KARONGI DISTRICT **SCHOOL YEAR: 2023-2024**

PHYSICS COMPREHENSIVE ASSESSMENT [MARKING GUIDE]

SENIOR 5

SECTION A: Compulsory Questions: Answer all questions (70mks)

1.**(b)** Planck's quantum theory states that energy is emitted or absorbed in discrete packets or "quanta" rather than continuously. **(2marks)**

2. Fill in the blanks: When the frequency of excitatory is the same as that of resonator, then the process is called **resonance (1mark)**. This phenomenon is the quickly increasing of amplitude when the frequency of exciting force approaches the frequency of free **oscillations (1mark)**.

3. (a)Frequency……. (ii)It is the number of wavelengths that pass a point in space per second. **(0.5mark)**

(b)Amplitude…….(iv)It is the maximum displacement measured from equilibrium or mean position. **(0.5mark)**

(c)Period……..(i)It is the time for one cycle to occur. **(0.5mark)**

(d)Intensity……(iii)It is the power radiated by a source which is proportional to the square of the amplitude. **(0.5mark)**

4. **Fossil fuels (1mark)** are made from decomposing plants and animals. These fuels are found in Earth's crust and contain carbon and hydrogen, which can be burned for energy. *Coal, oil, and natural gas* are **examples (2marks)** of fossil fuels.

5.

(a)The universal law of gravitation is an inverse square law. **TRUE(1mark)**

(b)The gravitation force is always attractive. **TRUE(1mark)**

(c)Gravity is the mysterious force that makes everything fall down towards the Earth. **TRUE(1mark)**

6.A common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies is:

(**c)Oscilloscope (3marks)**

7.

Simple harmonic motion (SHM) is a fundamental concept in physics that describes the repetitive back-and-forth motion exhibited by many systems in nature. It's prevalent in various real-life applications:

- Pendulum Clocks: The swinging motion of a pendulum in a clock follows SHM. The period of oscillation (time taken to complete one full swing) remains constant, making pendulum clocks reliable timekeepers.

- Musical Instruments: String instruments like guitars, violins, and pianos produce sound through vibrating strings, which execute SHM. The frequency of vibration determines the pitch of the note produced.

- Springs and Shock Absorbers: When a spring is stretched or compressed, it undergoes SHM. This property is used in various applications, such as shock absorbers in vehicles and springs in mattresses, providing cushioning and dampening effects.

- Tuning Forks: Tuning forks vibrate at a specific frequency when struck, producing a pure tone. This vibration follows SHM and is used in tuning musical instruments and calibrating equipment.

- Seismometers: Seismometers detect and measure ground motion caused by earthquakes. They typically consist of a mass suspended on a spring, which undergoes SHM when seismic waves pass through, allowing scientists to analyze earthquake characteristics.

- Simple Harmonic Motion in Biology: Biological systems also exhibit SHM. For instance, the beating of a heart follows a rhythmic pattern akin to SHM, ensuring efficient blood circulation.

- Electric Circuits: Electrical circuits containing components like capacitors and inductors can exhibit SHM when subjected to alternating current (AC). Understanding SHM in circuits is crucial for designing electronic devices and systems.

These examples illustrate how simple harmonic motion is not only a theoretical concept but also a practical phenomenon that influences various aspects of our daily lives and technological advancements. **(4marks)**

8.

Here are some key properties of waves:

- Reflection: When a wave encounters a boundary between two different mediums (e.g., air and water), it can bounce back instead of passing through. The angle of incidence (the angle between the incoming wave and the normal line to the surface) is equal to the angle of reflection (the angle between the reflected wave and the normal line). This principle is utilized in various applications, such as mirrors reflecting light and echoes reflecting sound waves. **(1mark)**

- Refraction: Refraction occurs when a wave changes direction as it passes from one medium to another, due to a change in its speed. This change in direction is caused

by a change in the wave's velocity, which occurs because the wavefronts are entering a new medium with a different density or optical properties. Refraction is responsible for phenomena like the bending of light as it passes through water or glass. **(1mark)**

