PILLAI COLLEGE OF ENGINEERING (Autonomous)

(Accredited 'A+' by NAAC)

END SEMESTER EXAMINATION SECOND HALF 2021

BRANCH: FE (COMP/IT)

Time: 02.00 Hours

Subject: Engineering Physics – I

Max. Marks: 45 **Date: 06-04-2022**

N.B 1. Q.1 is compulsory

2. Attempt any two from the remaining three questions

Q.1.	Attempt all the questions	M
	Newton's rings experiment was performed using yellow light. The rings appear closer as we move away from central spot. Justify the observation **Ans.** The Newton's rings are not equally spaced because the diameter of ring does not increase in the same proportion as the order of ring and rings get closer and closer as 'n' increases. $Dn^2 = 4.n.R.\lambda$ $D_5 - D_4 = (\sqrt{5} - \sqrt{4})\sqrt{\lambda R} = 0.236\sqrt{\lambda R}$ $D_{15} - D_{14} = (\sqrt{15} - \sqrt{14})\sqrt{\lambda R} = 0.131\sqrt{\lambda R}$ $D_{25} - D_{24} = (\sqrt{25} - \sqrt{24})\sqrt{\lambda R} = 0.101\sqrt{\lambda R}$ Hence the rings appear closer as we move away from central spot	3
b)	Show that concept of phase velocity is unacceptable **Ans.** $E = h\nu$----------------------------(1) $E = mc^2$---------------------------(2) Equating (1) and (2) $\nu = mc^2/h$ ----------------------(3) If the velocity of the matter wave is Vph , the Vph= $\frac{Distance}{Time} = \frac{\lambda}{T} = \lambda \times \nu$ Substituting (3) in above Equation Vph= $\lambda \times \nu = \lambda \times \frac{mc2}{h} = \frac{h}{p} X \frac{mc^2}{h} = \frac{c^2}{v}$ >>>>>>c **Matter waves travel faster than light, hence unacceptable**	
c)	Calculate the divergence of **F (x,y.z)= $e^x.\hat{\imath}$ + y.z. $\hat{\jmath} - y^2\hat{k}$** at point **(0,2,-1)** **Ans. F = $e^x\hat{\imath}$ +y. z.$\hat{\jmath}$ +$y^2\hat{k}$** $\nabla . F = \quad (\hat{\imath}\frac{\partial}{\partial x} + \hat{\jmath}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}) \quad [e^x\hat{\imath} + y.z.\hat{\jmath} + y2\,\hat{k}]$ $= e^x + z$	3

$= e^0 + (-1)$

= 0

d)

Differentiate between Type1 and Type II superconductor

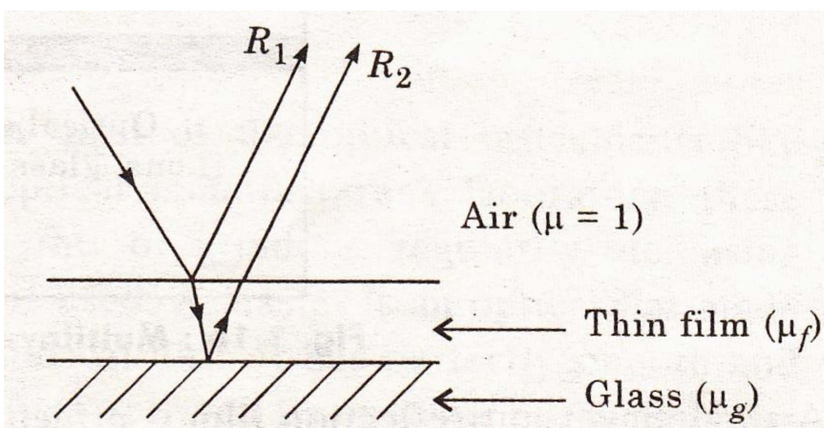
Ans.

