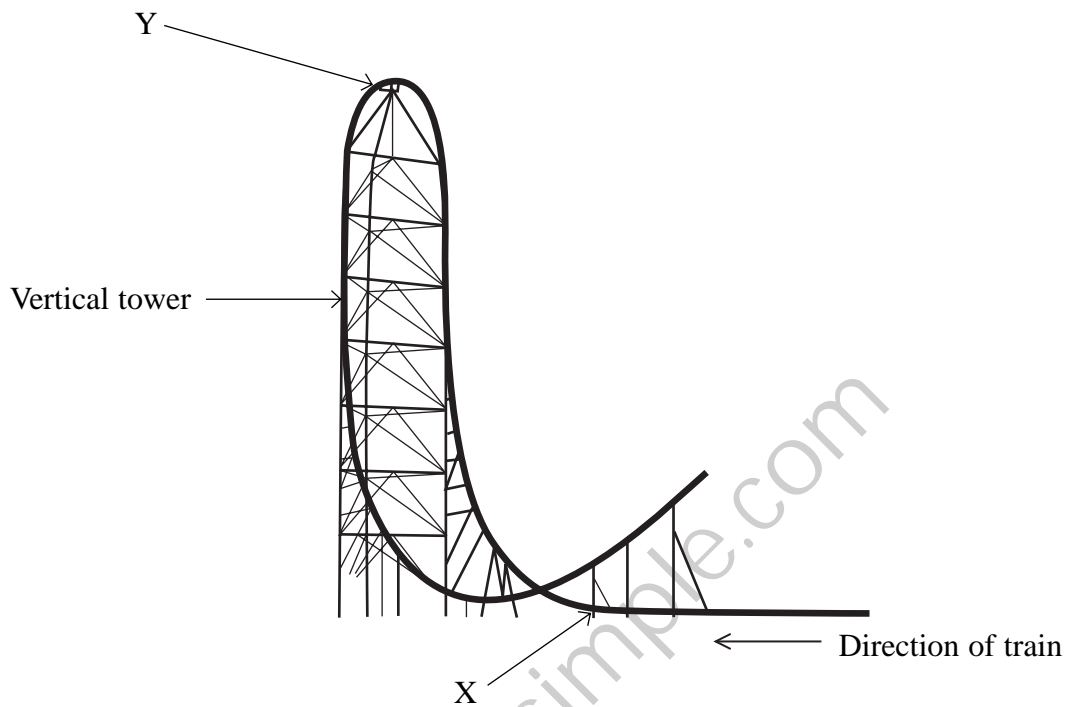


## Mechanics II QP1

- 1 Kingda Ka was the highest roller coaster in the world in 2007. A train is initially propelled along a horizontal track by a hydraulic system. It reaches a speed of  $57 \text{ m s}^{-1}$  from rest in  $3.5 \text{ s}$ . It then climbs a vertical tower before falling back towards the ground.



- (a) Calculate the average force used to accelerate a fully loaded train along the horizontal track.

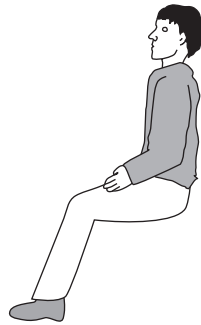
Total mass of fully loaded train =  $12\,000 \text{ kg}$

(2)

Force = .....

(b) Point X is just before the train leaves the horizontal track and moves into the first bend. Complete the free-body diagram below to show the two forces acting on a rider in the train at this point.

(3)



(c) The mass of the rider is  $m$  and  $g$  is the acceleration of free fall. Just after point X, the reaction force of the train on the rider is  $4mg$  and can be assumed to be vertical. This is referred to as a  $g$ -force of  $4g$ . Show that the radius of curvature of the track at this point is about 100 m.

(3)

.....

.....

.....

.....

.....

.....

.....

(d) Show that the speed of the train as it reaches the top of the vertical tower is about  $20 \text{ m s}^{-1}$ . Assume that resistance forces are negligible.

The height of the vertical tower is 139 m.

(2)

.....

.....

.....

.....

