Course: Physics-II (6442) **Semester: Spring, 2023**
Level: BEd (2.5/4-Year)

Total Marks: 100 **Pass Marks: 50**

ASSIGNMENT No. 1

(Units 1 - 4)

Q.1 Explain the concept of simple harmonic motion and its energy considerations. Also highlight applications of simple harmonic motion in daily life. **(20)**

Simple Harmonic Motion (SHM) is a type of periodic motion where an object oscillates back and forth around a stable equilibrium position under the influence of a restoring force that is directly proportional to the displacement from the equilibrium.

Key Concepts of Simple Harmonic Motion:

1. Equilibrium Position: It is the position where the object remains at rest with no net force acting on it. Any displacement from this position initiates the oscillatory motion.

2. Period (T): It is the time taken to complete one full oscillation or cycle. It is the reciprocal of the frequency (f), which is the number of oscillations per unit time.

3. Amplitude (A): It is the maximum displacement from the equilibrium position. The object oscillates between the equilibrium and maximum displacement positions.

4. Restoring Force: The restoring force acts on the object to bring it back towards the equilibrium position when displaced. It is proportional to the displacement and directed opposite to it. The most common example of the restoring force is the force exerted by a spring (Hooke's Law) or the force due to gravity in a pendulum.

Energy Considerations in Simple Harmonic Motion:

In SHM, energy interchanges between kinetic energy (KE) and potential energy (PE) as the object oscillates.

- Kinetic Energy: At the equilibrium position, the velocity is zero, and hence the kinetic energy is also zero. As the object moves away from the equilibrium position, the kinetic energy increases and reaches its maximum at the maximum displacement (amplitude). As the object moves back towards the equilibrium position, the kinetic energy decreases and becomes zero at the equilibrium position again.

- Potential Energy: The potential energy is maximum at the equilibrium position, as there is no displacement and the object is at rest. As the object moves away from the equilibrium, the potential energy decreases and becomes minimum at the maximum displacement. It increases again as the object moves back towards the equilibrium position.

Applications of Simple Harmonic Motion in Daily Life:

- Pendulum Clocks: The swinging motion of a pendulum in a clock follows simple harmonic motion, enabling accurate timekeeping.

- Springs and Oscillations: Springs used in car suspensions, trampolines, and shock absorbers rely on simple harmonic motion for their functioning.

- Musical Instruments: Various musical instruments, such as guitar strings, piano wires, and violin strings, vibrate in simple harmonic motion, producing musical tones.

- Seismic Waves: Earthquakes generate seismic waves that exhibit simple harmonic motion. The study of these waves provides insights into the behavior of the Earth's crust.

- Swings: The back and forth motion of a swing in a playground follows simple harmonic motion.

- Vibrations in Machinery: Simple harmonic motion is observed in the vibrations of engines, fans, and other mechanical systems. Understanding these vibrations is crucial for maintaining smooth operation and preventing damage.

- Molecular Vibrations: The movement of atoms within molecules and the oscillation of chemical bonds exhibit simple harmonic motion. It is significant in various fields such as chemistry and molecular biology.

These are just a few examples highlighting the ubiquitous presence of simple harmonic motion in our daily lives. Its understanding is vital for engineering, physics, and various scientific disciplines, leading to the development of technologies and systems that rely on its principles.

Q.2 a. Elaborate sinusoidal waves, derive its mathematical equation, and represent it graphically. **(20)**

b. What happens to the power if the frequency is increased by a factor of 10?

a. Sinusoidal waves, also known as sine waves, are a type of periodic waveform that follows a smooth, repetitive oscillation. They are characterized by their amplitude, frequency, and phase. Let's derive the mathematical equation for a sinusoidal wave and represent it graphically.

Mathematical Equation:
The mathematical equation for a sinusoidal wave is given by:
$y(t) = A * \sin(2\pi ft + \varphi)$
where:
- $y(t)$ represents the instantaneous value of the wave at time t.
- A is the amplitude, which determines the maximum displacement of the wave from its equilibrium position.
- f is the frequency, which specifies the number of oscillations (cycles) per unit of time.
- φ is the phase angle, which represents the offset or starting point of the wave.

