VICTORIA JUNIOR COLLEGE
2023 JC2 PRELIMINARY EXAMINATION
Higher 1

Name : ___________________________ CT group : ________________

PHYSICS **8867/02**

Paper 2 Structured Questions **20 September 2023**

WEDNESDAY

Candidates answer on the Question Paper. **8 am to 10 am (2 hours)**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group 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.
DO **NOT** WRITE ON ANY BARCODES.

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.

For Examiner's use	
Question	**Mark**
Section A	
1	
2	
3	
4	
5	
6	
Section B	
7	
8	
Total	**/ 80**

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

Data

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

Formulae

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

Section A

Answer ALL questions from this section

H1 P2- Errors and Uncertainties SSQ

1 John performs an experiment involving a spring. The unextended length of the spring was measured to be x_1 = 10.0 ± 0.1 cm. When a load was placed at the bottom of the vertically suspended spring, it extended to x_2 = 20.0 ± 0.1 cm. The spring constant k is known to be 20 N m^{-1} exactly.

(a) State Hooke's Law.

…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(b) Determine a value for the force F exerted on the spring together with its associated uncertainty.

F = (……………... ± ……………) N [4]

(c) When extended, the spring possesses elastic potential energy given by

$$U = \frac{1}{2}k(x_2 - x_1)^2$$

Calculate a value for the fractional uncertainty of U.

Fractional uncertainty = …………………… [3]

[Total: 8]

Forces + WEP (H1 P2 SSQ 1)

2

(a) Two identical massless springs and two identical 200 g masses are connected to one another and suspended from a support as shown in Fig. 2.1. The force constant of each spring is 24.0 N m^{-1}. The lower mass is lowered gently until it comes to rest and the system attains equilibrium.

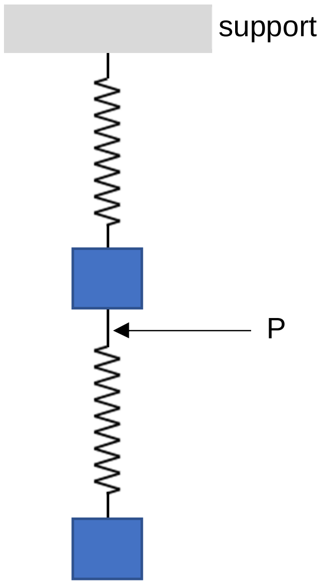

Fig. 2.1

(i) Calculate the extension of the upper and lower springs.

Extension of upper spring = …………………….. m

Extension of lower spring = …………………….. m
[3]

(ii) Determine the total elastic potential energy stored in the system at equilibrium.

Total elastic potential energy stored = …………………………… J [2]

The system is in a state of equilibrium shown in Fig. 2.1 when the connection between the lower spring and the upper mass breaks at point P, allowing the lower mass to fall away.

(iii) Calculate the acceleration of the upper mass at this instant.

Acceleration = ……………………… m s^{-2} [3]

(iv) A student wishes to calculate the speed of the upper mass at time t after the break at P using the equation $v = u + at$ where the acceleration is the value found in (iii). Comment on whether his method is correct.

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… [2]

[**Total: 10**]

H1 P2- Circular Motion SSQ (9m)

3 In the circus, there is an act called the Wheel of Steel. The apparatus consists of two rigid steel circular cages welded to a long steel truss. Two acrobats perform on this apparatus while it is rotating about its centre. The circular cages are 2.0 m in diameter and the truss is 4.0 m long. The acrobats are both 1.8 m tall and have a mass of 80 kg each. We assume that the centre of mass of the acrobats is 0.90 m from the bottom of their feet.

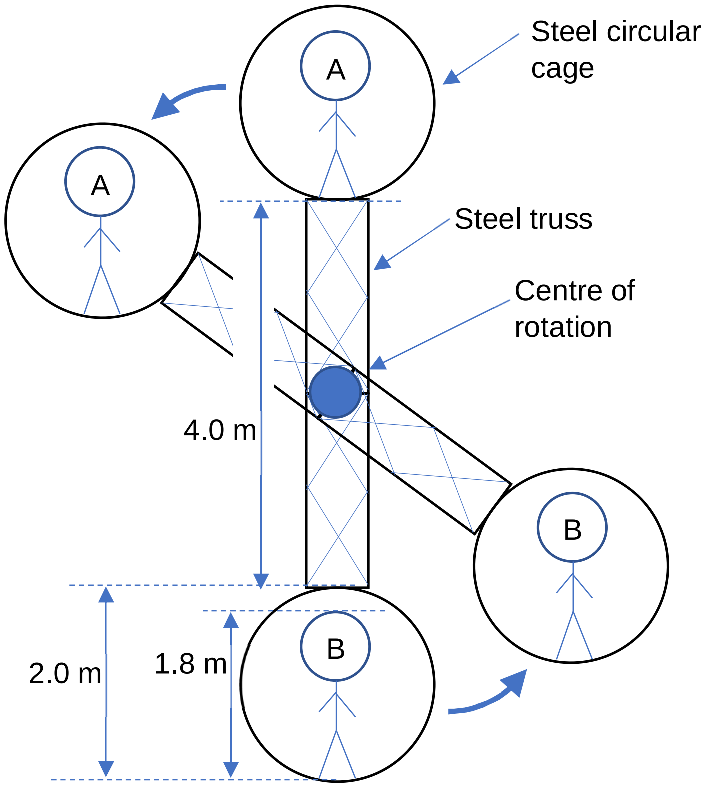

Fig. 3.1

(a) In the preparation phase, both acrobats A and B stay within the wheel, while the apparatus rotates at an increasing rate. At one point in the performance, the apparatus rotates with an angular velocity of 1.29 rad s^{-1} when acrobat B is at the bottom position. Calculate the tangential velocity of B at this instant.

