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Internal Assessment Test 1 – January 2022

Sub:	Engineering Physics Theory					Sub Code:	21PHY12	Branch:	CS/IS/CIV/MECH
Date:	24/01/2022	Duration:	90 min's	Max Marks:	50	Sem/Sec:	I Sem / A, B, C, D, E, Fand G		OBE

Answer any FIVE FULL Questions

Given: c = 3 × 10^8 m/s; h = 6.625 × 10^{-34}Js; k = 1.38 × 10^{-23} J/K; m_e = 9.1 × 10^{-31}kg; e = 1.6 × 10^{-19}C

		MARKS	CO	RBT
1 (a)	With the help of a neat diagram, explain the construction and working of Reddy shock tube.	[07]	CO3	L2
(b)	Calculate the energy of an electron if the de- Broglie wavelength associated with it is 1.5Å.	[03]	CO1	L3
2 (a)	State assumptions of Planck's law. Show that Planck's law reduces to Wien's law and Rayleigh Jeans' law at shorter and longer wavelength limits.	[07]	CO1	L3
(b)	State any three applications of shock waves.	[03]	CO3	L1
3 (a)	Derive time independent Schrodinger wave equation for a particle moving in one dimension.	[07]	CO1	L2
(b)	The distance between the two pressure sensors in a shock tube is 150 mm. The time taken by a shock wave to travel this distance is 0.3 ms. If the velocity of sound under the same condition is 340 m/s, find the Mach number of the shock wave.	[03]	CO3	L3
4 (a)	What is a black body? Explain with a neat sketch the characteristics of black body radiation spectrum.	[06]	CO1	L2
(b)	An electron has a speed of 4.8 x 10^5 m/s accurate to 0.12%. With what accuracy can the position of electron be located?	[04]	CO1	L3

PTO

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PTO

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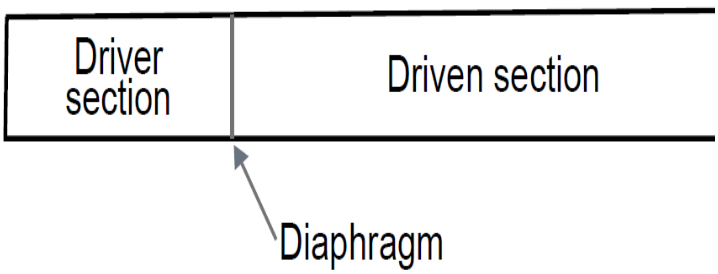
IAT-1 ODD SEM 2021-22

SCHEME

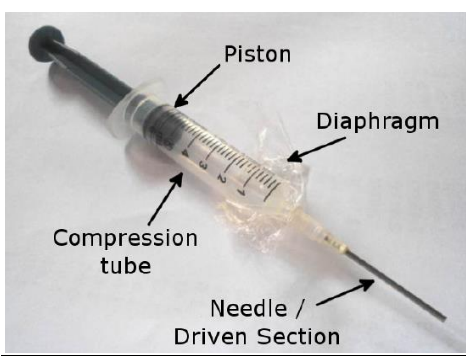
1.a) **Reddy shock tube:** 3 Marks

A shock tube is a device used to study the changes in pressure & temperature which occur due to the propagation of a shock wave. A shock wave may be generated by an explosion caused by the buildup of high pressure which causes diaphragm to burst.

It is a hand driven open ended shock tube. It was conceived with a medical syringe. A plastic sheet placed between the plastic syringe part and the needle part constitutes the diaphragm.



- A high pressure (driver) and a low pressure (driven) side separated by a diaphragm.
- When diaphragm ruptures, a shock wave is formed that propagates along the driven section.
- Shock strength is decided by driver to driven pressure ratio, and type of gases used.

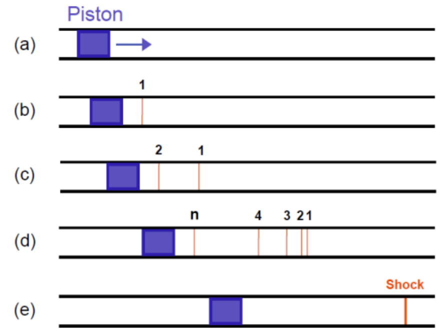


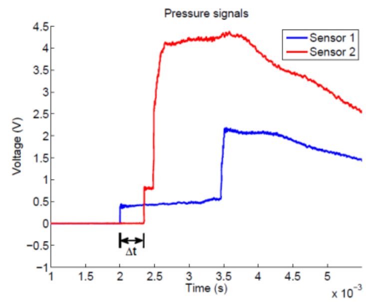
Working: **4 Marks**

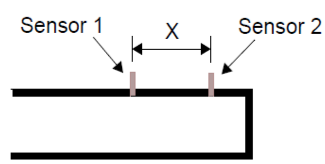
- The piston is initially at rest and accelerated to final velocity V in a short time t.
- The piston compresses the air in the compression tube. At high pressure, the diaphragm ruptures and the shock wave is set up. For a shock wave to form, $V_{piston} > V_{sound}$.

