REG.NO.:

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

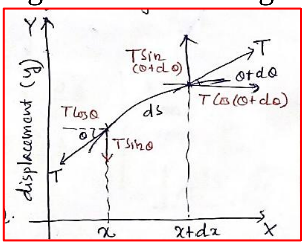
SCHOOL OF ADVANCED SCIENCES
CONTINUOUS ASSESSMENT TEST - I
WINTER SEMESTER 2024-2025

SLOT: E2+TE2

Programme Name & Branch	:	**B. Tech.**
Course Code and Course Name	:	**BPHY101L Engineering Physics**
Faculty Name(s)	:	Tulsi Anna, Anuradha C, Dhanoj Gupta, Laxmi Narayan Tripathi, Samuel P, Vijaya Chamundeeswari S P, Jitendra Kumar Behera, Pankaj Sheoran, Bhaskar Sen Gupta, Arunai Nambiraj N, Anuj Ram Baitha, Anusha P T, Kuraganti Vasu, Amrita Dey, Sridhar S, Sumangala T P, Kanhaiya Lal Pandey, Sangem Rajesh, Shobana M K, Premkumar S, Tarun, Krishna Chandar N, Abhinav Anand, Samir Ranjan Meher
Class Number(s)	:	VL2024250505302/5296/5282/5290/5277/5284/5295/5310/5269/5309/5216/5288/5300/5259/5279/5267/5286/5272/5263/5306/5293/5275/5265/5304
Date of Examination	:	**31-01-2025**
Exam Duration	:	**90 minutes** **Maximum Marks: 50**

General instruction(s):

- Answer All Questions
- M - Max mark; CO – Course Outcome; BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)
- Course Outcomes
  - CO1: Model waves in an elastic medium using Newtonian mechanics
  - CO2: Explain the properties of electromagnetic waves using the Maxwell's equations

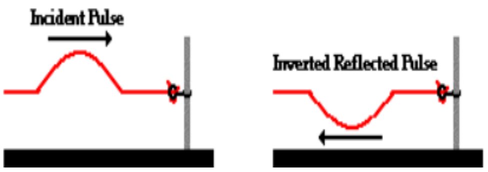
Q. No	Question	M	CO	BL
1.	Derive the classical wave equation for the transverse waves on a string under uniform tension T using the proper assumptions, and provide a clear and concise schematic of the balancing forces acting on it. Further determine the relationship between linear mass density and tension in terms of velocity using dimensional analysis. [**10 Marks**] **Answer Key:** Assumptions for tension and linear mass density **(2 marks)** Figures for balancing forces **(2 marks)**  1-D wave equation derivation $\frac{\partial^2 y}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2}$ **(4 marks)** Relationship between the linear mass density, wave velocity and impedance of a string.	10	CO1	BL2

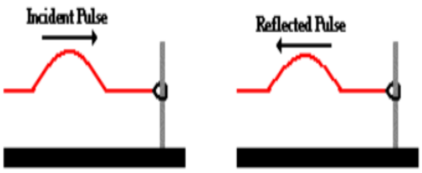
REG.NO.:

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ADVANCED SCIENCES
CONTINUOUS ASSESSMENT TEST - I
WINTER SEMESTER 2024-2025

SLOT: E2+TE2

<table>
<tr><td></td><td>Show $c = \sqrt{\frac{T}{\rho}}$
And calculate dimension too. (2 marks)
$c = \sqrt{\frac{MLT^{-2}}{ML^{-1}}} = LT^{-1}\ hence\ m/s^{-1}$</td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td>(a) Discuss with an appropriate diagram how the amplitude, velocity and phase of the wave changes when it is reflected from the fixed rigid end and free end of a string. [5 Marks]
Answer Key:
String fixed at one end: Here $z_2 = \infty$; it means second medium offers high impedance.
This gives reflection coefficient
$\frac{B_1}{A_1} = \frac{Z_1 - Z_2}{Z_1 + Z_2} = -1$; here amplitude and velocity will be same however reflected wave with 180^0 phase change can be seen.


(2.5 marks)
For free end, $z_2 = 0$; it means impedance is negligible. This will provide reflection coefficient
$\frac{B_1}{A_1} = \frac{Z_1 - Z_2}{Z_1 + Z_2} = 1$; here amplitude, velocity and phase will be same.


