{\partial P}\right)_T$ (b) $\dfrac{1}{P}\left(\dfrac{\partial P}{\partial V}\right)_T$ (c) $-\dfrac{1}{V}\left(\dfrac{\partial V}{\partial P}\right)_T$ (d) $-\dfrac{1}{P}\left(\dfrac{\partial P}{\partial V}\right)_T$

6. A classical particle has total energy E. The plot of potential energy (U) as a function of distance (r) from the centre of force located at $r = 0$ is shown in the figure. Which of the regions are forbidden for the particle ?



(a) I and II (b) II and IV (c) I and IV (d) I and III

7. The Fermi-Dirac distribution function $[n(\varepsilon)]$ is

(k_B is the Boltzmann constant, T is the temperature and ε_F is the Fermi energy)

(a) $n(\varepsilon)=\dfrac{1}{e^{\frac{\varepsilon-\varepsilon_F}{k_BT}}-1}$ (b) $n(\varepsilon)=\dfrac{1}{e^{\frac{\varepsilon_F-\varepsilon}{k_BT}}-1}$ (c) $n(\varepsilon)=\dfrac{1}{e^{\frac{\varepsilon-\varepsilon_F}{k_BT}}+1}$ (c) $n(\varepsilon)=\dfrac{1}{e^{\frac{\varepsilon_F-\varepsilon}{k_BT}}+1}$

8. For using a transistor as an amplifier, choose the correct option regarding the resistance of base-emitter (R_{BE}) and base-collector (R_{BC}) junctions

(a) Both R_{BE} and R_{BC} are very low (b) Very low R_{BE} and very high R_{BC}

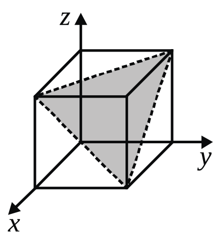
(c) Very high R_{BE} and very low R_{BC} (d) Both R_{BE} and R_{BC} are very high

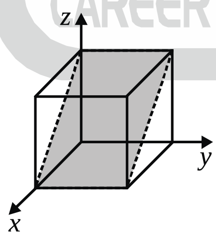
9. A unit vector perpendicular to the plane containing $\vec{A}=\hat{i}+\hat{j}-2\hat{k}$ and $\vec{B}=2\hat{i}-\hat{j}+\hat{k}$ is

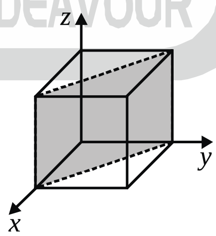
(a) $\frac{1}{\sqrt{26}}\left(-\hat{i}+3\hat{j}-4\hat{k}\right)$ (b) $\frac{1}{\sqrt{19}}\left(-\hat{i}+3\hat{j}-3\hat{k}\right)$

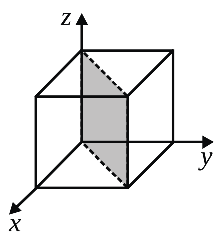
(c) $\frac{1}{\sqrt{35}}\left(-\hat{i}+5\hat{j}-3\hat{k}\right)$ (d) $\frac{1}{\sqrt{35}}\left(-\hat{i}-5\hat{j}-3\hat{k}\right)$

10. Which one of the following crystallographic planes represent (101) Miller indices of a cubic unit cell?

(a) 

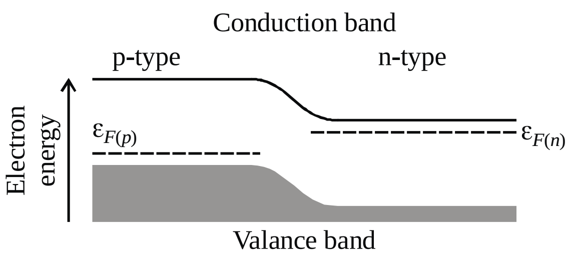
(b) 

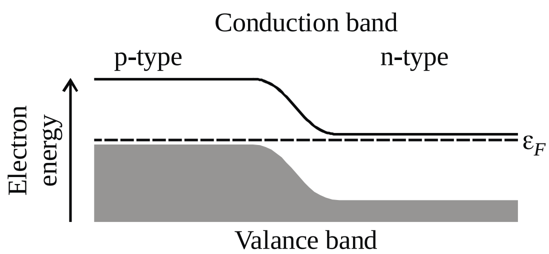
(c) 

