Catholic Junior College
JC2 Preliminary Examination
Higher 1

CANDIDATE NAME	
CLASS	**2T**

PHYSICS **8867/2**

Paper 2 Structured Questions **23 August 2024**

2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST
Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. You may use an HB pencil for any diagrams or graphs. Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.
Section B
Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

MARK SCHEME

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 7			
Q2	/ 7			
Q3	/ 7			
Q4	/ 8			
Q5	/ 8			
Q6	/ 7			
Q7	/ 16			
Q8	/ 20			
Q9	/ 20			
PAPER 2 (WEIGHTAGE: 67%)	/ 80			
PAPER 1 (WEIGHTAGE: 33%)	/ 30			
TOTAL	%			

This document consists of **27** printed pages and **1** blank page.

[Turn over

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
elementary charge,	e	$= 1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}\ \mathrm{kg}$
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	G	$= 6.67 \times 10^{-11}\ \mathrm{N\ m^{2}\ kg^{-2}}$
acceleration of free fall,	g	$= 9.81\ \mathrm{m\ s^{-2}}$

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$

Section A

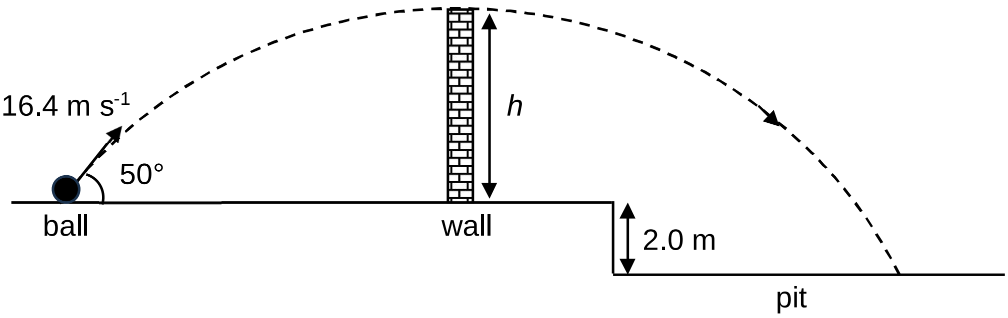
Answer **ALL** questions in this section.

1	**(a)**	A student writes down the following equation to describe the forces acting on a sphere falling under gravity through a medium of liquid, $$6\pi\eta r v^2 = \frac{4}{3}\pi r^3 (\rho - \rho_L) g$$ whereby r is the radius of the sphere, v the velocity, g the acceleration of free fall, η the coefficient of viscosity of the liquid with units: kg m^{-1} s^{-1}, ρ and ρ_L the densities of the sphere and the liquid respectively. By checking the homogeneity of the equation, deduce whether the equation is correct.	
			[2]
	L2	$6\pi\eta r v^2 = \frac{4}{3}\pi r^3 (\rho - \rho_L) g$ Units of left hand side: (kg m^{-1} s^{-1}) (m) (m s^{-1})^2 = (kg m^2 s^{-3}) Units of right hand side: (m^3) (kg m^{-3}) (m s^{-2}) = (kg m s^{-2}) Since the units on left and right hand sides are not equal, the equation is not correct.	**M1** **A1**
	(b)	The drag force F experienced by a steel sphere of radius r dropping at speed v through a liquid is given by $$F = Br^2 \rho v^2$$ where B is a constant. A student obtained the following set of data for a steel sphere dropping through a fluid. F = (8.0 ± 0.1) mN r = (3.0 ± 0.1) cm ρ = (1.00 ± 0.01) × 10^3 kg m^{-3} v = (24 ± 1) cm s^{-1}	

		(i)	Random errors are associated with the measurement of the diameter of the steel sphere.	
			1. Explain what is meant by a *random error*.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[1]
	L1		Random error is an error when the measured readings are scattered about the mean value with no fixed pattern. They have equal probability of having different magnitudes and signs.	**A1**
			2. Hence, explain how such a random error can be minimized in this experiment.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[1]
	L2		Difficult to ascertain the exact diameter of the steel sphere. Measure the diameter along different orientations of the steel sphere and take average.	**A1**
		(ii)	Using the data given, determine the value of *B* together with its associated uncertainty.	
			B = ………………±………………	[3]
	L3		$F = Br^2 \rho v^2$ $B = \frac{F}{r^2 \rho v^2}$ $= \frac{8.0 \times 10^{-3}}{(0.030)^2 (1000)(0.24)^2}$ $= 0.15432$	**C1**
			$\frac{\Delta B}{B} = \frac{\Delta F}{F} + 2\left(\frac{\Delta r}{r}\right) + \frac{\Delta \rho}{\rho} + 2\left(\frac{\Delta v}{v}\right)$ $\frac{\Delta B}{0.15432} = \frac{0.1}{8.0} + 2\left(\frac{0.1}{3.0}\right) + \frac{0.01}{1.00} + 2\left(\frac{1}{24}\right) = 0.1725$	**M1**

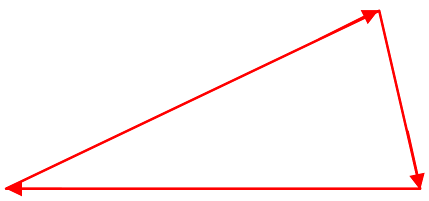
			$\Delta B = 0.15432 \times 0.1725 = 0.0266$ $B = 0.15 \pm 0.03$	A1