Formation of shock wave:

As the piston gains speed, compression waves are set up. Such compression waves increase in number. As the piston travels a distance, all the compression waves coalesce and a single shock wave is formed. This wave ruptures the diaphragm.







$$U_s = \frac{X}{\Delta t}$$

Mach number $M = \frac{V_{Shock}}{V_{Sound}}$

1.B. 1 Mark formula +1 mark substitution+ 1 mark answer

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$E = \frac{h^2}{\lambda^2 .2.m} = 1.07x10^{-17}\,J = 66.88eV$$

2 A 3 Marks

1. a black body is imagined to be consisting of large number of electrical oscillators.
2. an oscillator emits or absorbs energy in discrete units. It can emit or absorb energy by making a transition from one quantum state to another in the form of discrete energy packets known as photons whose energy is an integral multiple of hν where h is the planks constant and ν is

the frequency.

3. the key point in Planck's theory is the radical assumption of quantized energy states. This development marked the birth of quantum theory.

Based on these ideas, Planck was able to derive an expression that agreed remarkably well with the experimental curves. It is given by

$$E_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{e^{\left[\frac{h\gamma}{kT}\right]}-1}\right]d\lambda$$

Where h is Planck's constant, c is velocity of light, T is absolute temperature, λ is the wavelength and k is Boltzmann constant

Deduction of Weins law: 2 Marks

It is applicable at smaller wavelengths.

For smaller wavelengths $e^{\frac{h\gamma}{kT}} >> 1$

$$\therefore e^{\frac{h\gamma}{kT}} >> 1 = e^{\frac{h\gamma}{kT}}$$

So Planck's radiation law becomes

$$E_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{e^{\left[\frac{h\gamma}{kT}\right]}}\right]$$

Deduction of Rayleigh Jeans Law: 2 Marks

It is applicable at longer wavelengths.

For longer wavelengths $\frac{h\gamma}{kT} << 1$

$$\therefore e^{\frac{h\gamma}{kT}} = 1 + \frac{h\gamma}{kT} + \left(\frac{h\gamma}{kT}\right)^2 \frac{1}{2|} + \ldots\ldots\ldots\ldots = 1 + \frac{h\gamma}{kT}$$

$$E_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}.\frac{1}{1+\frac{h\gamma}{kT}-1}d\lambda = \frac{8\pi kT}{\lambda^4}d\lambda$$

2B **3 Marks** for any three application

Uses:

- Aerodynamics – hypersonic shock tunnels, scramjet engines.
- High temperature chemical kinetics – ignition delay
- Rejuvenating depleted bore wells
- Material studies – effect of sudden impact pressure, blast protection materials
- Investigation of traumatic brain injuries – Nerve activation
- Needle-less drug delivery
- Wood preservation – Sandlewood oil extraction

3A

Time independent Schrödinger equation

A matter wave can be represented in complex form as

$$\Psi = A\sin kx(\cos wt + i\sin wt)$$

$$\Psi = A\sin kxe^{iwt}$$

Differentiating wrt x

$$\frac{d\Psi}{dx} = kA\cos kxe^{iwt}$$

$$\frac{d^2\Psi}{dx^2} = -k^2 A\sin kxe^{iwt} = -k^2\Psi \quad \ldots\ldots\ldots\ldots (1)$$

From Debroglie's relation

$$\frac{1}{\lambda} = \frac{h}{mv} = \frac{h}{p}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\Pi p}{h}$$

$$k^2 = 4\Pi^2\frac{p^2}{h^2} \quad \ldots\ldots\ldots\ldots\ldots (2)$$ **4 Marks**