Tangential velocity of B = ………………….. m s^{-1} [2]

(b) In the first trick, the apparatus rotates fast enough until the acrobat A just loses contact with the floor of the cage and seems to be momentarily “weightless” with respect to the cage. (see Fig. 3.2)

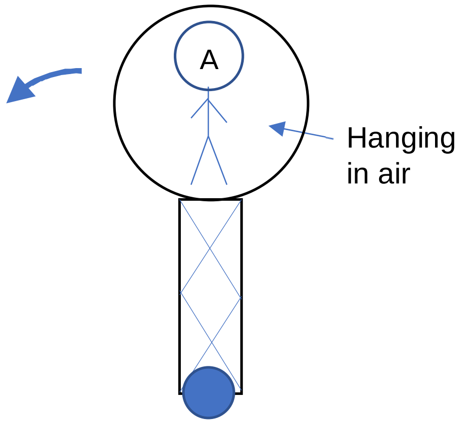

Fig. 3.2

Calculate the velocity of acrobat A when this happens.

Velocity of A = ………………………….. m s^{-1} [3]

(c) In the second trick, the apparatus is spun so fast that acrobat A can stand upside down and be in contact with the top part of the cage. (see Fig. 3.3)

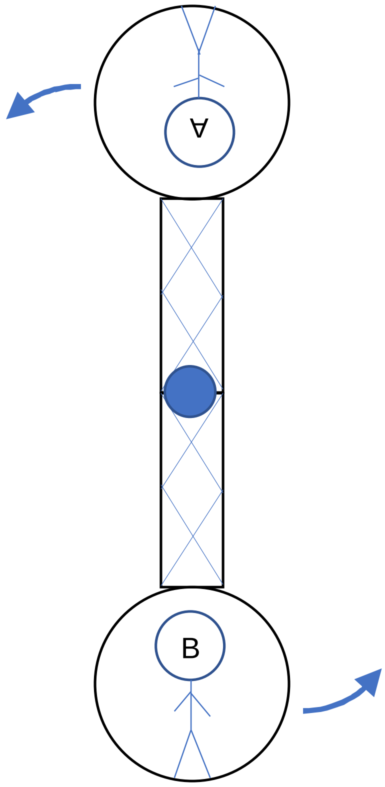

Fig. 3.3

Calculate the minimum velocity of acrobat A to accomplish this.

Minimum velocity required = …………………….. m s^{-1} [2]

(d) The apparatus is rotating at a constant angular velocity in the position shown in Fig. 3.4.

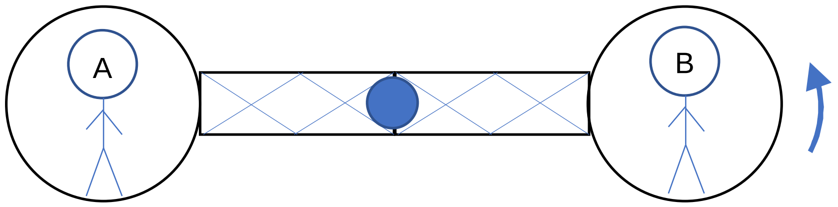

Fig. 3.4

In the space below, sketch and label the forces acting on acrobat A.

[2]

[Total: 9]

H1 P2 COE/DC SSQ (9m)

4 A battery of unknown e.m.f. ε and internal resistance r is connected to two identical resistors R, an ammeter and a voltmeter as shown in the diagram as shown in Fig. 4.1.

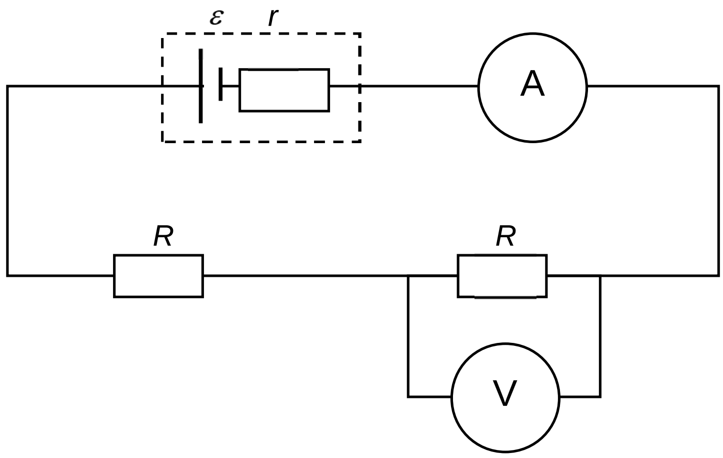

Fig. 4.1

Shown in Fig. 4.2 are the readings of the voltmeter and the ammeter that were taken as the resistance of both resistors *R* were increased in an identical manner.

