2.4 At the fairground

Learning objectives:

- When is the contact force on a passenger greatest on a 'big dipper'?
- What condition applies when a passenger just fails to keep in contact with his seat?

Specification reference: 3.4.1

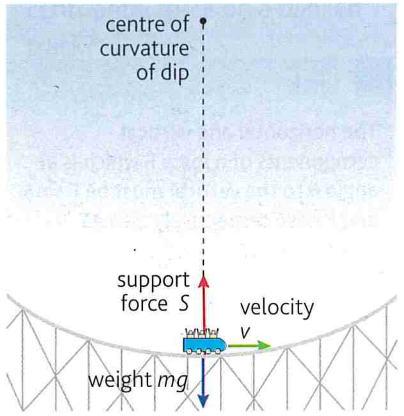

Figure 1 *In a dip*

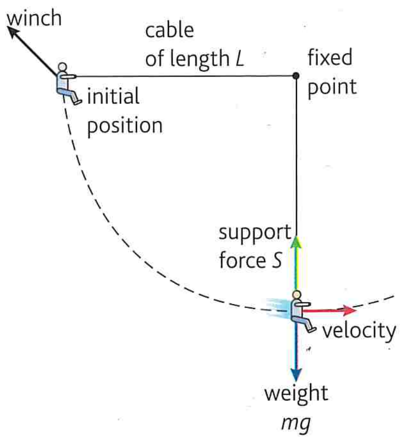

Figure 2 *The very long swing*

Many of the rides at a fairground or amusement park take people round in circles. Some examples are analysed below. It is worth remembering that centripetal acceleration values of more than 2–3*g* can be dangerous to the average person.

The Big Dipper

A ride that takes you at high speed through a big dip pushes you into your seat as you pass through the dip. The difference between the support force on you (acting upwards) and your weight acts as the centripetal force.

At the bottom of the dip, the support force S on you is vertically upwards, as shown in Figure 1.

Therefore, for a speed v at the bottom of a dip of radius of curvature r,

$$S - mg = \frac{mv^2}{r}$$

So the support force $S = mg + \frac{mv^2}{r}$

The extra force you experience due to circular motion is therefore mv^2/r.

The very long swing

In this 'ride', a person of mass m on a very long swing of length L is released from height h above the equilibrium position. The maximum speed is when the swing passes through the lowest point. This can be worked out by equating the gain of kinetic energy to the loss of potential energy.

$$\tfrac{1}{2}mv^2 = mgh$$

where v is its speed as it passes through the lowest point.

$$\text{Therefore} \quad v^2 = 2gh$$

The person on the swing is on a circular path of radius L. At the lowest point, the support force S on the person due to the rope is in the opposite direction to the person's weight, mg. The difference, $S - mg$, acts towards the centre of the circular path and provides the centripetal force. Therefore

$$S - mg = \frac{mv^2}{L}$$

Because $v^2 = 2gh$, then $S - mg = \frac{2mgh}{L}$

In other words, $\frac{2mgh}{L}$ represents the extra support force the person experiences due to circular motion. Prove for yourself that for $h = L$ (i.e. a 90° swing), the extra support force is equal to twice the person's weight.

The Big Wheel

This ride takes its passengers round in a vertical circle on the inside of the circumference of a very large wheel. The wheel turns fast enough to stop the passengers falling out as they pass through the highest position.

At maximum height, the reaction R from the wheel on each person acts downwards. So, the resultant force at this position $= mg + R$. This reaction force and the weight provide the centripetal force. Therefore, at the highest position when the wheel speed is v,

$$mg + R = \frac{mv^2}{r} \quad \text{where } r \text{ is the radius of the wheel}$$

$$\therefore R = \frac{mv^2}{r} - mg$$

At a certain speed v_0 such that $v_0^2 = gr$, then $R = 0$ so there would be no force on the person due to the wall.

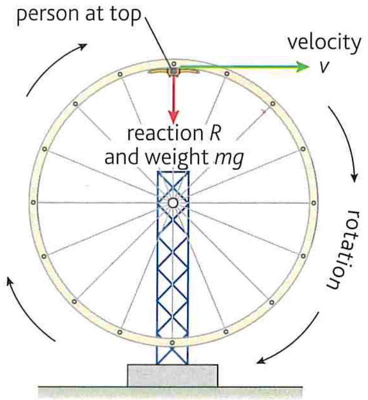

Figure 3 *The Big Wheel*

Application and How science works

Safe rides

Amusement rides are checked regularly to ensure they are safe. Accidents on such rides in the United Kingdom have to be investigated by the Health and Safety Executive (HSE). A passenger on a ride may experience 'g-forces' in different directions that may be back and forth, side to side or normal to the track. HSE have found that the g-forces in accidents were found to be within acceptable limits for amusement rides and other factors such as passenger behaviour and passenger height in relation to compartment design were more significant. In particular, a passenger should be able to sit back in their seat with their feet on the foot rests or floor and be able to comfortably reach the hand holds.

Figure 4 *g-forces at work*

Summary questions

$g = 9.8\,\text{m}\,\text{s}^{-2}$.

1 A train on a fairground ride is initially stationary before it descends through a height of 45 m into a dip which has a radius of curvature of 78 m, as shown in Figure 5.

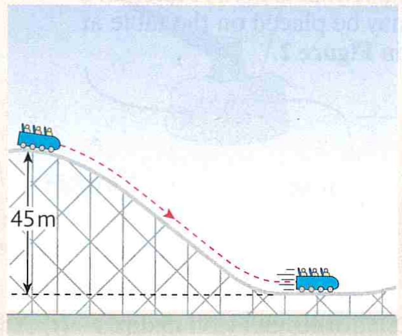

Figure 5

a Calculate the speed of the train at the bottom of the dip, assuming air resistance and friction are negligible.

b Calculate

i the centripetal acceleration of the train at the bottom of the dip,

ii the extra support force on a person of weight 600 N in the train.

2 A very long swing at a fairground is 32 m in length. A person of mass 69 kg on the swing descends from a position when the swing is horizontal. Calculate:

a the speed of the person at the lowest point,

b the centripetal acceleration at the lowest point,

c the support force on the person at the lowest point.

3 The Big Wheel at a fairground has a radius of 12.0 m and rotates once every 6.0 s. Calculate:

a the speed of rotation of the perimeter of the wheel,

b the centripetal acceleration of a person on the perimeter,

c the support force on a person of mass 72 kg at the highest point.

4 The wheel of the London Eye has a diameter of 130 m and takes 30 minutes to complete 1 revolution. Calculate the change due to rotation of the wheel of the support force on a person of weight 500 N in a capsule at the top of the wheel.