Sr. No	Type- I Superconductor	Type-II Superconductor
1	Type –I strictly follows Meissner effect	Type-II do not strictly follow Meissner effect.
2	Type I has a single critical magnetic field Hc	Type II has 2 critical magnetic fields H_{c1} and H_{c2}
3	Critical field is a weak field in order less than 0.1 Tesla.	Critical field is is a very strong field in order sevral Teslas.
4	Not used practically	Used in several applications
5	Magnetic cycle is reversible and they so not show hysteresis.	Magnetic cycle is irreversible and they show hysteresis.
6	Lead,Mercury, Alumininum,Tin in pure form	Alloys of Niobium,Vanadium,silicon,etc.

3

e)

Derive the condition of thickness and RI for a thin parallel film to act as highly reflecting film



Condition on Refractive Index	Condition on thickness
It says that the amplitudes of two rays R_1 and R_2 should be equal. As R_1 is reflected from the surface of film and R_2 is reflected from the surface of glass. Amplitude of $R_1 = \left(\frac{\mu_f - 1}{\mu_f + 1}\right)^2$ Amplitude of $R_2 = \left(\frac{\mu_g - \mu_f}{\mu_g + \mu_f}\right)^2$	It says that the thickness of film should be such that rays R_1 and R_2 should interfere Constructively (**opd=nλ**). Here, the optical path difference between R_1 and R_2 is given by **opd= $2\mu_f$.t.cosr** As both rays undergo phase reversal there is no additional path difference. For normal incidence, cos r =1. **$2\mu_f$.t = nλ** For minimum thickness $t=t_{min}$ and n=1 $t_{min} = \frac{\lambda}{2\mu f}$

3

The condition $\left(\frac{\mu_f - 1}{\mu_f + 1}\right)^2 = \left(\frac{\mu_g - \mu_f}{\mu_g + \mu_f}\right)^2$

after solving gives

$$\mu_f = \sqrt{\mu_g}$$

Q.2. **Attempt all the questions**

a) Show that an electron cannot exist in a nucleus **(4)**

Ans.

Let us assume the electron exist in the nucleus. If the electron is inside the nucleus, the uncertainty of position will not be greater than the dimension of the nucleus, i.e. 10^{-15} m

Maximum uncertainty of position (Δx max) $= 10^{-15} m$

$\Delta x_{max} . \Delta p_{min} = \frac{h}{2\pi}$

$\Delta p_{min} = \frac{h}{2\pi \ X \ \Delta x max} = \frac{h}{2\pi \ X \ 10{-}15} = 1.055 \ X \ 10^{-19}$ kg- m/s

$\Delta p_{min} = m_. \Delta v_{min}$

$\Delta v_{min} = 1.158 \ X \ 10^{11}$ m/s **(1M)**

The uncertainty of velocity is greater than the speed of light, Hence it should behave as a relativistic particle

The relativistic energy (E)= $\sqrt{mo2c2 + p2c2}$

$p^2c^2 >>> m_o^2c^2$ Hence E = pc

$E = \Delta p_{min \ X} \ c = 1.055 \ X \ 10^{-19} \ X \ 3 \ X \ 10^8 = 3.16 \ X \ 10^{-11}$ J = 197 Mev **(2M)**

The electron has the maximum energy in βde cay i.e around 100KeV. Therefore 197MeV cannot exist; hence an electron cannot be present in the nucleus. **(1M)**

b) A soap film of refractive index 4/3 and thickness 1.5×10^{-5} cm is illuminated by while light incident at an angle of 45°. The light reflected by it is examined by a spectroscope in which is found a dark band corresponding to a wavelength of 5000 A°. Calculate the order of interference band. **(5)**

Data	1. Refractive index (μ_f)= 4/3 2. Thickness(t) = $1.5 \ X \ 10^{-5}$ cm 3. Angle of incidence (i)= 45 4. Destructive Interference 5. Wavelength (λ) = 5000 AU= $5000 \ X \ 10^{-8}$ cm
To find	The order of interference (n)
Formulae	1. Snells Law $\mu = \frac{Sin\ i}{Sin\ r}$ 2. Condition for destructive interference in thin parallel film 2 μ t Cos r = n λ