- Diffraction: Diffraction is the bending of waves around obstacles and the spreading of waves when they pass through narrow openings. It occurs when the size of the obstacle or opening is comparable to the wavelength of the wave. Diffraction is observed in various wave phenomena, such as the spreading of sound waves around corners or the bending of light waves around small obstacles. **(1mark)**

- Interference: Interference happens when two or more waves interact with each other, resulting in the modification of their amplitudes. Constructive interference occurs when waves combine to produce a wave with a larger amplitude, while destructive interference occurs when waves combine to produce a wave with a smaller amplitude. Interference is a fundamental aspect of wave behavior and is observed in various contexts, such as the patterns produced by overlapping ripples on water or the interference fringes in double-slit experiments with light. **(1mark)**

- Polarization: Polarization refers to the orientation of the oscillations of a wave in a particular direction. For transverse waves, like light waves, polarization describes the direction of the electric field vector oscillations perpendicular to the direction of wave propagation. Polarization is essential in various optical technologies, such as polarized sunglasses, LCD displays, and 3D glasses. **(1mark)**

These properties are fundamental to understanding the behavior of waves in different contexts and are utilized in various technologies and applications

9.

A simple potentiometer is a device used for taking a number of electrical measurements. It is a piece of resistance wire, usually a metre long, fixed between the two points A and B (see the figure below) with a cell of output voltage V, connected between the two ends. The potential difference to be measured is put into a circuit together with an opposing variable p.d from the voltage divider. The voltage divider is then adjusted until its p.d, V_{AC} equals the p.d being measured.

The sliding contact in the diagram below is moved until the galvanometer indicates zero. This position is referred to as the balance point. The current in the lower part of the circuit is zero because the p.d V_{AC} equals the p.d E provided by the cell under test. The protective resistor serves only to prevent the galvanometer for damage.

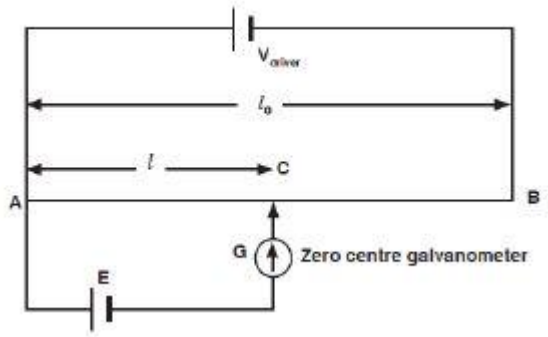
Electromotive force of the wire is always proportional to the length of the wire. So, the approximate value of E is determined as follows:

$E \propto l$, $E = kl$ ..... Equation (1)

$V_{driver} \propto l_{0,}$ $V_{driver} = kl_0$ ..... Equation (2)

Dividing Equation (1) to Equation (2) gives $\frac{E}{v_{driver}} = \frac{kl}{kl_0}$

$E = \frac{V_{driver} \times l}{l_0}$



(5marks)

10.Coulomb's law of electrostatics and Newton's law of gravitation are fundamental principles in physics that describe the forces between charged particles and massive objects, respectively. Here's a comparison between the two laws:

- Nature of Forces:

- Coulomb's law describes the electrostatic force between charged particles. It states that the force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

- Newton's law of gravitation describes the gravitational force between two masses. It states that the force between two point masses is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

- Force Formula:

-Coulomb's law: $F = \frac{kq_1q_2}{d^2}$, where F the electrostatic force, q_1 and q_2 are the magnitudes of the charges, d is the distance between them, and k is Coulomb's constant.

- Newton's law of gravitation: $F = \frac{Gm_1m_2}{d^2}$, where F is the gravitational force, m_1 and m_2 are the masses of the objects, d is the distance between them, and G is the gravitational constant.

- Strength of Force:

- The electrostatic force between charged particles is much stronger than the gravitational force between objects of similar masses. This is because the electrostatic force depends on the product of the charges, which can be much larger than the product of masses.