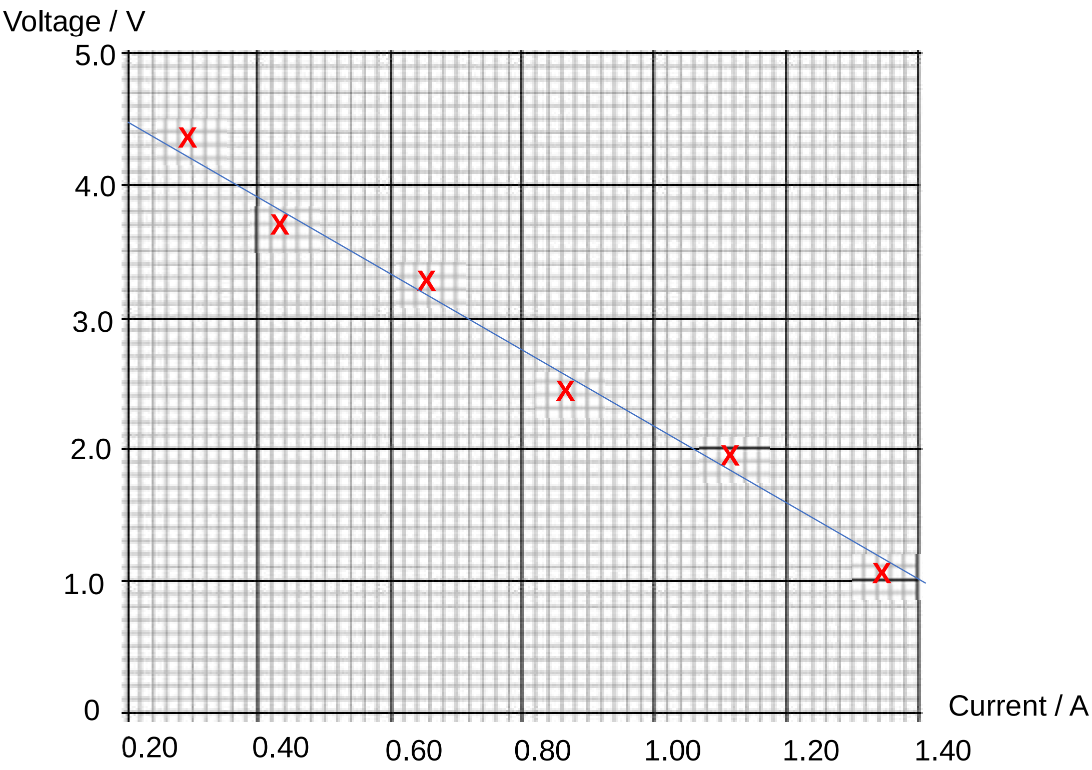

Fig. 4.2

(a) Show that the voltmeter reading *V* is related to the e.m.f. ε, the internal resistance *r* and the current I by the following equation

$$V = \frac{\varepsilon}{2} - \frac{r}{2}I$$

[1]

(b) By referring to Fig. 4.2, calculate the value of the internal resistance *r*.

r = ……………………… Ω [3]

(c) Hence, or otherwise, calculate the value of the e.m.f. ε.

ε = ……………………… V [1]

The resistor *R* that is not connected to the voltmeter is now replaced by a 5.0 Ω resistor, as shown in Fig. 4.3.

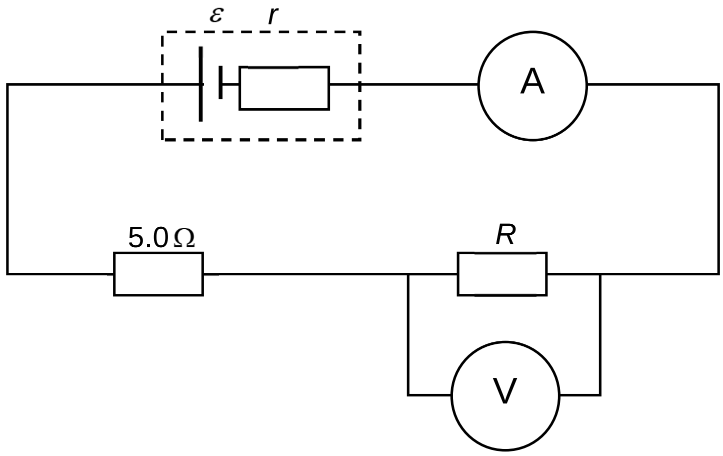

Fig. 4.3

(d) Deduce how the y-intercept and the gradient of the line would change.

……………………………………………………………………………………………………...

……………………………………………………………………………………………………...

……………………………………………………………………………………………………...

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

(e) A thermistor and a light dependent resistor (LDR) are now used to replace the 5.0 Ω resistor, as shown in Fig. 4.4.

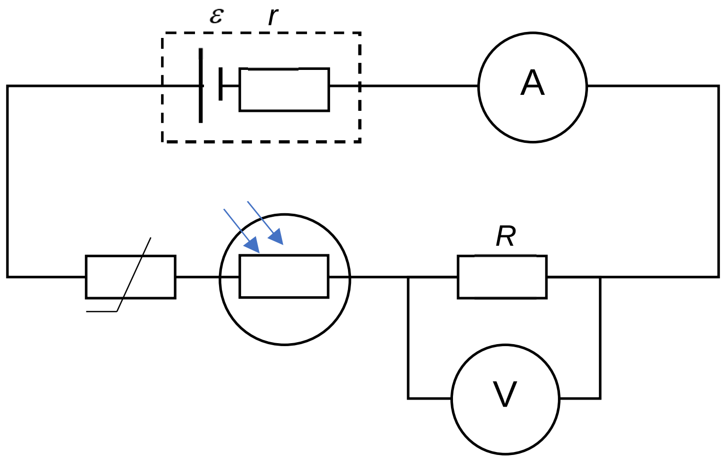

Fig. 4.4

At a certain temperature and light intensity, the voltmeter reads 1.0 V.

