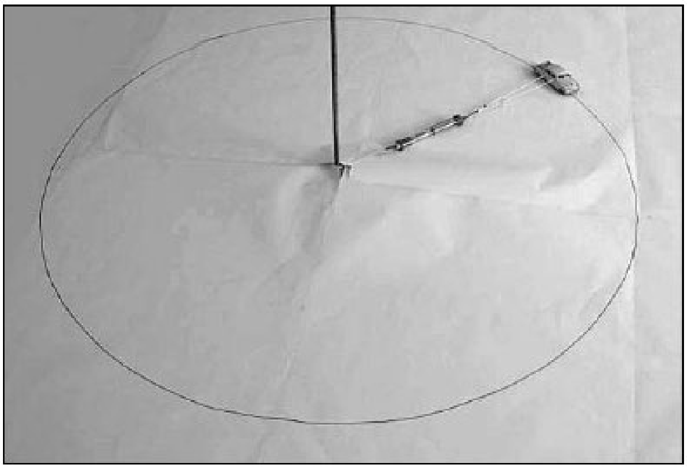
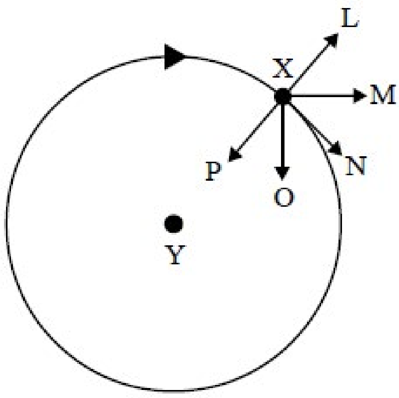
Multiple choice questions

Students set up an experiment to investigate circular motion. They use a battery-powered model car. The car is connected with a string to a fixed point as shown below. A diagram of the experimental arrangement they use is also shown below where Y represents the fixed point and X represents the car. The car has a mass of 2.4 kg. It moves at a constant speed of 2.0 m s^{-1}, around a circle of radius 1.6 m. Ignore mass of string and measuring device.

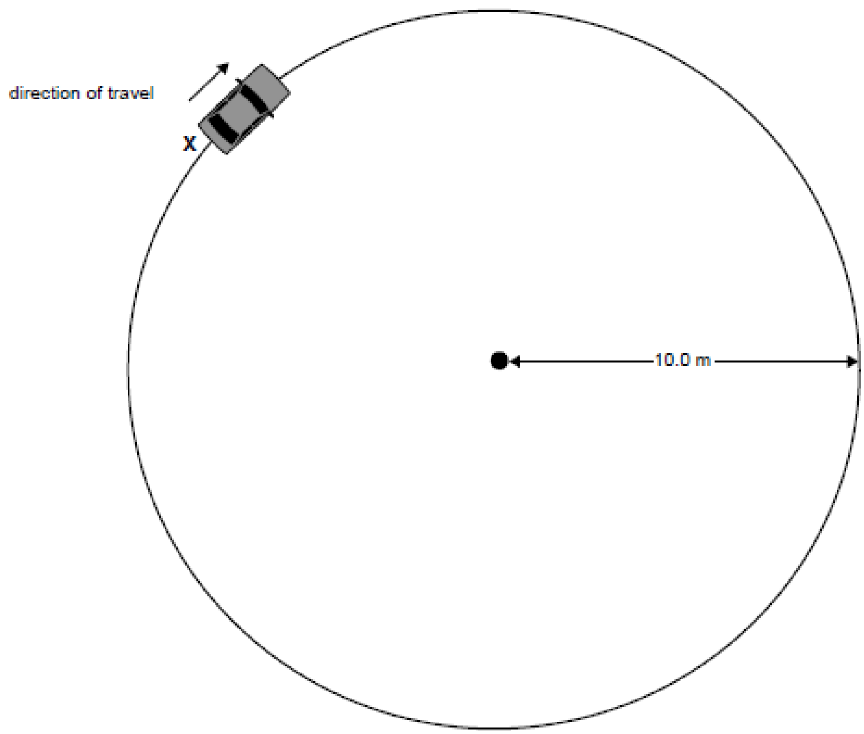


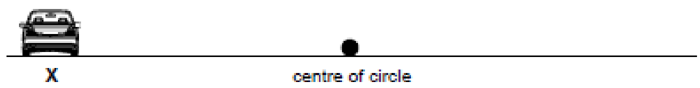


Example 1 **(2008 Question 4, 2 marks)**

Which of the arrows **(L – P)** best indicates the direction of the resultant force on the car when it is at the point X?

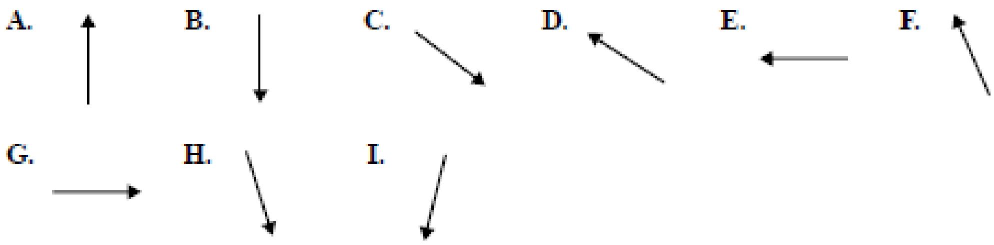
A small car travels in a circle of radius 10.0 m at a constant speed. The first figure shows the car from **above** and the second figure shows the car from **behind**.





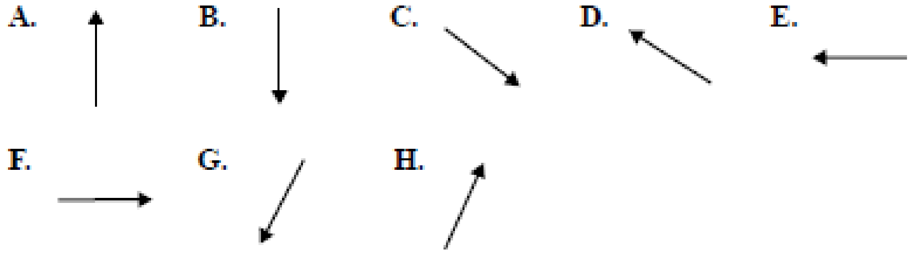
Example 2 **(2003 Question 11, 2 marks)**

In the position **X**, shown in the **top Figure**, which of the arrows (**A. – I.**) best shows the direction of the net force on the car?

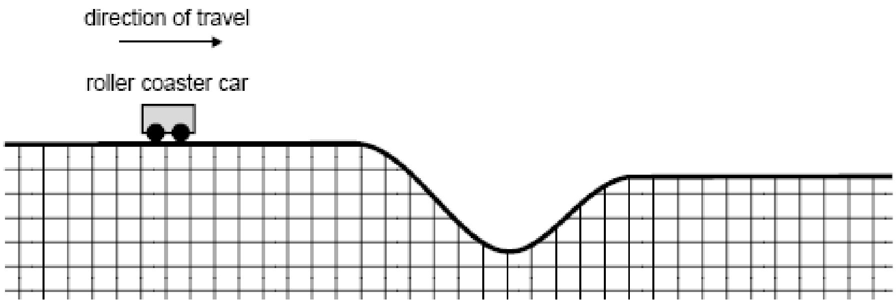


Example 3 **(2003 Question 13, 2 marks)**

In the position **X**, shown **in the lower figure**, which of the arrows (**A – H**) best shows the direction of the force that the **tyre** exerts on the **road**.