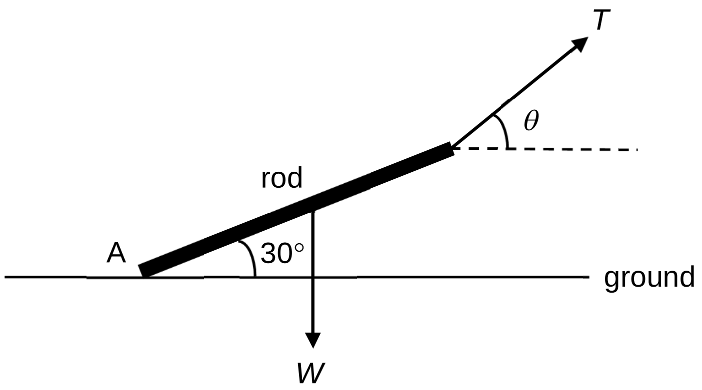
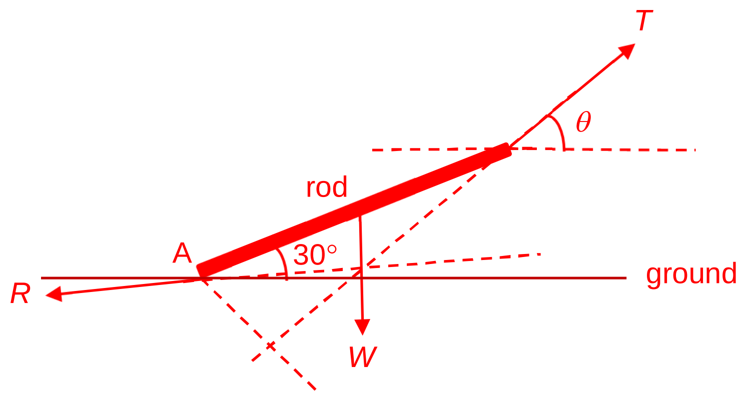
[Total: 7]

2	A ball was kicked over a wall of height h as shown with a velocity 16.4 m s^{-1} at an angle of 50° above the horizontal. At the highest point of the trajectory, the ball managed to just go over the wall. It landed into a pit 2.0 m deep.  **Fig. 2.1**		
	(a)	Calculate the height h of the wall.	
		h = ……………………………… m	[2]
	L2	Let v_y be the vertical velocity of ball at top of wall, u_y be initial velocity and a_y be the acceleration of ball. Taking upwards and rightwards as positive, consider the ball at its highest point of its trajectory. $v_y^2 = u_y^2 + 2a_y s_y$ $0 = \left(16.4 \sin 50^0\right)^2 + 2(-9.81)h$ h = 8.0445 m = 8.04 m (3 s.f.)	M1 A1
	(b)	Calculate the time of flight of the ball when it just hits the pit.	

		time = …..…………………..……..….. s	[3]
	L2	Let s_y be the displacement, u_y be the initial velocity, a_y be the acceleration and t be the time taken for the ball to hit the pit Taking upwards and rightwards as positive, consider the ball just before it hits the pit. $s_y = u_y t + \frac{1}{2} a_y t^2$ $-2.0 = (16.4 \sin 50^0) t + \frac{1}{2}(-9.81) t^2$ $9.81 t^2 - 25.12625773 t - 4 = 0$ $t = \frac{25.12625773 \pm \sqrt{(-25.12625773)^2 - 4(9.81)(-4)}}{2(9.81)}$ = 2.712 s or -0.1504 s t = 2.71 s or -0.150 s (rejected)	**C1** **M1** **A1**
	(c)	Calculate the vertical velocity of the ball just before it hits the pit.	
		vertical velocity = …..………….….……….. m s^{-1}	[2]
	L2	Let v_y be the vertical velocity of ball just before it hits the pit, u_y be the initial velocity, a_y be the acceleration and s_y be the displacement of the ball. Taking upwards and rightwards as positive, consider the ball just before it hits the pit. $v_y^2 = u_y^2 + 2as_y$ $v_y^2 = (16.4 \sin 50^0)^2 + 2(-9.81)(-2.0)$ v_y = –14.038 m s^{-1} = 14.0 m s^{-1} (downwards) (3 s.f.)	**M1** **A1**

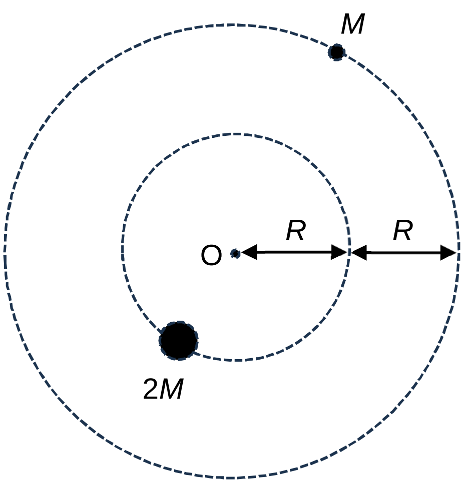
[Total: 7]

3	**(a)**	Three co-planar forces act on a body that is in equilibrium.		
		(i)	By drawing a vector diagram, describe how a vector diagram can be used to represent these forces.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		 Correct vector diagram with arrows joining from head to tail.	B1
			Arrow length represents the magnitude and the direction of the arrow represents the direction of force.	B1
		(ii)	Explain why the vector triangle cannot be used to show that a body is in rotational equilibrium.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[1]
	L2		The moments about a pivot cannot be found using the vector triangle.	B1

(b)	Fig. 3.1 shows a uniform thin rod of weight W = 1000 N, being towed at angle of 30° to the ground by a force T. It is moving at a constant horizontal velocity.  **Fig. 3.1**			
	(i)	On Fig. 3.1, indicate the direction of the reaction force R acting on the rod by the ground at point A.	[1]	
L2		 All three lines of action of forces meet at a common point. R is directed away from point A and has a leftwards component.	**B1**	
	(ii)	The force T is applied on the rod at an angle θ of 46° with respect to the horizontal. Determine T.		
		T = ………………………………….. N	[3]	