State and explain how the temperature and light intensity should be changed so that larger readings from the voltmeter can be obtained.

……………………………………………………………………………………………………...

……………………………………………………………………………………………………...

……………………………………………………………………………………………………...

…………………………………………………………………………………………………… [3]

[Total: 10]

5 Plutonium-239 decays by alpha-particle emission with a half-life of 2.4×10^4 yr. The alpha-particle has energy 8.2×10^{-13} J.

(a) Define *half-life*.

……………………………………………………………………………………………...

…………………………………………………………………………………………… [1]

(b) For a $^{239}_{94}\text{Pu}$ nucleus, state the number of protons and neutrons.

Number of protons = ……………. [1]

Number of neutrons = …………… [1]

The activity of a radioactive sample of plutonium-239 refers to the rate of decay of the plutonium-239 nuclei in the sample.

(c) A small power source to generate 2.5 W is to be made from a sample of $^{239}_{94}\text{Pu}$. Calculate the activity of the sample of plutonium-239, stating an assumption you have made.

Activity = ……………… [3]

(d) Determine the time that will elapse for 40% of $^{239}_{94}\text{Pu}$ to decay.

Time = ………………………… yr [2]

[Total: 8]

6 The Kolnbrein Dam in Austria is an arch dam that stores a reservoir of water, and then uses it to drive four turbines to generate electricity. (see Fig. 6.1)

Fig. 6.1

The maximum depth of the water in the reservoir is 190 m. (see Fig. 6.2)

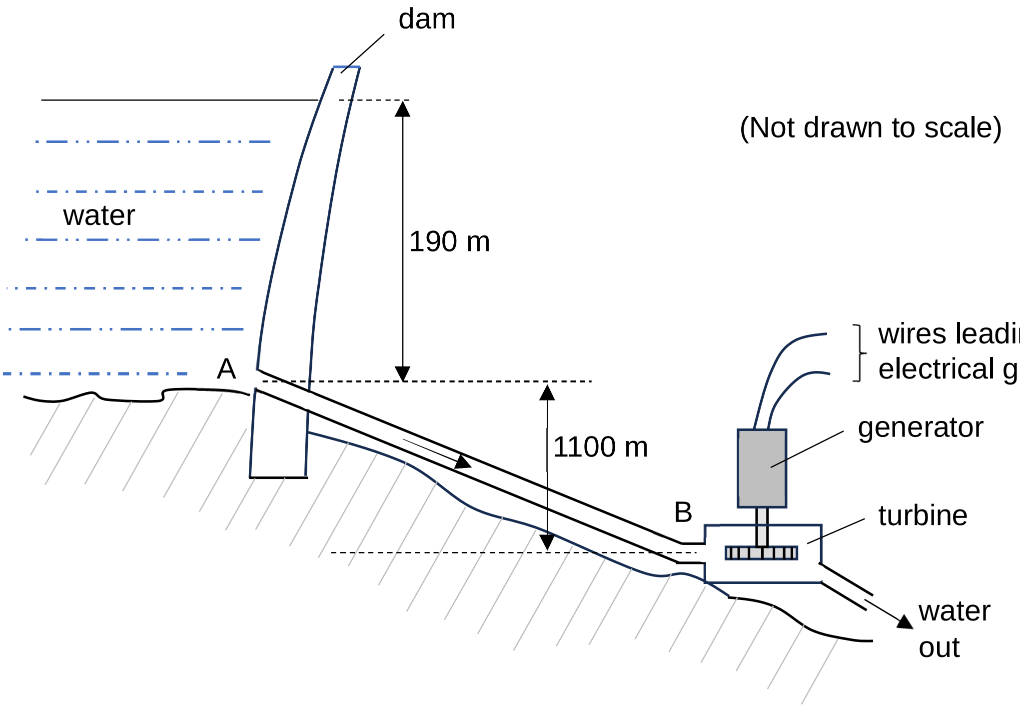

Fig. 6.2

(a)

(i) Calculate the pressure p_{water} due to the water alone at the opening A of the pipe at the bottom of the reservoir 190 m below the water surface, using the equation

$$P_{water} = h\rho g$$

where h = depth of water above opening A,
ρ = density of water = 1000 kg m^{-3},
g = acceleration due to gravity = 9.81 m s^{-2}.

P_{water} = ………………………. N m^{-2} [1]

The water in the pipe flows down an incline from point A to point B while decreasing in height by 1100 m. (see Fig. 6.2)

It is known that, for water flowing in a pipe, the pressures and speeds of the water at two points are related by Bernoulli's equation

$$p_1 + \frac{1}{2}\rho v_1^{\ 2} + h_1\rho g = p_2 + \frac{1}{2}\rho v_2^{\ 2} + h_2\rho g$$

where
p_1 and p_2 are the pressures at the two points,
v_1 and v_2 are the speeds of the water at the two points, and
h_1 and h_2 are the heights of the two points (measured from some arbitrary point).

(ii) Using Bernoulli's equation, show that the speed of the water as it exits the lower opening B of the pipe is 159 m s^{-1}. Assume that the pressure at B is equal to the atmospheric pressure p_{atm} = 1.01 x 10^5 Pa. Assume that the water enters the pipe at point A with zero speed.

