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)

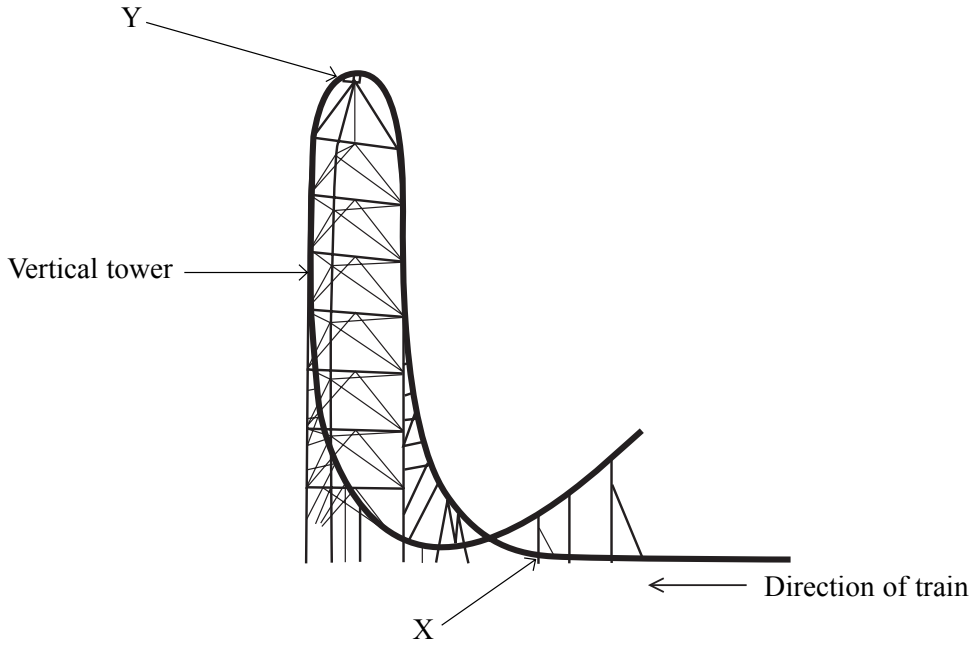
Minimum time =

(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)

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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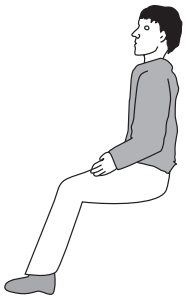
Force =

(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)

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(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)

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(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)

5 In order to make an object move around a circular path at a constant speed a resultant force must act on it.

(a) Explain why a resultant force is required and state the direction of this force.

(2)

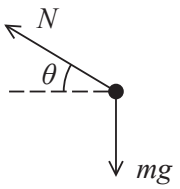
(b) When vehicles move around a bend on a level road, the resultant force is provided by friction between the tyres and the road. For a given vehicle and road surface there is a maximum value for this sideways frictional force.

Explain why roads designed for high-speed travel, such as motorways, do not have any sharp bends.

(2)

(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)

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

(2)

$\theta =$

(Total for Question = 9 marks)

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

☒ **A** 2.4×10^4 N away from the centre of the circle.

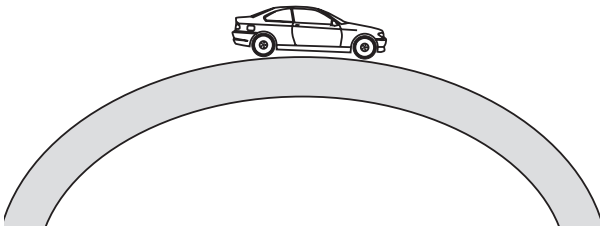
☒ **B** 2.4×10^4 N towards the centre of the circle.

☒ **C** 3.8×10^4 N away from the centre of the circle.

☒ **D** 3.8×10^4 N towards the centre of the circle.

(Total for Question = 1 mark)

6 A car, mass m, drives over a circular hump-back bridge of radius r with a constant speed v.



When it is at the top of the bridge, the force on the car from the bridge is given by

☒ **A** mg

☒ **B** $\frac{mv^2}{r} + mg$

☒ **C** $\frac{mv^2}{r} - mg$

☒ **D** $mg - \frac{mv^2}{r}$

(Total for Question = 1 mark)