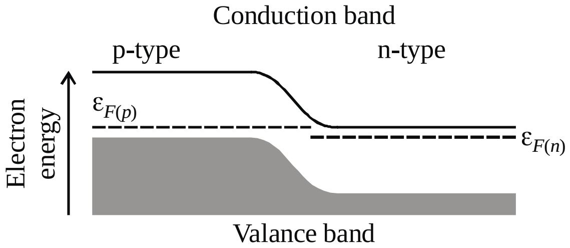
(d) 

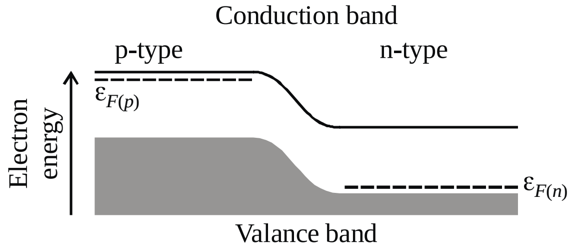
Q.11 – Q.30 carry two marks each.

11. For a forward biased p-n junction diode, which one of the following energy-band diagrams is correct?

(a) 

(b) 

(c) 

(d) 

12. For a quantum particle confined inside a cubic box of side L, the ground state energy is given by E_0. The energy of the first excited state is

(a) $2E_0$ (b) $\sqrt{2}E_0$ (c) $3E_0$ (d) $6E_0$

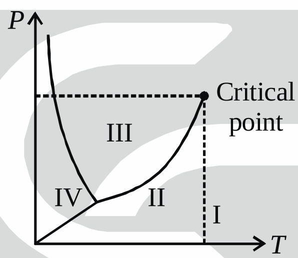
13. A thin lens of refractive index 3/2 kept inside a liquid of refractive index 4/3. If the focal length of the lens in air is 10 cm, then its focal length inside the liquid is

(a) 10 cm (b) 30 cm (c) 40 cm (d) 50 cm

14. The mass per unit length of a rod (length 2m) varies as $\rho = 3x$ kg/m. The moment of inertia (in kg m^2) of the rod about a perpendicular-axis passing through the tip of the rod (at $x = 0$) is

(a) 10 (b) 12 (c) 14 (d) 16

15. In the given phase diagram for a pure substance, regions I, II, III, IV respectively represent



(a) Vapor, Gas, Solid, Liquid (b) Gas, Vapor, Liquid, Solid
(c) Gas, Liquid, Vapor, Solid (d) Vapor, Gas, Liquid, Solid

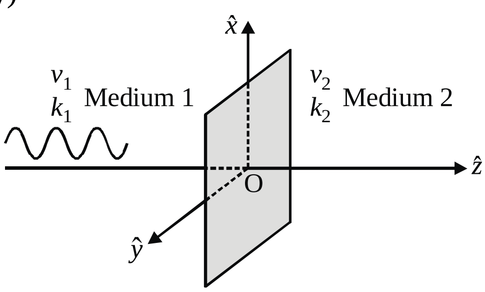
16. Light of wavelength λ (in free space) propagates a dispersive medium with refractive index $n(\lambda) = 1.5 + 0.6\lambda$. The group velocity of a wave travelling inside this medium in units of 10^8 m/s is

(a) 1.5 (b) 2.0 (c) 3.0 (d) 4.0

17. Consider the normal incidence of a plane electromagnetic wave with electric field given by

$$\vec{E} = E_0 \exp\left[i(k_1 z - \omega t)\right]\hat{x}$$

over an interface at $z = 0$ separating two media [wave velocities v_1 and v_2 $(v_2 > v_1)$ and wave vectors k_1 and k_2, respectively] as shown in figure. The magnetic field vector of the reflected wave is
(ω is the angular frequency)



(a) $\frac{E_0}{v_1}\exp\left[i(k_1z-\omega t)\right]\hat{y}$ (b) $\frac{E_0}{v_1}\exp\left[i(-k_1z-\omega t)\right]\hat{y}$

(c) $-\frac{E_0}{v_1}\exp\left[i(-k_1z-\omega t)\right]\hat{y}$ (d) $-\frac{E_0}{v_1}\exp\left[i(k_1z-\omega t)\right]\hat{y}$

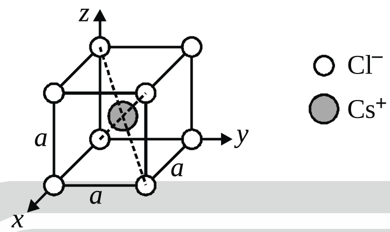
18. If the motion of a particle is described by $x = 5\cos(8\pi t)$, $y = 5\sin(8\pi t)$ and $z = 5t$, then the trajectory of the particle is