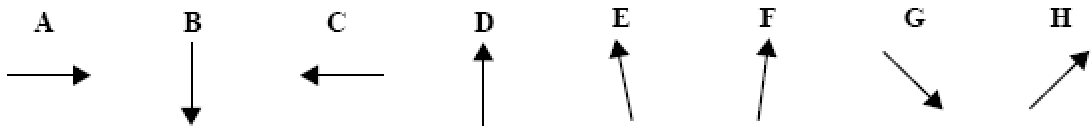


The diagram below shows a section of a roller coaster track, with a roller coaster car travelling at constant speed from the left.

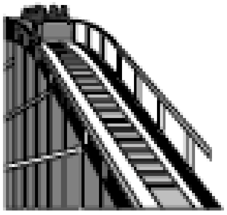


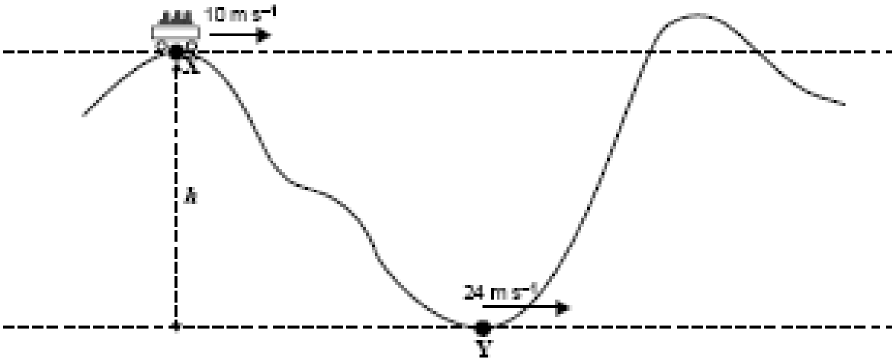
Example 4 (2001 Question 10, 2 marks)

Which of the arrows (**A–H**) best indicates the direction of the net force on the roller coaster car at the lowest point, assuming that friction and air resistance **cannot** be neglected?



Jo is riding on a roller-coaster at a fun fair. Part of the structure is shown below.

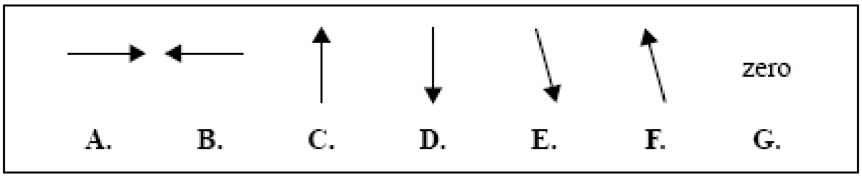


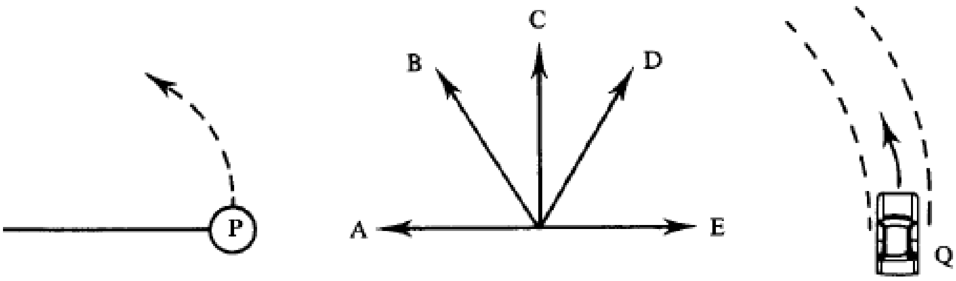


When Jo is at point **X** her velocity is 10 m s^{-1} in a horizontal direction, and at point **Y** it is 24 m s^{-1} in a horizontal direction. At **Y** the track has a radius of curvature of 12 m.

Example 5 (2000 Question 15, 3 marks)

Jo has a mass of 50 kg. What is the **magnitude** and **direction** of the **net** force on Jo at point **Y**? Use the key (**A**–**G**) below to select the best indication of the direction.





P is a frictionless puck travelling in a horizontal circle at constant speed at the end of a string. Q is a car travelling at constant speed on a horizontal circular track.

When they are in the position shown in the diagram, which of the vectors A, B, C, D or E best represents:

Example 6 (1981 Question 17, 1 mark)

i the acceleration of P?

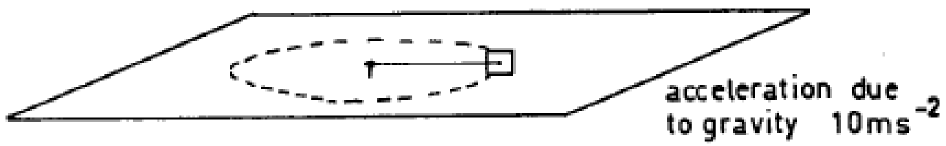
ii the resultant force on P?

Example 7 (1981 Question 18, 1 mark)

i the acceleration of Q?

ii the resultant force on Q?

A mass of 0.5 kg, tied to the end of a string of length 0.50 m, is travelling in a circular path at uniform speed on a horizontal frictionless table.



Example 8 (1979 Question 13, 1 mark)

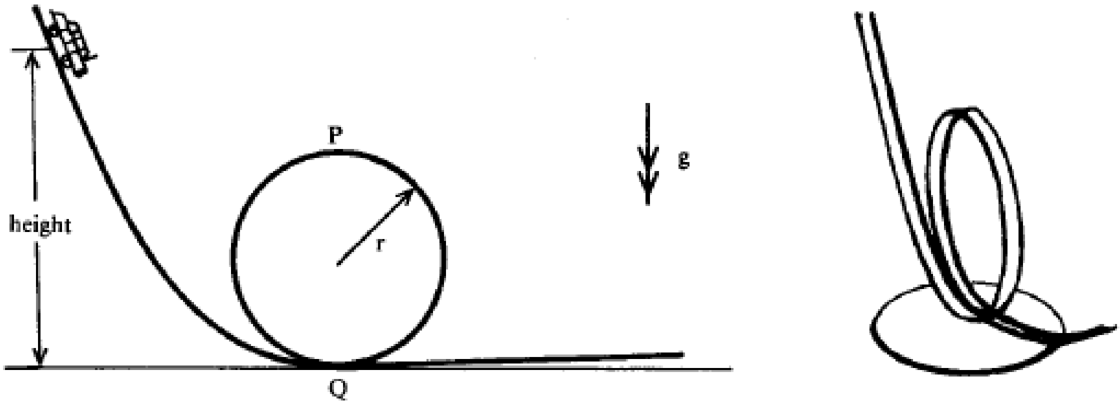
While the mass is travelling at a uniform speed

- **A.** its kinetic energy and momentum are both constant
- **B.** its kinetic energy is constant but its momentum is changing
- **C.** its kinetic energy is changing but its momentum is constant
- **D.** its kinetic energy and momentum are both changing.

Non-uniform circular motion

A 'loop the loop' toy is designed as shown in the diagram below. A toy car of mass *m* can be placed on the track at various heights above the ground so that, when released, it enters the loop which has a radius *r.* If the height is large enough, the car will complete the loop without falling away from the track.

In the questions below ignore the effects of friction.



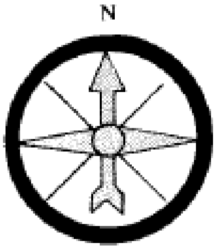
Example 9 **(1985 Question 32, 1 mark)**

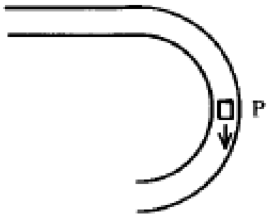
Which of the expressions (**A – E**) below gives the minimum height from which the car can be released if it is to just loop the loop?

