

Name: \_\_\_\_\_

Circular Motion

Questions

**Date:**

**Time:**

**Total marks available:**

**Total marks achieved:** \_\_\_\_\_

## **Questions**

Q1.

A particle moving in a circular path completes 8.0 revolutions in 5.0 s.  
Its angular velocity in  $\text{rad s}^{-1}$  is

- A** 1.6
- B** 10
- C** 40
- D** 250

**(Total for question = 1 mark)**

Q2. A fairground roundabout makes 8 revolutions in 1 minute. The angular velocity of the roundabout is

- A**  $0.10 \text{ rad s}^{-1}$
- B**  $0.42 \text{ rad s}^{-1}$
- C**  $0.84 \text{ rad s}^{-1}$
- D**  $0.94 \text{ rad s}^{-1}$

**(Total for Question = 1 mark)**

Q3. The drum of a washing machine rotates with an angular velocity of  $8.5 \text{ rad s}^{-1}$ .  
The time to complete 10 revolutions is

- A** 0.85 s
- B** 1.3 s
- C** 3.7 s
- D** 7.4 s

**(Total for Question = 1 mark)**

Q4. A racing car of mass 1200 kg travels at  $0.63 \text{ rad s}^{-1}$  around a bend of radius 50 m. The force on the car necessary for this motion is

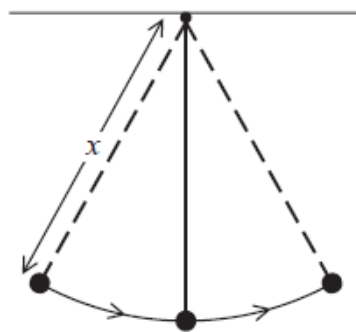
- A  $2.4 \times 10^4 \text{ N}$  away from the centre of the circle.
- B  $2.4 \times 10^4 \text{ N}$  towards the centre of the circle.
- C  $3.8 \times 10^4 \text{ N}$  away from the centre of the circle.
- D  $3.8 \times 10^4 \text{ N}$  towards the centre of the circle.

**(Total for Question = 1 mark)**

Q5.

A pendulum consists of a bob of mass  $m$  and a string of length  $x$ .

The diagram shows the pendulum swinging through the arc of a circle. At the bottom of its swing the tension in the string is  $T$  and the velocity of the bob is  $v$ .

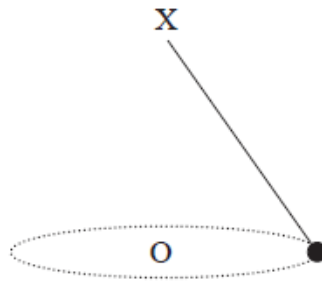


Which of the following is correct for the bob at the bottom of the swing?

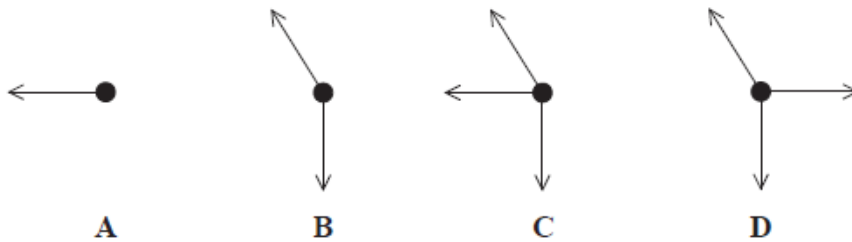
- A  $T = \frac{mv^2}{x} - mg$
- B  $T = \frac{mv^2}{x} + mg$
- C  $T = mg - \frac{mv^2}{x}$
- D  $T = \frac{mv^2}{x}$

Q6.

A mass is attached to a light thread which is fixed at X.  
The mass is moving at constant speed in a horizontal circle, centre O.



Which of the following is a correct free-body force diagram for this mass?



(1)

- A
- B
- C
- D

(Total for question = 1 mark)

Q7.

The photograph shows cars driving around a roundabout at a constant speed.



The resultant force  $F$  on a car causes it to follow a circular path.

Which of the following statements about  $F$  is **incorrect**?

