Level 3 International Foundation Diploma for Higher Education Studies
Ofqual Number: 603/0080/2 Quartz ID: 1125 / 1207

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Physics for University Study

SAMPLE EXAMINATION

This specimen assessment material is devised from previous past papers to reflect the single examination assessment approach now taken for this unit in the Level 3 International Foundation Diploma for Higher Education Studies.

Time allowed: 2 hours

Marking Scheme

This marking scheme has been prepared as a guide only to markers. This is not a set of model answers, or the exclusive answers to the questions, and there will frequently be alternative responses which will provide a valid answer. Markers are advised that, unless a question specifies that an answer be provided in a particular form, then an answer that is correct (factually or in practical terms) must be given the available marks.

If there is doubt as to the correctness of an answer, the relevant NCC Education materials should be the first authority.

Throughout marking, please credit any valid alternative point.

Candidate Name and ID number:		
Marker's comments:		
Moderator's comments:		
Mark:	**Moderated mark:**	**Final mark:**
Penalties applied for academic malpractice:		

Answer ALL questions

Marks

Question 1

a) A ball is dropped from a vertical height of 4.8 m above the ground as shown in figure 1. The ball was initially at rest and air resistance can be ignored.

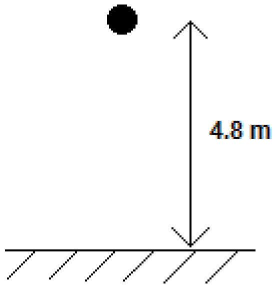


Figure 1

i) Describe the motion of the ball as it falls to the ground. **2**

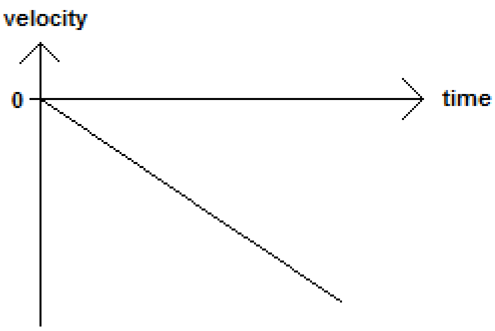
MARK SCHEME: the ball falls with a constant acceleration (1 mark) vertically downwards (1 mark)

ii) Calculate the speed of the ball just before it hits the ground. **2**

MARK SCHEME: use $v^2 = u^2 + 2as$; $v^2 = 0 + (2 \times 9.81 \times 4.8)$ (1 mark)
$v = \sqrt{(94.18)} = 9.70\ ms^{-1}$ (1 mark)
Accept any valid method e.g. calculate time and then speed

iii) On your answer paper, sketch a graph of velocity against time from the moment the ball is released until the moment before it hits the ground. Label your axes. **2**

MARK SCHEME:



Axes labels (1 mark); straight line from origin with negative gradient (1 mark)

Marks

b) A large rock of mass 240 kg is blown-up using dynamite. The explosion causes the rock to break into TWO (2) fragments, with one fragment having twice the mass of the other. The two fragments move in opposite directions after the explosion with velocities v_1 and v_2 respectively as shown in figure 2.

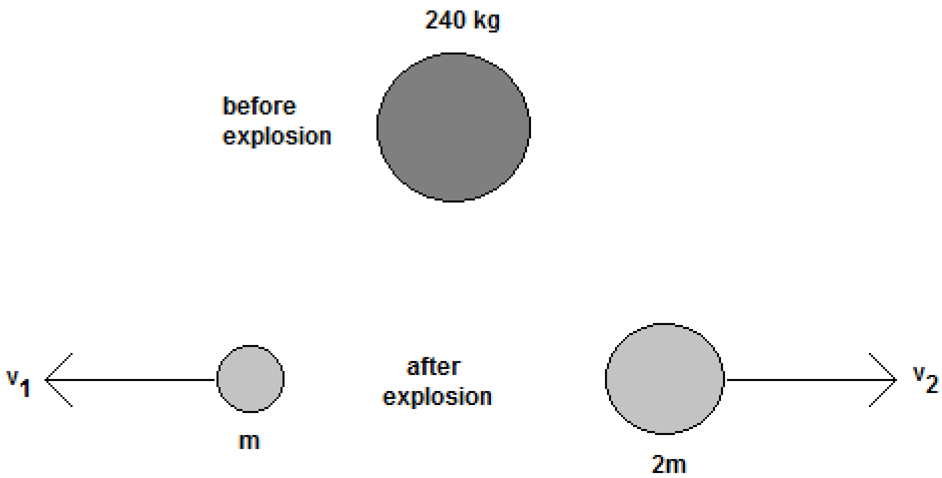


Figure 2

i) Calculate the ratio of the velocities v_1 / v_2. **2**

MARK SCHEME: momentum before explosion = 0
Momentum after explosion = $2mv_2 - mv_1 = 0$ (1 mark)
$2mv_2 = mv_1$; $v_1 / v_2 = 2$ (1 mark)

ii) State whether you expect the explosion to be elastic or inelastic and give a reason for your answer. **2**

MARK SCHEME: the explosion will be inelastic (1 mark), as energy will be lost as sound and heat during the explosion (1 mark)

Total 10 Marks

Marks

Question 2

a) THREE (3) cells of EMF 1.5 V, 2.2 V and 1.5 V respectively are connected in series with an ammeter and a 2.47 Ω resistor, as shown in figure 3. The cells have internal resistances of 0.88 Ω, 0.95 Ω and 0.88 Ω respectively.