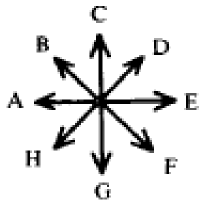
A. $\frac{9r}{4}$ **B.** $\frac{5r}{2}$ **C.** 2r **D.** r **E.** $\frac{r}{2}$

A car travels at increasing speed around a circular section of horizontal road of radius 50 m. When the car is at P, it is travelling south with a speed of 10 m s^{-1}. Its speed is increasing at the rate of

2.0 ms^{-2}.



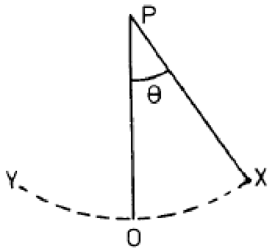




Example 10 (1983 Question 18, 1 mark)

Which arrow in the key best indicates the direction of the car's total acceleration at the instant the car is a P?

A pendulum bob suspended from P is released from X, and swings through midpoint O to Y.



Example 11 (1980 Question 23, 1 mark)

When it is passing through O, the tension in the string is

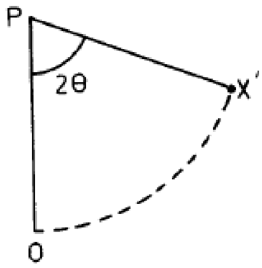
A. zero

B. greater than the weight of the pendulum bob

C. equal to the weight of the pendulum bob

D. slightly less than the weight of the pendulum bob

E. about half the weight of the pendulum bob



Example 12 (1980 Question 24, 1 mark)

The pendulum bob is now released from X', such that the string makes an angle 2θ with the vertical. The tension in the string as the bob passes through O will now be

A. double what it was before

B. greater than what it was before, but not double

C. the same as it was before

D. slightly less that it was before

E. half of what it was before

Short answer questions

The following information relates to Questions 1 and 2.

A racing car of mass 700 kg (including the driver) is travelling around a corner at a constant speed. The car's path forms part of a circle of radius 50 m, and the track is horizontal.

The magnitude of the central force provided by friction between the tyres and the ground is

11 200 N.

Example 13 (2010 Question 1, 2 marks)

What is the speed of the car?

Example 14 (2010 Question 2, 2 marks)

What is the acceleration of the car as it goes around the corner?

The following information relates to Questions 23 and 24.

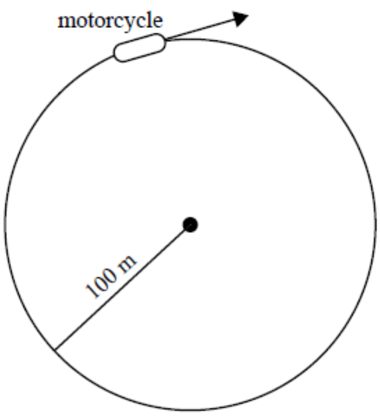
A motorcyclist is riding around a circle of radius of 100 m. The surface is flat and horizontal. The motorcyclist is travelling at a constant speed of 32.0 m s^{-1}. The motorcycle with rider has a mass of 250 kg.

Example 15 (2009 Question 3, 2 marks)

What is the magnitude of the net force on the motorcycle with rider?

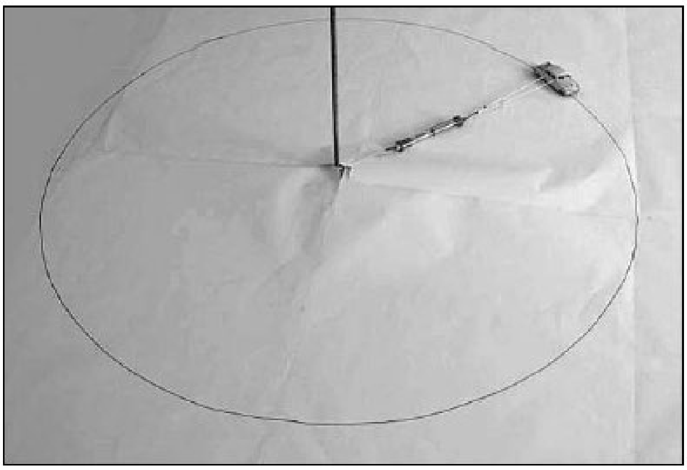
Example 16 (2009 Question 4, 2 marks)

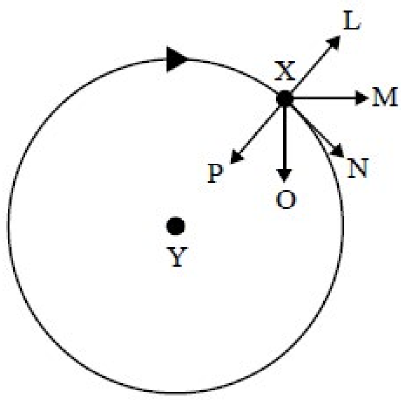
Draw an arrow to show the direction of the net force on the motorcycle.



Students set up an experiment to investigate circular motion. They use a battery-powered model car. The car is connected with a string to a fixed point as shown below. A diagram of the experimental arrangement they use is also shown below where Y represents the fixed point and X represents the car. The car has a mass of 2.4 kg. It moves at a constant speed of 2.0 m s^{-1}, around a circle of radius 1.6 m.

Ignore mass of string and measuring device.





Example 17 (2008 Question 3, 2 marks)

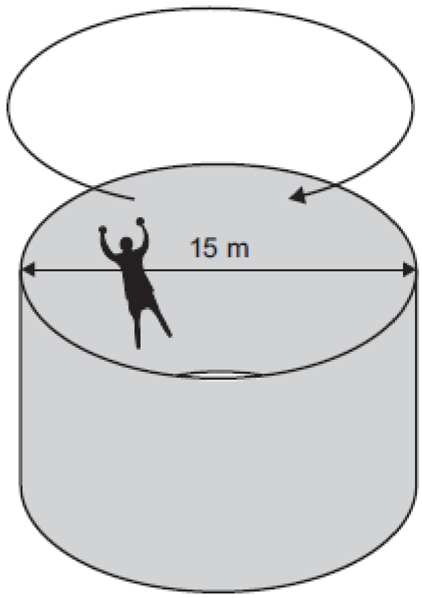
What is the tension in the string?

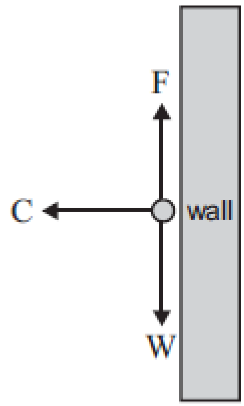
You must show your working.

Vivian, who weighs 60 kg, is at a fair ground and takes a ride on the Rotor. The Rotor is a large cylinder which, when spinning, pins riders against the internal wall. The first figure is a sketch of the situation. Initially Vivian is standing on the floor, and the Rotor speeds up. She feels the wall pushing harder and harder against her back.

When the friction between the wall and her back is large enough, the floor is lowered. Vivian is held against the wall, and does not slip down.

The **diameter** of the Rotor is 15 m.





The second figure is a force diagram showing all the forces acting on Vivian: force of wall on Vivian (C), weight force (W) and friction force (F).

Example 18 **(2006 Question 4, 2 marks)**

When the Rotor is moving **just fast enough** to stop Vivian slipping, what is the magnitude of force F?