- The gravitational force is weaker and typically dominates only at larger distances or between objects with much greater masses.

- Range:

- The electrostatic force acts between charged particles regardless of distance, but it becomes weaker as the distance between the charges increases due to the inverse square law.

- The gravitational force also acts between masses regardless of distance, but it becomes weaker much more rapidly with distance due to the inverse square law.

In summary, while both laws describe forces between objects, Coulomb's law deals with electrostatic forces between charged particles, whereas Newton's law of gravitation deals with gravitational forces between masses. Coulomb's law is typically stronger than Newton's law for similar-sized objects, and both laws follow an inverse square relationship with distance. **(6marks)**

11.

Data: $\lambda = 7.8 \times 10^2$nm, h=6.63×10^{-34}J.s, c=3×10^{8}m/s

To be found: E=?

Solution: $E = \frac{hc}{\lambda}$=2.55×10^{-19}J **(6marks)**

12(a) 3Types of damped oscillations:

(i)*Underdamping oscillation*: This is also called a lightly damped oscillation. For this oscillation, the displacement keeps varying with time and oscillations keep dying away slowly and slowly. $\delta < \omega_0$ **(1mark)**

(ii)*Overdamping oscillation*: This is also called excessive or heavy damping. In this oscillation, displacement decreases with increase in time but the vibrating system takes a longer time to come to rest. $\delta > \omega_0$ **(1mark)**

(iii)*Critically damped oscillation*: This is also called natural damping and is when there is an intermediate dissipating force and the system reaches equlibrium position as fast as possible without oscillating. This rapid return to the equilibrium position (x=0) reduces the motion to rest in a shortest possible time. $\delta = \omega_0$ **(1mark)**

(b) (i) $\ddot{x} + 4\dot{x} + 3x = 0$, δ=? ω_0 =?

From the equation of damped oscillation; $\ddot{x} + 2\delta\dot{x} + {\omega_0}^2 x = 0$.

$2\delta = 4$, $\delta = 2$kg/s

${\omega_0}^2 = 3$, $\omega_0 = \sqrt{3}$rad/s **(2marks)**

(ii) Since $\delta > \omega_0$, the equation represents over damping oscillation. **(1mark)**

13. Data: y=1cm=10^{-2}m, d=2×10^{-2}m, $\frac{e}{m}$ =1.8×10^{11}C/kg, v=1×10^{7}m/s

To be found: V=?

Solution: From $y = \frac{Vel^2}{2mdv^2}$, $V = \frac{2mdv^2}{el^2} = \frac{2\times2\times10^{-2}(1\times10^7)\times1\times10^{-2}}{1.8\times10^{11}\times(5\times10^{-2})^{-2}} = 88.89V$ **(7marks)**

14. Applying this Einstein's photoelectric equation ($hf = Wo + KEmax$) to fill the table.

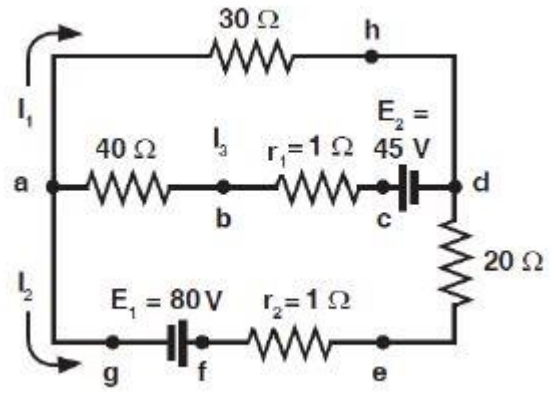
Metal	Work function, Wo/eV	Work function, Wo/Joule	Frequency used, f/Hz	Maximum K.E of ejected electrons, $KEmax$/Joule
Potassium	**2.30**	3.68×10^{-19}	$\mathbf{6\times10^{14}}$	0.32×10^{-19}
Lithium	2.9	$\mathbf{4.64\times10^{-19}}$	1×10^{15}	$\mathbf{1.99\times10^{-19}}$
Aluminium	4.1	$\mathbf{6.56\times10^{-19}}$	104×10^{15}	0.35×10^{-19}
Zinc	4.3	$\mathbf{6.88\times10^{-19}}$	$\mathbf{1.2\times10^{15}}$	1.12×10^{-19}