- (e) Riders will feel momentarily weightless if the vertical reaction force becomes zero.  
The track is designed so that this happens at point Y.

Calculate the radius of the track at point Y.

(2)

.....

.....

.....

.....

Radius = .....

**(Total for Question = 12 marks)**

Revisionmadesimple.com



(b) The student makes the following observations:

- the ball on the right returns and collides with a similar result; this repeats itself a number of times
- after a while, the middle balls are also moving
- shortly afterwards, the balls all come to rest.

Discuss these observations in terms of energy.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

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

Revisionmadesimple.com

- 3 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  $61 \text{ m}$ .



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

(2)

Time = .....

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

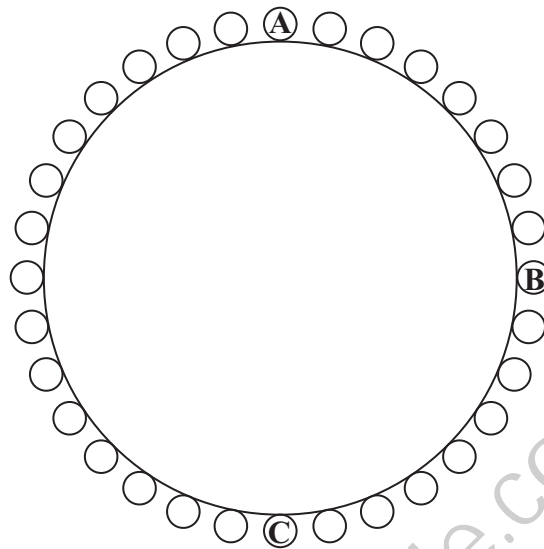
mass of cabin =  $9.7 \times 10^3 \text{ kg}$

(2)

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**.

(1)



- \*(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)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question = 9 marks)

- 4 The Gravitron is a theme park ride consisting of a circular chamber which rotates about a central, vertical axis.



External view of Gravitron

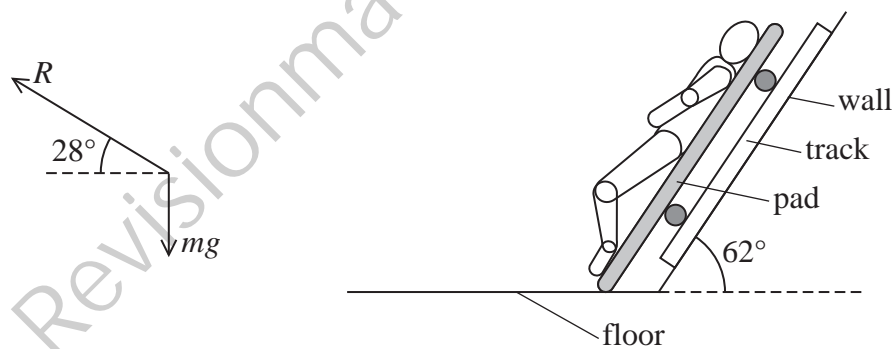


© Kyle R. Grantham

Internal view of Gravitron

The passengers lie back on pads which line the interior of the chamber. These are all inclined at  $62^\circ$  to the horizontal. Each pad is mounted on a small track on the Gravitron wall. As the Gravitron rotates faster and faster, a speed is reached where each pad rises up its track so that the passengers lose contact with the floor of the chamber.

The diagram is a free-body force diagram of a passenger as the pad rises up the track.  $R$  is the normal reaction force acting on the passenger and  $mg$  is the weight of the passenger. You can assume that no other forces act on the passenger.



- (a) (i) Show that when  $m$  is 80 kg the reaction force  $R$  is about 1700 N.

(2)

.....

.....

.....

.....



(ii) Calculate the centripetal acceleration of the passenger.

(2)

.....

.....

.....

Centripetal acceleration = .....

(iii) Calculate the speed of the passenger at the moment that the pad starts to rise up the track.  
The distance from the passenger's centre of mass to the centre of the Gravitron is 5.0 m.

(2)

.....

.....

.....

Speed = .....

(b) The Gravitron is limited to a maximum rate of rotation of 24 revolutions per minute.  
Calculate the linear speed of the passenger at this rate of rotation.