	L3		Let L be the length of rod. By principle of moments Sum of clockwise moments = sum of anticlockwise moments Taking pivot at point A, $W\left(\frac{L}{2}\cos 30^0\right)+\left(T\cos\theta\right)\left(L\sin 30^0\right)=\left(T\sin\theta\right)\left(L\cos 30^0\right)$ $\left(500\right)\left(\cos 30^0\right)+\left(T\cos 46^0\right)\left(\sin 30^0\right)=\left(T\sin 46^0\right)\left(\cos 30^0\right)$ $0.275637T = 433.0127019$ $T = 1570.95$ N $= 1570$ N (3 s.f.)	C1 M1 A1

[Total: 7]

4	(a)	State Newton's law of gravitation.	
		……………………………………………………………………………………………	
		……………………………………………………………………………………………	
		……………………………………………………………………………………………	[2]
	L1	Newton's law of gravitation states that the mutual force of attraction between two point masses is directly proportional to the product of their masses, and inversely proportional to the square of their separation.	B1 B1
	(b)	Two stars of mass M and $2M$, a distance of $3R$ apart, rotate in circles about their common centre of mass O. They form a binary star system as shown in Fig. 4.1.  **Fig. 4.1** The period of this binary star system is 3.42×10^5 s. The value of M is 3.14×10^{30} kg.	
		(i) Express the gravitational force of attraction between the two stars in terms of R.	

[Turn over

				[1]
L2		By Newton's law of gravitation, Gravitational force of attraction between the two stars: $F_G = \frac{G(2M)(M)}{(3R)^2} = \frac{(6.67\times10^{-11})(2)(3.14\times10^{30})^2}{9R^2}$ $= \frac{1.461\times10^{50}}{R^2}$ $= \frac{1.46\times10^{50}}{R^2}$		A1
	(ii)	Calculate the angular speed for each star.		
		angular speed = …………………………… rad s^{-1}		[2]
L2		Angular speed $\omega = \frac{2\pi}{T} = \frac{2\pi}{3.42\times10^5}$ $= 1.837 \times 10^{-5}$ rad s^{-1} $= 1.84 \times 10^{-5}$ rad s^{-1} (3 s.f.)		M1 A1
	(iii)	Determine the distance *R*.		
		R = …………………………… m		[3]
L3		Consider the star of mass *M*,		

			$F_G = M(2R)\omega^2$	C1
			$\dfrac{1.461\times10^{50}}{R^2} = (3.14\times10^{30})(2R)(1.837\times10^{-5})^2$	M1
			$R^3 = \dfrac{1.461\times10^{50}}{2(3.14\times10^{30})(1.837\times10^{-5})^2}$	
			$R = 4.10038 \times 10^9$ m $= 4.10 \times 10^9$ m (3 s.f.)	A1

[Total: 8]

5	A dry cell of e.m.f. 12.0 V and internal resistance 1.0 Ω is connected in series to a uniform wire XY of length 120 cm and diameter 1.3 mm, as shown in Fig. 5.1. The resistivity of the material of the wire is 1.2×10^{-6} Ω m.			

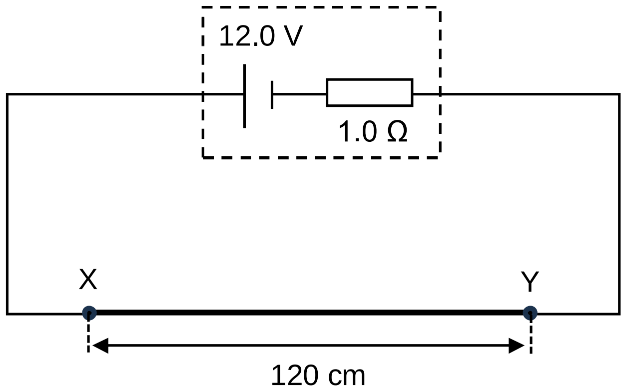


Fig. 5.1

	(a)	Define *resistivity* of a material.		
		………………………………………………………………………………………		
		………………………………………………………………………………………		[1]
	L1	Resistivity is the constant of proportionality that relates the resistance of a component to its length-to-cross sectional area ratio at constant temperature.		B1
	(b)	**(i)**	Calculate the resistance of the wire.	
			resistance = …………………………… Ω	[1]

L2			Resistance of the wire $R = \frac{\rho L}{A} = \frac{\left(1.2\times10^{-6}\right)\left(1.20\right)}{\pi\left(\frac{1.3\times10^{-3}}{2}\right)^2}$ $= 1.0849\ \Omega$ $= 1.08\ \Omega$ (3 s.f.)	A1
		(ii)	Show that the terminal voltage of the dry cell is 6.2 V.	
				[2]
L2			Current $I = \frac{\text{e.m.f.}}{\text{total resistance}}$ $= \frac{12}{1.0+1.0849}$ = 5.7557 A Terminal potential of dry cell $V = E - Ir$, where r is the internal resistance of the dry cell $V = 12.0-\left(5.7557\right)\left(1.0\right)$ = 6.244 V = 6.2 V (Shown)	C1 M1 A0
		(iii)	Calculate the percentage of energy dissipated as heat in the dry cell.	
			percentage = …..………..…………..…….... %	[2]
L2			Percentage $= \frac{I^2 r}{I^2\left(r+R\right)}\times100\%$ $= \frac{1.0}{\left(1.0+1.0849\right)}\times100\%$ = 47.96% = 48.0% (3 s.f.)	M1 A1
	(c)	(i)	If wire XY can be changed, suggest a value of the resistance of wire XY such that maximum power can be delivered to it.	
			……………………………………………………………………………………..…….	
			…………………………………………………………...………………………….…..	[1]

	L2		1.0 Ω	A1
		(ii)	Hence, state the percentage efficiency of the dry cell when maximum power is being delivered to wire XY.	
			………………………………………………………………………………………	
			………………………………………………………………………………………	[1]
	L2		50.0%	A1

[Total: 8]