[2]

At point B at the lower end of the pipe, the water divides into six water jets that exit the pipe via nozzles. These six water jets then hit the buckets of a water turbine with a speed of 159 m s^{-1}, exerting forces on the turbine in directions that are tangential to the rim of the turbine (see Fig. 6.3). The radius of the turbine is 1.7 m. The radius of the circular opening of each of the six nozzles is 8.1 cm.

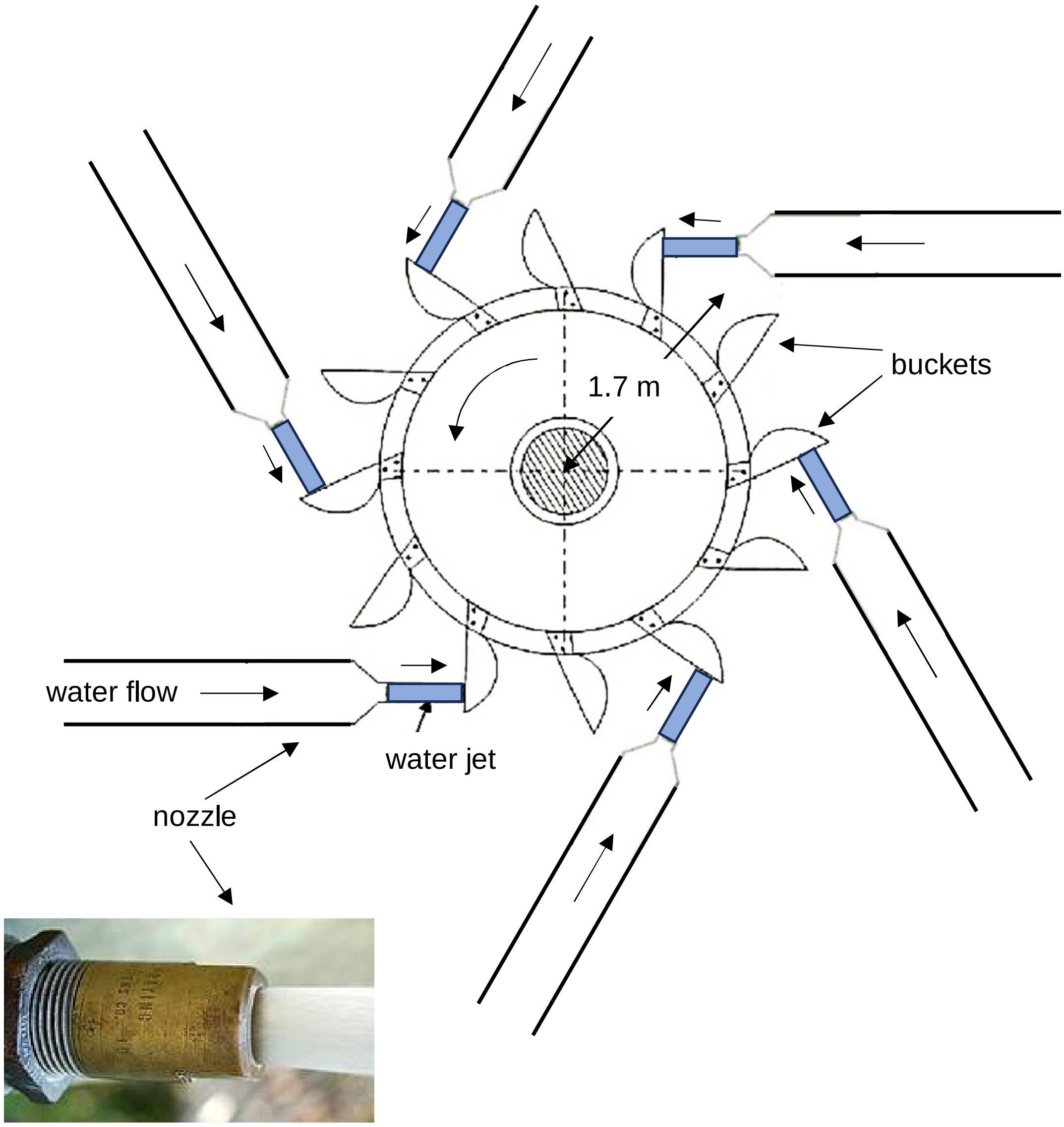

Fig. 6.3

(iii) Calculate the total mass of water that exits the six pipes per second to hit the turbine buckets.

Mass per second = ……………………….. kg s^{-1} [3]

The turbine turns a generator that rotates at a constant speed of 500 revolutions per minute (rpm) and generates 183 MW of electrical power. It has an efficiency of 92 % in converting the work done by the impacting water into electrical energy.

(iv) Using the given efficiency of the turbine-generator system, calculate the rate at which work is done by the force exerted by the water jets on the turbine (i.e., the power input).

Rate of work done = ………………………….. W [2]

(v) Calculate the tangential speed of the rim of the turbine.

Tangential speed = ……………………… m s^{-1} [2]

(vi) Hence, calculate the force exerted by the water jets on the turbine buckets.

Force = ……………………… N [2]

(b) Fig. 6.4 shows the water turbine with its buckets, and also the cross section of one of the buckets in the turbine. The right diagram also shows the way in which the direction of flow of water from the nozzle is changed after hitting the bucket.

