6.1 Circular Motion

Question Paper

Course	DP IB Physics
Section	6. Circular Motion & Gravitation
Topic	6.1 Circular Motion
Difficulty	Hard

Time allowed: 60

Score: /42

Percentage: /100

Question 1a

A proton of mass *m* moves with uniform circular motion. Its kinetic energy is *K* and its orbital period is *T*.

(a)
Show that the orbital radius *r* is given by:

$$r = \sqrt{\frac{KT^2}{2\pi^2 m}}$$

[2]

[2 marks]

Question 1b

The proton moves in a clockwise circle of circumference 1.25 mm. The net force on the proton is 65 fN.

(b)
Determine the linear speed of the proton.

[3]

[3 marks]

Question 1c

(c)
Calculate the proton's orbital frequency.

[3]

[3 marks]

Question 1d

(d)

(i)
State the mechanism by which protons are made to travel in circular paths.

[1]

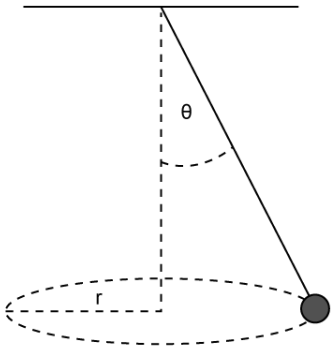
(ii)
Comment on the work done on the proton by this mechanism.

[2]

[3 marks]

Question 2a

A small ball is attached to a string and moves in a horizontal circular path. It completes one revolution every 2.5 s, with the string at an angle θ to the vertical.



(a)
Calculate the orbital radius r if $\theta = 12°$.

You may wish to use the following data:

$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

[3]

[3 marks]

Question 2b

(b)
Show that the length of the string l is given by:

$$l = \frac{g}{\omega^2 \cos\theta}$$

You may wish to use the following data:

$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

[2]

[2 marks]

Question 2c

The equation in part (b) seems to suggest that the length of the string *l* is dependent on the angle it makes to the vertical, θ.

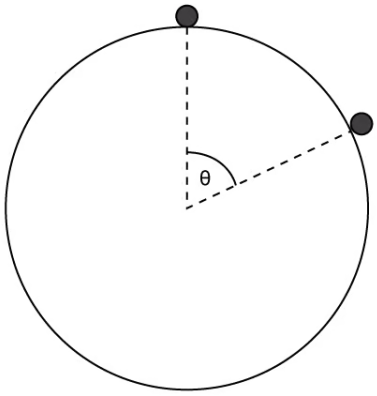
(c)
Comment on the relationship between the length of the string *l* and the angle it makes to the vertical, θ.

[2]

[2 marks]

Question 3a

A marble rolls from the top of a bowling ball of radius *R*.



(a)
Show that when the marble has moved so that the line joining it to the centre of the sphere subtends an angle of θ to the vertical, its speed *v* is given by:

$$v = \sqrt{2gR(1 - \cos\theta)}$$

[3]

[3 marks]

Question 3b

(b)

Deduce that, at the instant shown in the image in part (a), the normal reaction force N on the marble from the bowling ball is given by:

$$N = mg(3\cos\theta - 2)$$

[4]

[4 marks]

Question 3c

(c)

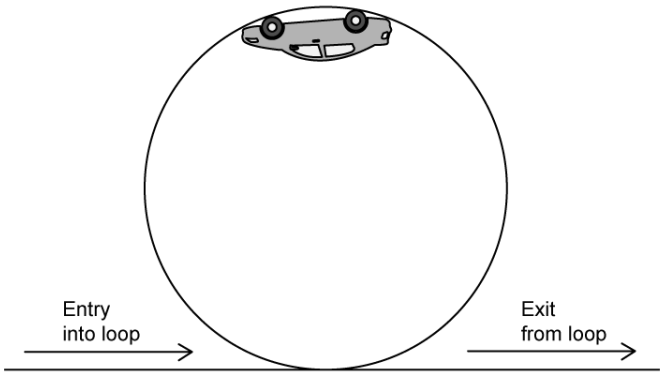
Hence, determine the angle θ at which the marble loses contact with the bowling ball.

[2]

[2 marks]

Question 4a

The 'loop-the-loop' is a popular ride at amusement parks, involving passengers in cars travelling in a vertical circle.



The loop has a radius of 8.0 m and a passenger of mass 70 kg travels at 10 m s^{-1} when at the highest point of the loop.

(a)
Calculate, at the highest point:

(i)
the centripetal acceleration of the passenger,

[1]

(ii)
the force that the seat exerts on the passenger.

[2]

[3 marks]

Question 4b

(b)
Stating any assumptions required, calculate the speed of the passenger at the point marked 'exit from loop' in part (a).

[3]

[3 marks]

Question 4c

Operators must ensure that the speed of the vehicle carrying passengers into the loop-the-loop is above a certain value.

(c)
Suggest a reason for this, and determine the minimum required speed.

[2]

[2 marks]

Question 5a

A popular trick to impress young observers is to swing a bucket of water in a vertical circle. If the bucket is swung fast enough, no water spills out.

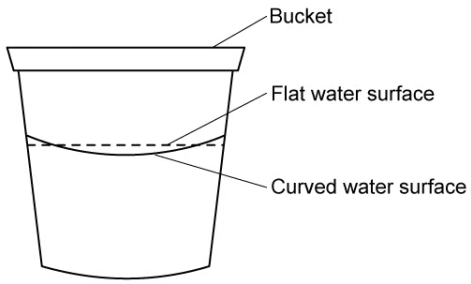
(a)
Estimate the minimum linear speed *v* required to swing a bucket in a vertical circle, such that no water spills.

[3]

[3 marks]

Question 5b

When the bucket of water is stirred with a spoon in uniform circular motion near the rim, the level of water in the bucket is observed to change from a flat horizontal dashed line to a curved solid line, as shown.



(b)

By considering the circular motion of a fluid particle in the water, explain this observation using relevant physical principles.

[4]

[4 marks]