[Physics for University Study]

[Day] [Month] [Year]

Examination Paper

Sample Assessment

Answer ALL questions.

Clearly cross out surplus answers.

Time: 2 hours

The maximum mark for this paper is 100.

Any reference material brought into the examination room must be handed to the invigilator before the start of the examination.

Candidates are allowed to use a scientific calculator during this examination.

Answer ALL questions		
		Marks
Question 1		
a)	Define kinetic energy and potential energy.	**1**
	Mark Scheme ***Kinetic energy is the energy of motion, while potential energy is the energy stored due to position or configuration (1 mark)***	
b)	A mass of 5 kg is lifted vertically upwards 10 meters. Calculate the potential energy gained by the mass at the top point. Consider $g = 10\ m/s^2$.	**2**
	Mark Scheme ***Potential energy (PE) = mgh*** ***mgh= 5 kg × 10 m/s² × 10 m (1 mark)*** ***mgh= 500 J. (1 mark)***	
c)	The mass in (b) above is then released and allowed to fall freely. What is the velocity of the mass at the bottom point? State the principle that you have used in your calculations.	**3**
	Mark Scheme ***Using the principle of conservation of mechanical energy, the potential energy gained is converted into kinetic energy at the bottom point (1 mark): KE = PE = 500 J. (1 mark)*** ***Applying the formula for kinetic energy, KE = ½ mv²,*** ***we get v² = 2 × KE / m = 2 ×500 J / 5 kg = 200 m²/s².*** ***Therefore, v = √200 m²/s² ≈ 14.1 m/s. (1 mark)***	

		Marks
d)	If the falling mass collides inelastically with another 5 kg mass stationary on the ground, estimate the total kinetic energy after the collision. Explain your reasoning and comment on the values of the total kinetic energy figures before and after the collision.	**3**
	Mark Scheme ***In an inelastic collision, some kinetic energy is lost due to internal deformation or sound waves.*** ***Here, let x be the combined velocity after the collision.*** ***Since momentum is conserved, the total momentum before (2 × 5 kg × 14 m/s) = 140 kg·m/s must equal the total momentum after (10 kg × x).*** ***Thus, x = 14 m/s. (1 mark)*** ***The total kinetic energy after the collision is ½ × 10 kg × 14^2 m/s^2 = 980 J (1 mark), which is less than the initial 1960 J (2 × 5 kg × 14^2 m/s^2) (1 mark) due to the energy loss.***	
e)	Does work have a direction associated with it? Explain.	**1**
	Mark Scheme ***No. Work is a simple number – a scalar, not a vector – so, there is no direction associated with it. (1 mark)***	
		Total 10 Marks
Question 2		
a)	Explain the meaning of wavelength and frequency in the context of waves.	**1**
	Mark Scheme ***Wavelength is the distance between two corresponding points on a wave (peak to peak or trough to trough), while frequency is the number of times a wave repetition occurs per unit time. (1 mark)***	
b)	Light with a wavelength of 500 nm strikes a metal surface with a work function of 2.0 eV. Calculate the threshold frequency for this metal.	**3**
	Mark Scheme ***Threshold frequency (v_0) = hc/Φ (1 mark)*** ***(v_0) = (6.63 x 10^-34 Js) / (2.0 eV * 1.602 x 10^-19 J/eV) (1 mark)*** ***(v_0) ≈ 5.00 x 10^14 Hz. (1 mark)***	