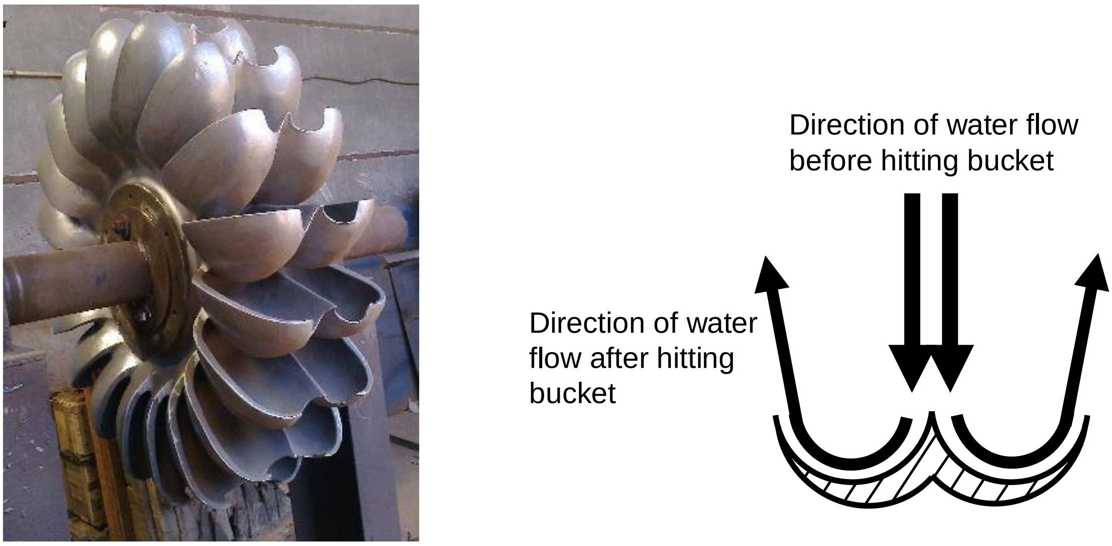

Fig. 6.4

(i) Suggest a physics-related reason for the unusual shape of the bucket. Explain your reasoning.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………… [2]

(ii) Suggest one way in which energy from the water is wasted (not converted to electricity).

……………………………………………………………………………………… [1]

[**Total: 15**]

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Section B

Answer ONE question from this section

7

(a) A tennis ball is thrown vertically **downwards** and bounces on the ground. The ball leaves the hand with an initial speed of 1.5 m s^{-1} and at a height of 0.65 m above the ground. The ball rebounds and is caught when it is travelling upwards with a speed of 1.0 m s^{-1}.

Assume that air resistance is negligible.

(i) Calculate the speed of the ball just before it strikes the ground.

speed = ... m s^{-1}
[2]

(ii) The ball is released at t = 0. It hits the ground at t_1 and is caught at time t_2.

On Fig 7.1, sketch the velocity-time graph for the vertical motion of the tennis ball from the time it leaves the hand to when it returns. Take the upward direction as positive.

Assume that the contact time between the ball and the ground is negligible. The initial velocity **X** and final velocity **Y** are marked on Fig 7.1. [3]

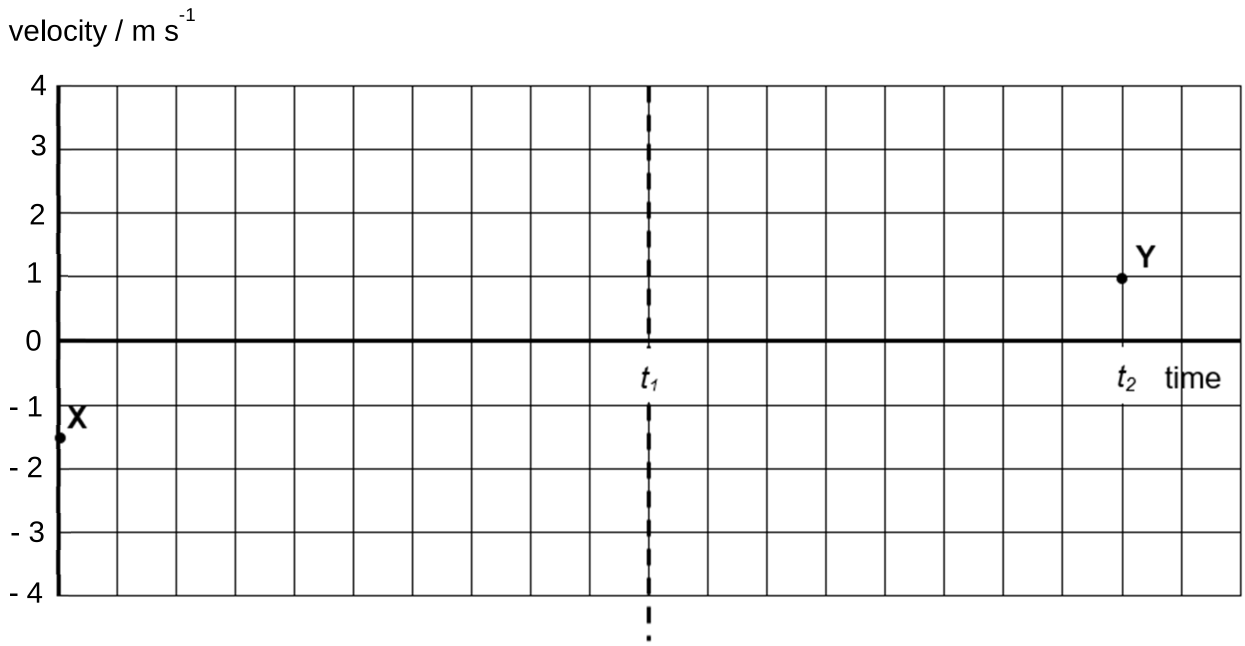

Fig. 7.1

(iii) Explain whether the bounce is elastic.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(iv) Sketch on Fig 7.1, the velocity-time graph of the tennis ball if air resistance is not negligible, up to the instant when it reaches the highest point after bouncing off the ground. Label this graph as **P**. [3]

(b) An amateur tennis player hits a tennis ball towards a hanging target as shown in Fig. 7.2.