6	Uranium-235 nuclei when bombarded by neutrons may undergo random nuclear reactions. One such reaction is $${}^{235}_{92}\text{Ur} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + \boxed{}$$ For the nuclear reaction, the binding energy per nucleon of Uranium-235 is approximately 7.5 MeV and that of Barium-144 is approximately 8.5 MeV.		
	(a) Complete the equation for this nuclear reaction.		[1]
	L1	${}^{235}_{92}\text{Ur} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2{}^{1}_{0}\text{n}$	B1
	(b)	Determine the binding energy per nucleon of Krypton-90, given that the minimum energy released for this reaction is 227 MeV.	
		binding energy per nucleon = ……………………………… MeV	[3]
	L2	Energy released = $\text{B.E.}_{\text{Ba}} + \text{B.E.}_{\text{Kr}} - \text{B.E.}_{\text{U}}$ $227 = (8.5 \times 144) + \text{B.E.}_{\text{Kr}} - (7.5 \times 235)$ $\text{B.E.}_{\text{Kr}} = 765.5$ MeV Therefore, the binding energy per nucleon of Krypton-90 $= \frac{765.5}{90}$ = 8.5056 MeV = 8.51 MeV (3 s.f.)	C1 M1 A1

[Turn over

	(c)	Explain the relevance of binding energy per nucleon to nuclear fission and nuclear fusion.	
		………………………………………………………………………………………………	
		………………………………………………………………………………………………	
		………………………………………………………………………………………………	
		………………………………………………………………………………………………	
		………………………………………………………………………………………………	
		………………………………………………………………………………………………	[3]
	L3	In nuclear fission or fusion, the products have higher binding energy per nucleon than the reactants. (Total binding energy of products is higher than that of reactants)	**B1**
		The higher the binding energy per nucleon of a nucleus, the more stable the nucleus is due to a lower energy content.	**B1**
		Therefore, these processes release energies when products of lower energy content are produced. OR	**B1**
		In nuclear fission or fusion, the products have higher binding energy per nucleon than the reactants.	
		Total binding energy of products is higher than that of reactants because the total number of nucleons of the products and the reactants are about the same. Total binding energy released when the products are formed is more than the total binding energy required to break up the reactants.	
		Hence, energy will be released from the process.	

[Total: 7]

7 In a coal-fired power plant, burning coal is used to boil water and produce high-pressure steam, which then turns the turbine of an electric generator, thus producing electricity. Hydroelectric power plants use falling water to directly turn the turbines of the generators. Reservoirs hold water just behind dams while the turbines are usually located at the base of a dam as shown in Fig. 7.1.

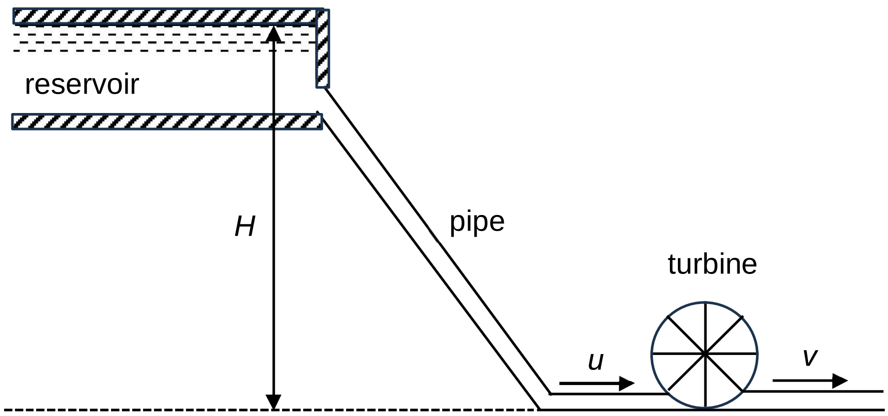


Fig. 7.1

The water emerges from the bottom of the dam through a circular pipe with speed u and hits the blades of the turbine with this speed. After colliding with the blades of the turbine, the water moves in the same direction with speed v.

Table 7.2 below shows the data for a given hydroelectric power plant.

Table 7.2

Difference in height H between water level in the reservoir and turbine	220 m
Diameter d of the pipe	0.060 m
Density ρ of water	1000 kg m^{-3}
Speed v of water after hitting the blades of the turbine	10 m s^{-1}
Temperature of water	15 °C

(a) State two advantages of generating electricity in hydroelectric power plants over coal-fired power plants.

1 ....

....

2 ....

.... [2]

L3 There is lesser pollution generating electricity in hydroelectric power plants. **B1**
Water used in generating electricity in hydroelectric power plants can be recycled or reused. Thus, it is more environmentally friendly. **B1**
Water is a cheaper source of energy than coal.

(b) **(i)** The kinetic energy of the water leaving the pipe is assumed to be equal to the potential energy of the water at the surface of the reservoir.

Neglect any losses due to resistive forces, calculate the speed u of the water as it leaves the pipe.

u = ... m s^{-1} [3]

L2 Let m be the mass of water.
Loss in potential energy = gain in kinetic energy **C1**

$$mgH = \frac{1}{2}mu^2$$

[Turn over

			$u=\sqrt{2gH}=\sqrt{2(9.81)(220)}$ $= 65.6993$ m s^{-1} $= 65.7$ m s^{-1} (3 s.f.)	**M1** **A1**
		(ii)	Show that the mass of water flowing through the pipe per unit time is 186 kg s^{-1}.	
				[3]
	L3		Let m be the mass, V be the volume, ρ be the density of the water. Mass of water flowing per unit time $=\frac{m}{t}=\frac{\rho V}{t}$ $=\frac{\rho Al}{t}=\rho Au$ $\rho Au=(1000)\pi\left(\frac{0.060^2}{4}\right)(65.6993)$ $= 185.7604$ kg s^{-1} $= 186$ kg s^{-1} (Shown)	**C1** **C1** **M1** **A0**
		(iii)	Calculate the power carried by the water before hitting the blades of the turbine.	
			power = ……………………………….. W	[2]
	L2		Power = $=\frac{\frac{1}{2}mu^2}{t}=\frac{1}{2}\left(\frac{m}{t}\right)u^2=\frac{1}{2}(185.7604)(65.6993)^2$ $= 4.00907\times10^5$ W $= 4.01\times10^5$ W (3 s.f.)	**M1** **A1**