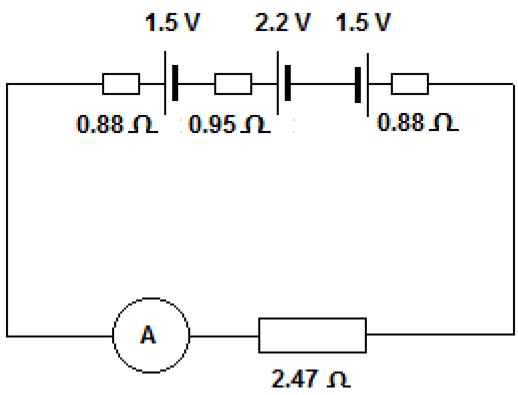


Figure 3

i) Calculate the reading on the ammeter. **2**

MARK SCHEME: Effective EMF = 1.5 + 2.2 - 1.5 = 2.2 V (1 mark)

I = V / R = 2.2 / 5.18 = 0.42 A (1 mark)

ii) Hence calculate the voltage across the cell whose EMF is 2.2 V. **2**

MARK SCHEME: Voltage across cells internal resistance = Ir

= 0.42 x 0.95 = 0.40 (1 mark)

Voltage across cell = 2.2 - 0.40 = 1.8 V (1 mark)

iii) State ONE (1) change that could be made to the circuit in figure 3 so the reading on the ammeter reduces. You must use all of the components shown, and no extra components can be added to the circuit. **1**

MARK SCHEME: If both 1.5 V cells are connected the same way round, but the 2.2 V cell is connected the other way round (so that it opposes the EMF of the 1.5 V cells), then the total EMF will reduce to 1.5 + 1.5 - 2.2 = 0.8 V (1 mark)

Marks

b) A student uses the circuit shown in figure 4 to produce the I - V characteristic graph of a metal conductor. The circuit has a 6.0 V power supply connected in series with a variable resistor and a metal conductor, and there are meters to obtain current and voltage values.

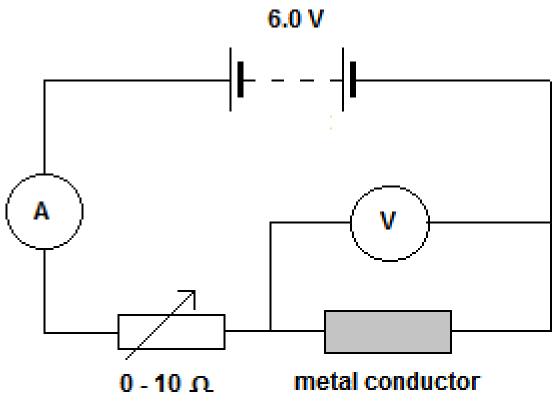


Figure 4

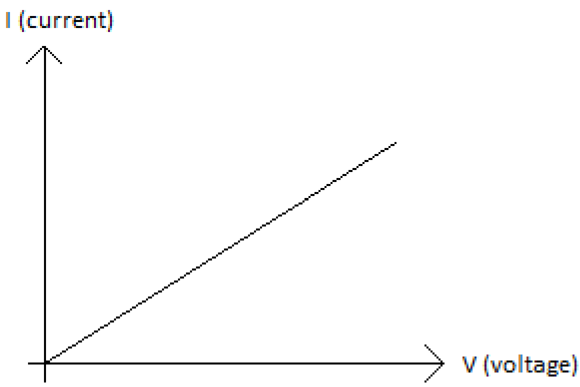
i) Explain how you could use the circuit in figure 4 to obtain sufficient readings to draw an I - V graph for the metal conductor, **and** state ONE (1) method you could use so that the metal conductor does not get hot. **2**

MARK SCHEME: Collect sufficient readings of I and V for the variable resistor in different positions (or different resistances) (1 mark). Prevent the metal conductor getting hot by disconnecting the power supply between readings (or add a switch to the circuit that is opened between readings) allowing the conductor to cool to room temperature (1 mark)

Marks

ii) On your answer paper, sketch the **I** - V graph for the metal conductor. Label your axes and ignore the effects of heating. **2**

MARK SCHEME:



Axis labels with current on y-axis (1 mark); straight line with positive gradient passing through the origin (1 mark) NB line can continue into the negative region, but this is not necessary for the mark

iii) If the voltmeter reads 3.0 V when the variable resistor is set to 5.0 Ω, state the resistance of the metal conductor. You do not need to do any calculation. **1**

MARK SCHEME: 5.0 Ω (1 mark)

Total 10 Marks

Marks

Question 3

a) A small ball of mass 35 g is dropped into a container of water. The ball is travelling with a vertical velocity of 14 ms^{-1} when it hits the surface of the water and reaches terminal velocity 0.88 s later when at a depth of 18 cm below the surface as shown in figure 5.

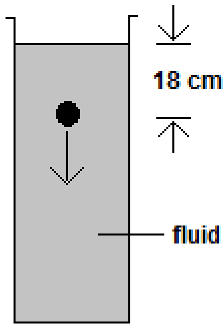


Figure 5

i) Calculate the deceleration of the ball before reaching terminal velocity when moving through the fluid. **2**

MARK SCHEME: use $s = ut + {}^1/_2at^2$
$a = -2(s - ut) / t^2 = 2(0.18 - 14x0.88) / 0.88^2$ (1 mark) = 31 ms^{-2} (1 mark)

ii) State ONE (1) assumption that needs to be made about the motion of the ball in order to carry out the calculation in part i) above. **1**

MARK SCHEME: deceleration remains constant (1 mark)

iii) Calculate the upthrust force acting on the ball when moving through the fluid with terminal velocity. **2**

MARK SCHEME: at terminal velocity weight = upthrust
Upthrust = mg = 0.035 x 9.81 (1 mark) = 0.34 N (1 mark)

Marks

b) A vertical stone column in the shape of a cylinder forms part of an ancient building as shown in figure 6. The column has a height of 12 m and diameter of 2.3 m. The stone has a density of 2200 kgm^{-3}.