(2.5 marks)</td><td rowspan="2">10</td><td rowspan="2">CO1</td><td rowspan="2">BL3</td></tr>
<tr><td></td><td>(b) For a stretched string of length l fixed in both ends show that the allowed wavelengths (λn) of the standing waves are given by $l = n\frac{\lambda_n}{2}$, where n is a positive non-zero integer. At what fraction of the total length of the string a node will appear when the string is oscillating at second harmonic frequency. [5 Marks]

Answer key: first find the solution of standing wave i.e. $\boldsymbol{y = (-2i)ae^{i\omega t}\sin(kx)}$
And apply boundary condition of at x=l (length of the string), y= 0 and frequency can be obtained i.e.,
$\boldsymbol{\omega_n = \frac{n\pi c}{l}\ or\ \nu_n = \frac{nc}{2l}}$ which leads to a relation $\boldsymbol{l = n\lambda_n/2}$, where n is a positive non-zero integer. [4 marks]</td></tr>
</table>

	If string is vibrating with second harmonic frequency, we can able to see node at *l*/2. [1 mark]			
3.	**(a)** A tension force of 125N was applied to a 137g string that is 4.35m long. A standing wave with 5 antinodes was produced. Calculate the (i) speed (ii) wavelength, (iii) frequency and (iv) frequency of the first three harmonics. [**5 marks**] **Answer key:** We know that $c = \sqrt{\frac{T}{\mu}}$ = 63.0 m/s **(1 marks)** Wavelength $\boldsymbol{\lambda_n} = \frac{\boldsymbol{2L}}{\boldsymbol{n}} = 1.74m$ here n=5 **(1 mark)** Frequency $\boldsymbol{\nu_n} = \frac{\boldsymbol{nc}}{\boldsymbol{2l}}$ = 36.2 Hz (**1.5 marks**) Frequency is 7.24 Hz for n=1, 14.48 Hz for n=2 and 26.10 Hz for n=3 **(1.5 marks)**	5	CO1	BL3
	(b) Two strings of linear densities μ_1 and μ_2 are joined together and stretched with tension *T*. A transverse wave is incident on the boundary. Find the fraction of the incident amplitude reflected and transmitted at the boundary if (i) $\frac{\mu_1}{\mu_2} = 4$ and (ii) $\frac{\mu_1}{\mu_2} = \frac{1}{4}$. [**5 marks**] **Answer key:** Using $Z_1 = \mu_1 c_1 = \mu_1\sqrt{\frac{T}{\mu_1}} = \sqrt{\mu_1 T}$ and $Z_2 = \sqrt{\mu_2 T}$ therefore we have $\frac{Z_1}{Z_2} = \sqrt{\frac{\mu_1}{\mu_2}}$ so Case 1: $\mu_1/\mu_2 = 4$; in this case $\frac{Z_1}{Z_2} = 2$ So fraction of incident amplitude at the boundary is given by $Reflection\ coefficient = \frac{Z_1 - Z_2}{Z_1 + Z_2} = \frac{1}{3}$ And $Transmission\ coefficient = \frac{2Z_1}{Z_1+Z_2} = \frac{4}{3}$ Case 2: $\mu_1/\mu_2 = 1/4$; in this case $\frac{Z_1}{Z_2} = 1/2$ $Reflection\ coefficient = \frac{Z_1 - Z_2}{Z_1 + Z_2} = -\frac{1}{3}$ $Transmission\ coefficient = \frac{2Z_1}{Z_1+Z_2} = \frac{2}{3}$	5		
4.	Using Maxwell's equations as a starting point, find the wave equation for the electromagnetic (EM) wave in free space for both the electric ***E*** and magnetic ***B*** fields. Comparing it with a classical wave equation find the speed of the electromagnetic wave. [**8 + 2 Marks**] **Answer Key:** Starting from Maxwell differential equations in free space derive	10	CO2	BL2

	$\nabla^2 E = \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2}$ $\nabla^2 B = \mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}$ **(4 + 4 marks)** $v = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.94 \, x \, 10^8 \, m/s$ Velocity of electromagnetic wave in free space. **(2 marks)**			
5.	**(a)** Define and discuss in detail physical meaning of divergence, and curl for a vector field using a relevant example for each. [**5 marks**] **Answer Key:** Define: Divergence and curl **(2 marks)** Physical meaning/properties **(1.5 marks)** Example using a vector field for both divergence and curl **(1.5 marks)**	10	CO2	BL2
	(b) With a theoretical argument show that Ampere's law fails for non-steady current and explain Maxwell's contribution to the Ampere law. [**5 Marks**] **Answer Key:** Theoretically Starting from the odd rule that divergence of curl is always zero, show that Amperes' law is zero for steady current first and for non-steady current with the help of equation of continuity $\nabla \cdot \mathbf{J} = -\frac{\partial \rho}{\partial t} = -\frac{\partial}{\partial t}(\epsilon_0 \nabla \cdot \mathbf{E}) = -\nabla \cdot \left(\epsilon_0 \frac{\partial \mathbf{E}}{\partial t}\right)$ Prove that fourth maxwell equation hence we can describe Maxwell's contribution to Amperes law $\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$ and define **displacement current**: $\mathbf{J}_d \equiv \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$			

****