EMRS TGT Tier II Descriptive Science Sample Questions with Model Solution 5

Q1. A sound wave travels with a speed of 330 m/s in air. If the frequency of the wave is 660 Hz, calculate its wavelength and explain the relationship between frequency and wavelength.

Answer

Introduction

Sound is a mechanical longitudinal wave that propagates through a medium due to vibrations of particles. The fundamental relation connecting speed, frequency, and wavelength of a wave is essential for understanding sound behaviour in different conditions.

Calculation of Wavelength

The wave equation is:
Wave speed = Frequency × Wavelength
Given:
Speed (v) = 330 m/s
Frequency (f) = 660 Hz
Wavelength (λ) = v ÷ f
$\lambda = 330 \div 660$
$\lambda = 0.5$ metres

Conceptual Explanation

Wavelength represents the distance between two successive compressions or rarefactions in a sound wave. Frequency indicates the number of vibrations per second.

Since speed in a given medium remains constant, wavelength and frequency are inversely proportional. This means that if frequency increases, wavelength decreases proportionally. High-frequency sounds therefore have shorter wavelengths, while low-frequency sounds have longer wavelengths.

Conclusion

The wavelength of the sound wave is 0.5 m. The inverse relationship between frequency and wavelength explains variations in pitch and wave characteristics.

Q2. Using displacement–time and velocity–time graphs, explain how the equations of uniformly accelerated motion can be derived graphically. Discuss the physical significance of the area under a velocity–time graph.

Displacement-Time Graph

For an object undergoing uniformly accelerated motion, the displacement-time graph is a curve (a parabola) that opens upwards. This curved line visually demonstrates that the object covers increasingly larger distances in equal time intervals, confirming that its velocity is constantly increasing.

Velocity-Time Graph and Derivations

To derive the equations of motion, we use the Velocity-Time (v-t) graph. Consider an object moving with an initial velocity **u** that accelerates uniformly at a rate **a** for a time **t**, reaching a final velocity **v**. The graph for this motion is a straight, upward-sloping line.

1. First Equation (Velocity-Time Relation) The slope (or gradient) of a velocity-time graph represents the object's acceleration.

- Slope = (Change in velocity) / (Time taken)
- **$a = (v - u) / t$**
- Rearranging this formula gives the first equation: **$v = u + at$**

2. Second Equation (Position-Time Relation) The physical significance of the area under a velocity-time graph is that it represents the total displacement (s) of the object. For uniform acceleration, the area under the straight line forms a trapezium. We can divide this trapezium into a rectangle and a triangle to find the total area.

- Area of the rectangle = $u \times t$
- Area of the triangle = $(1/2) \times \text{base} \times \text{height} = (1/2) \times t \times (v - u)$
- Since $(v - u) = at$ (from the first equation), the triangle's area becomes $(1/2) \times t \times at = (1/2)at^2$
- Adding the two areas together gives the total displacement: **$s = ut + (1/2)at^2$**

3. Third Equation (Position-Velocity Relation) We can also calculate the total displacement by finding the area of the entire trapezium directly using the formula: Area = [(sum of parallel sides) / 2] × height.

- **$s = [(u + v) / 2] \times t$**
- From the first equation, we know that $t = (v - u) / a$. Substituting this expression for t:
- $s = [(u + v) / 2] \times [(v - u) / a]$
- $2as = (v + u)(v - u)$
- $2as = v^2 - u^2$
- Rearranging this gives the third equation: **$v^2 = u^2 + 2as$**

Physical Significance

The area under the velocity–time graph directly gives displacement travelled. This shows how graphical representation provides both qualitative and quantitative understanding of motion.

Q3. Derive the expression for acceleration due to gravity using Newton's law of gravitation. Explain why its value varies with altitude and depth.

Answer

Introduction

Acceleration due to gravity represents the acceleration experienced by a body due to Earth's gravitational pull. Its expression can be derived using Newton's universal law of gravitation.

Derivation

According to Newton's law, gravitational force between Earth (mass M) and a body (mass m) at distance R is:

Gravitational force = $G M m / R^2$

This force equals the weight of the body:

Weight = $m g$

Equating both expressions:

$m g = G M m / R^2$

Cancelling m:

$g = G M / R^2$

Thus, acceleration due to gravity depends on Earth's mass and radius.

Variation with Altitude and Depth

At higher altitude, distance from Earth's centre increases, so g decreases.

At depth below Earth's surface, effective radius decreases and g reduces gradually, becoming zero at Earth's centre.

Conclusion

The value of g depends on distance from Earth's centre, explaining its variation with altitude and depth.

Q4. Derive expressions for kinetic energy and potential energy. Explain how their interconversion obeys the law of conservation of energy.

Answer

Introduction

Energy is the capacity to do work. Mechanical energy consists of kinetic energy (due to motion) and potential energy (due to position). Their derivations help understand energy transformation in physical systems.

Derivation of Kinetic Energy

Work done on a body equals force multiplied by displacement.

Using Newton's second law and equations of motion, work done in accelerating a body from rest to velocity v becomes:

Kinetic energy = $\frac{1}{2} m v^2$

Derivation of Potential Energy

When a body is lifted to height h against gravity, work done equals force multiplied by height:

Potential energy = $m g h$

Energy Interconversion

In free fall, potential energy decreases while kinetic energy increases. At highest point, kinetic energy is zero and potential energy is maximum. At ground level, potential energy becomes zero and kinetic energy is maximum.

Total mechanical energy remains constant throughout motion.

Conclusion

The derivations show that energy transforms between kinetic and potential forms while total energy remains conserved.

Q5. Explain alternating current in detail. Derive the relation between frequency, time period, and angular frequency of AC.

Answer

Introduction

Alternating current (AC) is an electric current that changes its magnitude and direction periodically. It is widely used in domestic and industrial power systems due to ease of transmission.

Nature of Alternating Current

In AC, voltage and current vary sinusoidally with time. The current increases to a maximum value, decreases to zero, reverses direction, and repeats this cycle continuously.

Time Period and Frequency

Time period is the time taken to complete one full cycle of AC. Frequency is the number of cycles per second.

Frequency equals 1 divided by time period.

Angular Frequency

Angular frequency represents rate of change of phase angle and is given by:

Angular frequency = 2π × frequency

Since frequency equals 1 divided by time period:

Angular frequency = 2π / time period

Conclusion

Alternating current varies sinusoidally with time, and its frequency, time period, and angular frequency are interrelated. These relations are fundamental in analysing AC circuits and power systems.