



# A2 Level Physics

Chapter 6 – Further Mechanics

6.4.2 Centripetal Force

Worked Examples

## Centripetal Force

### Exam Style Question 1

- (a) (i) State Newton's first law of motion.
- (ii) Define the newton.
- (b) A jet plane on the deck of an aircraft carrier is accelerated before take-off using a catapult. The mass of the plane is  $3.2 \times 10^4 \text{ kg}$  and it is accelerated from rest to a velocity of  $55 \text{ m s}^{-1}$  in a time of  $2.2 \text{ s}$ . Calculate
- (i) the mean acceleration of the plane
- (ii) the distance over which the acceleration takes place
- (iii) the mean force producing the acceleration.
- (c) The jet plane describes a horizontal circle of radius  $870 \text{ m}$  flying at a constant speed of  $120 \text{ m s}^{-1}$ .
- (i) State the direction of the resultant horizontal force acting on the plane.
- (ii) Calculate the magnitude of this horizontal force.
- (d) By changing the velocity of the plane it can be made to fly in a vertical circle of radius  $1500 \text{ m}$ . At a particular point in the vertical circle, the contact force between the pilot and his seat may be zero and the pilot experiences "weightlessness".
- (i) State and explain at what point in the circle this weightlessness may occur.
- (ii) Calculate the speed of the plane at which weightlessness occurs.



## Centripetal Force

### Exam Style Question 1

**(a)(i) State Newton's first law of motion.**

A body will remain at rest or continue to move with constant velocity unless acted upon by a force.

**(ii) Define the newton.**

The force which gives a mass of  $1 \text{ kg}$  an acceleration of  $1 \text{ m s}^{-2}$ .

**(b) Calculate**

**(i) the mean acceleration of the plane**

Use  $v = u + at$  and rearrange it for  $a$

$$a = \frac{v - u}{t} = \frac{(55 \text{ m s}^{-1} - 0 \text{ m s}^{-1})}{2.2 \text{ s}}$$
$$a = 25 \text{ m s}^{-2}$$

**(ii) the distance over which the acceleration takes place**

Use  $s = ut + \frac{1}{2}at^2$

$$s = (0)(2.2 \text{ s}) + \frac{1}{2}(25 \text{ m s}^{-2})(2.2 \text{ s})^2$$
$$s = 60.5 \text{ m}$$

**(iii) the mean force producing the acceleration.**

Use  $F = ma$

$$F = (3.2 \times 10^4 \text{ kg})(25 \text{ m s}^{-2})$$
$$F = 8 \times 10^5 \text{ N}$$

**(c) (i) State the direction of the resultant horizontal force acting on the plane.**

Towards the centre of the circle.

## Centripetal Force

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## Centripetal Force

### Exam Style Question 1

- (c) (ii) Calculate the magnitude of this horizontal force.

$$\text{Use } F = \frac{mv^2}{r}$$

$$F = \frac{(3.2 \times 10^4 \text{ kg})(120 \text{ m s}^{-1})^2}{(870 \text{ m})}$$
$$F = 5.3 \times 10^5 \text{ N}$$

- (d) (i) State and explain at what point in the circle this weightlessness may occur.

At the top of the circle when the weight provides the required centripetal force.

- (d) (ii) Calculate the speed of the plane at which weightlessness occurs.

Use  $a = \frac{v^2}{r}$  but remember when weightlessness occurs  $a = g$  therefore:

$g = \frac{v^2}{r}$  and rearrange for  $v$ :

$$v = \sqrt{gr} = \sqrt{(9.81 \text{ m s}^{-2})(1500 \text{ m})}$$
$$v = 121.3 \text{ m s}^{-1}$$



## Centripetal Force

### Exam Style Question 2

- (a) The Earth rotates about its axis. Show that its angular speed is approximately  $7 \times 10^{-5} \text{ rad s}^{-1}$ .
- (b) A stone is resting on the ground at a point on the equator.