		(iv)	Calculate the maximum possible force the water could exert on the turbine blades.	
			maximum force = ……………………………………… N	[2]
	L2		$F = \frac{dp}{dt} = \frac{dm}{t}(u - v) = 185.7604(65.6993 - 10)$ $= 1.0346 \times 10^4$ N $= 1.04 \times 10^4$ N (3 s.f.)	**M1** **A1**
		(v)	Determine the maximum possible power imparted to the turbine.	
			maximum power = ……………………………………… W	[3]
	L2		Power imparted to the turbine equals to the loss in kinetic energy of water per unit time. $= \frac{\frac{1}{2}mu^2 - \frac{1}{2}mv^2}{t} = \frac{1}{2}\left(\frac{m}{t}\right)(u^2 - v^2)$ $= \frac{1}{2}(185.7604)(65.6993^2 - 10^2)$ $= 3.9162 \times 10^5$ W $= 3.92 \times 10^5$ W (3 s.f.)	**C1** **M1** **A1**
	(c)	Suggest a possible reason why a low temperature of water of 15 ^{0}C is used.		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		[1]
	L2	A low temperature of water is used so as to cool the thermoelectric power plants.		**B1**

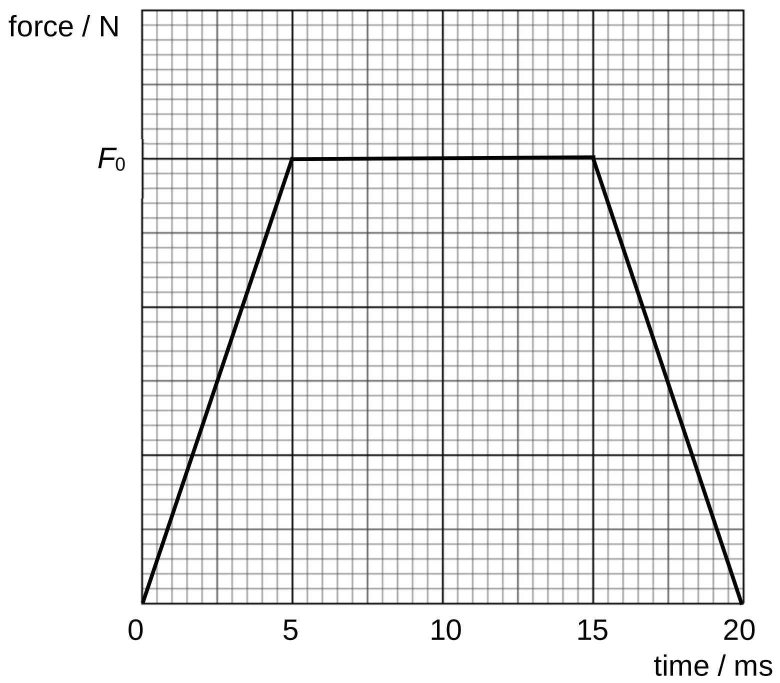
[Total: 16]

[Turn over

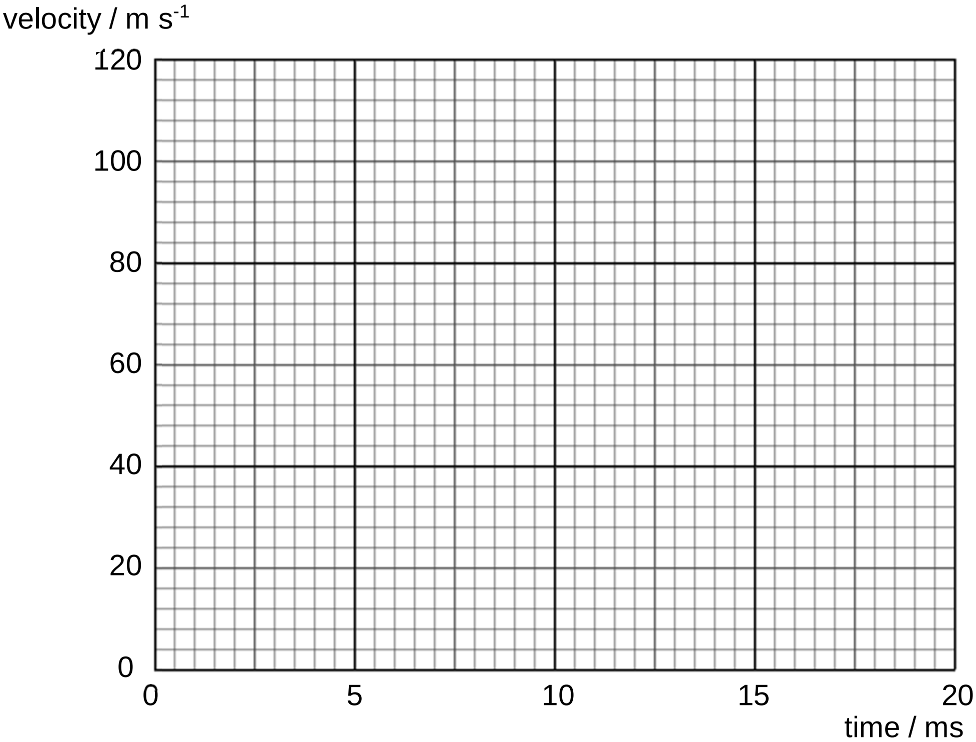
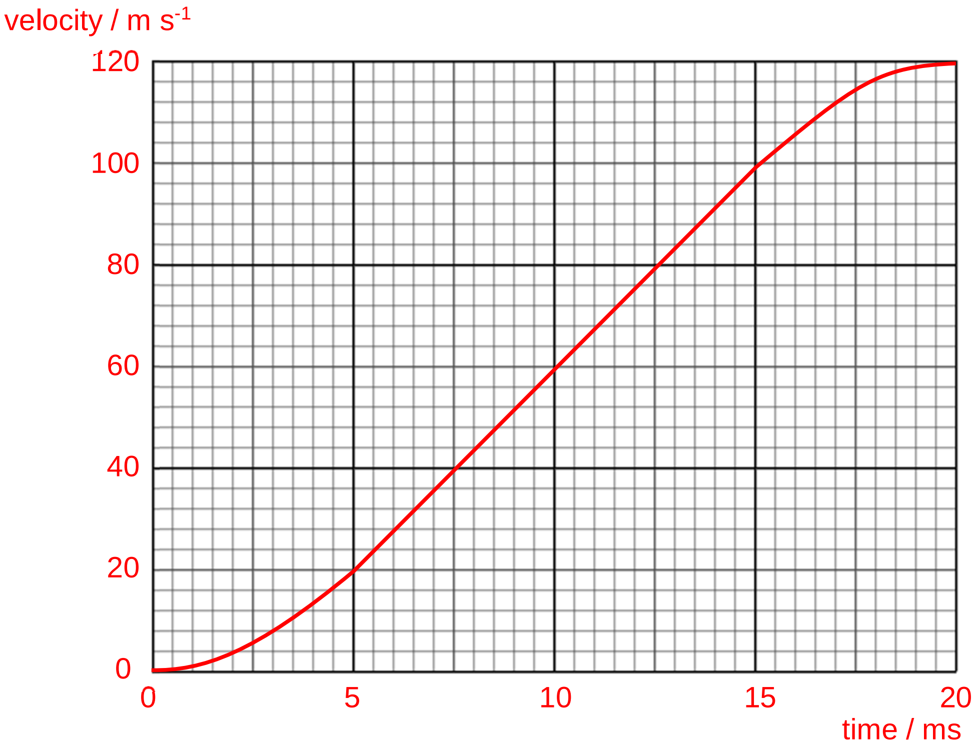
Section B