		Marks
c)	If the incident light has a frequency of 8.0 x 10^{14} Hz, explain what happens to the light upon interaction with the metal surface.	**3**
	Mark Scheme ***Since the incident light frequency (8.0 x 10^{14} Hz) is greater than the threshold frequency, some photons have enough energy to eject electrons from the metal (1 mark). These ejected electrons will have kinetic energy (1 mark), with the remaining photon energy accounting for the work function (1 mark). This phenomenon is called the photoelectric effect.***	
d)	Describe THREE (3) applications of the photoelectric effect in technology.	**3**
	Mark Scheme ***Applications of the photoelectric effect include: (1 mark each)*** • ***Photovoltaic cells (solar panels) for converting light into electricity.*** • ***Photomultiplier tubes for amplifying light signals in photodetectors.*** • ***Electron microscopes for high-resolution imaging.***	
		Total 10 Marks
Question 3		
a)	Define momentum and the principle of conservation of momentum	**2**
	Mark Scheme ***Momentum (p) is the product of mass (m) and velocity (v) (1 mark). The principle of conservation of momentum states that the total momentum of a closed system remains constant before and after any interaction. (1 mark)***	
b)	A 0.05 kg ball moving at 3 m/s collides head-on with a stationary 0.1 kg ball. Calculate the velocities of the balls after the collision. Assume an elastic collision.	**3**
	Mark Scheme ***Applying the principle, the total momentum before the collision (0.05 kg * 3 m/s + 0.1 kg * 0 m/s) = 0.15 kg·m/s must equal the total momentum after. (1 mark)*** ***Let V_1 and V_2 be the velocities of the 0.05 kg and 0.1 kg balls after the collision, respectively.*** ***Therefore, 0.15 kg·m/s = 0.05 kg * V_1 + 0.1 kg * V_2. (1 mark)*** ***Solving for V_1 and V_2 gives V_1 = 4 m/s and V_2 = -2 m/s (negative sign indicating the opposite direction). (1 mark)***	

		Marks
c)	Explain the concept of de Broglie wavelength and its relationship to particle momentum	**2**
	Mark Scheme ***De Broglie wavelength (λ) is the wavelength associated with a particle, related to its momentum (p) by the equation λ = h/p, where h is Planck's constant (1 mark). This concept links wave-particle duality. (1 mark)***	
d)	Calculate the de Broglie wavelength of a neutron with a momentum of 1.0 x 10^-25 kg·m/s.	**3**
	Mark Scheme λ ***= h/p (1 mark)*** λ ***= (6.63 x 10^-34 Js) / (1.0 x 10^-25 kg • m/s) (1 mark)*** $\approx$ ***0.663 nm. (1 mark)***	
		Total 10 Marks
Question 4		
a)	Define Kirchhoff's first law and explain its significance in electric circuits	**1**
	Mark Scheme ***Kirchhoff's first law, also known as the law of conservation of charge, states that the total current entering any junction in an electric circuit is equal to the total current leaving the junction. In other words, the sum of currents at any junction in a circuit is zero.*** ***This law is significant as it ensures the conservation of electric charge, providing a fundamental principle for understanding and analysing complex electric circuits. (1 mark)***	
b)	A cylindrical wire made of Nichrome (resistivity 1.0 x 10^-6 Ω·m) has a length of 5.0 m and a diameter of 1.0 mm. • Calculate the cross-sectional area of the wire in square meters. • Calculate the resistance of the wire in ohms.	**4**
	Mark Scheme ***The diameter is 1.0 mm, so the radius (r) is 0.5 mm = 0.0005 m. (1 mark)*** ***Area (A) of the wire =*** πr^2 ***Area =*** π ***** (0.0005)*** ^{2} ***Area=*** 7.85×10^{-8} m^2 ***(1 mark)*** ***Resistance (R) = ρ (resistivity) * L (length) / A*** ***Resistance=*** 1.0×10^{-6} ***Ω·m * 5.0 m /*** 7.85×10^{-8} m^2 ***(1 mark)*** ***Resistance= 6.36 Ω. (1 mark)***	