(7marks=1mark for each)

15(a) Kirchoff's Current Law (KCL) states that "The algebraic sum of the currents flowing at a node of junction in an electric circuit is zero" **(2marks)**

Kirchoff's Voltage Law (KVL) states that "The algebraic sum of the potentials around a closed electric circuit is zero." **(2marks)**

(b)



Solution:

Using KCL, at Junction a, $I_3 = I_1 + I_2$ **(1mark)**

Using KVL: Considering the loop ahdcba,

$I_3(40 + 1) + 30I_1 = 45,$

$(I_1 + I_2)(40 + 1) + 30I_1 = 45$

$71I_1 + 41I_2 = 45$ .....Equation (1) **(1mark)**

In the loop agfedcaba,

$I_3(40 + 1) + I_2(20 + 1) = 80 + 45$

$(I_1 + I_2)(40 + 1) + I_2(20 + 1) = 80 + 45$

$71I_1 + 62I_2 = 125$ .....Equation (2) **(1mark)**

Solving Equation (1) and Equation (2) simultaneously gives;

$I_1 = -0.87A$, $I_2 = 2.6A$ and $I_3 = 1.7A$. **(2marks)**

SECTION B: Attempt any three questions of your choice (30mks)

16.

a)(i)Factors (Any two factors) affecting photoelectric emission are:

- ✓ The intensity of the incident radiation,
- ✓ The type of the metal surface,
- ✓ The frequency of the incident radiation **(2marks)**

(ii) Postulates (Any two postulates) of Planck's quantum theory:

- ✓ The matter is composed of a large number of oscillating particles, having different frequencies.
- ✓ The radiant energy which is emitted or absorbed by the blackbody is not continuous but discontinuous in the form of small discrete packets of energy and each such packet of energy is called a "quantum". In case of light, the quantum of energy is called a "photon".
- ✓ The energy of each quantum is directly proportional to the frequency (f) of the radiation, i.e E=hf where E is the energy, h the Planck's constant and f the frequency of the radiation.
- ✓ The oscillator emits energy, when it moves from one quantized state to the other quantized state. The total amount of energy emitted or absorbed by a body will be some whole number quanta. Hence E=nhf, where n is an integer. **(2marks)**

b) (i) Threshold frequency f_0=4.4 x10^{14}Hz **(1mark)**

The work function $\phi = hf_0$

=6.62x10^{-34}x 4.4x10^{14}J= 29.128x10^{-20} J

Or $\phi = \frac{29.125x10^{-20}}{1.6x10^{-19}} eV = 1.82eV$ **(2marks)**

c)(i)The energy of the level n=3

$$E_n = \frac{-13.6eV}{n^2}$$

$$E_3 = \frac{-13.6eV}{3^2}$$

$$E_3 = \frac{-13.6eV}{3^2}$$

$$E_3 = -1.51eV$$ **(3marks)**

17.

Data: $P.E = \frac{1}{2}m\omega^2x^2$, $K.E = \frac{1}{2}mv^2$, $x = Asin(\omega t + \varphi)$

To be found: Proving if the total mechanical energy E is conserved.

Solution: Total Mechanical energy, $E = PE + KE$, i.e $E = \frac{1}{2}m\omega^2x^2 + \frac{1}{2}mv^2$……(i) **(3marks)**

From $x = Asin(\omega t + \varphi)$, $v = \frac{dx}{dt} = A\omega\cos(\omega t + \varphi)$. Putting x and v in equation (i), we find:

$E = \frac{1}{2}m\omega^2[Asin(\omega t + \varphi)]^2 + \frac{1}{2}m[A\omega\cos(\omega t + \varphi)]^2$ **(2marks)**

$E = \frac{1}{2}m\omega^2A^2[\sin^2(\omega t + \varphi) + \cos^2(\omega t + \varphi)]$ **(2marks)**

Since $\sin^2(\omega t + \varphi) + \cos^2(\omega t + \varphi) = 1$, then $E = \frac{1}{2}m\omega^2A^2$ **(2marks)**which is constant.