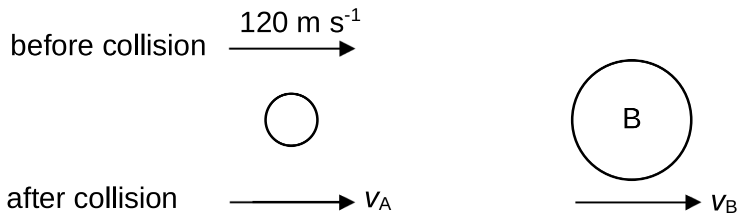
Answer **ONE** question from this section.

8	**(a)**	A student makes the following statements of Newton's first and third laws of motion: *"First Law: Every body continues in its state of motion unless it is acted upon by a resultant external force."* *"Third Law: Action and reaction forces always occur in pairs and are equal in magnitude and opposite in direction."*		
		(i)	The statement of the first law is incomplete in two aspects. Identify the two aspects and hence rewrite it with the appropriate amendments.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		The body can also remain in a state of rest (i.e. remain stationary) if no resultant force acts on it. The uniform motion is in a straight line (velocity is constant) if no resultant force acts on it.	**B1** **B1**
		(ii)	The statement of the third law is correct but fails to emphasize an important aspect of the action and reaction forces. Identify this aspect and rewrite this third law to make this emphasis.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		Action and reaction pairs act on different bodies. Newton's third law of motion states that If body A exerts a force on body B, then body B will exert a force equal in magnitude and opposite in direction on body A.	**B1** **B1**
	(b)	State Newton's second law of motion.		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		[2]

	L1	Newton's second law of motion states that the rate of change of momentum of a body is proportional to the net force acting on it, and the direction of momentum change is in the direction of the net force.		B1 B1
	(c)	A small metal sphere of mass 5.0 g is accelerated from rest to a speed of 120 m s^{-1} in a tube. A force is applied over a period of 20 ms as shown in Fig. 8.1.  **Fig. 8.1**		
		(i)	Calculate the final momentum of the metal sphere.	
			momentum = ……………………………… kg m s^{-1}	[2]
	L1		Let p be the final momentum of the sphere of mass m and velocity v. $p = mv = 0.0050 \times 120$ $= 0.60$ kg m s^{-1} (2 s.f.)	M1 A1
		(ii)	Calculate the maximum value of the applied force F_0.	
			F_0 = ……………………………………… N	[3]

[Turn over

	L2		Change in momentum = Area under the graph $0.60 - 0 = \frac{1}{2}(0.0050)F_0 + 0.0100F_0 + \frac{1}{2}(0.0050)F_0$ $0.60 = 0.015\ F_0$ $F_0 = 40$ N	C1 M1 A1
		(iii)	On Fig. 8.2, sketch a graph to show how the velocity of the metal sphere varies during the acceleration.  **Fig. 8.2**	[3]
	L3			

			Between time t: 0 - 5 s: Gradient increases at an increasing rate. Between time t: 5 - 15 s: Gradient increases at a constant rate. Between time t:15 - 20 s: Gradient increases at a decreasing rate.	**B1** **B1** **B1**
	(d)	The metal sphere in **(c)** is projected horizontally towards a stationary sphere B of mass M as shown in Fig. 8.3. It collides elastically with sphere B. After the collision, the metal sphere in **(c)** and sphere B move off with velocities v_A and v_B respectively, in the direction as shown.  **Fig. 8.3**		
		(i)	Show that $v_A = 120\left(\frac{0.0050 - M}{0.0050 + M}\right)$.	
				[3]
	L3		Let m be the mass of the metal sphere with incoming speed u_A of 120 m s^{-1}. Applying the principle of conservation of momentum, $mu_A = mv_A + Mv_B$ ----------- (1) For elastic collision, relative speed of separation = relative speed of approach $v_B - v_A = 120$ Therefore, $v_B = 120 + v_A$ ------------ (2) Substitute equation (2) into equation (1); $mu_A = mv_A + M(120 + v_A)$ $(m - M)(120) = (m + M)v_A$ $v_A = 120\left(\frac{m - M}{m + M}\right)$ $= 120\left(\frac{0.0050 - M}{0.0050 + M}\right)$ (Shown)	**M1** **M1** **M1** **A0**