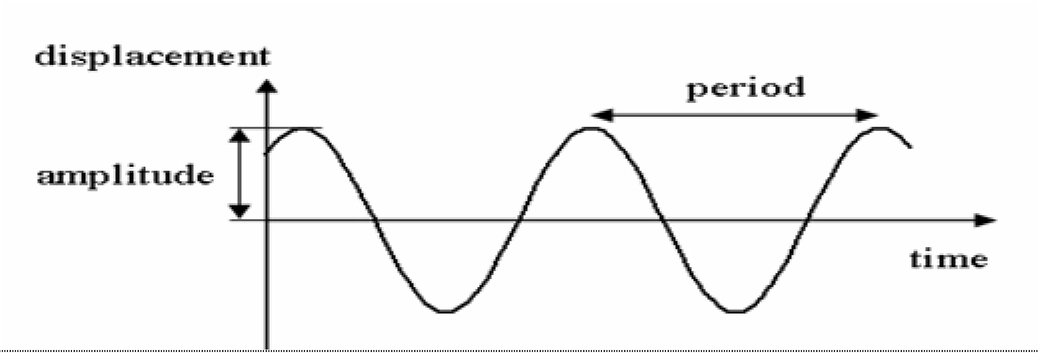
		Marks
c)	TWO (2) resistors, R1 = 2 ohms and R2 = 5 ohms are connected in parallel. Calculate the total current flowing through the circuit if the voltage source is 12 volts.	**3**
	Mark Scheme ***The total resistance (Rt) of the parallel circuit is:*** ***1/Rt = 1/R1 + 1/R2 (1 mark) = 1/2 Ω + 1/5 Ω = 7/10 Ω. (1 mark)*** ***Therefore, the total current (It) is:*** ***It = V / Rt = 12 V / (7/10 Ω) = 17.14 A. (1 mark1)***	
d)	Explain the difference between electrical current and electric field.	**2**
	Mark Scheme ***electric current is the flow of electric charge through a conductor. It is measured in amperes (A). (1 mark)*** ***An electric field is a non-contact force field that surrounds and exerts a force on any charged particle within it. It is measured in volts per meter (V/m). (1 mark)***	
		Total 10 Marks
Question 5		
a)	Explain the difference between nuclear fission and nuclear fusion.	**2**
	Mark Scheme ***Both nuclear fission and nuclear fusion are processes that release enormous amounts of energy from the nucleus of an atom. However, they differ significantly in their mechanisms and characteristics:*** ***Nuclear Fission: (1 mark)*** ***A heavy nucleus (uranium-235 or plutonium-239) is split into two smaller nuclei by absorbing a neutron. This splitting releases a large amount of energy in the form of heat, radiation, and additional neutrons. These neutrons can trigger further fission reactions, creating a chain reaction.*** ***Nuclear Fusion: (1 mark)*** ***Two light nuclei (deuterium, and tritium) collide and combine to form a heavier nucleus, releasing energy as heat and radiation. This process requires extremely high temperatures and pressures to overcome the electrostatic repulsion between the nuclei.***	

		Marks
b)	Define half-life (t_2) in the context of radioactive decay.	**1**
	Mark Scheme ***Half-life (t_2) is the time it takes for half of the radioactive nuclei in a sample to decay. It is a characteristic property of each radioactive isotope and independent of the initial amount present. (1 mark)***	
c)	A sample of iodine-131 has an initial activity (A_0) of 100 decays per second. If its half-life is EIGHT (8) days, what is its activity after SIXTEEN (16) days?	**3**
	Mark Scheme ***Calculate the number of half-lives that have passed: 16 days / 8 days/half-life = 2 half-lives. (1 mark)*** ***After each half-life, the activity halves: $A_1 = A_0/2$ and $A_2 = A_1/2 = A_0/4$. (1 mark)*** ***Therefore, the activity after 16 days is A_2 = 100 decays/second / 4 = 25 decays/second. (1 mark)***	
d)	Explain the concept of exponential decay as it applies to radioactive decay.	**3**
	Mark Scheme ***Exponential decay describes the decrease in the number of radioactive nuclei remaining over time (1 mark), following a mathematical function where the activity A remaining at time t is proportional to the initial activity A_0 and decays exponentially with a rate constant λ: $A = A_0e^{(-\lambda t)}$ (1 mark). This means, as time increases, the activity decreases at a decreasing rate (1 mark).***	
e)	In order of decreasing strength, state the FOUR (4) known fundamental forces in nature.	**1**
	Mark Scheme ***1 mark for all FOUR (4) forces correctly stated in the correct order.*** ***(1) the strong nuclear force between subatomic particles,*** ***(2) the electromagnetic forces between electric charges,*** ***(3) the weak nuclear force, which arises in certain radioactive decay processes, and*** ***(4) the gravitational force between objects.***	
		Total 10 Marks