This shows that the total mechanical energy of the oscillating system is conserved. **(1mark).**

18.

(a) Kepler's laws:

First Law: This law is called the law of orbits and states that planets move in ellipses with the sun as one of their foci. It can also be stated that planets describe ellipses about the sun as one focus. **(2marks)**

Second Law: This is called the law of areas and states that the line joining the sun and the planet sweeps out equal areas in equal periods of time. **(2marks)**

Third Law: The law of periods states that the square of the period T of revolution of any planet is proportional to the cube of its mean distance R from the sun. **(2marks)**

(b)According to Kepler's law, ${R_{earth}}^3 = k{T_{earth}}^2$ and ${R_{planet}}^3 = k{T_{planet}}^2$.

Dividing these equations and making T_{planet} the subject gives ${T_{planet}}^2 = {T_{earth}}^2 . {R_{planet}}^3 / {R_{earth}}^2$, But $R_{planet} = 5R_{earth}$.

$$T_{planet} = (5)^{\frac{3}{2}} \times T_{earth}$$

$$T_{planet} = (5)^{\frac{3}{2}} \times 1year = 5^{\frac{3}{2}}years$$

(2marks)

(c) Assuming that a planet's orbit is circular, then the mean distance from the sun is constant-radius. Suppose, a planet of mass m_2 moving around the sun of mass m_1. If the motion of the planet is circular, there are two types of forces: (i) *Gravitational force* of attraction F_1 between the sun and the planet, $F_1 = \frac{Gm_1m_2}{R^2}$. (ii)Centripetal force F_2 responsible for keeping the planet moving in a circular motion around the sun, $F_2 = \frac{mv^2}{R}$.

For the planet tomove around the sun in orbit of constant radius: F_1=F_2

$$\frac{Gm_1m_2}{R^2} = \frac{mv^2}{R}$$

$$v^2 = \frac{Gm_1}{R}$$

But linear velocity $v = \omega R$ and $\omega = \frac{2\pi}{T}$ where ω *is the angular velocity*.

So,

$$\frac{4\pi^2R^2}{T^2} = \frac{Gm_1}{R}$$

$$R^3 = kT^2$$

This is true with the third Kepler's law of planetary motion. **(2marks)**

19. **[*Introduction*: (2marks), *Body*: (6marks), *Conclusion*: (2marks)]**

The concept of wave-particle duality challenges our traditional understanding of the behavior of light by suggesting that light exhibits both wave-like and particle-like characteristics, depending on the experimental conditions. This duality is a fundamental aspect of quantum mechanics and has been supported by various experiments. Here's an explanation along with real-life evidence:

- Wave Nature of Light:

- In the 17th century, scientists like Christiaan Huygens proposed that light behaves as a wave, which explained phenomena like interference and diffraction.

- Evidence: Interference patterns observed in double-slit experiments, where light waves produce a pattern of alternating bright and dark bands when passing through two closely spaced slits.

- Particle Nature of Light:

- In the early 20th century, Albert Einstein introduced the concept of photons, suggesting that light can also be viewed as particles (photons) with discrete energy packets.

- Evidence: Photoelectric effect experiments, where shining light on a metal surface ejects electrons, and the energy of these ejected electrons is dependent on the frequency (color) of the light, not its intensity. This phenomenon is better explained by the particle nature of light.

- Quantum Mechanics and Complementarity:

- The famous double-slit experiment, conducted with individual photons, electrons, or even larger particles, demonstrates wave-particle duality. When particles are not observed, they exhibit wave-like interference patterns, but when observed, they behave like particles.