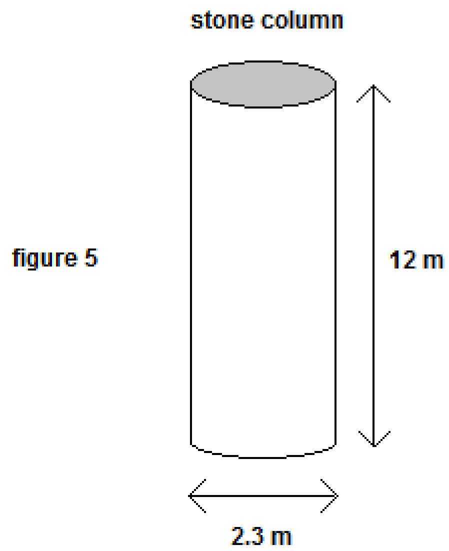


Figure 6

i) Calculate the weight of the stone column. **2**

MARK SCHEME: M = ρV
= 2200 x (12 x π x 1.15²) = 1.097x10⁵ kg (1 mark)
Weight = mg = 1.097x10⁵ x 9.81 = 1.1x10⁶ N (1 mark)

ii) Calculate the pressure exerted by the stone column on the ground. **1**

MARK SCHEME: P = F/A = 1.1x10⁶ / π x 1.15² = 2.6x10⁵ Pa (1 mark)
OR use P = ρgh = 2200 x 12 x 9.81 = 2.6x10⁵ Pa

iii) If the maximum compressive stress of this stone column is 14 MPa, state whether it will collapse under its own weight. Give a reason for your answer. **2**

MARK SCHEME: the stone column will NOT collapse under its own weight (1 mark), as the maximum compressive stress (F/A) is greater than the pressure exerted by the column on the ground (1 mark)

Total 10 Marks

Marks

Question 4

a) A student makes a solenoid by winding a coil of copper wire onto a cardboard tube, and a direct current is passed through the solenoid as shown in figure 7.

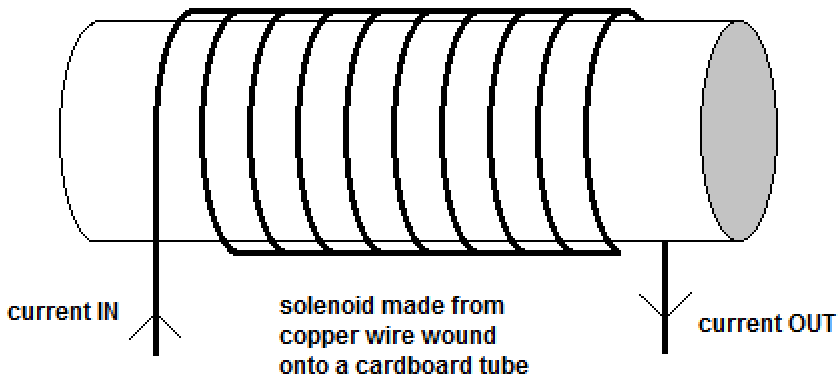
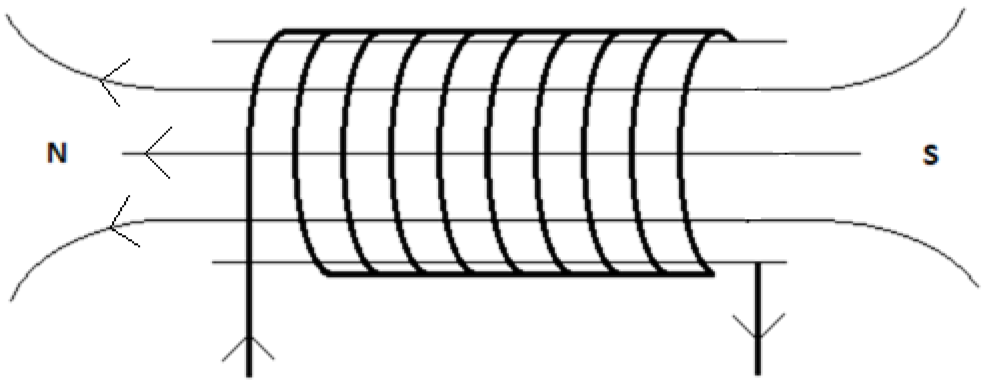


Figure 7

i) On your answer paper, sketch the solenoid and show the shape of the magnetic field pattern inside and at each end of the solenoid. Label each end North (N) and South (S) and use arrows on the magnetic field lines to indicate its direction. **2**

MARK SCHEME:



Correct magnetic field pattern inside and at ends of solenoid (1 mark)

Arrows showing field moving from N to S (1 mark)

Marks

ii) If the magnetic flux density inside the solenoid is 3.7 mT and it has a cross-sectional area of 5.3 cm^2, calculate the magnetic flux passing through the solenoid. **2**

MARK SCHEME: $\Phi = AB = 5.3 \times 10^{-4} \times 3.7 \times 10^{-3}$ (1 mark)

$= 2.0 \times 10^{-6}$ Wb (1 mark)

iii) State ONE (1) method the student could use to investigate the shape of the magnetic field inside the solenoid. **1**

MARK SCHEME: use a Hall probe OR use a compass (1 mark)

b) A coil of wire with 1400 turns and cross-sectional area 7.1 cm^2 is situated in a uniform magnetic field of flux density 8.5×10^{-4} T as shown in figure 8. The coil is made to rotate at a constant rate of 200 revolutions s^{-1} in the direction shown, so that its axis remains in the plane of the paper.