Graphical Representation:
To represent a sinusoidal wave graphically, we can plot the displacement (y-axis) as a function of time (x-axis). The graph will show the variation of the wave over time.

Here's an example of a sinusoidal wave with an amplitude of 1, frequency of 1 Hz, and a phase angle of 0:

````
```
  ^
  |    /\
  |   /  \
  |  /    \
  | /      \
  |/________\
       Time (t)
```
````

In this example, the wave starts from its equilibrium position (the x-axis) at time t = 0. As time progresses, the wave oscillates symmetrically around the equilibrium position. The amplitude determines the maximum height of the wave, and the frequency determines the number of complete oscillations per second.

b. If the frequency of a sinusoidal wave is increased by a factor of 10, the power of the wave remains unaffected. The power of a sinusoidal wave is directly related to its amplitude, not its frequency.

The power (P) of a sinusoidal wave is given by:
P = (A^2 * R) / 2
where A is the amplitude of the wave and R is the resistance through which the wave is passing.

As the frequency increases, the amplitude can remain the same, and hence the power will not change. However, it's important to note that increasing the frequency may have other effects, such as changes in the behavior of the wave propagation or the ability to transmit information in certain applications.

Q.3 Explain the Lorentz of Transformation of Derivative, also discuss its frequencies. **(20)**

The Lorentz transformation of derivatives refers to the mathematical relationship between the derivatives of a physical quantity in one inertial frame of reference and its derivatives in another frame of reference moving relative to the first at a constant velocity. The Lorentz transformation equations are a fundamental component of Einstein's theory of special relativity.

Let's consider the transformation of a derivative with respect to time, which is commonly referred to as the "time derivative."

In the context of the Lorentz transformation, the time derivative of a physical quantity is related to its time derivative in another frame of reference as follows:

dt' = γ(dt - (v/c^2)dx)

where dt' is the time interval in the primed frame of reference, dt is the time interval in the unprimed frame of reference, dx is the spatial interval between the two frames of reference, v is the relative velocity between the frames, c is the speed of light in a vacuum, and γ is the Lorentz factor given by:

$\gamma = 1/\sqrt{(1 - (v^2/c^2))}$

The Lorentz transformation for the time derivative accounts for the time dilation effect, which is a consequence of special relativity. It states that the time experienced in a moving frame of reference appears dilated (slower) compared to the time experienced in the stationary frame.

Regarding frequencies, the Lorentz transformation also affects the frequency of a wave or oscillation. The frequency transformation can be derived from the time derivative transformation. For a wave or oscillation in the unprimed frame with frequency f, the frequency in the primed frame is given by:

$f' = \gamma(f - (v/c)fx)$

where f' is the frequency in the primed frame, fx is the component of velocity perpendicular to the direction of propagation of the wave, and other symbols have the same meaning as before.

This frequency transformation accounts for the phenomenon known as the Doppler effect, where the observed frequency of a wave changes when there is relative motion between the source of the wave and the observer.

the Lorentz transformation of derivatives, particularly the time derivative, describes how the rates of change of physical quantities in one inertial frame of reference relate to rates of change in another frame of reference moving relative to the first. The transformation also affects frequencies, introducing time dilation and the Doppler effect as consequences of special relativity.

Q.4 What are the salient features of Newton's Corpuscular Theory? Explain its drawbacks. **(20)**

Newton's Corpuscular Theory, also known as the Particle Theory of Light, was proposed by Sir Isaac Newton in the 17th century. According to this theory, light is composed of tiny, fast-moving particles called "corpuscles" that are emitted from a source and travel in straight lines until they interact with matter.

Salient features of Newton's Corpuscular Theory:

1. Particle nature of light: Newton's theory suggests that light is made up of discrete particles or corpuscles. These corpuscles are emitted by a light source and travel in straight lines until they encounter a medium or an obstacle.