		(ii)	Using the equation in **(d)(i)**, show that the fractional loss of kinetic energy of the metal sphere in **(c)** is given by $\dfrac{0.020M}{(0.0050+M)^2}$.	
				[3]
	L2		Fractional loss of kinetic energy of the metal sphere in **(c)** $=\left(\dfrac{\frac{1}{2}mu_A^2-\frac{1}{2}mv_A^2}{\frac{1}{2}mu_A^2}\right)$ $=1-\left(\dfrac{v_A}{u_A}\right)^2$ $=1-\left(\dfrac{0.0050-M}{0.0050+M}\right)^2$ $=\dfrac{(0.0050+M)^2-(0.0050-M)^2}{(0.0050+M)^2}$ $=\dfrac{(0.000025+0.010M+M^2)-(0.000025-0.010M+M^2)}{(0.0050+M)^2}$ $=\dfrac{0.020M}{(0.0050+M)^2}$ (Shown)	**C1** **M1** **M1** **A0**

[Total: 20]

9 A negatively charged particle of mass, $m = 3.32 \times 10^{-23}$ g and charge $-q = -1.6 \times 10^{-19}$ C is travelling with a velocity of $v = 8.43 \times 10^{4}$ m s^{-1} in a vacuum. It enters a region of uniform magnetic field of flux density 0.50 T as shown in Fig. 9.1. The magnetic field is normal to the path of the charged particle and is into the plane of the paper.

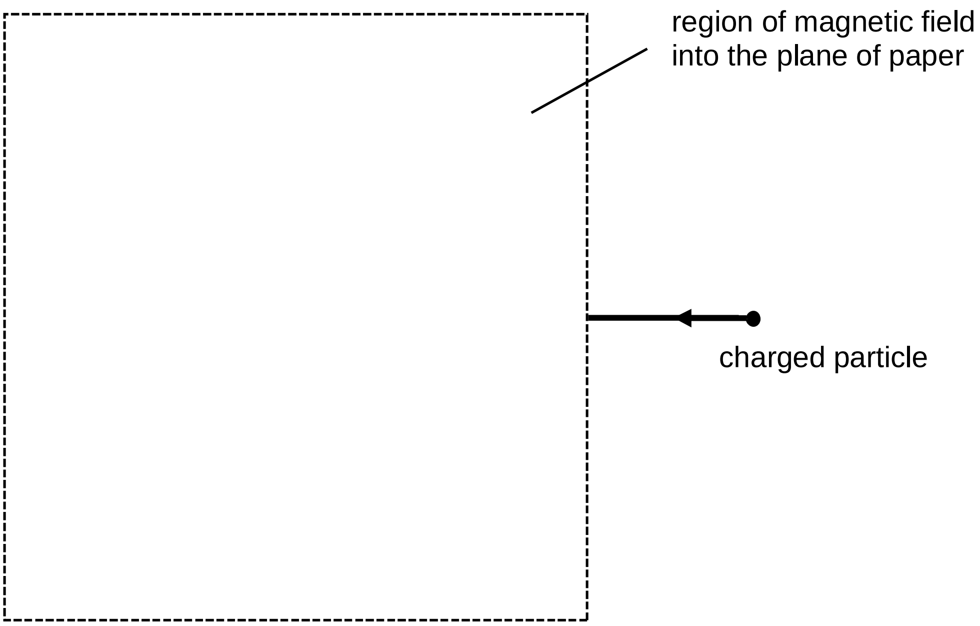


Fig. 9.1

(a) Define magnetic flux density.

………………………………………………………………………………………………

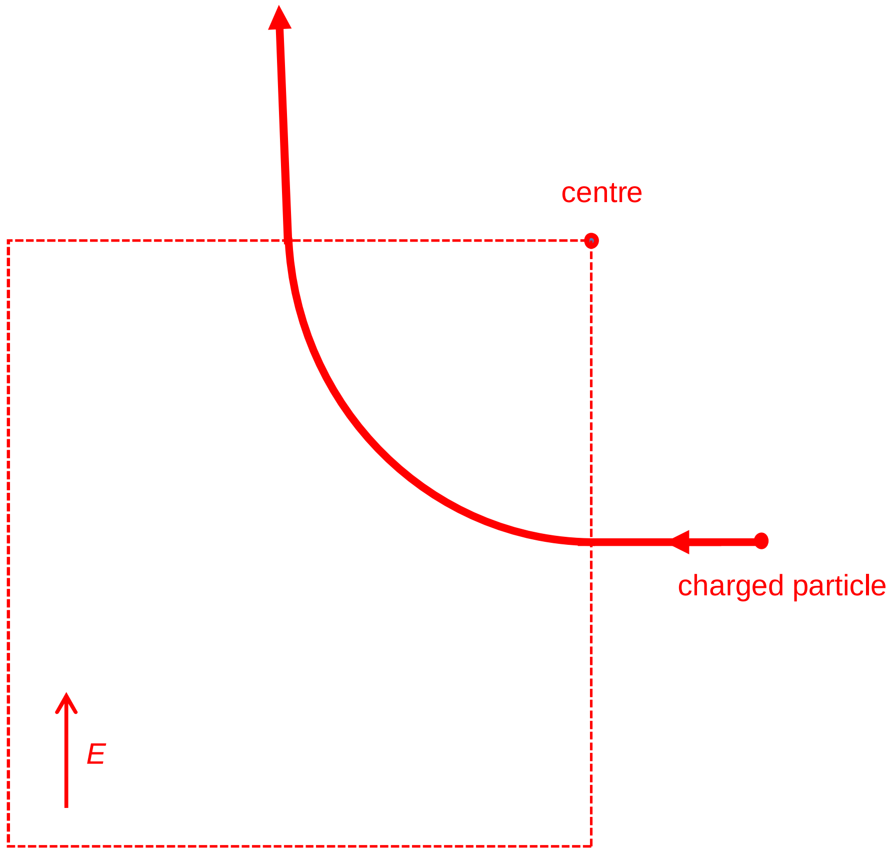
………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