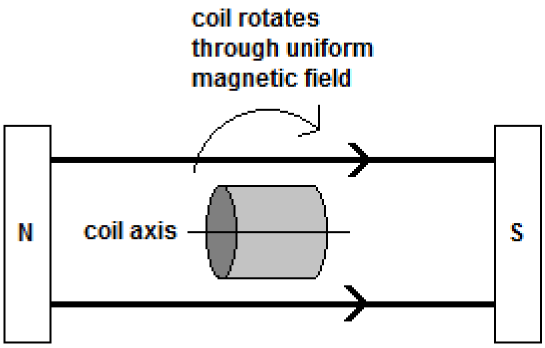


Figure 8

i) Calculate the angular speed of the rotating coil. **2**

MARK SCHEME: $= 2\pi f = 2 \times \pi \times 200$ (1 mark)

$= 400\pi\ s^{-1}$ or $1.3 \times 10^{3}\ s^{-1}$ (1 mark)

ii) Calculate the maximum induced EMF in the coil as it rotates in the uniform magnetic field. **2**

MARK SCHEME: $BAN\omega = 8.5 \times 10^{-4} \times 7.1 \times 10^{-4} \times 1400 \times 400\pi$ (1 mark)

= 1.1 V (1 mark)

Marks

iii) State the effect of Lenz's law as the rate of rotation of the coil is increased. **1**

MARK SCHEME: Lenz's law will oppose the increase in angular speed, so the induced EMF will be less than expected OR so some of the (rotational) energy will be converted into heat (1 mark)

Total 10 Marks

Marks

Question 5

Gas particles trapped inside a rigid well-insulated container are shown in figure 9. The particles are moving randomly and collide with other particles and the walls of the container.

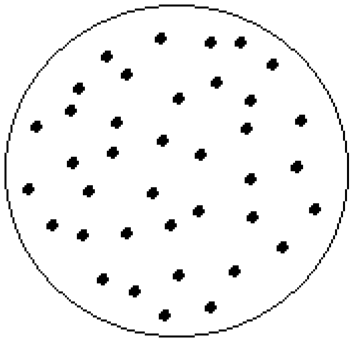


Figure 9

a) Explain what will happen to the energy of the gas particles as the temperature of the gas increases. Give a reason for your answer. **2**

MARK SCHEME: The speed of the gas particles will increase, and so the KE of the particles will also increase (1 mark) as container will not change shape or allow heat transfer (1 mark)

b) Use Newton's second law to explain how the gas particles are able to exert pressure on the walls of the container. **2**

MARK SCHEME: when a gas particle collides with the side of the container it rebounds, so there is a change in momentum (1 mark) and a force (and therefore pressure) is applied (1 mark)

c) If the container has a volume of 0.05 m^3 and contains ONE (1) mole of gas that exerts a pressure of 1.2×10^5 Pa, calculate the average speed of the gas particles. Assume the molar mass of gas in the container is 0.044 kg. **2**

MARK SCHEME: $pV = {}^1/_3 Nm\langle c^2 \rangle$; $c^2 = 3pV / Nm$
$c^2 = (3 \times 1.2 \times 10^5 \times 0.05) / 0.044$ (1 mark); $c = 640\ ms^{-1}$ (1 mark)

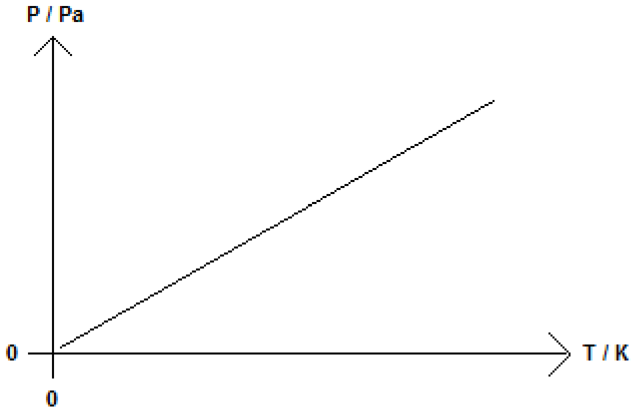
d) Calculate the temperature of the gas in the container. **2**

MARK SCHEME: $pV = nRT$; $T = pV/nR$
$= (1.2 \times 10^5 \times 0.05) / (1 \times 8.31)$ (1 mark) $= 722$ K (1 mark)

Marks

e) The temperature of the gas is now slowly decreased until it is just above absolute zero. On your answer paper, sketch a graph of pressure against temperature during this change. **2**

MARK SCHEME:



Straight line (1 mark); line should not reach (0,0) but would extrapolate to pass through it (1 mark)

Total 10 Marks

Marks

Question 6

a) A helium nucleus consists of TWO (2) protons and TWO (2) neutrons and has a diameter of approximately 3.02×10^{-15} m.

i) Apart from the electromagnetic force, state the name of ONE (1) other significant force that acts between the protons in the helium nucleus, and state which of these forces must be stronger. **2**

MARK SCHEME: Strong (nuclear) force (1 mark); strong nuclear force must be the stronger force (1 mark)

ii) Calculate the density of the helium nucleus. **2**

MARK SCHEME: $\rho = M / V$

$= (2 \times 1.67 \times 10^{-27} + 2 \times 1.68 \times 10^{-27}) / {}^4/_3\pi(1.51 \times 10^{-15})^3$ ***(1 mark)***

$= 4.6 \times 10^{17}\ kgm^{-3}$ ***(1 mark)***

iii) Calculate the size of the electromagnetic force acting between protons in the helium nucleus. Assume the protons are separated by a distance of approximately 2.0×10^{-15} m. **2**

MARK SCHEME: $F = kQ_1Q_2 / r^2$

$= (8.99 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}) / (2.0 \times 10^{-15})^2$ ***(1 mark)*** $= 58$ N ***(1 mark)***

b) A helium nucleus has a mass of 4.002 atomic mass units (AMUs).

i) Calculate the binding energy per nucleon of the helium nucleus. **3**

MARK SCHEME: binding energy of helium nucleus $E = \Delta mc^2$

$\Delta m = (2 \times 1.673 \times 10^{-27} + 2 \times 1.675 \times 10^{-27}) - (4.002 \times 1.661 \times 10^{-27})$

$= 4.9 \times 10^{-29}$ kg ***(1 mark)***

Binding energy $E = \Delta mc^2 = 4.9 \times 10^{-29} \times (3.0 \times 10^8)^2 = 4.41 \times 10^{-12}$ J ***(1 mark)***

Binding energy per nucleon $= 4.41 \times 10^{-12} / 4 = 1.103 \times 10^{-12}$ J ***(1 mark)***

Marks

ii) Explain why the binding energy per nucleon is an indication of the stability of a nucleus. **1**

MARK SCHEME: a higher binding energy per nucleon generally indicates a more stable nucleus (1 mark)

OR a higher binding energy per nucleon indicates that more energy is required to break up the nucleus, hence more stable

Total 10 Marks

Marks

Question 7

a) A uniform wooden swing in a fairground has a mass of 43 kg and is connected by FOUR (4) rigid metal rods of length 8.5 m to a pivot point, as shown in figure 10. The swing is initially stationary and has a horizontal length of 4.7 m.

