1 (a) A speedometer can be fitted to a bicycle. A magnet is attached to a spoke on one wheel. The magnet passes a sensor once during each revolution of the wheel and an e.m.f. is generated across the sensor. This produces pulses of e.m.f. as the wheel turns. The radius of the wheel and the time between the pulses are used to determine the speed of the bicycle.

(i) The radius of the bicycle wheel including the inflated tyre is 0.40 m.
Calculate the speed of the bicycle if the magnet passes through the sensor once every 1.2 s.

(2)

Speed =

(ii) Explain how the reading on the speedometer is affected if the tyre is **not** fully inflated.

(2)

(iii) In normal use there is a small current in the sensor. When the magnet passes the sensor the magnetic field is perpendicular to the velocity of the electrons. There is a magnetic force on the electrons.

Calculate the magnitude of the magnetic force on an electron moving at 7.4×10^{-4} m s^{-1}.

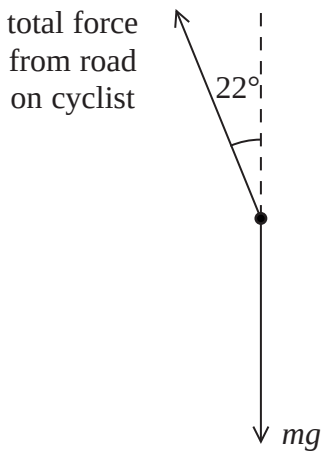
magnetic flux density = 0.050 T

(2)

Magnetic force =

(b) A cyclist leans to one side as he travels around a bend as shown.

The cyclist is travelling at 9.0 m s^{-1} and leans at an angle of 22° to the vertical.
A simplified free-body force diagram for the cyclist and the bicycle is shown below.



Determine the radius of the bend.

combined mass of cyclist and bicycle = 80 kg

(3)

Radius =

(Total for Question = 9 marks)

2 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 × 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)

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.

(2)

(Total for Question = 6 marks)

3 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.

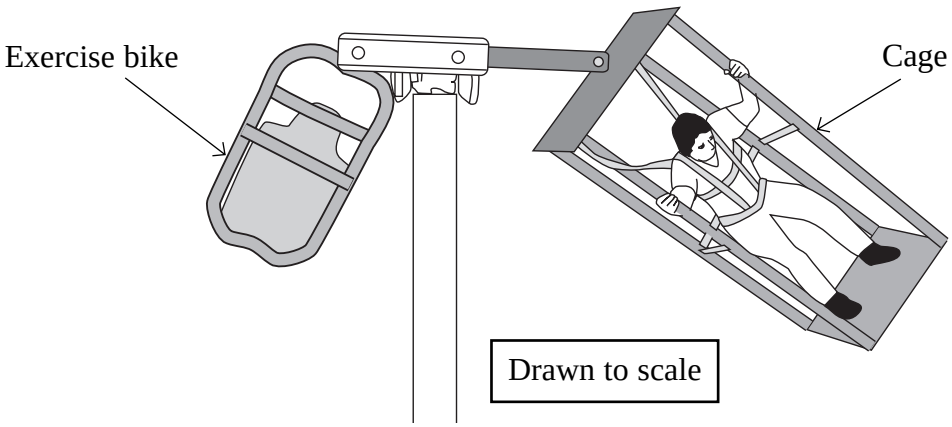
The angle to the vertical of the supporting ropes depends on the speed of rotation, but does not depend on the mass of the rider.

(5)

(Total for Question = 5 marks)

4 Astronauts can be weakened by the long-term effects of microgravity. To keep in shape it has been suggested that they can do some exercise using a Space Cycle: a horizontal beam from which an exercise bike and a cage are suspended. One astronaut sits on the exercise bike and pedals, which causes the whole Space Cycle to rotate around a pole. Another astronaut standing in the cage experiences artificial gravity. When rotated at 20 revolutions per minute, this is of similar strength to the gravitational field on Earth.

Space Cycle



(a) Calculate the angular velocity, in rad s^{-1}, corresponding to 20 revolutions per minute.

(2)

Angular velocity =

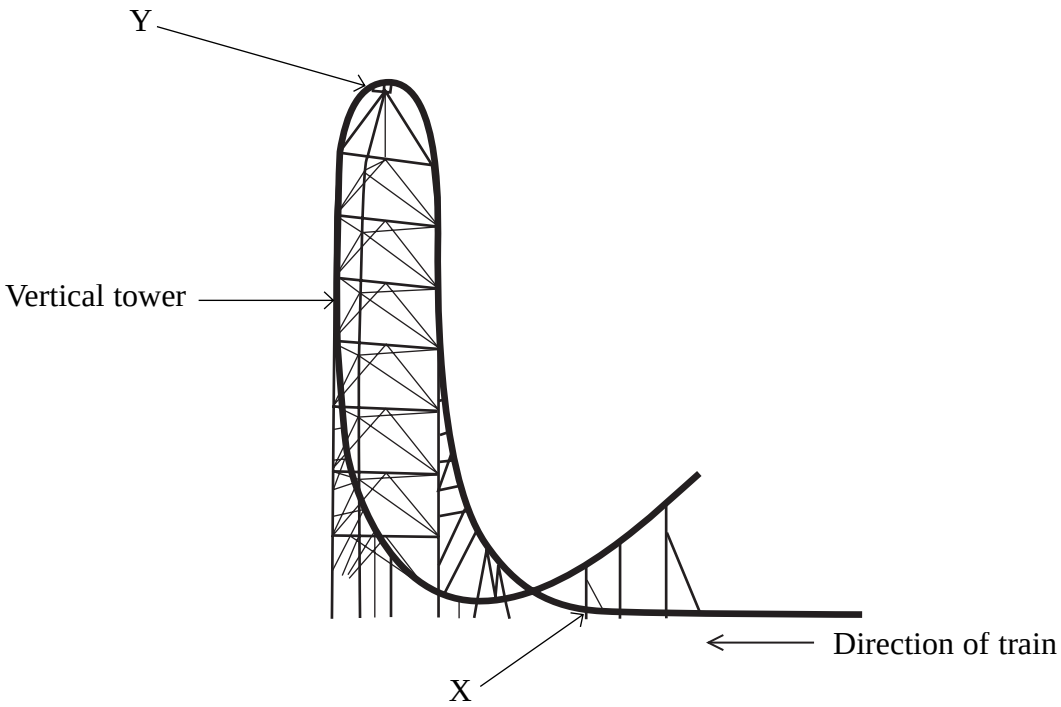
(b) Use the diagram to estimate the radius of the path followed by the cage's platform and hence calculate the platform's acceleration.

(3)

Acceleration =

(Total for Question = 5 marks)

5 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 m s^{-1} from rest in 3.5 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 kg

(2)

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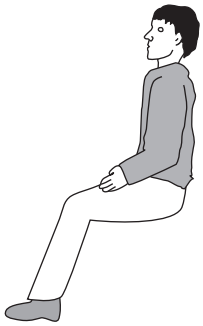
Force =

(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 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)

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Radius =

(Total for Question = 12 marks)