Exercise 1.4 Projectile motion

This exercise contains questions to help you solve problems associated with projectile motion without the effect of fluid resistance. Projectiles subject to the effects of fluid resistance are examined qualitatively only.

1 A glass marble, rolling at 1.0 ms^{-1} along a table top, reaches the edge of the table and falls to the floor. The height of the table top is 1.0 m above the floor. Ignore any effects due to air friction and use g = 10 ms^{-2}.

- **a** Sketch a simple diagram to show the path that the marble takes after it leaves the table top until it hits the floor.
- **b** Explain the shape of the path you have drawn by considering the horizontal and vertical components of the marble's velocity.
- **c** Calculate the time it takes for the marble to reach the floor after it leaves the edge of the table.
- **d** When the marble hits the floor, calculate how far from the edge of the table the marble has travellled.

2 A plane flying horizontally at a speed of 70 ms^{-1} releases a crate of supplies for some charity workers at their base on the ground below.

- **a** If the plane had been 80 m above the ground when it released the crate, using g = 10 ms^{-2} and assuming no effects due to air friction:
  - **i** calculate the vertical component of the crate's velocity just before it hits the ground,
  - **ii** hence determine the magnitude and direction of the crate's velocity just before it hits the ground.
- **b** Where will the plane be relative to the crate when the crate hits the ground?

3 At a shooting gallery, a man fires a bullet from a rifle horizontally at a target.

The target is 75.00 m away.

The bullet leaves the rifle at a speed of 150.0 ms^{-1}.

Ignoring any effects of air friction on the bullet, and using g = 10 ms^{-2}:

- **a** calculate the time it takes for the bullet to hit the target,
- **b** using the equation $v^2 = u^2 + 2as$, with the appropriate value for v, show that the bullet hits the target 1.25 m below the horizontal,
- **c** calculate the total velocity vector for the bullet just as it hits the target.

4 Mercurio, the human cannonball in a circus show, is fired from a cannon at an initial velocity of 20 ms^{-1} at an angle of 30° above the horizontal.

How far away from the cannon should the net be placed to catch Mercurio if he is to land at the same horizontal level as the cannon?

Assume no effects due to air friction and use g = 10 ms^{-2}.

5 Two cricketers practise by throwing a cricket ball to each other, as shown in Figure 1.7

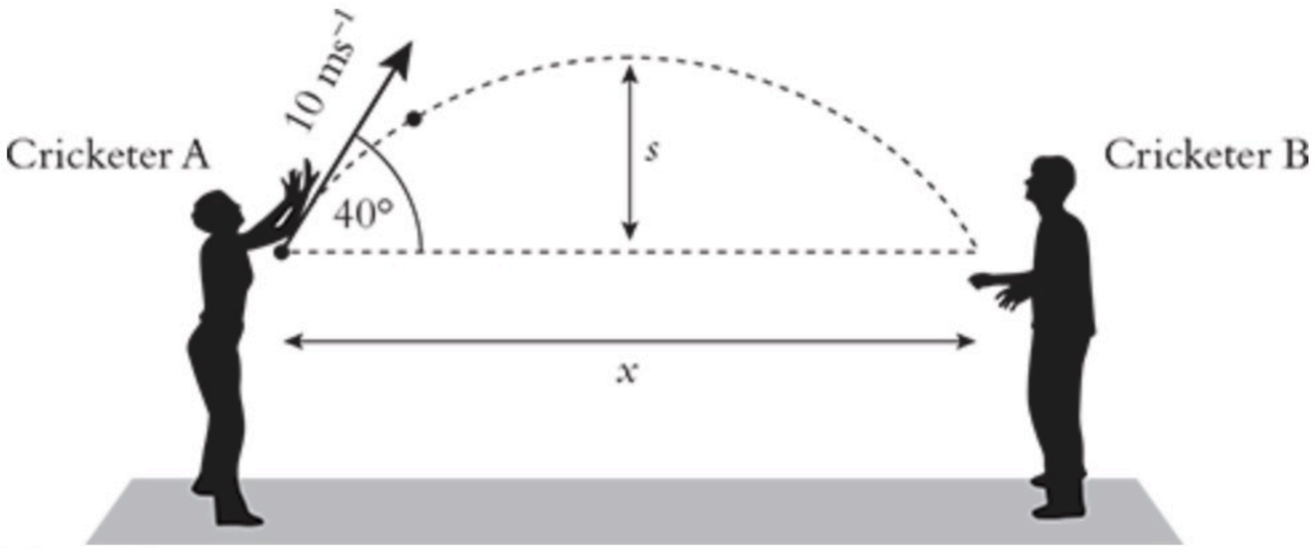

Figure 1.7

Ignoring any effects of air friction and using $g = 9.81$ ms^{-2}, calculate:

a the vertical component of the ball's velocity as it leaves cricketer A's hands,

b the time it takes for the ball to reach its highest point,

c the height, *s*, that the ball reaches above the cricketer's hands,

d how far apart, *x*, the two cricketers are.

6 A projectile is fired from ground level to the top of a building which is 200 m away and 150 m high. If the projectile lands on the roof of the building 8.0 s later, ignoring any effects due to air friction, determine the initial velocity of the projectile. Use $g = 10$ ms^{-2}.

TIP

With questions like this, sketch a diagram to help you visualise what is happening.

7 Physics questions about the motion of projectiles usually make the assumption that there are no effects due to fluid resistance. It is a simplification that allows physicists to model the motion of projectiles easily. Sometimes, however, the simple model and what happens in real life are not the same.

Figure 1.8 shows two ways in which the velocity of an object changes when it is dropped from a large height above the ground. Line A shows the simple model that assumes no effects due to fluid resistance, and curve B shows what actually happens in real life. Use $g = 10\ \text{ms}^{-2}$.

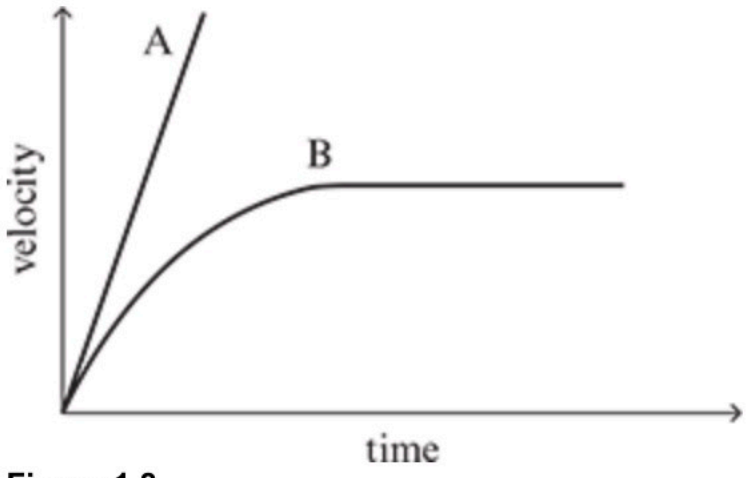

Figure 1.8

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a State what the gradient of line A should be.

b Suggest why curve B is the shape it is. Your answer should make reference to the gradient of the curve and why it is not constant.

c Suggest why curve B flattens out to a horizontal line. How do physicists describe this motion?

d Sketch, on Figure 1.8, possible curves for an object of the:

i same mass but less density, labelled curve C,

ii same mass but greater density, labeled curve D.

8 Abdul is playing a game of lawn tennis. When he serves, he tries to hit the ball from a height of 2.5 m. He wants the ball to travel 18.2 m horizontally before landing on the other side of the net. The net is 0.91 m high at its lowest point and is 11.9 m from Abdul.

Assume that the tennis ball travels horizontally from Abdul's racket, and there are no effects due to air friction. Use g = 10 ms^{-2}.

a Show that the time it takes for an object to fall, from rest, a distance of 2.5 m is 0.707 s.

b What does this suggest the initial horizontal speed of the tennis ball to be as it leaves Abdul's racket?

c How much time will the tennis ball have taken to reach the net?

d Show that the tennis ball will pass over the net.

In fact, according to the Lawn Tennis Association, the tennis ball may leave a server's racket at a speed of up to 230 km hr^{-1}.

e Calculate the (faster) speed of the tennis ball in ms^{-1}.

f How much time would this serve take for the ball to travel 18.2 m from the server?

g Is the time you calculated in part **f** sufficient for the ball to travel the vertical distance of 2.5 m in order to land in the serving box on the other side of the net?

h Suggest how a real serve in a tennis game differs from Abdul's 'ideal' serve described in this question. Outline what the effects of any differences are.