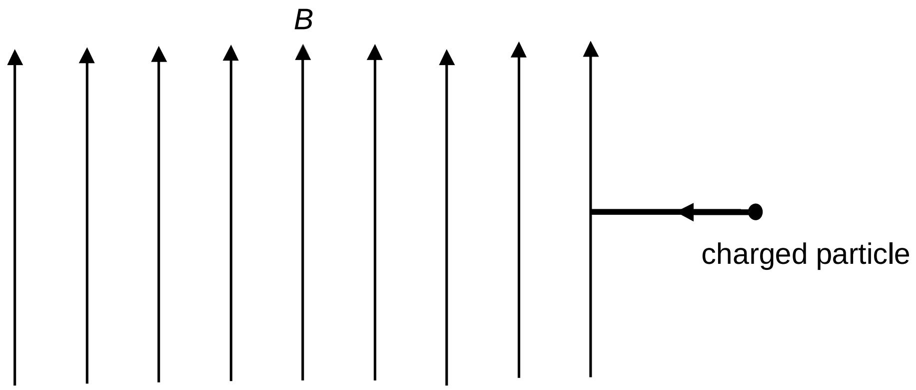
L1 The magnetic flux density at a point is the force per unit current per unit length experienced by a straight current-carrying conductor placed at right angle to a uniform magnetic field. **B1** **B1**

(b) Calculate the radius of the path of the charged particle in the magnetic field.

radius = ……………………………………… m [3]

	L2	Magnetic force provides centripetal force. $Bqv\sin\theta = \frac{mv^2}{r}$ θ = 90^0 since the velocity of the charged particle is perpendicular to the magnetic field. $r = \frac{mv}{Bq\sin 90^0} = \frac{(3.32\times10^{-26})(8.43\times10^{4})}{(0.50)(1.60\times10^{-19})}$ = 0.03498 m = 0.035 m (2 s.f.)		C1 M1 A1
	(c)	(i)	On Fig. 9.1, sketch the path of the charged particle as it passes through, and beyond the region of the magnetic field. [2]	
	L2		 Circular path turning clockwise in the field region. Straight line tangential to the circle upon exiting from field.	B1 B1
		(ii)	Explain the motion of the charged particle upon leaving the magnetic field.	
			………………………………………………………………………………	
			………………………………………………………………………………	
			………………………………………………………………………………	
			………………………………………………………………………………	[2]
	L2		According to Newton's first law of motion, an object will continue in its state of motion unless a resultant force acts on it. Upon leaving the magnetic field, the charged particle will continue moving in a path tangential to its initial motion since there is no more magnetic force acting on the charged particle.	B1

			Hence, the charged particle will move in a straight line upon leaving the magnetic field.	**B1**
	(d)	A uniform electric field is now also applied in the region so that the same charged particle can pass undeflected through the field.		
		On Fig. 9.1, draw an arrow labelled *E* to show the direction of the electric field.		[1]
	L2	Direction of electric field *E* drawn correctly with arrow pointing upwards.		**B1**
	(e)	**(i)**	Explain how the combination of magnetic and electric fields allows the charged particle of only one speed to pass undeflected through the field.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		There is an electric force acting downwards and a magnetic force acting upwards on the charged particle in the field. The magnetic force is dependent on the speed of the charged particle. If the two forces are equal, then the charged particle will pass through the fields undeflected with a single speed *v*.	**B1** **B1**
		(ii)	Hence, deduce an expression for *v* in terms of the magnetic flux density *B* and the electric field strength *E*.	
				[2]
	L2		Electric force F_E = magnetic force F_B $qE = Bqv$ $v = \dfrac{E}{B}$	 **M1** **A1**
	(f)	The charged particle is replaced by other particles. The electric and magnetic fields remain unchanged. State and explain the effect, if any, on the path of a particle that has		
		(i)	mass *m*, charge –*q* and speed 2*v*,	

			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		The magnetic force (Bqv) is greater than the electric force (qE) acting on the charged particle. Therefore, the charged particle deflects upwards.	**M1** **A1**
		(ii)	mass m, charge $+q$ and speed v.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[2]
	L2		The magnetic force is equal to the electric force acting on the charged particle. Therefore, the charged particle undergoes no deviation.	**M1** **A1**
	(g)	The direction of the magnetic field is now changed such that it is now pointing upwards as shown in Fig. 9.2. With the application of an appropriate electric field, a charged particle now moves in a circular motion.  **Fig. 9.2** If the electric field is removed, explain why the path taken by the charged particle is no longer circular.		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		
		…………………………………………………………………………………………		[2]
	L3	The upward electric force acting on the charged particle balances the downward gravitational force acting on it. When the electric field is removed, the only vertical		**B1**

		force acting on the charged particle is the gravitational force. Therefore, it will fall freely under the influence of gravity. The resultant force acting on the charged particle is no longer just the magnetic force providing the centripetal force that causes the charged particle to move in a circle. Therefore, the resultant force acting on the charged particle is no longer pointing towards the centre of the circle.	**B1**

[Total: 20]

-- END OF PAPER 2 --

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