- Evidence: The interference pattern disappears when detectors are placed to observe the particles, emphasizing the concept of complementarity in quantum mechanics.

- Young's Double-Slit Experiment:

- Thomas Young's experiment with light passing through two slits showed that interference patterns can only be explained if light behaves as a wave.

- Evidence: The interference pattern observed on a screen behind the slits demonstrates the wave-like nature of light.

- Quantum Entanglement:

- Entanglement experiments with pairs of entangled photons reinforce the dual nature of light. Changes in one entangled photon's state instantaneously affect the state of the other, regardless of the distance between them.

- Evidence: Experimental observations of non-local correlations between entangled particles challenge classical ideas of locality and support the particle aspect of light.

In summary, wave-particle duality challenges the classical notion of light as purely a wave or particle. The evidence from various experiments highlights the need for a quantum mechanical understanding, where the nature of light depends on the experimental context and observation, introducing a new layer of complexity to our understanding of the behavior of light.

20. **[*Introduction*: (2marks), *Body*: (6marks), *Conclusion*: (2marks)]**

Harnessing Fossil Fuels for Electrical Power Generation

Fossil fuels, including coal, oil, and natural gas, have long been the backbone of global energy production, supplying a significant portion of the world's electricity. The process of generating electrical power from fossil fuels involves several stages, from extraction to combustion, and has both advantages and drawbacks.

- Extraction and Processing: Fossil fuels are primarily extracted from the earth's crust through mining, drilling, or extraction processes. Coal is mined from underground or surface mines, while oil and natural gas are extracted through drilling wells. Once extracted, fossil fuels undergo processing to remove impurities and refine them into usable forms for combustion.

- Combustion: The most common method of generating electricity from fossil fuels is combustion. In power plants, fossil fuels are burned in large boilers or combustion chambers, where the heat produced is used to convert water into steam. The high-pressure steam then drives turbines connected to generators, which produce electrical power through electromagnetic induction. This process is known as steam turbine power generation and is widely employed in coal-fired, oil-fired, and natural gas-fired power plants.

Advantages of Fossil Fuel Power Generation:

- Reliability: Fossil fuel power plants can provide continuous and reliable electricity generation, ensuring a stable supply to meet the demands of modern societies.

- Infrastructure: The infrastructure for fossil fuel power generation, including power plants and distribution networks, is well-established and widespread, making it easier to implement and maintain.

- Energy Density: Fossil fuels have high energy densities, meaning they contain a large amount of energy per unit mass, which makes them efficient for power generation.

- Cost-Effectiveness: Historically, fossil fuel power generation has been cost-effective due to abundant fuel reserves and established infrastructure.

Challenges and Drawbacks:

- Environmental Impact: The combustion of fossil fuels releases carbon dioxide (CO2) and other greenhouse gases into the atmosphere, contributing to climate change and air pollution. Additionally, fossil fuel extraction can lead to habitat destruction and ecosystem degradation.

- Resource Depletion: Fossil fuel reserves are finite and non-renewable, leading to concerns about resource depletion and energy security in the long term.

- Health Risks: The combustion of fossil fuels produces pollutants such as sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter, which can have adverse effects on human health, including respiratory problems and cardiovascular diseases.

- Climate Change: The combustion of fossil fuels is a major contributor to global warming and climate change, as it releases CO2, a greenhouse gas that traps heat in the Earth's atmosphere, leading to rising temperatures, melting ice caps, and extreme weather events.

Conclusion:

Fossil fuels have played a crucial role in powering modern civilization and meeting the world's energy needs. However, their continued use for electricity generation poses significant environmental, social, and economic challenges. As the world transitions towards cleaner and more sustainable energy sources, such as renewable energy and nuclear power, it is essential to mitigate the adverse impacts of fossil fuel power generation through technological innovation, policy interventions, and global cooperation. By investing in cleaner energy alternatives and promoting energy efficiency measures, we can reduce our dependence on fossil fuels and build a more sustainable energy future for generations to come.

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