(2)

.....

.....

.....

Linear speed = .....

(c) An advert for the ride states that 'children feel more comfortable on the ride than adults'.

Suggest why children might feel more comfortable on this ride.

(2)

.....

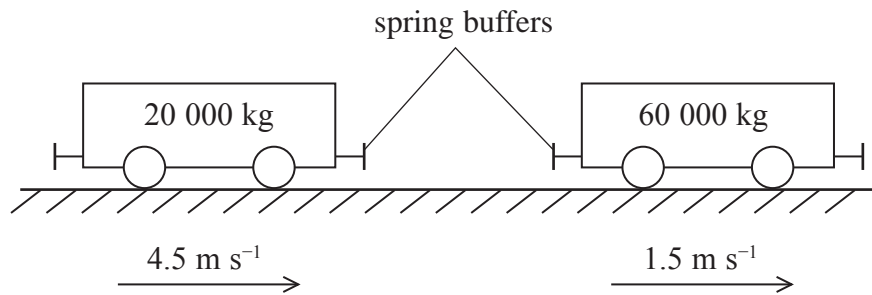
.....

.....

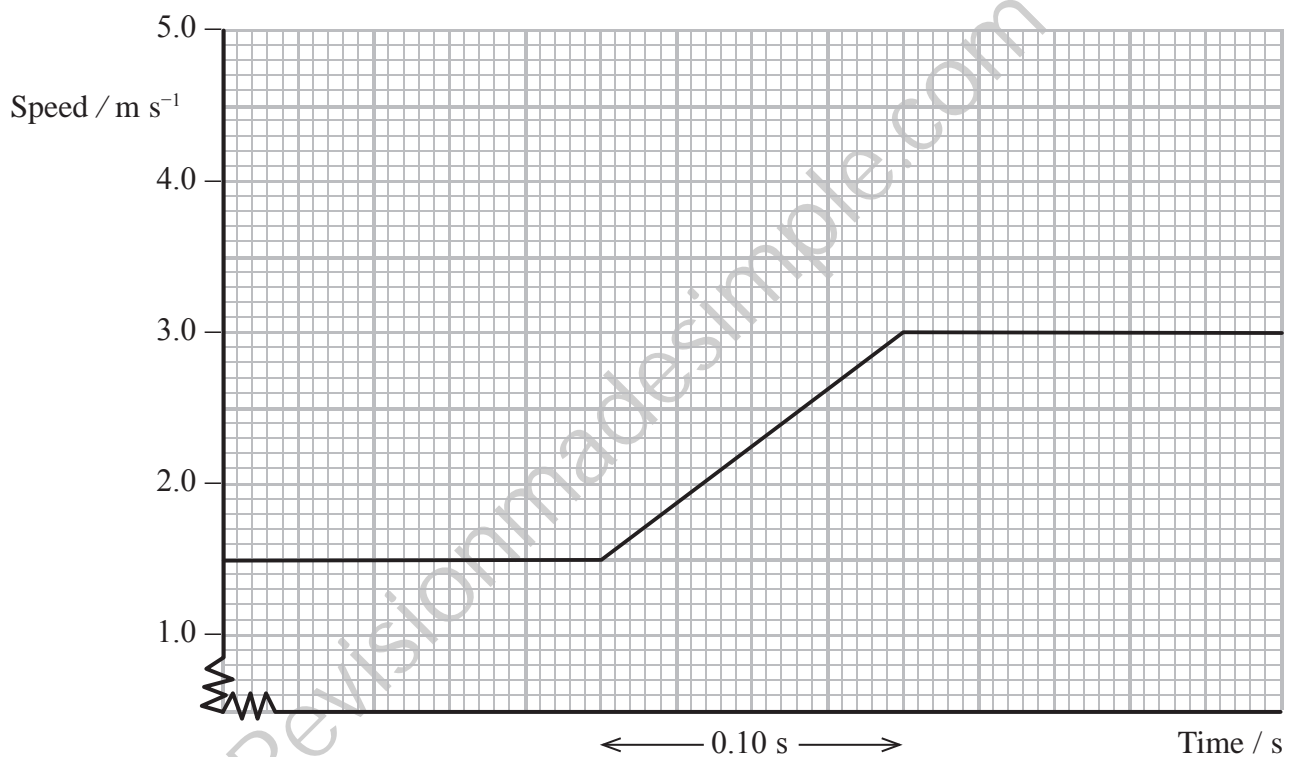
.....