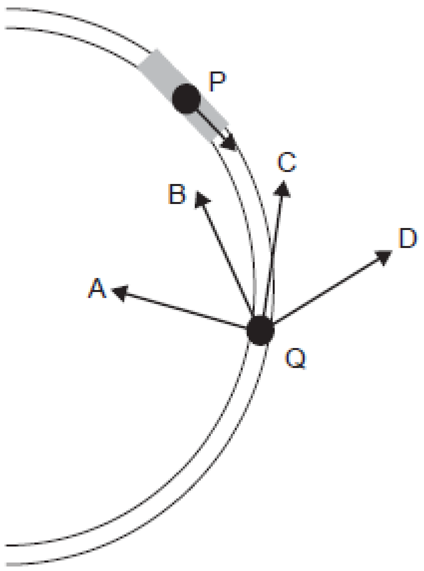
The Rotor **continues to speed up** so that its final speed at the wall is 11 m s^{-1}.

Example 19 **(2006 Question 5, 2 marks)**

What is the magnitude of the force (C) of the wall on Vivian?

The safe speed for a train taking a curve on level ground is determined by the force that the rails can take before they move sideways relative to the ground. From time to time trains derail because they take curves at speeds greater than that recommended for safe travel.

The figure below shows a train at position P taking a curve on horizontal ground, at a constant speed, in the direction shown by the arrow.



Example 20 (2005 Question 5, 2 marks)

At point P shown on the figure, draw an arrow that shows the direction of the force exerted by the rails **on the wheels** of the train.

The radius of curvature of a track that is safe at 60 km/h is approximately 200 m.

Example 21 (2005 Question 6, 3 marks)

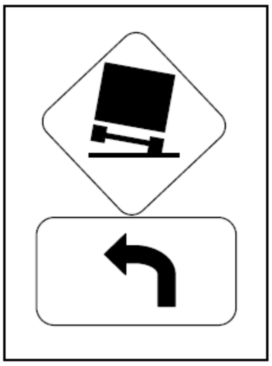
What is the radius of curvature of a track that would be safe at a speed of 120 km/h, assuming that the track is constructed to the same strength as for a 60 km/h curve?

Example 22 (2005 Question 7, 2 marks)

At point Q the driver applies the brakes to slow down the train on the curve.

Which of the arrows **(A – D)** indicates the direction of the **net** force exerted **on the wheels** by the rails?

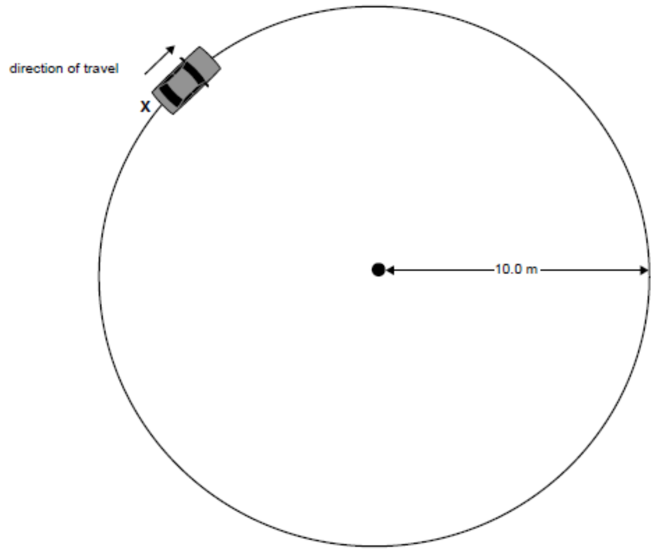
The sign below is often seen just before a circular bend in the road as a warning for trucks to slow down.

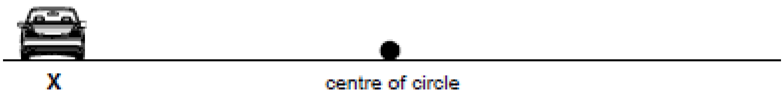


Example 23 (2004 Question 10, 2 marks)

The typical recommended speed for traffic on these circular bends is 50 km h^{-1}. Suggest **one** way to make it safer for trucks travelling around the bend at this recommended speed of 50 km h^{-1}. Give a reason for your answer.

A small car travels in a circle of radius 10.0 m at a constant speed. The first figure shows the car from **above** and the second figure shows the car from **behind**.





Example 24 (2003 Question 12, 2 marks)

On **the second figure**, draw arrows to show all the separate forces acting on the car at the position **X**, ignoring air resistance. (You must show both the **direction** and **point of application** of each separate force.)

Eddie Irvine and his Formula 1 racing car are taking a corner in the Australian Grand Prix. A camera views the racing car head-on at point X on the bend where it is travelling at constant speed. At this point the radius of curvature is 36.0 m. The total mass of car and driver is 800 kg.

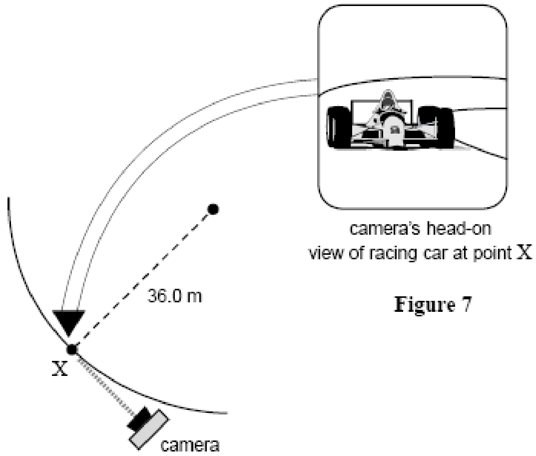


Figure 7

The magnitude of the horizontal force on the car is 6400 N.

Example 25 (1999 Question 14, 2 marks)

Calculate the speed of the car.

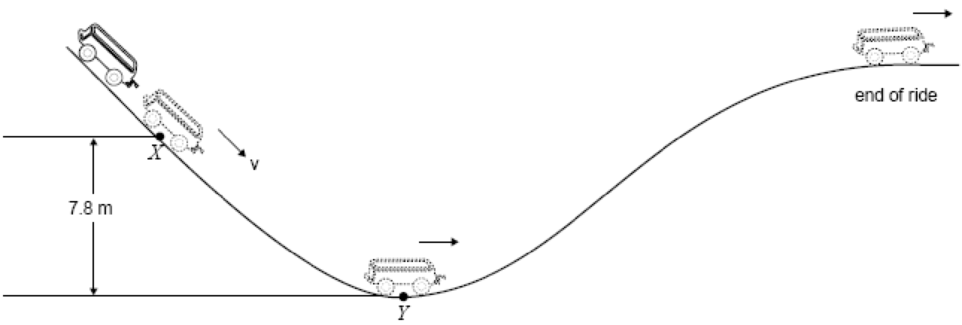
Example 26 (1999 Question 15, 4 marks)

Explain:

• why the car needs a horizontal force to turn the corner

• where this force comes from.

A cart on a roller coaster rolls down a track as shown below. The upper section of the track is straight and the lower section forms part of a circle. The effect of friction can be ignored in the following questions.



Example 27 (1998 Question 13, 1 mark)

On the sketch of the roller coaster, draw **one** arrow which shows the direction of the net force on the cart when it is at the point *X*.

Example 28 (1998 Question 14, 1 mark)

On the sketch of the roller coaster, draw **one** arrow which shows the direction of the net force on the cart when it is at the point *Y*.

The mass of the cart is 500 kg, and at point *X* it is travelling at a speed of 10 m s^{-1}.

