Tutorial 1

Waves:

- Simple harmonic motion, damped oscillation,
- forced oscillation and resonance; Beats;
- Stationary waves in a string;
- Pulses and wave packets; Phase and group velocities;
- Reflection and Refraction from Huygens' principle.

Q1:

During an earthquake, a horizontal shelf moves vertically. If its motion can be regarded simple harmonic, calculate the maximum value of amplitude of oscillation so that the books resting on it stay in contact with it always. Take $g = 9{\cdot}8\ ms^{-2}$ and $T = 0{\cdot}5$ s. *10*

2013

Q2:

The dispersion relation for deep water waves is given by

$$\omega^2 = gk + ak^3$$

where g and a are constants. Obtain expressions for phase velocity and group velocity in terms of the wavelength λ. ω and k represent the angular frequency and wave number, respectively. *5+10=15*

2013

Q3:

The displacement associated with a three-dimensional plane wave is given by

$$\Psi(x, y, z, t) = a \cos\left[\frac{\sqrt{3}}{2}kx + \frac{1}{2}ky - \omega t\right].$$

Calculate the angles made by the propagating wave with the x, y and z-axes. *10*

2013

Q4:

In a certain engine, a piston undergoes vertical SHM with an amplitude of 10 cm. A washer rests on the top of the piston. As the motor is slowly speeded up, at what frequency will the washer no longer stay in contact with the piston ? *10*

2014

Q5:

Find out the phase and group velocities of a radio wave of frequency $\omega = \sqrt{2}\ \omega_p$ in the ionosphere (as a dielectric medium) of refractive index $n = \sqrt{1 - \frac{\omega_p^2}{\omega^2}}$. Here, ω_p is the ionospheric plasma frequency. *15*

2015

Q6:

The equation of a progressive wave moving on a string is $y = 5 \sin \pi(0 \cdot 01x - 2t)$. In this equation, y and x are in centimetres and t is in seconds. Calculate amplitude, frequency and velocity of the wave. If two particles at any instant are situated 200 cm apart, what will be the phase difference between these particles? 10

2016

Q7:

Find the velocity of sound in a gas in which two waves of wavelengths 1·00 m and 1·01 m produce 10 beats in 3 seconds. 10

2017

Q8:

When the two waves of nearly equal frequencies interfere, then show that the number of beats produced per second is equal to the difference of their frequencies. *10*

2018

Q9:

Why do we prefer to work with a critically damped ballistic galvanometer in a laboratory ? What is external critical damping resistance ? *10*

2019

Q10:

The equation for displacement (X) of a point on a damped oscillator is given by

$$x = 5\, e^{-0{\cdot}25t} \sin\left(\frac{\pi}{2}\right)t \text{ metres.}$$

Find the velocity of oscillating point at $t = \frac{T}{4}$ and T, where T is the time period of the oscillator. What is the direction of velocity in each case ? *10*

2020

Q11:

What is damped harmonic oscillation ? Write the equation of motion and obtain the general solution for this oscillation. Discuss the cases of dead beat, critical damping and oscillatory motion based on the general solution.

What would be the logarithmic decrement of the damped vibrating system, if it has an initial amplitude 30 cm, which reduces to 3 cm after 20 complete oscillations ? *20*

2021

Q12:

An observer on a railway platform observed that as a train passed through the station at 108 km/hr, the frequency of the whistle appeared to drop by 350 Hz. Find the frequency of the whistle. (Velocity of sound in air = 380 m s^{-1}) 10

2022

Q13:

Show that the mean kinetic and potential energies of non-dissipative simple harmonic vibrating systems are equal. 10

2022

Q14:

Write equation for damped harmonic oscillations and obtain expression for logarithmic decrement.

In a damped harmonic motion, the first amplitude is 10 cm, which reduces to 2 cm after 50 oscillations, each of period 4 seconds. Determine the logarithmic decrement. Also, calculate the number of oscillations in which the amplitude decreases to 25%. *20*

2023

Q15:

Show that the group velocity is equal to particle velocity. Also prove that the group velocity of the photons is equal to c, the velocity of light. ***15***

(Asked in Section B) 2014

Q16.

A weakly damped harmonic oscillator consisting of spring-mass system has the following parameters :

Mass $m = 0{\cdot}25$ kg, Spring constant $k = 100\ \mathrm{N\,m^{-1}}$,

Damping coefficient $\gamma = 1\ \mathrm{N\,s\,m^{-1}}$

A periodic force $F = 5\cos\omega t$ (newton) is applied to the system. Determine *(i)* the amplitude of the oscillator at resonance and *(ii)* the Q-value of the oscillator. 15

2024

Q17.

A harmonic oscillator is represented by the equation

$$m\frac{d^2x}{dt^2} + \gamma\frac{dx}{dt} + kx = 0;$$

where $m = 0{\cdot}25$ kg, $\gamma = 0{\cdot}07$ kg s^{-1} and $k = 85\ \mathrm{Nm^{-1}}$. Determine (i) the period of oscillation, and (ii) the number of oscillations in which its amplitude will become half of its original value. *15*

2025