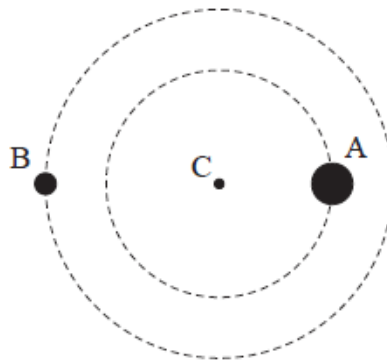
- A**  $F$  is equal to the product of the mass and angular velocity of the car.
- B**  $F$  is equal to the product of the momentum and angular velocity of the car.
- C**  $F$  is in the same direction as the acceleration of the car.
- D**  $F$  is perpendicular to the momentum of the car.

**(Total for question = 1 mark)**

Q8.

The diagram shows two black holes, A and B, orbiting each other.

Assume that the centre of mass C of the system is the centre of a circular orbit for each black hole as shown in the diagram.



Black hole A is in an orbit of radius  $2.9 \times 10^{10}$  m and black hole B is in an orbit of radius  $3.6 \times 10^{10}$  m. Both orbit with the same period, so the total distance between them is  $6.5 \times 10^{10}$  m.

(a) Calculate the force between the black holes.

mass of Sun,  $M_{\odot} = 1.99 \times 10^{30} \text{ kg}$

mass of black hole A =  $36M_{\odot}$

mass of black hole B =  $29M_{\odot}$

(2)

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Force = .....

(b) By considering the orbit of one black hole about C, determine the period of the orbit.

(3)

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Period = .....

**(Total for question = 5 marks)**

Q9.

The Starflyer is a fairground ride which operates 60 m above the ground. As it begins to spin, the chairs in which the riders sit move outwards.



Consider the chair and rider as a single object. By drawing a free-body force diagram and considering the forces acting, explain the following observations.

*The angle to the vertical of the supporting ropes depends on the speed of rotation, but does not depend on the mass of the rider.*

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**(Total for question = 5 marks)**

Q10.

The photograph is of a roundabout in a children's playground.



A child of mass 20 kg sits on the roundabout without holding the bars.

The distance from the centre of the roundabout to the centre of gravity of the child is 0.80 m. The maximum frictional force between the roundabout and the child is  $0.35 \times$  the weight of the child.

(a) Calculate the minimum time taken for one revolution of the roundabout if the child is not to slide off.

(4)

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Minimum time = .....

(b) State and explain how this time would change if a child of larger mass sat at the same place on the roundabout.

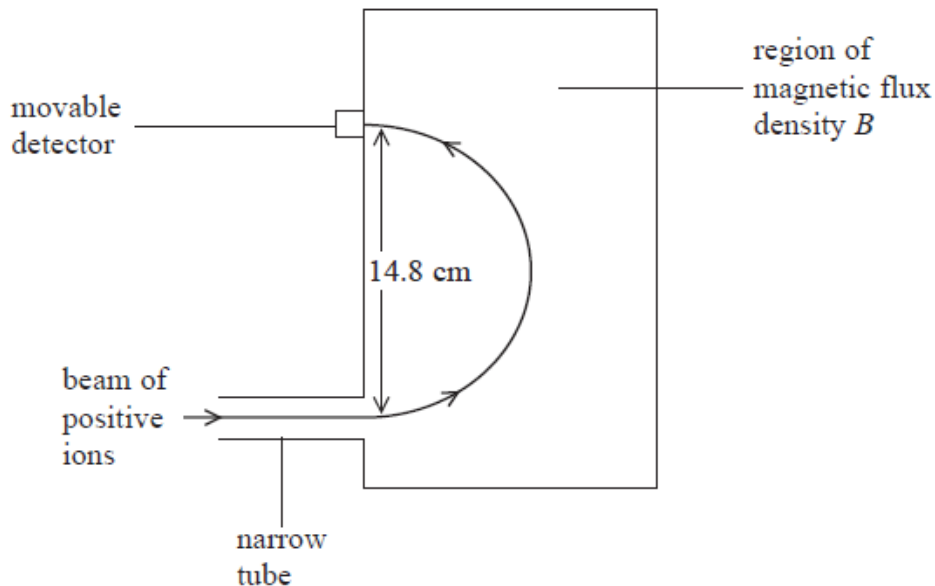
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(Total for question = 6 marks)

Q11.