Example 29 (1998 Question 15, 2 marks)

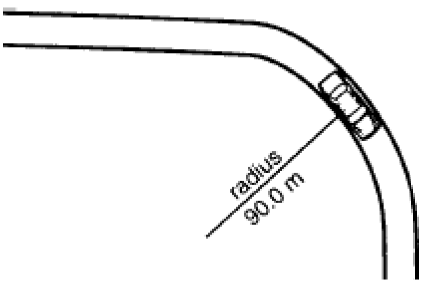
Calculate the speed of the cart at the point *Y*.

Example 30 (1998 Question 16, 2 marks)

Calculate the **net** force acting on the cart at the point *Y* if the radius of curvature of the track at this point is 8.0 m.

A traffic engineer needs to put a maximum speed-limit sign on a dangerous bend. If a car travels too fast the sideways frictional force will not be large enough to keep it on the road.

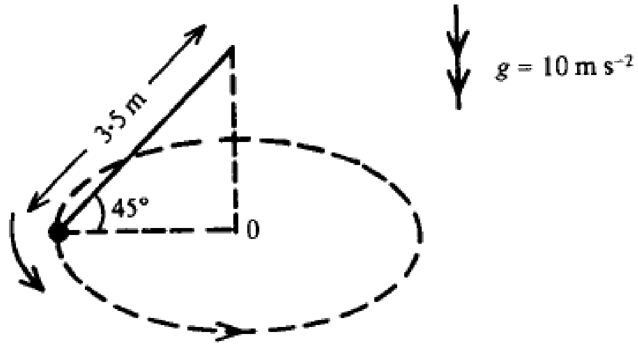
The maximum sideways frictional force that the tyre-road combination can produce without slipping is estimated to be 2 800 N for a car of mass 1 200 kg.



Example 31 (1997 Question 10, 2 marks)

If the bend is modelled on the arc of a circle of radius 90.0 m as shown above, calculate the maximum speed that a car can have and remain on the road without slipping.

A mass of 0.10 kg is attached to a light string of length 3.5 m and caused to move in a horizontal circle at constant speed. The situation is pictured below.



The string makes an angle of 45^0 to the ground and the acceleration of gravity is 10 m s^{-2}.

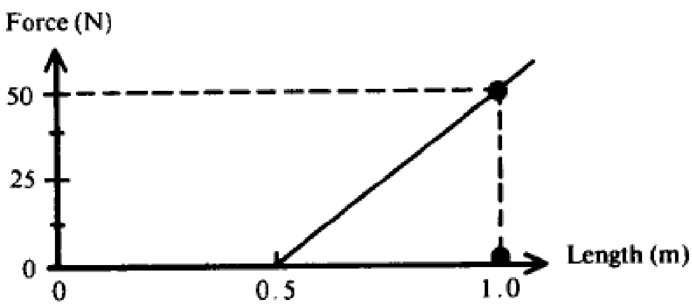
Example 32 (1985 Question 25, 1 mark)

What is the tension in the string?

Example 33 (1985 Question 26, 1 mark)

At what speed is the mass moving.

A light spring has a force-length relationship as shown below.



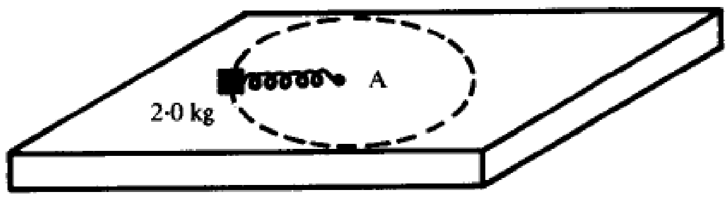
Example 34 (1984 Question 15, 1 mark)

What is the spring constant?

Example 35 (1984 Question 16, 1 mark)

How much work is necessary to change the length of the spring from 0.75 m to 1.0 m?

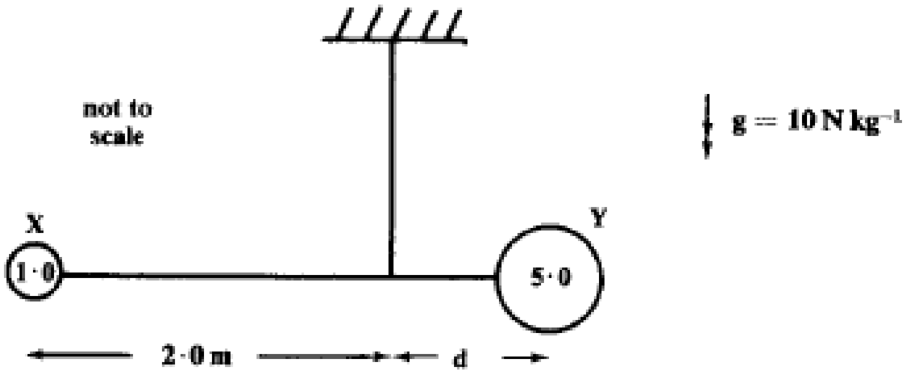
This spring is now placed on a horizontal frictionless surface as shown below. One end is fixed and can pivot about the point A; the other end has a mass of 2.0 kg attached to it. The mass is set moving at a constant speed in a circle of radius 1.0 m.



Example 36 (1984 Question17, 1 mark)

What is the speed of the mass?

Two masses, of 1.0 kg and 5.0 kg, are attached to a light rod and suspended from a string as shown.



When the rod is horizontal, ie. The masses are balanced, the length d is 0.4 m.

Example 37 (1982 Question 8, 1 mark)

What is the tension in the string?

The horizontal rod is now set into motion so that both masses rotate about the vertical string with a frequency of 2 revolutions per second.

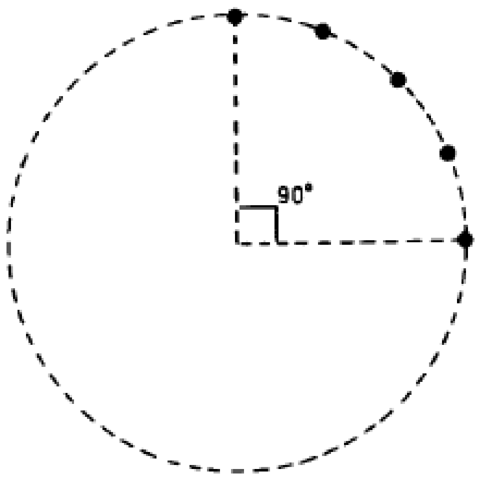
Example 38 (1982 Question 9, 1 mark)

What is the speed of mass X?

Example 39 (1982 Question 10, 1 mark)

What is the value of the ratio $\frac{\text{acceleration of } Y \text{ towards string}}{\text{acceleration of X towards string}}$

An object is travelling in a horizontal circle of radius 0.20 metre. A student takes a multi-flash photograph of this object, using a flash which fires every 0.125 second. The following diagram represents this photograph.



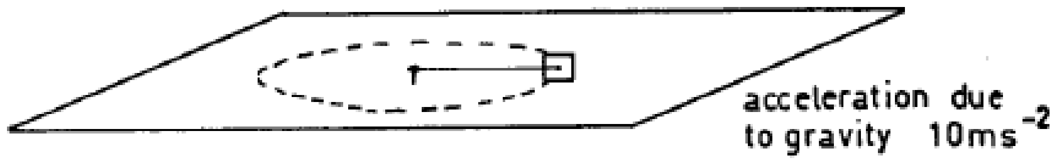
Example 40 (1980 Question 10, 1 mark)

What is the speed of the object?

Example 41 (1980 Question 11, 1 mark)

What is the acceleration of the object towards the centre of the circle?

A mass of 0.5 kg, tied to the end of a string of length 0.50 m, is travelling in a circular path at uniform speed on a horizontal frictionless table.