Calculation	1. $\frac{4}{3} = \frac{Sin\ i}{Sin\ r}$ r = 32 ∘ 2. n = $\frac{2\ \mu\ t\ Cos\ r}{\lambda} = \frac{2\ X\ \frac{4}{3}\ X\ 1.5\ X\ 10-5\ Xcos(32)}{5000\ X\ 10-8}$ = 0.62
Result	Order = 0

c) Derive Maxwell's first and second equation in the integral form and differential form. Give its significance — **6**

Q.3. **Attempt all the questions**

a) Explain Meissner effect with neat diagram — **4**

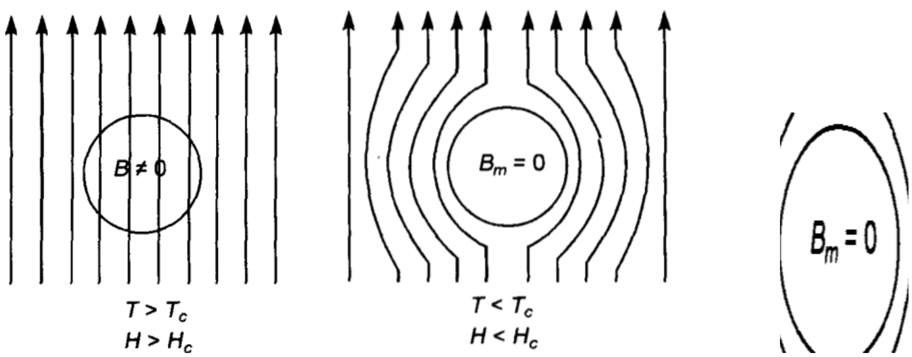


Figure 1 Figure 2 Figure 3

- Magnetic flux lines pass through a normal material as indicated in Figure 1
- When a specimen which is placed in the magnetic field, is cooled through the transition temperature for superconductivity, the magnetic flux originally present is ejected from the specimen as shown in Figure 2. This effect is known as Meissner effect.
- In pure superconducting state practically no magnetic flux is able to penetrate into the specimen, which thus behaves as perfect diamagnet as shown Figure 3.
- The flux exclusion takes place at all temperatures less than the critical temperature. In other words, as temperature is raised above the critical temperature the flux suddenly penetrates into the specimen reaching normal state.
- The Meissner effect contradicts the fundamental principles of electromagnetism.
-

The magnetic induction inside the specimen is given by

$$B = \mu_0(H + M) \qquad \textbf{Normal state}$$

where H is the external applied field and M is the magnetisation produced within the specimen.

At $T < T_C, B = 0$ **and** $\mu_0(H + M) = 0$ **superconducting state**

$\therefore \qquad M = -H$

The susceptibility of the material is

$$\chi = \frac{M}{H} = -1 \qquad \textbf{Perfect Diamagnetsim}$$

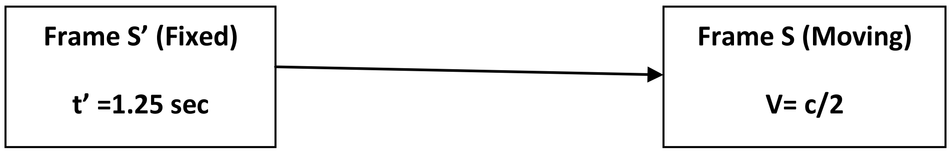
Thus, superconducting state is characterized by perfect diamagnetism.

b)

Spacecraft S’ is at rest, eventually heading toward Alpha Centauri, when Spacecraft S passes it at relative speed c/2. The captain of S’ sends a radio signal that lasts 1.2 s according to that ship’s clock. Use the Lorentz transformation to find the time interval of the signal measured by the communications officer of spaceship S

Ans.