(a) circular (b) elliptical (c) helical (d) spiral

19. A γ-ray photon emitted from a ^{137}Cs source collides with an electron at rest. If the Compton shift of the photon is 3.25×10^{-13} m, then the scattering angle is closest to (Planck's constant $h = 6.626 \times 10^{-34}$ J s, electron mass $m_e = 9.109\times10^{-31}$ kg and velocity of light in free space $c = 3\times10^8$ m/s)

(a) 45º (b) 60º (c) 30º (d) 90º

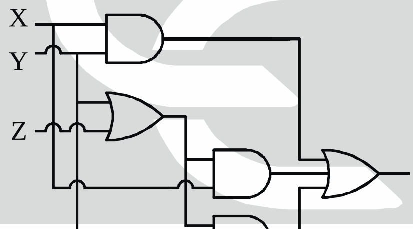
20. The location of Cs^+ and Cs^- ions inside the unit cell of CsCl crystal is shown in the fugure.
The Bravais lattice of CsCl is



(a) simple cubic (b) body centered orthorhombic

(c) face centered cubic (d) basic centered orthorhombic

21. The output of following logic circuit can be simplified to



(a) X + YZ (b) Y + XZ (c) XYZ (d) X + Y + Z

22. The amount of work done to increase the speed of an electron from $c/3$ to $2c/3$ is
($c = 3 \times 10^8$ m/s and rest mass of electron is 0.511 MeV)

(a) 56.50 keV (b) 143.58 keV (c) 168.20 keV (d) 511.00 keV

23. During the charging of a capacitor C in a series RC circuit, the typical variations in the magnitude of the charge $q(t)$ deposited on one of the capacitor plates, and the current $i(t)$ in the circuit, respectively are best represented by

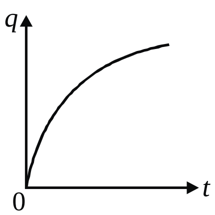


Fig. I

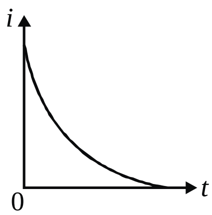


Fig. II

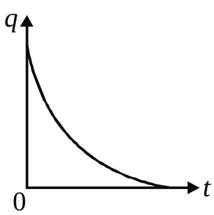


Fig. III

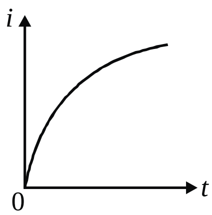
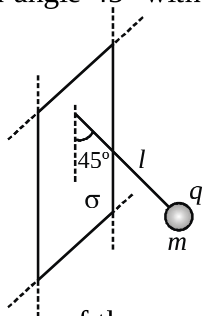


Fig. IV

(a) Fig. I and Fig. II (b) Fig. I and Fig. IV (c) Fig. III and Fig. II (d) Fig. III and Fig. IV

24. A small spherical ball having charge q and mass m, is tied to a thin massless non-conducting string of length l. The other end of the string is fixed to an infinitely extended thin non-conducting sheet with uniform surface charge density σ. Under equilibrium, the string makes an angle 45° with the sheet as shown in the figure. Then σ is given by

(g is the acceleration due to gravity and ε_0 is the permittivity of free space)



(a) $\dfrac{mg\varepsilon_0}{q}$ (b) $\sqrt{2}\dfrac{mg\varepsilon_0}{q}$

(c) $2\dfrac{mg\varepsilon_0}{q}$ (d) $\dfrac{mg\varepsilon_0}{q\sqrt{2}}$

25. During free expansion of an ideal gas under adiabatic condition, the internal energy of the gas

(a) Decreases (b) Initially decreases and then increases

(c) Increases (d) Remains constant

26. Which one of the following is an impossible magnetic field $\vec{B}$?

(a) $\vec{B} = 3x^2 z^2\,\hat{x} - 2xz^3\,\hat{z}$ (b) $\vec{B} = -2xy\,\hat{x} + yz^2\,\hat{y} + \left(2yz - \dfrac{z^3}{3}\right)\hat{z}$