Marks

Question 6		
a)	Define specific heat capacity and explain its role in thermal energy transfer.	**2**
	Mark Scheme ***Specific heat capacity (c) is the amount of heat energy required to raise the temperature of 1 kg of a substance by 1°C (1 mark). It quantifies the material's resistance to temperature change and plays a crucial role in heat transfer, determining how much heat needs to be exchanged to achieve a specific temperature change. (1 mark)***	
b)	A 1 kg block of copper (c = 385 J/kg°C) initially at 20°C is dropped into 2 litres of water (c = 4186 J/kg°C) initially at 80°C. Calculate the final equilibrium temperature of the mixture.	**5**
	Mark Scheme ***(1 marks for each step)*** • ***Calculate the heat gained by water: Q_water = m_water * c_water * (T_final - T_initial) = 2 kg * 4186 J/kg°C * (T_final - 80°C)*** • ***Calculate the heat lost by copper: Q_copper = m_copper * c_copper * (T_initial - T_final) = 1 kg * 385 J/kg°C * (20°C - T_final)*** • ***At thermal equilibrium, heat gained by water equals heat lost by copper: Q_water = -Q_copper*** • ***Solve the equation for T_final: T_final = (m_copper * c_copper * T_initial + m_water * c_water * T_initial) / (m_copper * c_copper + m_water * c_water)*** • ***T_final = (1 kg * 385 J/kg° C * 20° C + 2 kg * 4186 J/kg° C * 80° C) / (1 kg * 385 J/kg° C + 2 kg * 4186 J/kg° C) ≈ 52° C***	
c)	Describe TWO (2) factors that can affect the rate of heat transfer by conduction in materials.	**3**
	Mark Scheme ***(1 mark for each of the factors and 1 mark for both explanations correctly stated)*** • ***Thermal conductivity: Higher thermal conductivity implies faster heat transfer through the material due to its efficient transport of heat energy via atomic vibrations. Metals generally have higher conductivity than non-metals.*** • ***Cross-sectional area: A larger cross-sectional area allows for the passage of more heat energy per unit time, increasing the rate of heat transfer. For example, a thicker metal rod conducts heat slower than a thinner one.***	
		Total 10 Marks

Marks

Question 7		
a)	Define simple harmonic motion and illustrate its key characteristics with a diagram.	**5**
	Mark Scheme ***Simple harmonic motion (SHM) is a periodic oscillatory motion about an equilibrium point where the restoring force is directly proportional to the displacement from the equilibrium. Key characteristics include:*** ***Constant restoring force: The force pulling the object back to equilibrium is proportional to the displacement. (1 mark)*** ***Fixed frequency: The oscillation repeats at a specific frequency, independent of the amplitude. (1 mark)*** ***Definite period: The time taken to complete one full oscillation cycle is constant. (1 mark)*** ***Displacement: The displacement varies sinusoidally with time. (1 mark)*** ***(1 mark for the diagram if both axes correctly drawn labelled, the 'period' indicated, and the 'amplitude' indicated.)*** 	
b)	A mass of 0.2 kg attached to a spring with a spring constant of 100 N/m oscillates with a frequency of 2 Hz. Calculate the amplitude of its oscillation.	**4**
	Mark Scheme ***(1 mark for each step)*** • ***Angular frequency (ω) = 2πf*** • ***(ω) = 2π * 2 Hz = 4π rad/s*** • ***Spring constant (k) = ω² * m = (4π rad/s)² * 0.2 kg = 16π N/m*** • ***Amplitude = √(k / ω²) = √(16 π N/m / 4 π rad/s²) = 2 m***	

		Marks
c)	Explain the phenomenon of resonance in mechanical systems and its potential applications.	**1**
	Mark Scheme ***Resonance occurs when the frequency of an external driving force matches the natural frequency of a system, leading to significantly amplified oscillations. This amplifies vibrations and can be dangerous in structures or machines if not controlled. However, it also has applications in tuning instruments, vibration monitoring, and energy harvesting (1 mark).***	
		Total 10 Marks
Question 8		
a)	Define electric potential at a point due to a point charge and derive its mathematical relationship with charge and distance.	**3**
	Mark Scheme ***Electric potential (V) at a point due to a point charge (q) at a distance (r) is defined as the work done per unit charge to bring a small test charge from infinity to that point (1 mark). Mathematically, it's given by: V = k * q / r, (1 mark) where k is the Coulomb constant (8.99 x 10^9 Nm^2/C^2). (1 mark).***	
b)	TWO (2) point charges, +2 μC and −4 μC, are placed 1 meter apart. Calculate the potential difference between a point midway between them and a point 0.5 meters away from the −4 μC charge.	**4**
	Mark Scheme • ***Potential at the midpoint (V_mid): (1 mark)*** • ***Let d be the distance between each charge and the midpoint. V_mid = k * (2 μC) / d - k * (-4 μC) / d = 0 mV (since potentials from opposite charges cancel out). (1 mark)*** • ***Potential at 0.5 m from -4 μC (V_near): V_near = k * (-4 μC) / (0.5 m) = -32 x 10^9 Vm / m = -32 kV. (1 mark)*** • ***Potential difference (ΔV) = V_near - V_mid = -32 kV - 0 mV = -32 kV. (1 mark)***	