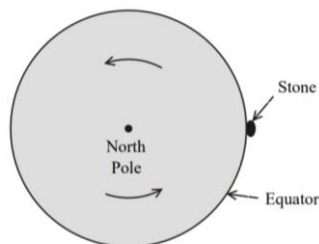


Figure 1

- (i) The radius of the Earth is  $6400 \text{ km}$ . Calculate the acceleration of the stone as it follows its circular path.
- (ii) Draw an arrow on Figure 1 to show the direction of the stone's acceleration.
- (iii) In the space below, draw a labelled free-body force diagram for the stone when it is at the point shown in Figure 1.
- (iv) With reference to your free-body force diagram, explain how the stone's acceleration is produced.



## Centripetal Force

### Exam Style Question 2

- (a) Show that its angular speed is approximately  $7 \times 10^{-5} \text{ rad s}^{-1}$ .

$$\text{Use } \omega = \frac{2\pi}{T}$$

Remember the time the Earth takes to rotate about its axis is 24 hours therefore:

$$\omega = \frac{2\pi}{(24 \text{ h} \times 3600)} = 7.27 \times 10^{-5} \text{ rad s}^{-1}$$

- (b) (i) The radius of the Earth is  $6400 \text{ km}$ . Calculate the acceleration of the stone as it follows its circular path.

$$\text{Use } a = r\omega^2$$

$$a = (6400 \times 10^3 \text{ m})(7.27 \times 10^{-5} \text{ rad s}^{-1})^2$$
$$a = 0.034 \text{ m s}^{-2}$$

- (b) (ii) Draw an arrow on Figure 1 to show the direction of the stone's acceleration.

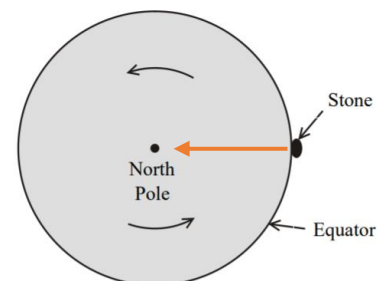


Figure 1

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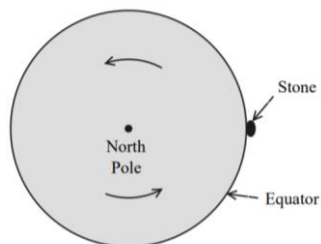


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## Centripetal Force

### Exam Style Question 2

- (b) (iii) In the space below, draw a labelled free-body force diagram for the stone when it is at the point shown in Figure 1.

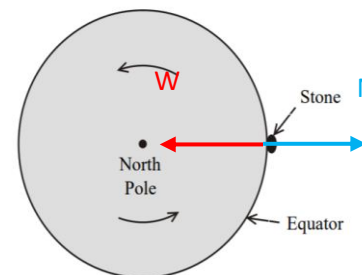


Figure 1

- (b) (iv) With reference to your free-body force diagram, explain how the stone's acceleration is produced.

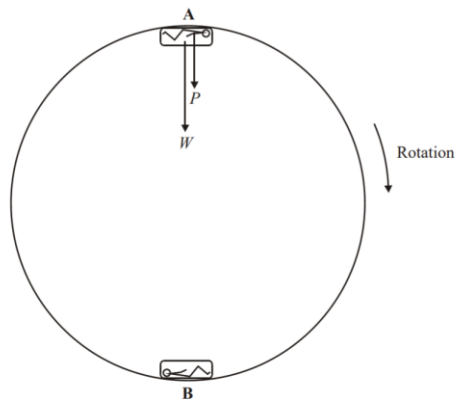
N is less than W therefore resultant force towards the centre which produces the acceleration.



## Centripetal Force

### Exam Style Question 3

Riders on a theme park ride lie back in capsules round the rim of a large wheel. Initially the wheel is horizontal but it then moves into a vertical plane in which it rotates. The diagram shows the wheel when it is rotating in a vertical plane.