Total energy of a particle

E = Kinetic energy + Potential Energy

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

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

$$p^2 = (E - V)2m$$

Substituting in (2)

$$k^2 = \frac{4\Pi^2(E-V)2m}{h^2}$$

∴ From (1)

$$\boxed{\frac{d^2\Psi}{dx^2} + \frac{8\Pi^2 m(E-V)\Psi}{h^2} = 0}$$

3 Marks

3B . **1 Mark formula +1 mark substitution+ 1 mark answer**

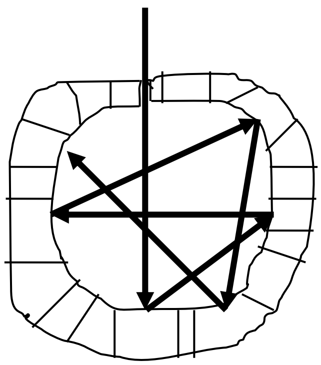
$$M = \frac{V_{Shock}}{V_{Sound}} = \frac{\frac{d}{t}}{340} = \frac{\frac{150x10^{-3}}{0.3x10^{-3}}}{340} = 1.47$$

4A . **2 Marks**

Black body : It is an object which absorbs all radiations incident on it and emit those radiations on heating. Its absorption coefficient is 100%.

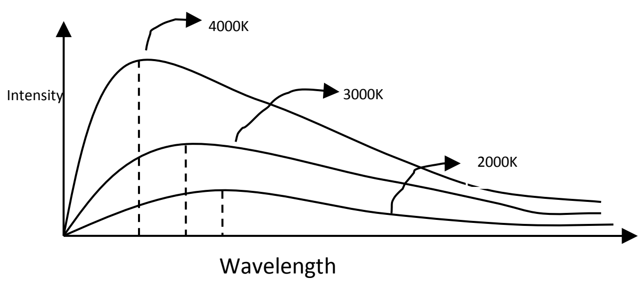
White body : It reflects all the incident energy.

Black body :



A good approximation of a black body is a small hole leading to the inside of a hollow object as shown in the above fig. Any radiation that falls inside through the hole gets reflected in every direction and finally all the energy is absorbed. The nature of the radiation emitted from the hole depends only on the temperature of the cavity walls. The distribution of the radiated energy varies with wavelength and temperature as shown in the following graph.

Features of Black body spectrum:



Interpretation of the graph: **4 Marks**

1. A black body emits over wide range of wavelengths at different temperatures.
2. At each temperature, there exists a wavelength at which maximum energy is radiated.
3. As the temperature increases, the amount of energy radiated (the area under the curve) increases and the peak shifts towards shorter wavelengths.

4. As temperature increases, energy emitted also increases.

4B 1 Mark formula +1 mark substitution+ 2 marks answer

V= 0.12 % of 4.8x10^5

$$\Delta v = v = 567 m/s$$

$$\Delta x = \frac{h}{\Delta P} = \frac{h}{m.\Delta v} = 1.007 X 10^{-7} m$$

5A

HEISENBERG'S UNCERTAINTY PRINCIPLE:

The position and momentum of a particle cannot be determined accurately and simultaneously. The product of uncertainty in the measurement of position (Δx) and momentum (Δp) is always greater than or equal to $\frac{h}{2\Pi}$. **1 Mark**

$$(\Delta x).(\Delta p) \geq \frac{h}{4\Pi}$$ **1Mark**

TO SHOW THAT ELECTRON DOES NOT EXIST INSIDE THE NUCLEUS:

We know that the diameter of the nucleus is of the order of 10^{-14}m.If the electron is to exist inside the nucleus, then the uncertainty in its position Δx cannot exceed the size of the nucleus

$$\Delta x = 5x10^{-15} m$$

Now the uncertainty in momentum is

$$\Delta x = 5x10^{-15} m$$

$$\Delta P = \frac{h}{4\pi x \Delta x} = 0.1x10^{-19} kg.m/s$$

Then the momentum of the electron can atleast be equal to the uncertainty in momentum.

$$P \approx \Delta P = 0.1x10^{-19} kg.m/s$$ **3 Marks**

Now the energy of the electron with this momentum supposed to be present in the nucleus is given by (for small velocities -non-relativistic-case)

$$E = \frac{P^2}{2m} = 548.8x10^{-13} J = 343 MeV$$

. The beta decay experiments have shown that the kinetic energy of the beta particles (electrons) is only a fraction of this energy. This indicates that electrons do not exist within the nucleus. They are produced at the instant of decay of nucleus ($n \rightarrow p + e + \bar{\nu}$ / $p \rightarrow n + \overset{+}{e} + \nu$). **2 Marks**