Example 42 (1979 Question 12, 1 mark)

What is

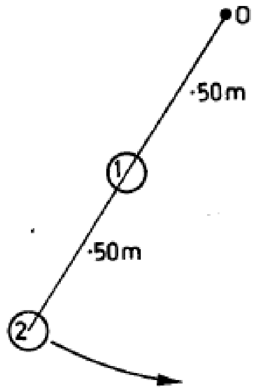
(i) the magnitude,

(ii) the direction, of the force *of the table* on the mass?

Example 43 (1979 Question 14, 1 mark)

If the string breaks when stretched with a force just greater than 4.0×10^2 N, what is the maximum possible speed it can have?

Two spheres of equal mass are attached to a string of length 1.00 m as in the figure. The string and the spheres are whirled in a horizontal circle about O at a constant rate.



Example 44 (1972 Question 15, 1 mark)

What is the ratio $\frac{\text{speed of sphere 2}}{\text{speed of sphere 1}}$?

Example 45 (1972 Question 16, 1 mark)

What is the ratio $\frac{\text{acceleration of sphere 2}}{\text{acceleration of sphere 1}}$?

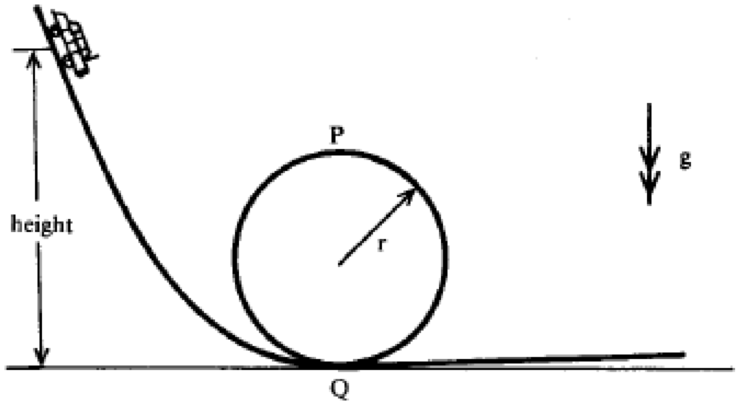
Example 46 (1972 Question 17, 1 mark)

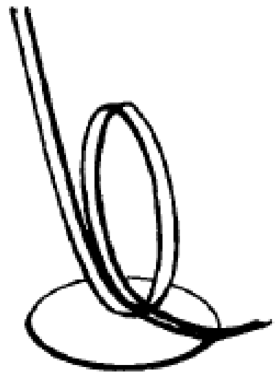
What is the ratio $\frac{\text{tension in string between spheres 1 and 2}}{\text{tension in string between spheres 1 and O}}$?

Non-uniform circular motion

A 'loop the loop' toy is designed as shown in the diagram below. A toy car of mass *m* can be placed on the track at various heights above the ground so that, when released, it enters the loop which has a radius *r.* If the height is large enough, the car will complete the loop without falling away from the track.

In the questions below ignore the effects of friction.



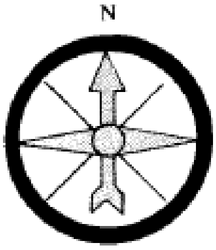


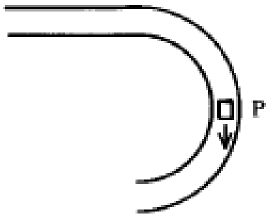
Example 47 (1985 Question 31, 1 mark)

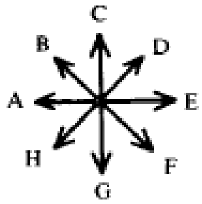
Write an expression, in terms of the symbols *g* and *r*, for the minimum speed, *v*, that the car can have at the point P if it is not to lose contact with the track.

A car travels at increasing speed around a circular section of horizontal road of radius 50 m. When the car is at P, it is travelling south with a speed of 10 m s^{-1}. Its speed is increasing at the rate of

2.0 ms^{-2}.







Example 48 (1983 Question 19, 1 mark)

What is the magnitude of the component of the car's acceleration in the westerly direction at the instant the car is at P?

Example 49 (1983 Question 20, 1 mark)

What is the magnitude of the acceleration of the car at the instant the car is at P?

Question 8 (5 marks)

In an experiment, a ball of mass 2.5 kg is moving in a vertical circle at the end of a string, as shown in Figure 5.

The string has a length of 1.5 m.

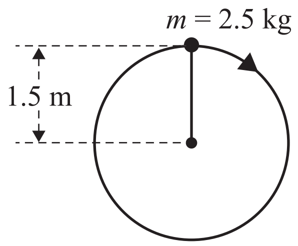


Figure 5

a. Calculate the minimum speed the ball must have at the top of its arc for the string to remain tight (under tension). 2 marks

m s^{-1}

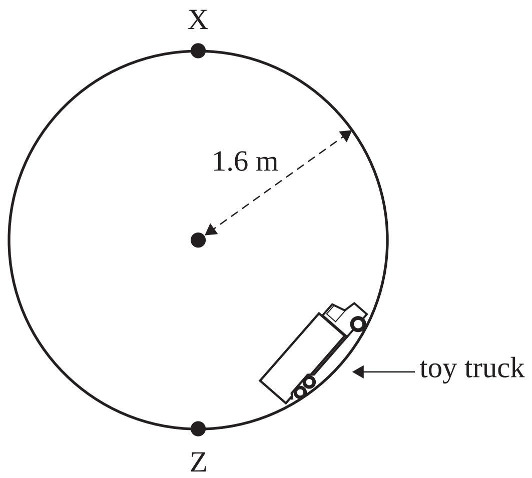
b. In another experiment, the ball is moving at 6.0 m s^{-1} at the top of its arc.

Calculate the speed of the ball at the lowest point. 3 marks

m s^{-1}

Use the following information to answer Questions 8 and 9.

A toy truck travels on a track around a vertical loop of radius 1.6 m, as shown below. Assume that the toy truck is a point mass.



Question 8

The minimum speed at which the toy truck must be moving at point X for it to stay on the track is closest to

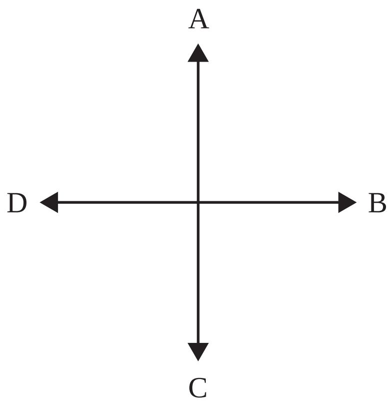
A. 1.6 m s^{-1}

B. 3.2 m s^{-1}

C. 4.0 m s^{-1}

D. 16 m s^{-1}

Question 9



Which direction best shows the direction of the resultant force on the toy truck at point Z?

A. A

B. B

C. C

D. D

Question 8 (9 marks)

A 250 g toy car performs a loop in the apparatus shown in Figure 8.