HINT :- The moving frame is S and fixed frame is S’



LORENTZ TRANSFORMATION

$$\begin{aligned} x' &= \gamma\,(x - vt) \\ y' &= y \\ z' &= z \\ t' &= \gamma\left(t - \frac{v}{c^2}x\right) \end{aligned}$$

Where $\Upsilon = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

4

In the above example we consider S’ as fixed so formula becomes $t=\Upsilon\,(t' - \frac{v}{c^2}\,x')$. Since the clock is fixed in stationary S’ frame x’=0

The above equation clock is fixed in stationary S’ frame . x’ =0

$$t=\Upsilon\,(t' - \frac{v}{c^2} \bullet 0) = t' \cdot \Upsilon = \frac{t'}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1.2}{\sqrt{1-\frac{(c/2)^2}{c^2}}} = 1.4 \text{ sec}$$

c)

Derive Schrödinger’s Time dependent wave equation .Extend to the time independent form

Ans.

6

Ans For a 1 dimensional classical wave

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\cdot\frac{d^2y}{dx^2}$$ where $y \to$ displacement, $v \to$ velocity

The solution of above equation is

$$y(x,t) = A e^{i(kx-\omega t)}$$

Similarly we can write the wave function

$$\Psi(x,t) = A e^{i(kx-\omega t)} \to (1)$$

$k \to$ wave constant, $\omega \to$ angular frequency

where $k = \frac{2\pi}{\lambda} = \frac{2\pi}{\left(\frac{h}{p}\right)} = \frac{p}{\hbar}$

$$\omega = 2\pi\nu = 2\pi\left[\frac{E}{h}\right] = \frac{E}{\hbar}$$

Eqn 1 becomes $\boxed{\Psi = A e^{\frac{i}{\hbar}(p\cdot x - E\cdot t)}} \to (2)$

Differentiating Eqn (2) wrt x

$$\frac{\partial \Psi}{\partial x} = A e^{\frac{i}{\hbar}(px - Et)}\cdot\frac{ip}{\hbar} = \frac{ip}{\hbar}\Psi$$

Differentiating above Eqn again wrt x

$$\frac{\partial^2\Psi}{\partial x^2} = \frac{ip}{\hbar}\times\frac{ip}{\hbar}\cdot\Psi = \frac{i^2p^2}{\hbar^2}\Psi$$

$$\boxed{p^2\Psi = -\hbar^2\frac{\partial^2\Psi}{\partial x^2}} \to (3)$$

Differentiating Eqn (2) wrt 't'

$$\frac{\partial\Psi}{\partial t} = A e^{\frac{i}{\hbar}(px - Et)} \times \frac{i}{\hbar}\times(-E) = -\frac{iE}{\hbar}\cdot\Psi$$

$$\frac{i\,\partial\Psi}{\partial t} = \frac{E}{\hbar}\cdot\Psi \qquad \boxed{E\Psi = i\hbar\frac{\partial\Psi}{\partial t}} \to 4$$

The total energy of a particle is the sum of kinetic energy and potential energy (V).

$$E = \frac{1}{2}mv^2 + V$$

$$E = \frac{(mv)^2}{2m} + V = \frac{p^2}{2m} + V$$

Operating the above equation with wavefunction $\Psi(x,t)$

$$E\cdot\Psi(x,t) = \frac{p^2\Psi(x,t)}{2m} + V\Psi(x,t)$$

Substituting (3) and (4) in above equation

$$\boxed{i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V\cdot\Psi(x,t)} \to 5$$

The above is Schrodinger's Time Dependent wave equation. The first term represents total energy, second term represents kinetic energy and third term represents potential energy.

The wave function Ψ is a function of position (x) and time (t). The time dependent part can be eliminated by separation of variables.

$$\Psi(x,t) = \psi(x)\cdot\phi(t)$$

But $\Psi(x,t) = A e^{i(kx-\omega t)} = \underbrace{A e^{ikx}}_{\psi(x)}\cdot e^{-i\omega t}$

$$\boxed{\Psi(x,t) = \psi(x)\cdot e^{-i\omega t}} \to 6$$

Diff Eqn 6 wrt 't'

$$\frac{\partial\Psi}{\partial t} = A e^{ikx}\cdot[-i\omega]\,e^{-i\omega t}$$

$$= \psi(x)\cdot\left[-i\frac{E}{\hbar}\right]\cdot e^{-\frac{i}{\hbar}Et} \qquad \left(\text{Since } \omega = E/\hbar\right)$$

$$\boxed{i\hbar\frac{\partial\Psi}{\partial t} = \psi(x)\cdot E\cdot e^{-\frac{iEt}{\hbar}}} \to 7$$