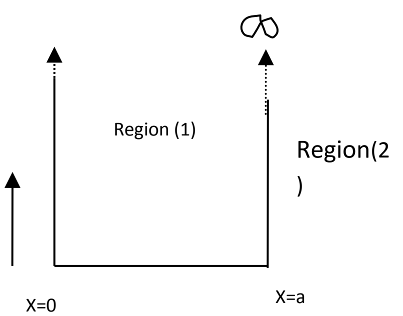
5B (1+1+1 mark)

Mach number is the ratio of velocity of fluid causing the shock wave generation to the velocity of sound in the medium. It represents the compressibility nature of the medium.
Ultrasonic wave : Sound waves of frequency greater than 20,000Hz.
Acoustic waves: A longitudinal wave that consists of a sequence of pressure pulses propagating in a medium. The speed of an acoustic wave in a material medium is determined by the temperature, pressure, and elastic properties of the medium.

6A

Particle in an infinite potential well problem:

Consider a particle of mass m moving along X-axis in the region from X= 0 to X = a in a one dimensional potential well as shown in the diagram. The potential energy is assumed to be zero inside the region and infinite outside the region.



Applying, Schrodingers equation for region (1) as particle is supposed to be present in region (1)

$$\frac{d^2\Psi}{dx^2} + \frac{8\Pi^2 mE\psi}{h^2} = 0 \because V = 0 \text{ for region (1)}$$

But $k^2 = \frac{8\Pi^2 mE}{h^2}$

$$\therefore \frac{d^2\Psi}{dx^2} + k^2\Psi = 0$$

Auxiliary equation is $(D^2 + k^2)x = 0$

Roots are D = +ik and D = -ik

The general solution is

$$x = Ae^{ikx} + Be^{-ikx}$$
$$= A(\cos kx + i\sin kx) + B(\cos kx - i\sin kx)$$
$$= (A+B)\cos kx + i(A-B)\sin kx$$
$$= C\cos kx + D\sin kx$$

2 Marks

The boundary conditions are

1. At x=0, $\Psi = 0 \therefore C = 0$

2. At x=a, $\Psi = 0$

D sin ka = 0 $\Rightarrow$ ka = nΠ ....(2)

where n = 1, 2 3…

$$\therefore \Psi = D\sin\left(n\frac{\Pi}{a}\right)x$$

From (1) and (2) E = $\frac{n^2h^2}{8ma^2}$ **2 Marks**

To evaluate the constant D:

Normalisation: For one dimension

$$\int_0^a \Psi^2 dx = 1$$

$$\int_0^a D^2 \sin^2(\frac{n\Pi}{a})xdx = 1$$

But $\cos 2\theta = 1 - 2\sin^2\theta$

$$\int_0^a D^2 \frac{1}{2}(1-\cos 2(\frac{n\Pi}{a})x)dx = 1$$

$$\int_0^a \frac{D^2}{2}dx - \int_0^a \frac{1}{2}\cos 2(\frac{n\Pi}{a})x)dx = 1$$

$$\frac{D^2 a}{2} - \quad [\sin 2\left(\frac{n\Pi}{a}\right)\frac{x}{2}]_0^a = 1$$

$$D^2\frac{a}{2} - 0 = 1$$

D = $\sqrt{\frac{2}{a}}$

$$\therefore \Psi_n = \sqrt{\frac{2}{a}}\sin\left(n\frac{\Pi}{a}\right)x$$ **3 Marks**

6.b) 1 Mark formula +1 mark substitution+ 1 mark answer

$$E = \frac{n^2h^2}{8ma^2}$$

$$n = 3 \;\; E_3 = 1.67x10^{-17}\,J = 104.82eV$$

7A 2 Mark formula +1 mark substitution+ 2 mark answer

$$E = \frac{hc}{\lambda}$$

$$\Delta E = -\frac{hc}{\lambda^2}\Delta\lambda = 8.27x10^{-27}\,J$$

$$\Delta t = \frac{h}{4\pi.\Delta E} = 6.37x10^{-9}\,s$$

7B 2 Mark formula +1 mark substitution+ 2 mark answer

Probability over a segment from x = 0 to x = L/3

$$= \int_{x=0}^{x=L/3}\psi^2 dx = \int_0^{L/3}\sqrt{\left(\frac{2}{L}\right)^2}\sin^2\frac{n\pi}{L}x.dx = 0.402$$