(c) $\vec{B} = (xz + 4y)\,\hat{x} - yx^3\,\hat{y} + \left(x^2 z - \dfrac{z^2}{2}\right)\hat{z}$ (d) $\vec{B} = -6xz\,\hat{x} + 3yz^2\,\hat{y}$

27. The maximum number of intensity minima that can be observed in the Fraunhofer diffraction pattern of a single slit (width 10 μm) illuminated by a laser beam (wavelength 0.630 μm) will be

(a) 4 (b) 7 (c) 12 (d) 15

28. The eigenvalues of $\begin{pmatrix} 3 & i & 0 \\ -i & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$ are

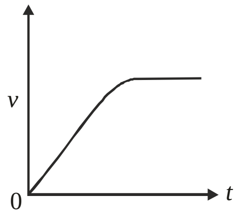
(a) 2, 4 and 6 (b) $2i$, $4i$ and 6 (c) $2i$, 4 and 8 (d) 0, 4 and 8

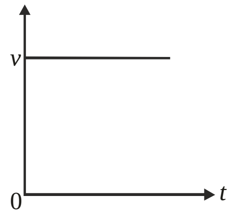
29. A red star having radius r_R at a temperatrue T_R and a white star having radius r_w at a temperatrue T_W, radiate the same total power. If these stars radiate as perfect black bodies.

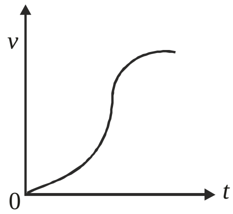
(a) $r_R > r_w$ and $T_R > T_W$ (b) $r_R < r_w$ and $T_R > T_W$

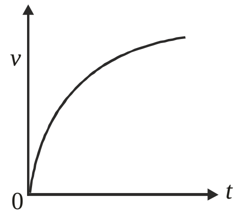
(c) $r_R > r_w$ and $T_R < T_W$ (d) $r_R < r_w$ and $T_R < T_W$

30. A ball of mass m is falling freely under gravity through a viscous medium in which the drag force is proportional to the instantaneous velocity v of the ball. Neglecting the buoyancy force of the medium. which one of the following figures best describes the variation of v as a function of time t ?

(a)


(b)


(c)


(d)


SECTION-B

Multiple Select Questions (MSQ)

Q.1 – Q.10 carry TWO marks each.

1. Consider an object moving with a velocity $\vec{v}$ in a frame which rotates with a constant angular velocity $\vec{\omega}$.The Coriolis force experienced by the object is

(a) along $\vec{v}$ (b) along $\vec{\omega}$
(c) perpendicular to both $\vec{v}$ and $\vec{\omega}$ (d) always directed towards the axis of rotation

2. A thermodynamic system is described by the P,V,T Choose the valid expression(s) for the system.

(a) $\left(\frac{\partial P}{\partial V}\right)_T\left(\frac{\partial V}{\partial T}\right)_P=-\left(\frac{\partial P}{\partial T}\right)_V$ (b) $\left(\frac{\partial P}{\partial V}\right)_T\left(\frac{\partial V}{\partial T}\right)_P=\left(\frac{\partial P}{\partial T}\right)_V$

(c) $\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial T}{\partial P}\right)_V=-\left(\frac{\partial V}{\partial P}\right)_T$ (d) $\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial T}{\partial P}\right)_V=\left(\frac{\partial V}{\partial P}\right)_T$

3. In the X-ray diffraction pattern recorded for a simple cubic solid (lattice parameter a = 1Å) using X rays of wavelength 1Å. the first order diffraction peak(s) would appear for the

(a) (100) planes (b) (112) planes (c) (210) planes (d) (220) planes

4. Which of the following statement(s) is/are true?

(a) Newton's laws of motion and Maxwell's equations are both invariant under Lorentz transformations.
(b) Newton's laws of motion and Maxwell's equation are both invariant under Galilean transformations.
(c) Newton's laws of motion are invariant under Galilean transformations and Maxwell's equations are invariant under Lorentz transformations.
(d) Newton's laws of motion are invariant under Lorentz transformations and Maxwell's equations are invariant under Galilean transformations.

5. For an underdamped harmonic oscillator with velocity $v(t)$

(a) Rate of energy dissipation varies linearly with $v(t)$
(b) Rate of energy dissipation varies as square of $v(t)$
(c) The reduction in the oscillator frequency compared to the undamped case is independent of $v(t)$
(d) For weak damping, the amplitude decays exponentially to zero.