Diff eqn (6) wrt x twice

$$\boxed{\frac{\partial^2\Psi}{\partial x^2} = e^{-i\frac{E}{\hbar}t}\cdot\frac{\partial^2\psi}{\partial x^2}} \to 8$$

Subs (7) and (8) in Eqn (5)

$$\psi(x)\cdot E\cdot e^{-\frac{iEt}{\hbar}} = -\frac{\hbar^2}{2m}\,e^{-\frac{iEt}{\hbar}}\,\frac{\partial^2\psi}{\partial x^2} + V(x)\cdot\psi(x)\cdot e^{-\frac{iEt}{\hbar}}$$

$$\boxed{E\,\psi(x) = -\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V(x)\cdot\psi(x)} \to (9)$$

The above is Schrödinger's 1-d time independent wave equation.

Q.4.	**Attempt all the questions**	
a)	State Galilean transformations for position. Explain the necessity of Lorentz transformation **x' = x-vt** **y'= y** **z'= z** **t' = t**	4

LORENTZ TRANSFORMATION

Consider two coordinate systems S (*x; y; z; t*) and S' (x' *y', z'; t'*) that coincide at
t = *t'*= 0. The frame S is stationary and S' is moving along the x axis with a velocity 'v'

Lets say at time $t = t' = 0$, a light pulse is produced at $x = x' = 0; y = y' = 0; z = z' = 0$. The light pulse will travel the same distance in both frames of reference.
If 'c' is the velocity of light, then the distance covered shall be (c. t) i.e (velocity X time)

$x^2 + y^2 + z^2 = (ct)^2$ - (1)

$x'^2 + y'^2 + z'^2 = (ct')^2$ - (2)

The Galilean transformations are $x' = x - vt$, $y' = y$, $z' = z$ and $t' = t$

Substituting the above Galilean transformation in Eqn (2)

$(x - vt)^2 + y^2 + z^2 = (ct)^2$

This is an additional term which is missing

$x^2 + y^2 + z^2 \; - 2xvt + v^2t^2 = c^2t^2$

The Galilean transformation does not stand true . The additional terms above involve both space and time.
We can avoid an unwanted term such as ($- 2xvt + v^2t^2$) above is to assume that *t'* is a function of both *x* and *t*.

b)

An electron is bound in a 1-dimensional potential well of width 2Å but of infinite height. Find its energy values in the ground state and in first two excited states

Data:- $L = 2\text{Å} = 2\times10^{-10}\ m$

To find:- E_1, E_2 and E_3

Formulae :- $E_n = \dfrac{n^2h^2}{8mL^2}$

Calculations:

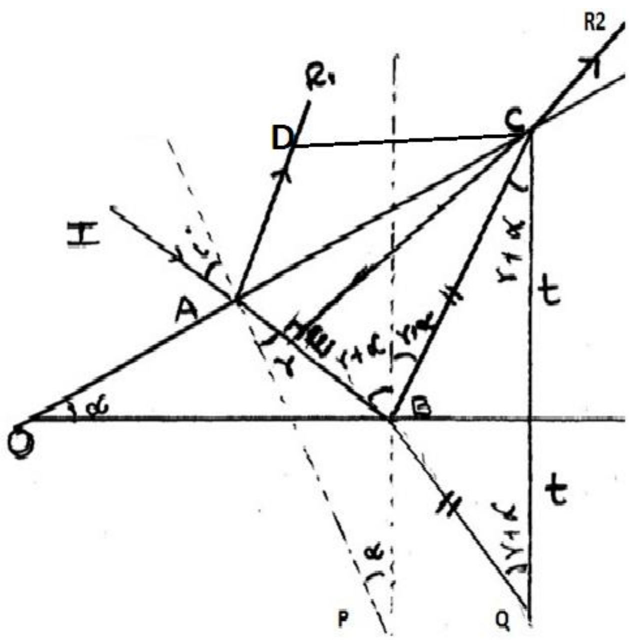
$$E_1 = \frac{1^2\times(6.63\times10^{-34})^2}{8\times9.11\times10^{-31}\times(2\times10^{-10})^2} = 1.507\times10^{-18}\ J$$

$$E_2 = 4\times E_1 = 6.031\times10^{-18}\ J \;;\; E_3 = 13.57\times10^{-18}\ J$$