A mass-spectrometer is an instrument that is used to measure the masses of molecules. Molecules of a gas are ionised and travel through a vacuum in a narrow tube. The ions enter a region of uniform magnetic flux density  $B$  where they are deflected in a semicircular path as shown.



(a) State why it is necessary for the molecules to be ionised.

(1)

(b) State the direction of the magnetic field.

(1)

(c) The ions have a charge of  $+e$  and a speed of  $1.20 \times 10^5 \text{ m s}^{-1}$ . When  $B$  has a value of  $0.673$  T, the ions are detected at a point where the diameter of the arc is  $14.8 \text{ cm}$ .

Calculate the mass of an ion.

(3)

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Mass of an ion = .....

(d) Ions with a smaller mass but the same charge and speed are also present in the beam. On the diagram sketch the path of these ions.

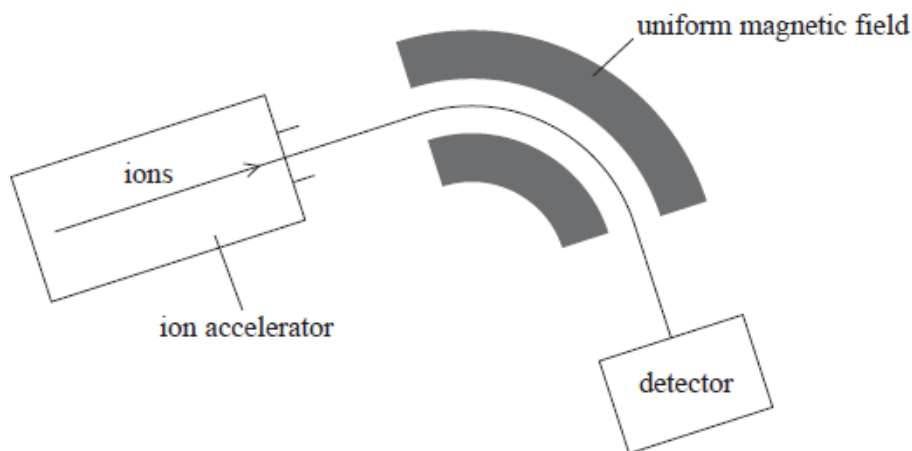
(1)

**(Total for question = 6 marks)**

Q12.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

After passing through the velocity selector the ion beam enters a region of uniform magnetic flux with the ions travelling at right angles to the field.   
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(i) Explain why the ions travel in a circular path.

(2)

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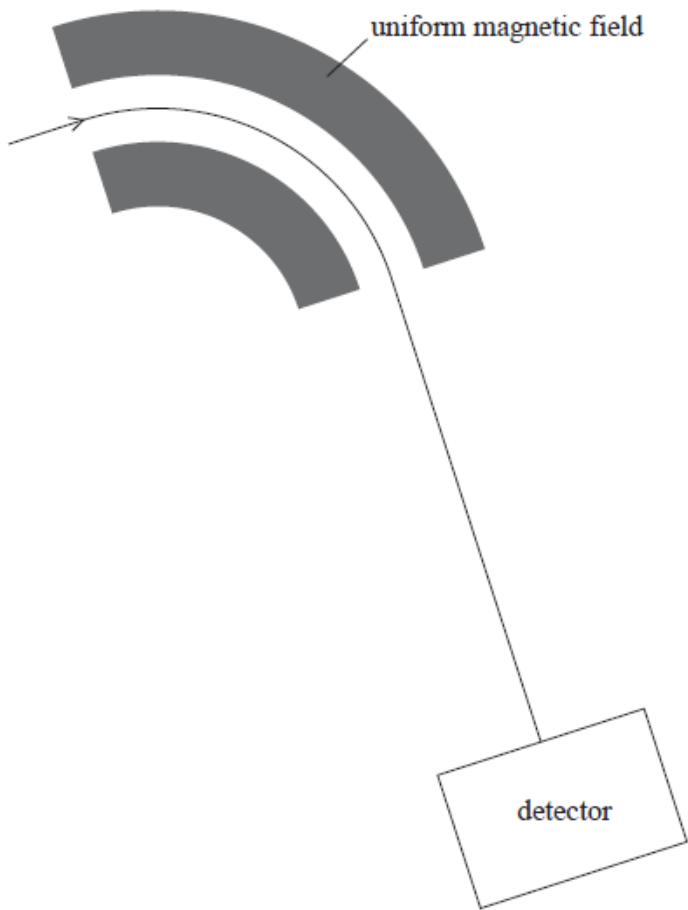
(ii) Calculate the radius of the circular path.