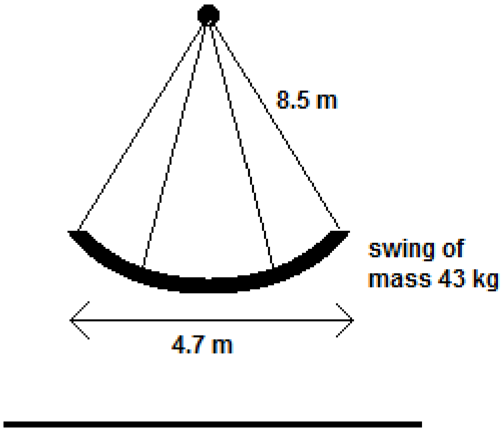


Figure 10

i) Calculate the tension in ONE (1) metal rod, assuming that the tension is equally distributed between the FOUR (4) rods. **2**

MARK SCHEME: rods support the swing, so T = $^{1}/_{4}$ weight (1 mark)
T = (43 x 9.81) / 4 = 110 N (accept 105 N) (1 mark)

ii) If a child of mass 48 kg now sits at the left-hand end of the swing, calculate the moment of the system about the pivot point. Assume the swing is locked in the position shown in figure 10. **1**

MARK SCHEME: moment = force x perpendicular distance from pivot
= 48 x 9.81 x 2.35 = 1100 Nm (1 mark)

Marks

iii) The swing is now unlocked so that it is free to move. On your answer paper, sketch a diagram showing the position of the swing relative to the pivot point with the child sitting at the left-hand end, when it is in equilibrium. **2**

MARK SCHEME:

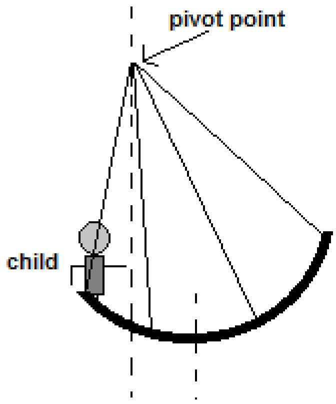


Diagram should show the child on the left of the pivot point (1 mark), and the centre of the swing on the right of the pivot point (1 mark)

b) Several more people now get in the swing so that their total mass is now 263 kg, and the swing is balanced as shown in figure 10. The swing is pulled to one side so that its centre of mass moves through a horizontal distance of 2.6 m and released so that it oscillates with a frequency of 0.03 Hz.

i) Calculate the maximum speed of the swing as it oscillates. **2**

MARK SCHEME: $v_{max} = 2\pi fA = 2 \times \pi \times 0.03 \times 2.6$ (1 mark) $= 0.49\ ms^{-1}$ (1 mark)

ii) Calculate the maximum centripetal force acting on the swing as it oscillates. **2**

MARK SCHEME: (occurs at maximum speed); $F_c = mv^2 / r$ $= (43 + 263) \times 0.490^2 / 8.5$ (1 mark) $= 8.6$ N (1 mark)

iii) Hence calculate the maximum resultant force acting on the swing. **1**

MARK SCHEME: resultant force = weight - centripetal force $= (306 \times 9.81) - 8.64 = 3000$ N (1 mark)

Total 10 Marks

Marks

Question 8

a) If sodium gas is excited by applying a high voltage across it, light is emitted at specific wavelengths. If this light is passed through a diffraction grating, the emission line spectrum for sodium can be observed. Part of this spectrum is shown in figure 11, where TWO (2) coloured lines can be seen at wavelengths of 589 nm and 590 nm respectively.

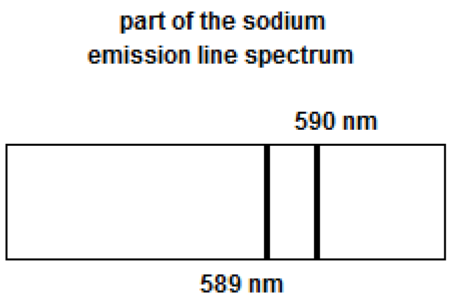


Figure 11

i) Calculate the energy of the photons emitted by the excited sodium gas, that give rise to each emission line in figure 11. **3**

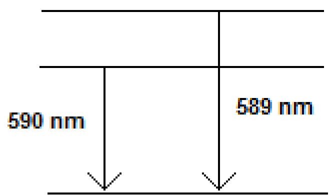
MARK SCHEME: E = hf = hc / λ = (6.63x10^{-34} x 3.0x10^{8}) / 5.89x10^{-7}

= 3.38x10^{-19} J (1 mark)

E = (6.63x10^{-34} x 3.0x10^{8}) / 5.90x10^{-7} (1 mark) = 3.37x10^{-19} J (1 mark)

ii) On your answer paper, sketch part of the energy level diagram for sodium showing the transitions that give rise to the light emitted in figure 11. Label each transition with the wavelength of light emitted. **2**

MARK SCHEME:



Energy level diagram showing THREE (3) levels and TWO (2) transitions (1 mark); transitions correctly labelled (1 mark)

Marks

iii) Explain why the sodium emission spectrum provides evidence for discrete energy levels in the sodium atom. **1**

MARK SCHEME: The spectrum is not continuous OR the spectrum has separate lines at definite wavelengths, so photons are only emitted with specific (discrete) energies (1 mark)

b) A photon of light falls onto the surface of sodium metal whose work function is 2.28 eV, resulting in the emission of an electron with kinetic energy 3.54 eV.