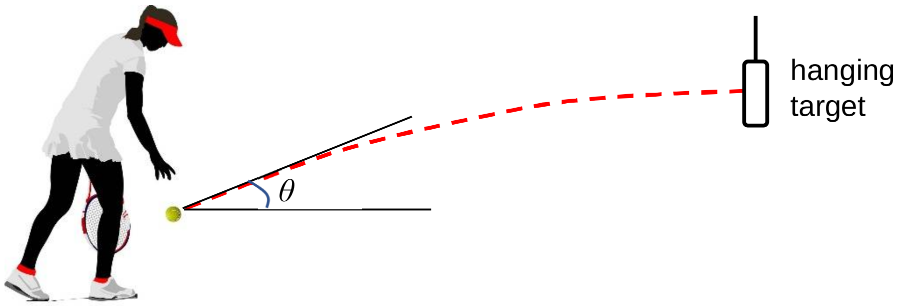

Fig. 7.2

The tennis ball leaves the racquet with a speed of 30 km h^{-1} at an angle θ above the horizontal. The mass of the tennis ball is 58 grams. Assume negligible air resistance.

(i) Assuming that the tennis player hits the ball when it is momentarily at rest, calculate the change in momentum of the ball during the hit.

change in momentum = ………….. kg m s^{-1} [2]

(ii) The vertical component of velocity of the tennis ball when it leaves the racquet is measured to be 1.5 m s^{-1}. Determine the horizontal component of velocity and θ.

horizontal component of velocity = ………………. m s^{-1}

angle θ = ………………. [4]

(iii) The tennis ball hits the soft-padded target of mass 200 grams when it is at its highest point. The two objects then move together for a fraction of a second after the collision. Determine the speed of the two objects when they move together.

speed = ………………. m s^{-1} [2]

(iv) The tennis player intends to strike the target again from the same location but with twice the speed of the ball. Suggest whether θ should be increased, decreased, or kept constant. Explain your reasoning.

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… [2]

[**Total: 20**]

8

(a) Define

(i) electric field strength

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [1]

(ii) magnetic flux density

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [2]

(iii) the tesla

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [2]

(b) In 1932, Ernest Lawrence built the first cyclotron, an early form of particle accelerator that accelerates charged particles in a confined space with a combination of electric field and magnetic field. Though it was succeeded by more powerful designs later, the cyclotron is still used in nuclear medicine today.

Fig. 8.1 shows the basic structure of a cyclotron. A pair of electromagnets generate a uniform magnetic field vertically through a pair of semicircular metal chambers, referred to as “dees”. The dees are hollow, allowing charged particles to move. An e.m.f. source that changes its polarity at regular intervals is connected to the dees.

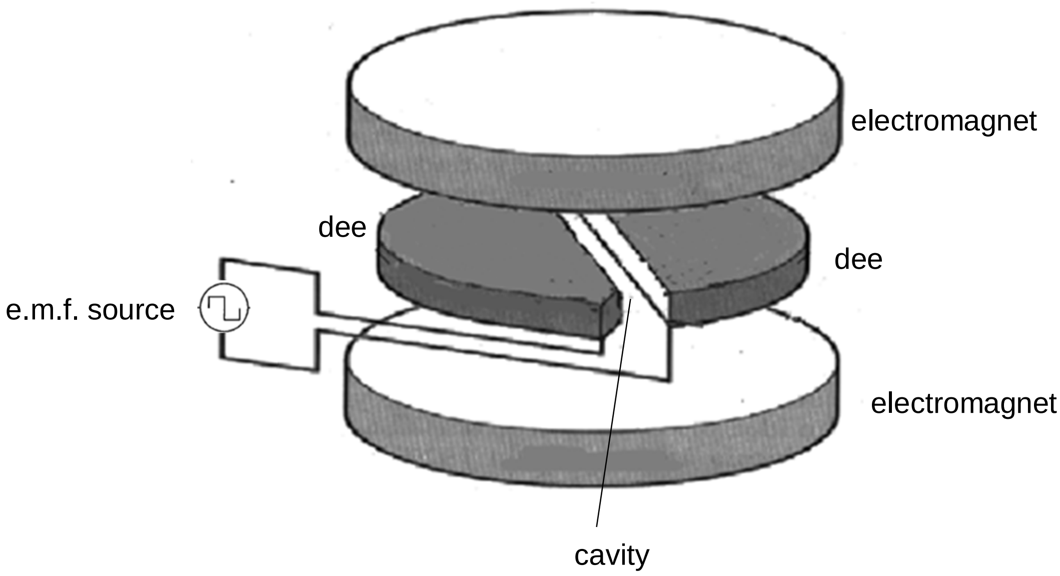

Fig. 8.1

Fig. 8.2 shows the top view of the dees. A potential difference is applied across the dees to generate a uniform electric field as protons are injected at the edge of D2 at negligible initial speed. There is no electric field elsewhere.