- (a) State the direction of the centripetal acceleration of the rider at *A*.
- (b) Explain why the resultant force on the rider at *A* has to be in this same direction.
- (c) The radius of the wheel is  $8.0\text{ m}$  and the time for 1 *revolution* at maximum speed is  $4.5\text{ s}$ . Show that at this speed the resultant force acting on a rider of mass  $60\text{ kg}$  is about  $900\text{ N}$ .
- (d) Calculate the weight  $W$  of the rider.
- (e) Calculate  $P$ , the magnitude of the push from the capsule on the rider, when he is at point *A*.
- (f) Draw labelled arrows on the diagram to show the two principal forces acting on the rider when he is at point *B*.



## Centripetal Force

### Exam Style Question 3

(a) State the direction of the centripetal acceleration of the rider at *A*.  
Towards the centre.

(b) Explain why the resultant force on the rider at *A* has to be in this same direction.

$$F = ma$$

Therefore acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force and so  $a$  and  $F$  are in the same direction.

(c) The radius of the wheel is  $8.0\text{ m}$  and the time for 1 *revolution* at maximum speed is  $4.5\text{ s}$ . Show that at this speed the resultant force acting on a rider of mass  $60\text{ kg}$  is about  $900\text{ N}$ .

We need to use  $F = \frac{mv^2}{r}$  but we don't have  $v$  so:

$$v = \frac{2\pi r}{T} = \frac{2\pi \times 8}{4.5\text{ s}} = 11.170 \dots \text{ m s}^{-1}$$

Now use:

$$F = \frac{mv^2}{r} = \frac{(60\text{ kg})(11.170 \dots \text{ m s}^{-1})^2}{8\text{ m}} = 935.78 \dots \text{ N}$$
$$\therefore F = 936\text{ N}$$

(d) Calculate the weight  $W$  of the rider.

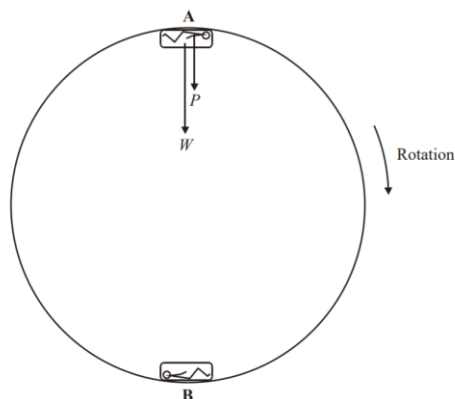
Use  $W = mg$

$$W = (60\text{ kg})(9.81\text{ m s}^{-2})$$
$$W = 589\text{ N}$$

## Centripetal Force

### Exam Style Question 3

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- Calculate the weight  $W$  of the rider.
- Calculate  $P$ , the magnitude of the push from the capsule on the rider, when he is at point *A*.
- Draw labelled arrows on the diagram to show the two principal forces acting on the rider when he is at point *B*.



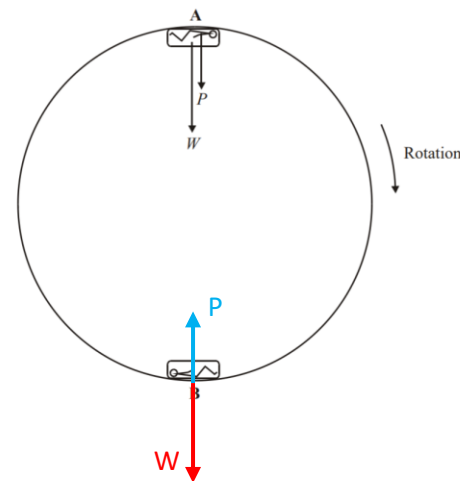
## Centripetal Force

### Exam Style Question 3

- Calculate  $P$ , the magnitude of the push from the capsule on the rider, when he is at point *A*.

$$F_{net} = W + P$$
$$P = F - W = 936\text{ N} - 589\text{ N}$$
$$P = 347\text{ N}$$

- Draw labelled arrows on the diagram to show the two principal forces acting on the rider when he is at point *B*.



Please see **'6.4.1 Centripetal Force notes'** pack  
for exam style questions.

For more revision notes, tutorials and worked  
examples please visit [www.tutorpacks.co.uk](http://www.tutorpacks.co.uk).