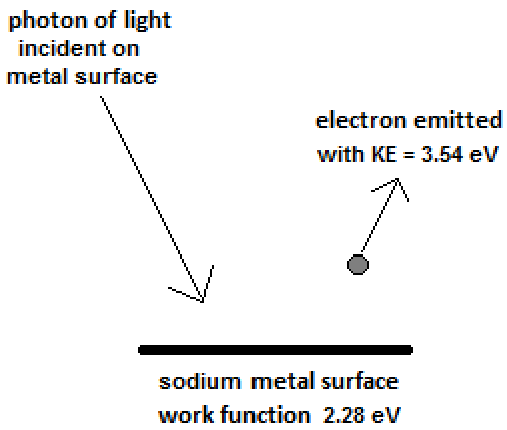


Figure 12

i) Calculate the energy of the photon that causes this electron to be emitted. **1**

MARK SCHEME: $E = \Phi + KE_{max} = 2.28 + 3.54 = 5.82$ eV (1 mark)

Accept 9.31×10^{-19} J

ii) Define work function, and state ONE (1) assumption that has been made about the electron's kinetic energy value. **2**

MARK SCHEME: work function is the minimum energy required to release an electron from the metal surface (1 mark). Assume that the KE of the electron is its maximum possible value (1 mark)

iii) Calculate the threshold frequency of an incident photon so that electron emission will occur. **1**

MARK SCHEME: $f = \Phi / h = (2.28 \times 1.6\times10^{-19}) / 6.63\times10^{-34}$

$= 5.50\times10^{14}$ Hz (1 mark)

Total 10 Marks

Marks

Question 9

a) A large rubber ball of mass 12 kg is dropped from a balloon and falls vertically through the air until it reaches terminal velocity of 78 ms^{-1}. There is a horizontal wind blowing with a constant velocity of 43 ms^{-1} as shown in figure 13.

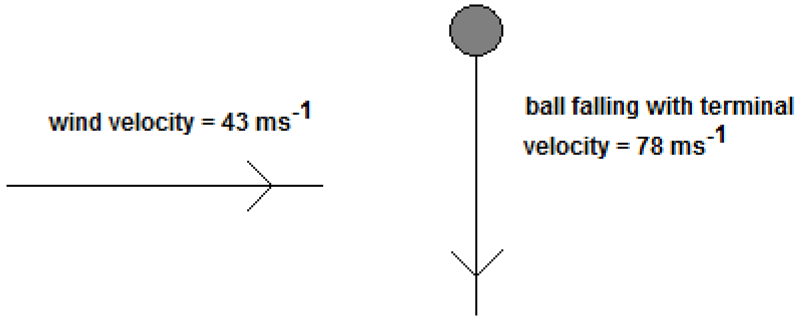


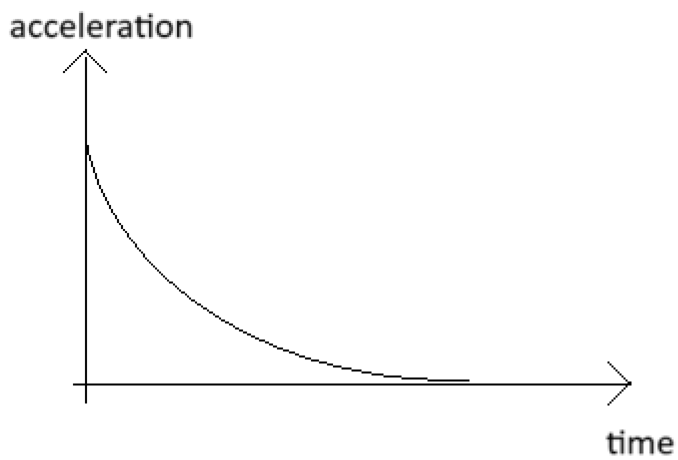
Figure 13

i) Calculate the magnitude and direction of the speed of the ball as it falls through the air at terminal velocity. **3**

MARK SCHEME: resultant speed = $\sqrt{(43^2 + 78^2)}$ = 89 ms^{-1} (1 mark)
Angle to horizontal = $\tan^{-1}(78 / 43)$ = 61^0 (1 mark)
Velocity of ball is 89 ms^{-1} at 61^0 below the horizontal (1 mark)

ii) On your answer paper, sketch a graph of acceleration against time for the ball from the moment it is dropped from the balloon until just after it reaches terminal velocity. Label your axes. **2**

MARK SCHEME:



Axis labels (1 mark); correct shape of curve from origin (1 mark)

Marks

iii) Calculate the amount of gravitational potential energy lost by the ball from the moment it is dropped from the balloon until it reaches terminal velocity. **2**

MARK SCHEME: ΔGPE = ΔKE = 0.5 x 12 x 78^2 (1 mark)
= 3.7×10^4 J (1 mark)

b) When the ball hits the ground it deforms for 0.75 s before rebounding but does not break.

i) Calculate the average force acting on the ball while in contact with the ground. **2**

MARK SCHEME: F = (mv - mu) / t = (12 x 78) / 0.75 (1 mark)
= 1200 N (1 mark)

ii) State how the elastic potential energy of the rubber will change during the time when the ball is in contact with the ground. **1**

MARK SCHEME: EPE of the rubber will increase (until maximum deformation) and then decrease until it loses contact (1 mark)

Total 10 Marks

Marks

Question 10

a) Two waveforms are shown in figure 14. The top waveform has double the frequency of the bottom waveform, and they move in opposite directions along the same line so at one moment in time they coincide with each other so that the top waveform is superimposed on the bottom waveform.