5

c)

Derive the condition for constructive and destructive interference in a wedge shaped film



Consider 2 glass plates OX and OY forming a a wedge shaped with an angle α at the apex.
Consider a monochromatic ray of light from source I ,incident at "A".At point A the ray is partly reflected along AR1 and partly refracted along AB. The ray AB travels from a denser medium to rarer medium., So it bends away from the normal. The ray at point B is partly reflected along BC. Similar situation arise at point C ,giving rise to reflected ray CR2.Rays AR1 and CR2 are not parallel but when produced backwards they appear to diverge from the same point. The rays are produced from the same incident ray from I, hence they fulfill all conditions for a steady interference pattern

Let 'i' be the angle of incidence and 'r' be the angle of refraction.

The reflected rays can interfere constructively or destructively depending on the path difference.

OPTICAL PATH DIFFERENCE (Δ) = (Path ABC in film of RI μ) – (Path AD in air)

6

$\Delta = \mu$ (AB +BC) -AD…………………(1)

To calculate AD consider ΔACD

Sin i $=\frac{AD}{AC}$ …………………. (1)

Construct a $\perp$ from C to AB .i.e CE.

Consider ΔAEC , Angle ACE = r

Sin r = $\frac{AE}{AC}$ ………………….. (2)

$\mu = \frac{Sin\ i}{Sin\ r} = \frac{AD}{AC}$ X $\frac{AC}{AE}$; Therefore AD= μ. AE …………………..(2)

Substituting (2) in (1)

$\Delta = \mu$ (AB +BC) -μ. AE

Consider a point Q at a thickness 't' from OX such that BC=BQ, therefore the above equation becomes

$\Delta = \mu$ (AB +BQ) -μ. AE

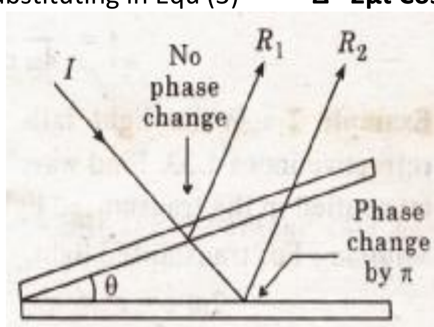
$\Delta = \mu$ (AQ) -μ. AE = μ. EQ……………………(3)

For EQ consider ΔCEQ, Angle CEQ= 90°.

Angle BCQ = Angle BQC = (r+α)

In ΔCEQ,Cos (r+α) $=\frac{EQ}{CQ} = \frac{EQ}{2t}$

Therefore EQ = 2t. Cos (r+α) . Substituting in Equ (3) **Δ= 2μt Cos(r+α)**



Stokes Relation: A phase change of π or path difference λ/2 occurs when light waves are reflected at the surface of denser medium and no change of phase occurs when light waves are reflected at the surface of rarer medium. Since R1 is reflected from the surface of denser medium it suffers a phase change of π.

Effective Path Difference = 2μt Cos(r+α) + $\frac{\lambda}{2}$

Condition for Constructive Inteference	**Condition for Destructive Inteference**
Optical Path Difference for Constructive Interference Δ=nλ……..(n=1,2,3) **2μt Cos (r+α) +** $\frac{\lambda}{2}$ =nλ Taking ($\frac{\lambda}{2}$) on RHS **2μt Cos (r+α) =$\frac{\lambda}{2}$(2n+1)**	Optical Path Difference for Destructive Interference Δ=(2n+1)$\frac{\lambda}{2}$……..(n=0,1,2,3) **2μt Cos(r+α) +** $\frac{\lambda}{2}$ =(2n+1)$\frac{\lambda}{2}$ Taking $\frac{\lambda}{2}$on RHS **2μt Cos (r+α) =nλ**