6. The gradient of a scalar field $S(x,y,z)$ has the following characteristic(s)

(a) Line integral of a gradient is path-independent
(b) Closed line integral of a gradient is zero
(c) Gradient of S is a measure of the maximum rate of change in the field S
(d) Gradient of S is a scalar quantity

7. The relation between the nuclear radius (R) and the mass number (A), given by R = 1.2 $A^{1/3}$ fm,, implies that

(a) The central density of nuclei is independent of A
(b) The volume energy per cucleon is a constant
(c) The attractive part of the nuclear force has a long range
(d) The nuclear forec is charge dependent

8. An atomic nucleus X with half-life Tx decays to a nucleus Y, which has half-life T_Y. The condition(s) for secular equilibrium is(are)

(a) $T_x \simeq T_Y$ (b) $T_x < T_Y$ (c) $T_x \ll T_Y$ (d) $T_x \gg T_Y$

9. Consider a classical particle subjected to an attractive inverse-square force field. The total energy of the particle is E and the eccentricity is ε .The particle will follow a parabolic orbit if

(a) $E > 0$ and $\varepsilon = 1$ (b) $E < 0$ and $\varepsilon < 1$ (c) $E = 0$ and $\varepsilon = 1$ (d) $E < 0$ and $\varepsilon = 1$

10. Out of the following statements, choose the correct option(s) about a perfect conductor.

(a) The conductor has an equipotential surface

(b) Net charge, if any, resides only on the surface of conductor

(c) Electric field cannot exist inside the conductor

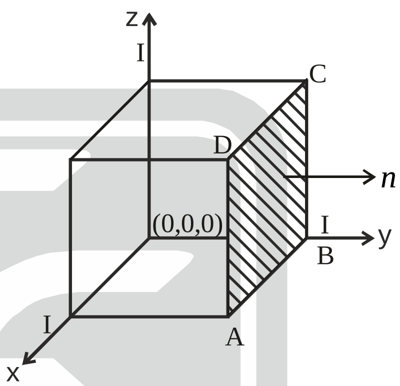
(d) Just outside the conductor, the electric field is always perpendicular to its surface

SECTION-C

Numerical Answer Type (NAT)

Q.1 – Q.10 carry ONE mark each.

1. The flux of the function $\vec{F} = (y^2)\hat{x} + (3xy - z^2)\hat{y} + (4yz)\hat{z}$ passing through the surface ABCD along $\hat{n}$ is _______. (Round off to 2 decimal places)



2. An object of 2 cm height is placed at a distance of 30 cm in front of a concave mirror with radius of curvature 40 cm. The height of the image is ________cm.

3. Two gases having molecular diameters D_1 and D_2 and mean free paths λ_1 and λ_2 respectively, are trapped separately in identical containers. If $D_2 = 2D_1$, then $\lambda_1 / \lambda_2 =$ ______.
(Assume there is no change in other thermodynamic parameters)

4. An infinitely long very thin straight wire carries uniform line charge density $8\pi \times 10^{-2}\, C/m.$ The magnitude of electric displacement vector at a point located 20 mm away from the axis of the wire is _________C/m^2.

5. The electrostatic energy (in units of $\frac{1}{4\pi\varepsilon_0}$ J) of a uniformly charged spherical shell of total charge 5C and radius 4 m is _______(Round off to 3 decimal places)

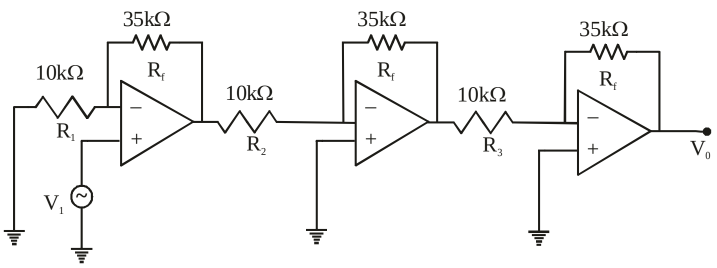
6. In a typical human body, the amount of radiactive ^{40}K is 3.24×10^{-5} precent of its mass. The activity due to ^{40}K in a human body of mass 70 kg is __________kBq.
(Round off to 2 decimal places)
(Half-life of 40K = 3.942×10^{16} s, Avogardo's number $N_A = 6.022 \times 10^{23}$ mol^{-1})

7. Light of wavelength 680 nm is incident normally on a differaction gratting having 4000 line/cm. The diffraction angle (in degrees) corresponding to the third-order maximum is __________
(Round off to 2 decimal places)