The protons are accelerated to D1, in which it moves in a semi-circular path as indicated by the dashed line.

Note that the diagram is not drawn to scale. The actual gap between the two dees is very small, so that the time taken for the proton to cross from one dee to another is negligible. The magnetic field also has negligible effect on the protons while they are moving between the dees.

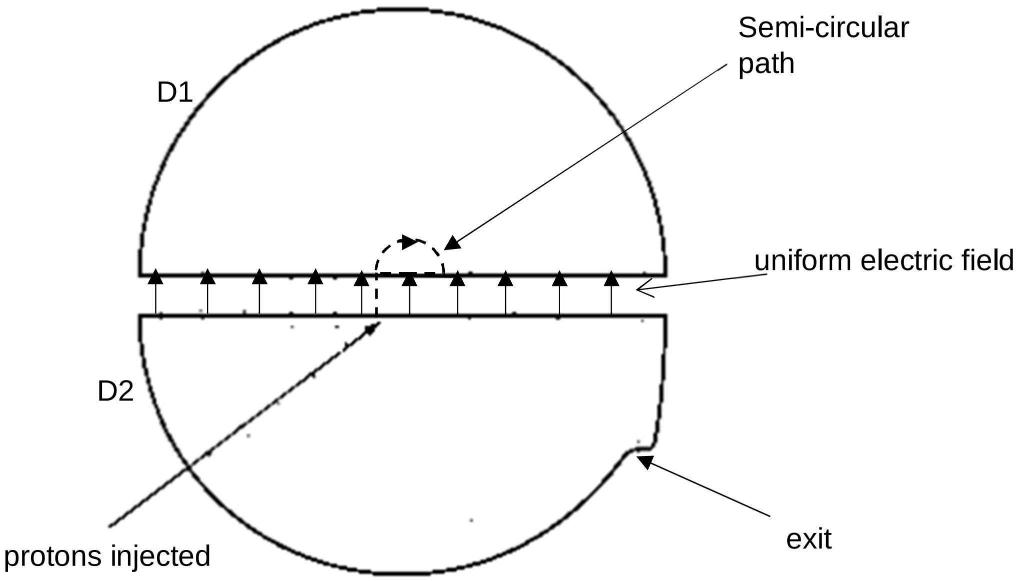

Fig 8.2 (plan view, not drawn to scale)

(i) Referring to Fig. 8.2, state the direction of the magnetic field.

………………………………………………………………………………………… [1]

(ii) Explain why the proton moves in the semi-circular path indicated.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

(iii) Show that the radius of the semi-circular path of the proton, *r*, is

$$r = \frac{mv}{Be}$$

where

m is the mass of proton

v is the speed of proton

B is the magnetic flux density

e is the elementary charge

[2]

(iv) Hence, show that the time t to travel in D1 until it emerges into the gap is

$$t = \frac{\pi\ m}{Be}$$

[2]

(v) Hence, explain why the proton spends the same time in each dee, regardless of its speed.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

………………………………………………………………………………………… [1]

(c) The e.m.f. source is set such that when the proton emerges from D1, the polarity of the applied potential difference changes while the magnitude remains the same. As a result, the emerging proton is accelerated towards D2. This process is repeated until the proton exits the cyclotron. A plausible path of a proton within the dees is depicted in Fig. 8.3.

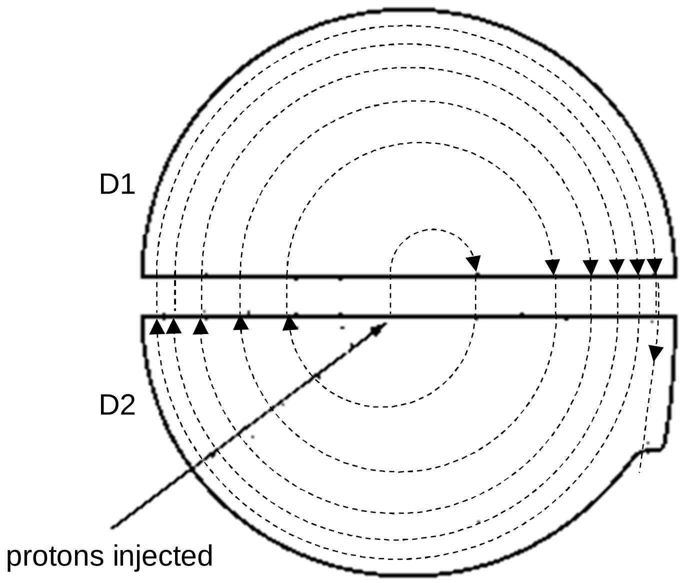

Fig. 8.3

(i) Sketch on Fig. 8.4, the variation of the speed of a proton with time as it goes through **four** semi-circles, starting from the moment it is injected.

Fig. 8.4

[3]

(ii) Show that the kinetic energy of the proton when it exits the cyclotron is

$$E = \frac{e^2B^2R^2}{2m}$$

where R is radius of the dees.

[2]

(iii) A typical large cyclotron in the 1950s used a magnetic field of flux density of about 2.0 T and the dees had a radius of 2.3 m.

Calculate the kinetic energy of protons collected at the exit of this cyclotron.

kinetic energy = …………………… MeV [2]

[**Total: 20**]