Marks

c)	Briefly explain the working principle of a capacitor and describe its role in storing electrical energy.	**3**
	Mark Scheme ***A capacitor consists of two conducting plates separated by an insulating dielectric material. When a voltage is applied across the plates, positive charges accumulate on one plate and negative charges on the other, attracted by the opposite polarity. This separation of charges creates an electric field between the plates. The dielectric material helps increase the electric field strength while preventing direct contact between the plates. (1 mark)*** ***The energy stored in a capacitor depends on the capacitance (C), the voltage across the plates (V), and the electric field strength (E) as follows:*** ***Energy (E) = 1/2 * C * V^2 (1 mark)*** ***Capacitors play a crucial role in various electronic circuits by (1 mark for stating any of the following):*** • ***Blocking DC (direct current) while allowing AC (alternating current) to pass, useful for filtering and signal processing.*** • ***Smoothing out voltage fluctuations by providing a temporary reservoir of charge.*** • ***Tuning circuits by storing and releasing specific frequencies.***	
		Total 10 Marks
Question 9		
a)	Define magnetic flux and explain its relationship to the magnetic field and the area through which it passes.	**2**
	Mark Scheme ***Magnetic flux (Φ) is the measure of the total magnetic field passing through a given area (1 mark). It is given by the product of the magnetic field strength (B) and the area (A) perpendicular to the field: Φ = B * A. (1 mark)***	
b)	A current-carrying wire experiences a force of 0.3 N per meter in a magnetic field of 0.6 T. Calculate the current flowing through the wire if its length in the field is 2 meters.	**4**
	Mark Scheme ***(1 mark each)*** ***Force per unit length (F/L) = B * I*** ***(F/L) = 0.3 N/m*** ***Current (I) = F/L / B*** ***Current (I)= 0.3 N/m / 0.6 T = 0.5 A***	

		Marks
c)	Describe the principle of electromagnetic induction and explain its role in the operation of a generator.	**4**
	Mark Scheme ***Electromagnetic induction is the phenomenon where a changing magnetic field induces an electric field and voltage in a conductor, and vice versa. (1 mark) This principle forms the basis for generators, transformers, and various electromagnetic devices. (1 mark)*** ***In a generator, rotating magnets create a changing magnetic field through a coil of wire (1 mark). This induces a voltage in the coil, causing current to flow. The type and configuration of the magnet and coil determine the generated voltage and power output. (1 mark)*** ***Electromagnetic induction plays a crucial role in various applications, including:*** • ***Generation of electricity in power plants*** • ***Electric motors and actuators*** • ***Transformers for voltage and current manipulation*** • ***Sensors and detectors for electromagnetic fields***	
		Total 10 Marks
Question 10		
a)	Briefly explain the Bohr model of the atom and state TWO (2) of its limitations.	**3**
	Mark Scheme ***The Bohr model of the atom proposed that electrons orbit the nucleus in fixed, quantised energy levels. It visualised the atom as a miniature solar system with electrons at specific distances from the nucleus (1 mark). While successful in explaining the spectra of simple atoms like hydrogen, the Bohr model had limitations: (1 mark for each of the below up to 2):*** • ***It could not explain the spectra of complex atoms with multiple electrons.*** • ***It did not account for the wave-like nature of electrons and their existence in probability clouds around the nucleus.*** • ***It could not explain electron spin and its effects on atomic properties.***	