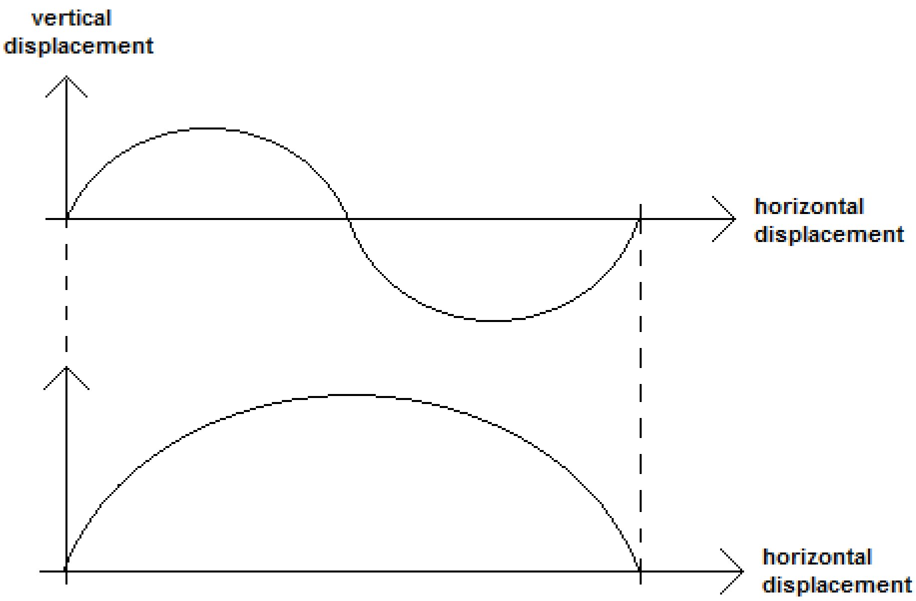


Figure 14

On your answer paper, use the principle of superposition to sketch the resulting waveform when the two waveforms shown in figure 14 coincide. **2**

MARK SCHEME:

Graph starts and finishes at zero amplitude (1 mark). Shape has been sketched correctly (1 mark)

Marks

b) A string is stretched between two points 0.72 m apart, as shown in figure 15. One end of the string vibrates with a frequency of 26 Hz so that a wave travels along the string to the fixed end and reflects back, forming the fundamental (first harmonic) stationary wave.

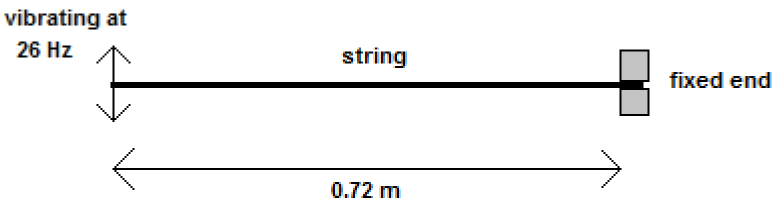


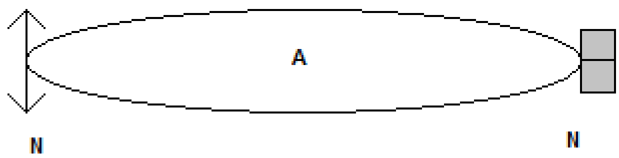
Figure 15

i) Calculate the wavelength of the stationary wave produced on the string. **1**

MARK SCHEME: λ = 0.72 x 2 = 1.44 m (1 mark)

ii) On your answer paper, sketch the stationary wave that is formed and label the positions of any nodes and antinodes. **2**

MARK SCHEME:



ONE (1) loop shown (1 mark)

nodes and antinodes correctly positioned (1 mark)

iii) Explain why the principle of superposition cannot be used to explain the formation of the stationary wave on the string. **2**

MARK SCHEME: The incident and reflected waves occur at different moments in time so do not superpose (1 mark). If they did they would be exactly out of phase and would cancel (resulting in zero amplitude) (1 mark)

Marks

c) A narrow beam of electrons can be diffracted by passing it through a thin piece of graphite. The electron beam consists of electrons travelling one after the other. The resulting diffraction pattern indicates that electrons are able to interfere with each other in the same way as light passing through a diffraction grating.

i) Describe a property of the electrons in the beam so they can interfere with each other. **1**

MARK SCHEME: the electrons must have wave properties (or must have a wavelength) so they are able to superpose and interfere to cause the diffraction pattern (1 mark)

ii) If the electrons are travelling at a speed of 1.22×10^{6} ms^{-1}, calculate their de Broglie wavelength. **2**

MARK SCHEME: $\lambda = h / mv = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 1.22 \times 10^{6})$ ***(1 mark)*** $= 5.97 \times 10^{-10}$ m ***(1 mark)***

Total 10 Marks

End of paper

Formulae and data sheet

Fundamental constants and values

Quantity	Symbol	Value	Units
Speed of light in a vacuum	c	3.00×10^{8}	ms^{-1}
Permeability of free space	μ_o	$4\pi \times 10^{-7}$	Hm^{-1}
Permittivity of free space	ε_0	8.85×10^{-12}	Fm^{-1}
Magnitude of the charge of electron	e	1.60×10^{-19}	C
The Planck constant	h	6.63×10^{-34}	Js
Gravitational constant	G	6.67×10^{-11}	$Nm^{2}kg^{-2}$
Avogadro constant	N_A	6.02×10^{23}	Mol^{-1}
Molar gas constant	R	8.31	$JK^{-1}mol^{-1}$
The Boltzmann constant	k	1.38×10^{-23}	JK^{-1}
The Stefan constant	σ	5.67×10^{-8}	$Wm^{-2}K^{-4}$
The Wien constant	α	2.90×10^{-3}	mK
Electron rest mass	m_e	9.11×10^{-31}	Kg
Electron charge/mass ration	e / m_e	1.76×10^{11}	Ckg^{-1}
Proton rest mass	m_p	$1.67(3) \times 10^{-27}$	Kg
Proton charge/mass ratio	e/m_p	9.58×10^{7}	Ckg^{-1}
Neutron rest mass	m_n	$1.67(5) \times 10^{-27}$	Kg
Gravitational field strength	g	9.81	Nkg^{-1}
Acceleration due to gravity	g	9.81	ms^{-2}
Atomic mass unit	u	1.661×10^{-27}	Kg