2. Rectilinear propagation: Newton proposed that light corpuscles move in straight lines unless acted upon by external forces or obstacles. This explains why shadows are formed when light is blocked by objects.

3. Particle interaction: According to Newton, the interaction between light corpuscles and matter occurs when the corpuscles collide with particles of the medium. This interaction results in various phenomena such as reflection, refraction, and absorption.

4. Different colors: Newton's theory explained the phenomenon of different colors by suggesting that corpuscles of light have different sizes and velocities. The size and velocity of the corpuscles determine the color perceived by an observer.

Drawbacks of Newton's Corpuscular Theory:

1. Wave-like behavior of light: Newton's theory failed to explain various wave-like behaviors of light, such as interference and diffraction. These phenomena could only be explained by the wave nature of light, which was later established by the wave theory of light proposed by Christiaan Huygens and further developed by Thomas Young and Augustin-Jean Fresnel.

2. Particle interactions and diffraction: Newton's theory assumed that light corpuscles interact with matter through direct collisions, similar to billiard balls. However, this explanation could not account for the phenomenon of diffraction, where light waves bend around obstacles or pass through narrow slits.

3. Wave-particle duality: Later experimental observations and theoretical developments revealed that light exhibits both particle-like and wave-like properties. Newton's Corpuscular Theory solely emphasized the particle nature of light and failed to incorporate the wave-particle duality concept.

4. Speed of light: Newton believed that the speed of light corpuscles was infinite. However, subsequent experiments conducted by Ole Rømer and later by Albert A. Michelson and Edward W. Morley established that light does have a finite speed.

Newton's Corpuscular Theory provided an initial explanation for the behavior of light based on the particle nature of light corpuscles. However, it had limitations and failed to account for several wave-like properties and phenomena associated with light. The wave theory of light eventually gained more acceptance and was able to explain a wider range of optical phenomena. It wasn't until the 20th century with the development of quantum mechanics that the dual nature of light as both particles (photons) and waves was fully understood.

Q.5 Derive the formulate for Relativistic momentum and Relativistic energy of a practical. **(20)**

To derive the formulas for relativistic momentum and relativistic energy, we start with the concepts of special relativity and the relativistic energy-momentum relationship.

1. Relativistic Momentum (p):
In classical physics, momentum (p) is defined as the product of an object's mass (m) and its velocity (v):

$$p = m * v$$

In special relativity, the classical momentum formula needs to be modified to account for relativistic effects. According to special relativity, the momentum of an object with mass (m) and velocity (v) is given by the relativistic momentum formula:

$$p = \gamma * m * v$$

where γ (gamma) is the Lorentz factor, defined as:

$$\gamma = 1 / \sqrt{1 - (v^2 / c^2)}$$

Here, c represents the speed of light in a vacuum, which is approximately 3.00×10^8 meters per second.

2. Relativistic Energy (E):
In classical physics, the total energy (E) of an object is given by the sum of its kinetic energy (K) and potential energy (U):

$$E = K + U$$

In special relativity, the classical energy formula needs to be modified to incorporate the relativistic effects. According to special relativity, the energy of an object with mass (m) and velocity (v) is given by the relativistic energy formula:

$$E = \gamma * m * c^2$$

where γ (gamma) is the Lorentz factor defined earlier, and c represents the speed of light in a vacuum.

It is worth noting that the relativistic energy formula includes the rest energy of the object, which is given by $E_0 = m * c^2$. The rest energy is the energy equivalent of the object's mass, as described by Einstein's famous equation $E = m * c^2$.

The relativistic energy formula accounts for the increase in energy as an object's velocity approaches the speed of light. As the object's velocity increases, γ becomes larger, resulting in a larger factor multiplying the rest energy, and hence an increase in the total energy.

In conclusion, the formulas for relativistic momentum and relativistic energy are derived by modifying the classical formulas to incorporate the effects of special relativity. These formulas account for the changes in momentum and energy that occur at high velocities, approaching the speed of light.