(2)

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Radius = .....

(iii) The diagram shows the path of the chlorine-35 ions in the field. Chlorine-37 ions enter the magnetic field with the same velocity.



1. Add another line to the diagram to show the path of these chlorine-37 ions.

(1)

2. Explain any differences in the paths.

(2)

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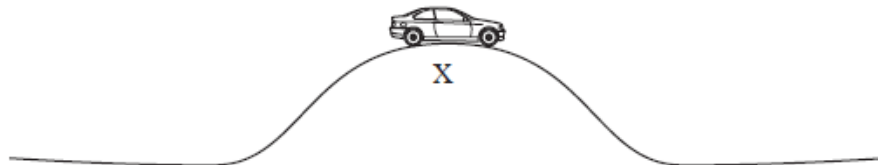
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**(Total for question = 7 marks)**

Q13.



The diagram shows a car of mass 950 kg at the highest point X of the bridge.



The bridge forms part of a vertical circle of radius 20.0 m.

(a) Calculate the total upward force  $R$  of the road on the car:

(i) when the car is stationary at X,

(1)

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$R =$  .....

(ii) when the car is passing point X at a speed of  $12.0 \text{ m s}^{-1}$

(3)

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$R =$  .....

(b) The car is repeatedly driven over the bridge at gradually increasing speeds. Above a certain speed the car loses contact with the road at X. State why this happens.

(1)

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**(Total for question = 5 marks)**

Q14.

The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of  $0.26 \text{ m s}^{-1}$  and moves around a circle of radius 61 m.

(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

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Time = .....

(b) Calculate the centripetal force acting on each cabin.

mass of cabin =  $9.7 \times 10^3 \text{ kg}$

(2)

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Centripetal force = .....

(c) (i) The diagram shows just the circle and the cabins. Draw arrows to show the direction of the centripetal force acting on a person in a cabin when the person is at each of positions **A**, **B** and **C**.

(3)

\*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

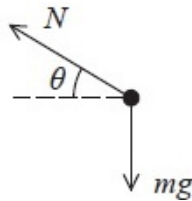
State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)



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 (c) Some cycling tracks are banked. When cornering, a cyclist moves up the track until the sideways frictional force is zero.

The free-body force diagram for a cyclist and bicycle is shown. The normal contact force exerted by the track is  $N$  and the weight of cyclist and bicycle is  $mg$ .



(i) By considering the vertical and horizontal motion, show that

$$\tan \theta = gr/v^2$$

where  $r$  is the radius of the cyclist's path and  $v$  is the cyclist's speed.

(3)

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 (ii) Calculate the value of  $\theta$  for a cyclist travelling at  $11.0 \text{ m s}^{-1}$  around a bend of radius  $18.7 \text{ m}$ .

(2)

$\theta =$  .....

**(Total for Question = 9 marks)**

Q16.

The first satellite weather picture was taken in 1960. Today more than 200 weather satellites are in use. Some of these satellites are in a geostationary orbit around the Earth, so that they

remain at the same point above the Earth's surface all the time.

(a) (i) Show that the magnitude of the gravitational field strength  $g$  at a point outside of the Earth is given by

$$g = \frac{GM}{r^2}$$

where  $r$  is the distance of the point from the centre of the Earth and  $M$  is the mass of the Earth.

(2)

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(ii) Use this expression together with an expression for the centripetal acceleration to show that the radius of a satellite's orbit is given by

$$r^3 = \frac{GMT^2}{4\pi^2}$$

where  $T$  is the time for one orbit of the satellite.