Electricity

Current and pd	$I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$	$R = \frac{V}{I}$
emf	$\varepsilon = \frac{E}{Q}$	$\varepsilon = I(R + r)$
resistors in series	$R = R_1 + R_2 + R_3 + \ldots\ldots\ldots$	
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$	
resistivity	$\rho = \frac{RA}{L}$	
power		$P = VI = I^2R = \frac{V^2}{R}$

Formulae and data sheet – Mechanics and Circular Motion

	Moments	moments = Fd
	Velocity and acceleration	$v = \frac{\Delta s}{\Delta t}$ $\quad a = \frac{\Delta v}{\Delta t}$
	Equation of motion	$v = u + at$ $\quad s = \frac{(u+v)}{2}t$
		$v^2 = u^2 + 2as$ $\quad s = ut + \frac{at^2}{2}$
	Force	$F = ma$
	Work, energy and power	$W = Fs\cos\theta$ $\quad E_k = {}^1/_2\, mv^2$
		$P = \frac{\Delta W}{\Delta t}, P = Fv$ $\quad \Delta E_p = mg\Delta h$
		$efficiency = \frac{useful\ output\ power}{input\ power}$
	Momentum	force $F = \frac{\Delta(mv)}{\Delta t}$
		Impulse $F\Delta t = \Delta(mv)$
Circular Motion	angular velocity	$\omega = \frac{v}{r}$ $\quad \omega = 2\pi f$
	Centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r$
	Centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$
Materials	Young's modulus	$E = \frac{\text{stress}}{\text{strain}} = \frac{Fl}{eA}$
	Hooke's law	$F = k\,e$
	Elastic PE	$EPE = {}^1/_2\, k\, e$

Formulae and data sheet - Mechanical Oscillations, Thermal Physics, Gravitation

Oscillations	Acceleration	$a = -(2\pi f)^2 x$
	Displacement	$x = A\cos(2\pi f t)$
	Speed	$v = \pm 2\pi f\sqrt{A^2 - x^2}$
	Maximum speed	$v_{max} = 2\pi f A$
	Maximum acceleration	$a_{max} = (2\pi f)^2 A$
	For a mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$
	For a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
Thermodynamics	First law of thermodynamics	$Q = \Delta U + W$
		$W = p\Delta V$
	Isothermal change	$pV = constant$
Gas laws and thermal physics	gas law	$pV = nRT \quad pV = NkT$
	Kinetic theory model	$pV = \frac{1}{3}Nm(c_{rms})^2$
	Kinetic energy of gas molecules	$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$
	Energy to change temperature	$Q = mc\Delta T$
	Energy to change state	$Q = ml$
Liquid pressure	Hydrostatic pressure	$p = \rho gh$

Gravitational Fields	Newton's law of gravitation	$F = G\frac{Mm}{r^2}$
	Gravitational field strength	$g = \frac{GM}{r^2}$
	Gravitational potential	$V = \frac{GM}{r}$
	Orbital period	$T = \frac{orbital\ circumference}{orbital\ speed}$

Formulae and data sheet - Capacitors, Electric and Magnetic Fields

Electric Fields and Capacitors	Force between two points charges	$F = \frac{1}{4\pi\varepsilon_o}\frac{Q_1 Q_2}{r^2}$
	Force on a charge	$F = EQ$
	Field strength for a uniform field	$E = \frac{V}{d}$
	Field strength for a radical field	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	Electrical potential	$\Delta W = Q\Delta V$
		$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
	Capacitance	$C = \frac{Q}{V}$
	Decay of charge	$Q = Q_o e^{\frac{-t}{RC}}$ $V = V_o e^{\frac{-t}{RC}}$
	Time constant	RC
	Capacitor energy stored	$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$
	Capacitors in parallel	$C = C_1 + C_2 + C_3$
	Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Electrons in a field		$F = \frac{eV}{d}$ $F = Bev$ $r = \frac{mv}{Be}$
		$\frac{1}{2}mv^2 = eV$ $\frac{QV}{d} = mg$ $F = 6\pi\eta rv$
Magnetic field	Force on a current	$F = BIl$
	Force on a moving charge	$F = BQv$
	Magnetic flux	$\phi = BA$
	Magnetic flux linkage	$N\phi = BAN$
	Magnitude of induced emf	$\varepsilon = N\frac{\Delta\phi}{\Delta t}$
	Emf induced in a rotating coil	$N\phi = BANcos\theta$ $\varepsilon = BAN\omega \sin \omega t$
	Transformer equation	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ $efficiency = \frac{I_s V_s}{I_p V_p}$

Waves	Malus' law	$I = I_o\cos^2\Theta$
	Wave equation	$v = f\lambda$
	Young's double slit	$w = \lambda D/s$
	Diffraction grating	$d \sin\theta = n\lambda$
Radioactivity	Radioactive decay	$A = -\lambda N$
	Half-life	$T^1/_2 = ln2/\lambda$
	Activity	$A = A_0e^{-\lambda t}$

Photon physics	Photon energy	$E = hf$
	Photoelectric effect	$hf = \Phi + E_{k\ max}$
	De Broglie wavelength	$\lambda = \frac{h}{mv}$
	Mass-energy relationship	$E = mc^2$

Learning Outcomes Matrix

Question	Learning Outcomes assessed	Marker can differentiate between varying levels of achievement
1	1, 2	Yes
2	3	Yes
3	2	Yes
4	3	Yes
5	7	Yes
6	5	Yes
7	2, 6	Yes
8	7	Yes
9	1, 2	Yes
10	3	Yes

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.			