8. Sodium (Na) exhibits body-centered-cubic (BCC) crystal structure with atomic radius 0.186 nm. The lattice parameter of Na unit cell is _________nm. (Round off to 2 decimal places)

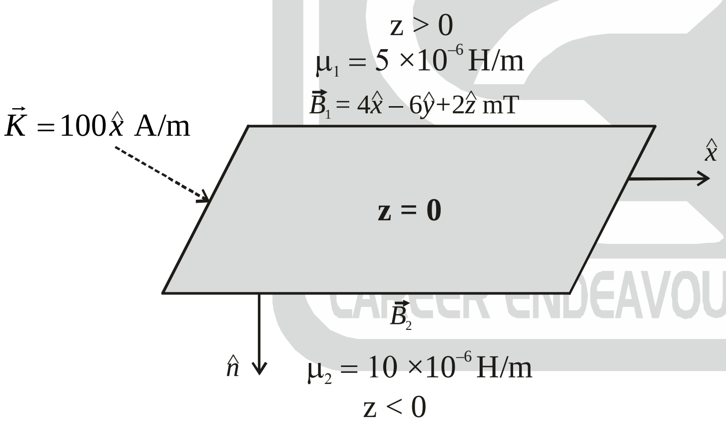
9. The 7th bright fringe in the Young's double slit experiment using a light of wavelength 550 nm shifts to the central maximum after covering the two slits with two sheets of different refractive indices n_1 and n_2 but having smae thickness 6 μm. The value of $|n_1 - n_2|$ is __________.
(Round off to 2 decimal places)

10. For the input voltage V_i = (200 mV) sin (400 t), the amplitude of the output voltage (V_0) of the given OPAMP circuit is __________V. (Round off to 2 decimal places)



Q.11 – Q.20 carry TWO marks each.

11. A surface current $\vec{K} = 100\,\hat{x}$ A/m flows on the surface z = 0, which separates two media with magnetic permeabilities μ_1 and μ_2 as showin in the figure. If the magnetic field in the region 1 is $\vec{B}_1 = 4\hat{x} - 6\hat{y} + 2\hat{z}\ mT$, then the magnitude of the normal component of $\vec{B}_2$ will be ______mT.



12. The value of $\left| \int_0^{3+i} (\bar{z})^2\, dz \right|^2$, along the line 3$y$ = x, where $z = x + iy$ is _______.

13. The decimal equivalent of the binary number 110.101 is _________.

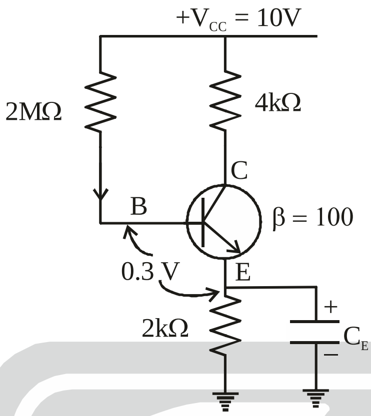
14. If the wavelength of $K\alpha_2$ X-ray line of an element is 1.544 Å, then the atomic number (Z) of the element is ________.

15. A di-atomic gas undergoes adiabatic expansion against the piston of a cylinder. As a result, the temperature of the gas drops from 1150 K to 400 K. The number of moles of the gas required to obtain 2300 J of work from the expansion is ______. (Round off to 2 decimal places)

16. Given the wave function of a particle $\psi(x)=\sqrt{\frac{2}{L}}\sin\left(\frac{\pi}{L}x\right)$ for $0<x<L$ and 0 elsewhere, the probability of finding the particle between $x = 0$ and $x = L/2$ is ______.
(Round off to 1 decimal place)

17. If the diameter of the Earth is increased by 4 % without changing the mass, then the length of the day is _______hours. (Take the length of the day before the increment as 24 hours. Assume the Earth to be a sphere with uniform density) (Round off to 2 decimal places)

18. The value of emitter current in the given circuit is _______ μA . (Round off to 1 decimal place)



19. A proton is confined within a nucleus of size 10^{-13} cm. The uncertainty in its velocity is ______$\times 10^8$ m/s. (Round off to 2 decimal places) (Planck's constant h = 6.626×10^{-34} J s and proton mass $m_p = 1.672 \times 10^{-27}$ kg)

20. The Zener current I_Z for the given circuit is ________mA.