(3)

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(iii) Hence calculate a value for the radius of the geostationary orbit.

$$M = 6.0 \times 10^{24} \text{ kg}$$

(3)

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Radius = .....

(b) State why all geostationary satellites are in an orbit above the Earth's equator.

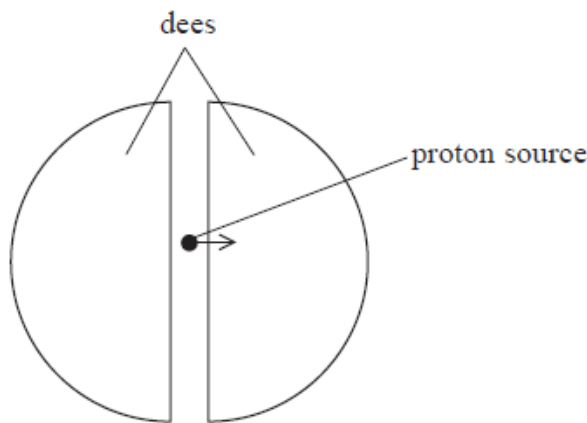
(1)

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**(Total for question = 9 marks)**

Q17.

A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



(i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

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(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

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(iv) Show that the magnetic flux density  $B$  of the applied magnetic field is given by

$$B = \frac{2\pi fm}{e}$$

where  $f$  is the frequency of the alternating potential difference,  $m$  is the mass of the proton and  $e$  is the charge on the proton.

(3)

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(v) In a particular cyclotron  $B$  is 1.2 mT.  
Calculate the frequency  $f$  of the alternating potential difference.

(2)

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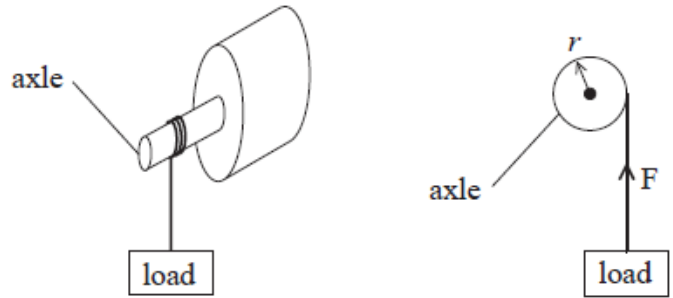
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$f = \dots\dots\dots$

Q18.

Motors usually have a rotating component which can do work  $W$ .

(a) A motor lifts a load in a time  $t$ . The axle of the motor has a radius  $r$  and exerts a force  $F$ .



The power produced by a motor can be calculated by using the following word equation.

**Power = moment of the force exerted by the rotating axle × angular velocity**

Derive this equation, starting with power  $P = \frac{W}{t}$ .

(4)

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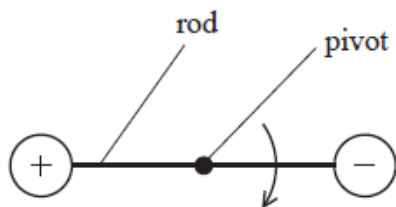
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(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

stationary charged sphere 



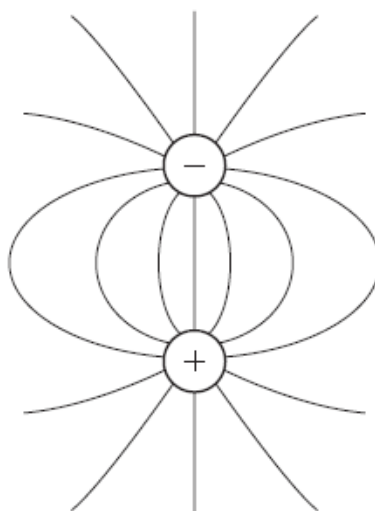
 stationary charged sphere

(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10  $\mu\text{C}$

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	Angular velocity / rad s <sup>-1</sup>
Electric car	$2.0 \times 10^4$	300
Vacuum cleaner	$1.4 \times 10^3$	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

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**(Total for question = 13 marks)**