		Marks
b)	Describe the process of alpha decay in a radioactive nucleus and write the balanced nuclear equation for the decay of uranium-238.	**3**
	Mark Scheme ***Alpha decay involves the spontaneous emission of an alpha particle (a helium nucleus consisting of two protons and two neutrons) from a radioactive nucleus. This results in a daughter nucleus with two fewer protons and two fewer neutrons. (1 mark)*** ***The balanced nuclear equation for the alpha decay of uranium-238 (^{238}U) is:*** $^{238}U \rightarrow {}^{234}Th + \alpha + Q$ ***(1 mark)*** ***where ^{234}Th is the daughter nucleus (thorium-234), α is the alpha particle, and Q is the energy released during the decay process. (1 mark)***	
c)	Calculate the energy released in the alpha decay of uranium-238, given that the mass of uranium-238 is 238.05079 u, the mass of thorium-234 is 234.04363 u, and the mass of an alpha particle is 4.00260 u.	**4**
	Mark Scheme ***Calculate the mass defect (Δm) using the given masses:*** ***Δm = (mass of uranium-238) - (mass of thorium-234 + mass of alpha particle)*** ***Δm = 238.05079 u - (234.04363 u + 4.00260 u) = 0.00456 u (1 mark)*** ***Convert the mass defect to energy using Einstein's mass-energy equivalence:*** ***$E = \Delta m * c^2$ (1 mark)*** ***where c is the speed of light (3×10^8 m/s) and 1 u is equivalent to 931.5 MeV/c^2*** ***E = 0.00456 u * 931.5 MeV/c^2 = 4.25 MeV (1 mark)*** ***Therefore, the energy released in the alpha decay of uranium-238 is approximately 4.25 MeV. (1 mark)***	
		Total 10 Marks

End of paper

Learning Outcomes matrix

Question	Learning Outcomes / Assessment Criteria assessed	Marker can differentiate between varying levels of achievement
1	2.8, 2.7	[must be 'Yes']
2	4.1, 4.2, 7.7, 7.8	Yes
3	7.7, 2.3, 7.9	Yes
4	3.5, 3.3, 3.7, 3.1	Yes
5	5.1, 5.4	Yes
6	7.1, 7.3, 7.6	Yes
7	6.1, 6.2, 6.3	Yes
8	3.2, 3.9, 3.12	Yes
9	3.15, 3.16, 3.19	Yes
10	5.1, 5.3, 5.4,	Yes
[insert as many rows as there are questions in the QP]		

Grade descriptors

<table>
<tr><th>Learning Outcome</th><th>Pass
(40-59%)</th><th>Merit
(60-69%)</th><th>Distinction
(70-100%)</th></tr>
<tr><td>1.Recognise, describe, analyse and work with kinematics and solve equations of motion.</td><td rowspan="4">Demonstrates an adequate awareness and understanding of concepts, terminology, principles and processes with a reasonable discussion and application of principles, tools and techniques and satisfactory reference to theory and science.

Where required, demonstrates an adequate ability to perform calculations correctly using appropriate techniques and methods.</td><td rowspan="4">Demonstrates a consistent and accurate awareness and understanding of concepts, terminology, principles and processes with a detailed discussion and application of principles, tools and techniques and precise reference to theory and science.

Where required, demonstrates a robust ability to perform calculations consistently correctly using appropriate techniques and methods.</td><td rowspan="4">Demonstrates an outstanding awareness and understanding of concepts, terminology, principles and processes with a highly comprehensive and sophisticated discussion and application of principles, tools and techniques and critical and meticulous reference to theory and science.

Where required, demonstrates an excellent ability to perform calculations consistently correctly and to the highest standard using appropriate techniques and methods.</td></tr>
<tr><td>2.Recognise and employ the principles of dynamics, momentum and its conservation, Newton's laws of motion and the related notions of forces, work, energy and power.</td></tr>
<tr><td>3.Recognise, identify and describe the principles of electricity and its related concepts (i.e., electric current, electric forces and fields, potential difference and power, resistance and resistivity, circuits, Kirchhoff's laws and capacitors) as well as magnetic fields and electromagnetism.</td></tr>
<tr><td>4.Recognise, identify, analyse and describe the different types of waves.</td></tr>
</table>

5.Recognise, define and describe atomic structure and nuclear physics.			
6.Identify, analyse and discuss the principles and equations of simple harmonic, and damped and forced oscillations.			
7.Recognise, describe and analyse the principles of thermal physics, ideal gases and quantum physics.			