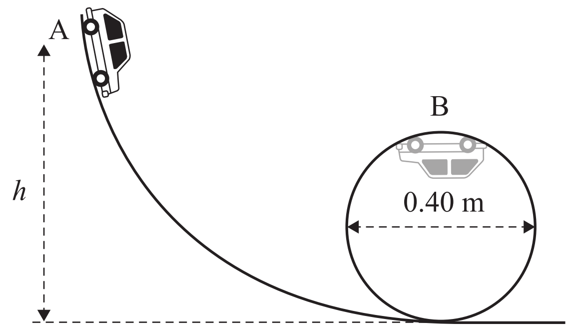


Figure 8

The car starts from rest at point A and travels along the track without any air resistance or retarding frictional forces. The radius of the car's path in the loop is 0.20 m. When the car reaches point B it is travelling at a speed of 3.0 m s^{-1}.

a. Calculate the value of *h*. Show your working. 3 marks

m

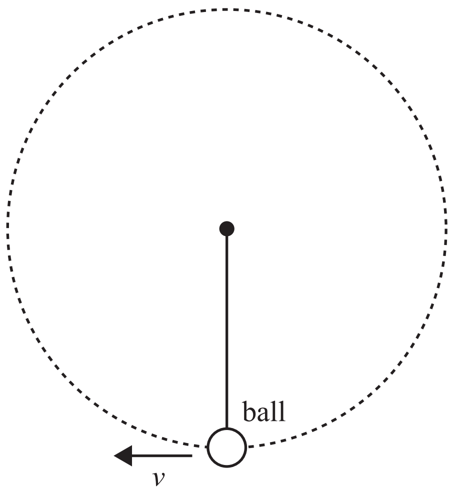
b. Calculate the magnitude of the normal reaction force on the car by the track when it is at point B. Show your working. 3 marks

N

c. Explain why the car does not fall from the track at point B, when it is upside down. 3 marks

Question 8

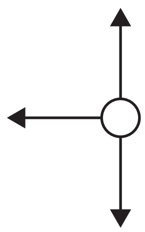
A ball is attached to the end of a string and rotated in a circle at a constant speed in a vertical plane, as shown in the diagram below.



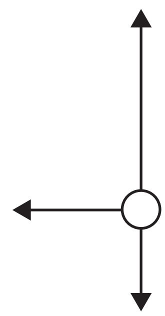
The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.

Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?

A.



B.



C.

D.

Question 8 (6 marks)

Figure 8 shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while suspended from the ceiling by a 0.75 m long string.

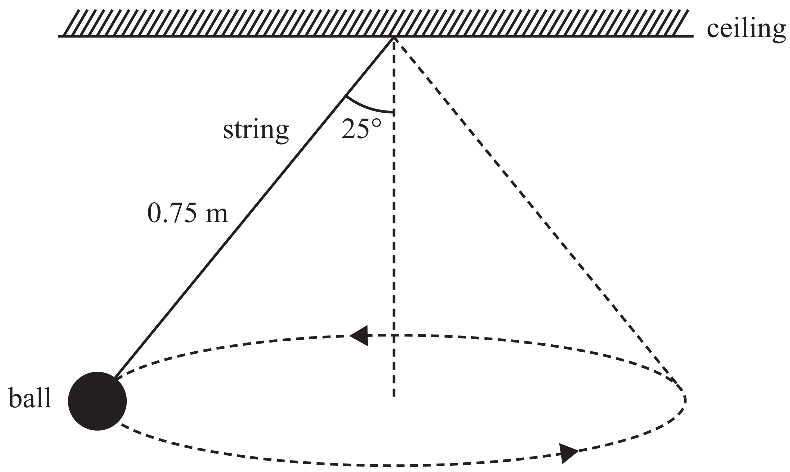


Figure 8

a. Use labelled arrows to indicate on Figure 8 the two physical forces acting on the ball. 2 marks

b. Calculate the speed of the ball. Show your working. 4 marks

m s^{-1}

Question 9 (10 marks)

Abbie and Brian are about to go on their first loop-the-loop roller-coaster ride. As competent Physics students, they are working out if they will have enough speed at the top of the loop to remain in contact with the track while they are upside down at point C, shown in Figure 9. The radius of the loop CB is r.

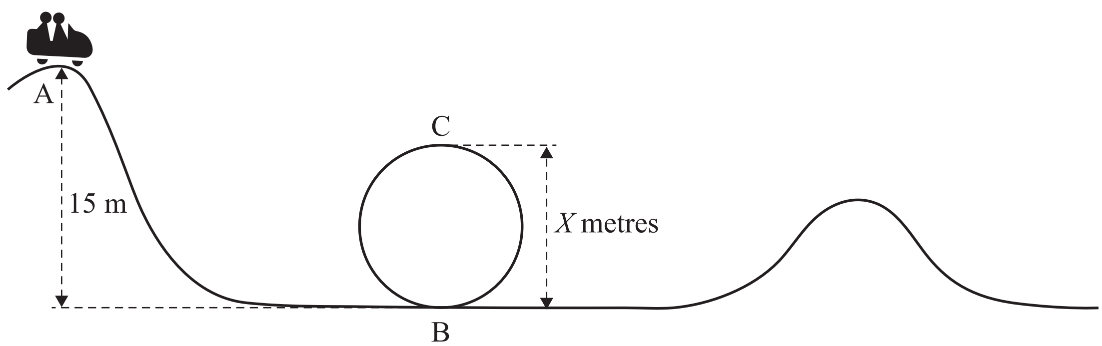


Figure 9

The highest point of the roller-coaster (point A) is 15 m above point B and the car starts at rest from point A. Assume that there is negligible friction between the car and the track.

a. What is the speed of the car at point B at the bottom of the loop? Show your working. 2 marks

m s^{-1}

b. By considering the forces acting on the car, show that the condition for the car to just remain in contact with the track at point C is given by $\frac{v^2}{r} = g$. Show your working. 2 marks

c. What is the maximum height of the loop (X metres) that will ensure that the car stays in contact with the track at point C? Show your working. 3 marks

m

d. If friction is taken into account, will Abbie and Brian need to increase or decrease their predicted value for the radius of the loop? Explain your answer. 3 marks

Question 7 (7 marks)

A spherical mass of 2.0 kg is attached to a piece of string with a length of 2.0 m. The spherical mass is pulled back until it makes an angle of 60° with the vertical, as shown in Figure 4. The spherical mass is then released. Ignore the mass of the string.

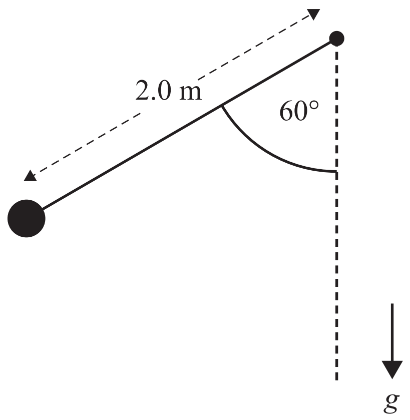


Figure 4

a. Show that the maximum speed of the spherical mass is 4.4 m s^{-1}. 2 marks

b. At what part of its path is the spherical mass at its maximum speed? Explain your reasoning. 2 marks

c. Calculate the maximum tension in the string. 3 marks

N

Question 9 (5 marks)

A small ball of mass 0.30 kg travels horizontally at a speed of 6 m s^{-1}. It enters a vertical circular loop of diameter 0.80 m, as shown in Figure 6. Assume that the radius of the ball and that the frictional forces are negligible.