**(Total for Question = 10 marks)**

- 5 A railway truck of mass 20 000 kg is moving at a speed of  $4.5 \text{ m s}^{-1}$ . It catches up and collides with a loaded truck of total mass 60 000 kg which is moving in the same direction at  $1.5 \text{ m s}^{-1}$ .



The graph shows the speed of the heavier truck before, during and after the collision.



- (a) (i) By means of a calculation, show that the speed of the lighter truck after the collision will be zero.

(2)

.....

.....

.....

.....

.....

(ii) Add a second line to the graph to show the speed of the lighter truck before, during and after the collision.

(1)

(iii) Calculate the force that each truck exerts on the other truck.

(2)

.....  
.....  
.....

Force = .....

(b) The collision between the railway trucks is elastic.

(i) State what is meant by an elastic collision.

(1)

.....

(ii) Show that the total kinetic energy halfway through the collision is less than the total kinetic energy after the collision.

(3)

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

(iii) Suggest a reason for this.

(1)

.....  
.....

**(Total for Question = 10 marks)**

6 When an object moves in a circular path at constant speed, a resultant force is required. (

a) State why a resultant force is required and the direction of this force.

(2)

.....

.....

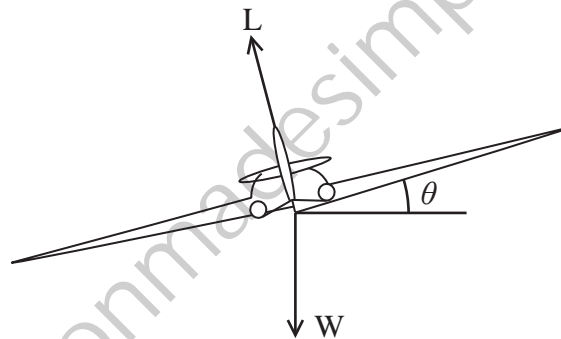
.....

.....

.....

(b) When an aeroplane is flying there is an upward force called lift which acts at right angles to the wings. When the aeroplane is flying in a straight line, the lift force is equal to the weight of the aeroplane.

The diagram shows an aeroplane that is moving in a horizontal circle at constant speed.



\*(i) Explain, in terms of forces, why the aeroplane is able to fly in a circular path.

(2)

.....

.....

.....

.....

.....

- (ii) The aeroplane has a mass of  $2.4 \times 10^6$  kg and is flying in a horizontal circle at a speed of  $85 \text{ m s}^{-1}$  when  $\theta$  is  $25^\circ$ .

By considering both the horizontal and vertical motion, calculate the radius of the circular path of the aeroplane.

(4)

Radius = .....

**(Total for Question = 8 marks)**

Revisionmadesimple.com

7 (a) State the principle of conservation of momentum.

(2)

.....

.....

.....

.....

(b) State the relationship between the resultant force acting on an object and the momentum of the object.

(1)

.....

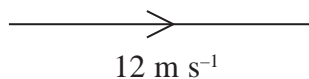
.....

Revisionmadesimple.com

(c) A car is travelling due east with a velocity of  $12 \text{ m s}^{-1}$ . The driver of the car changes direction to travel due north with a velocity of  $15 \text{ m s}^{-1}$ .

- (i) The initial velocity is shown in the diagram.  
Complete the vector diagram to represent the change in velocity. You do not need to draw it exactly to scale.

(2)



- (ii) Determine the change in velocity of the car.

(3)

.....

.....

.....

.....

Magnitude of change of velocity = .....

Direction of change of velocity = .....

- (iii) The mass of the car is  $1500 \text{ kg}$  and the change in velocity took  $4.0 \text{ s}$ .

Calculate the average force that was needed.

(2)

.....

.....

.....

.....

Force = .....

**(Total for Question = 10 marks)**