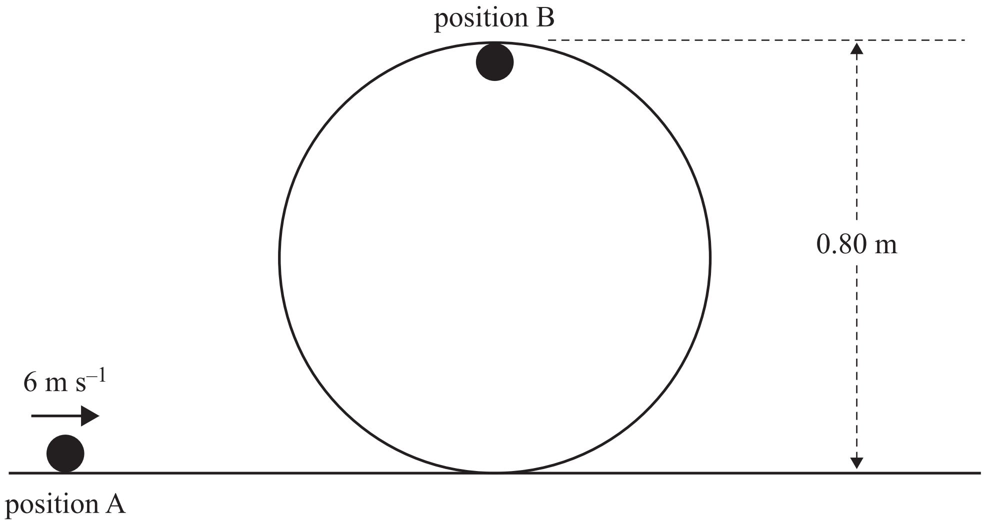


Figure 6

a. Show that the kinetic energy of the ball at position A in Figure 6 is 5.4 J. 1 mark

b. Will the ball remain on the track at the top of the loop (position B in Figure 6)? Give your reasoning. 4 marks

Question 8 (5 marks)

A Formula 1 racing car is travelling at a constant speed of 144 km h^{-1} (40 m s^{-1}) around a horizontal corner of radius 80.0 m. The combined mass of the driver and the car is 800 kg. Figure 8a shows a front view and Figure 8b shows a top view.

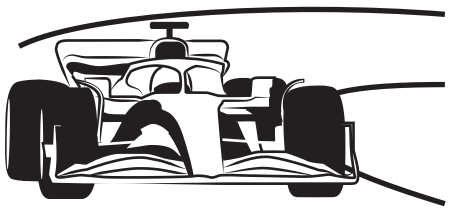


Figure 8a – Front view

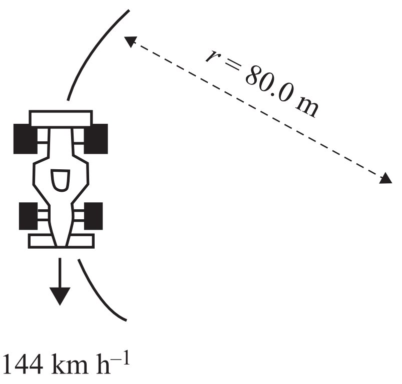


Figure 8b – Top view

a. Calculate the magnitude of the net force acting on the racing car and driver as they go around the corner. 2 marks

N

b. On Figure 8b, draw the direction of the net force acting on the racing car using an arrow. 1 mark

c. Explain why the racing car needs a net horizontal force to travel around the corner and state what exerts this horizontal force. 2 marks

Question 11 (9 marks)

Lee ties a small ball of mass 100 g to a string and rotates it in a vertical circle, as shown in Figure 11a. Assume that the ball is rotated at a constant speed of 3.0 m s^{-1}. The radius, *r*, of the circle is 0.60 m. Figure 11b shows a side view.

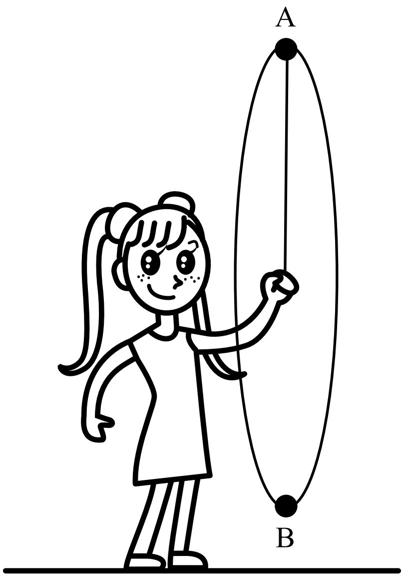


Figure 11a

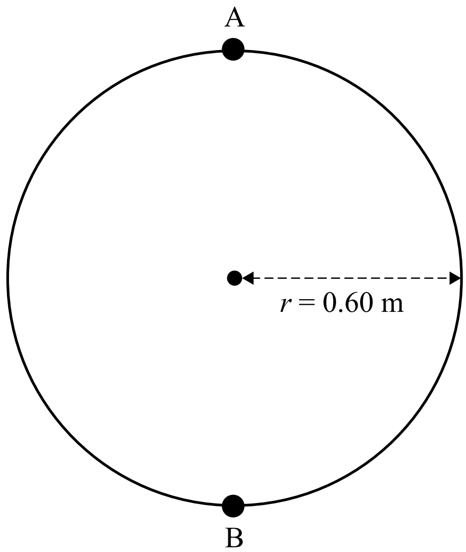


Figure 11b

a. On Figure 11b, draw arrows to represent each of the forces acting on the small ball at position A, at the top of the circle, and at position B, at the bottom of the circle. Label each arrow clearly and use the lengths of the arrows to show the relative approximate magnitudes of the forces. No calculations are required. 4 marks

b. Calculate the tension force in the string when the ball is at position B. Use $g = 10$ m s^{-2}. 2 marks

N

c. Lee now increases the speed of the ball to a new constant speed, which is greater than 3.0 m s^{-1}, and notices that the string breaks when the ball is at position B.

Explain why the string is more likely to break at position B than at position A. 3 marks

9b. Giorgos swings his racquet from point D through point C, which is horizontally behind him at shoulder height, as shown in Figure 11, to point B. Eka models this swing as circular motion of the racquet head. The centre of the racquet head moves with constant speed in a circular arc of radius 1.8 m from point C to point B.

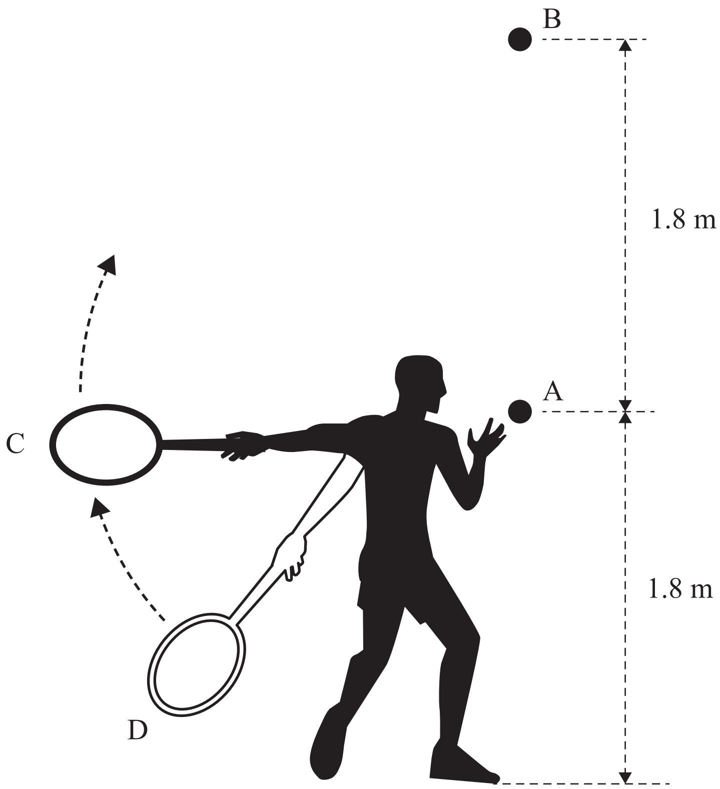


Figure 11

The racquet passes point C at the same time that the ball is released at point A and then the racquet hits the ball at point B. It takes ball 0.6 s to get from A to B.

Calculate the speed of the racquet at point C. 2 marks

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m s^{-1}