Additional Topic 2 questions

Test yourself

2.1 Motion

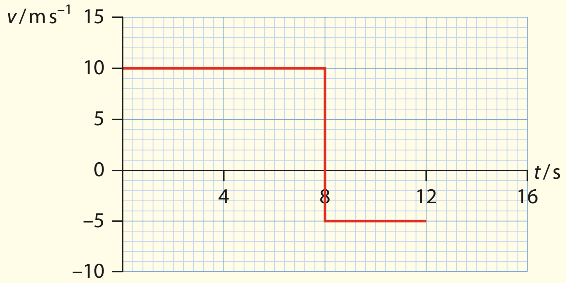
Uniform motion

1 A person walks a distance of 3.0 km due south and then a distance of 2.0 km due east. If the walk lasts for 3.0 h, find:

a the average speed for the motion

b the average velocity.

2 An object moving in a straight line according to the velocity–time graph shown below has an initial position of 8.00 m.

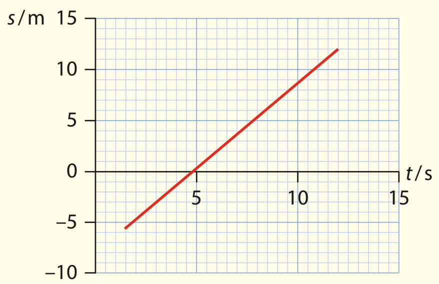


a Find the position after 8.00 s.

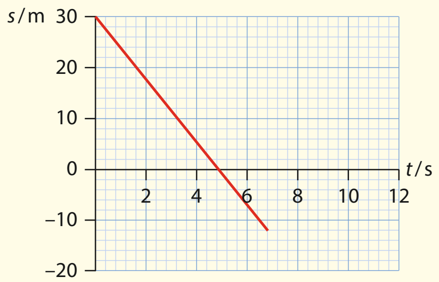
b Find the position after 12.00 s.

c Calculate the average speed and average velocity for this motion.

3 Find the velocity of the two objects whose displacement–time graphs are shown below.



a



b

Accelerated motion

4 The acceleration of a car is assumed constant at 1.5 m s^{-2}. Determine how long it will take the car to accelerate from 5.0 m s^{-1} to 11 m s^{-1}.

5 A body has an initial velocity of 3.0 m s^{-1} and after travelling 24 m the velocity becomes 13 m s^{-1}. Determine how long this took.

6 A ball is thrown upwards with a speed of 24 m s^{-1}.

a Find the time when the velocity of the ball is 12 m s^{-1}.

b Find the time when the velocity of the ball is −12 m s^{-1}.

c Calculate the position of the ball at the times found in **a** and **b**.

d Determine the velocity of the ball 1.5 s after launch.

e Predict the maximum height reached by the ball.

(Take the acceleration of free fall to be 9.8 m s^{-2}.)

7 A stone is thrown vertically upwards with an initial speed of 10.0 m s^{-1} from a cliff that is 50.0 m high.

a Find the time when it reaches the bottom of the cliff.

b Find the speed just before hitting the ground.

c Determine the total distance travelled by the stone.

(Take the acceleration of free fall to be 9.81 m s^{-2}.)

8 A rock is thrown vertically down from the roof of a 25.0 m high building with a speed of 5.0 m s^{-1}.

a Find the time when the rock hits the ground.

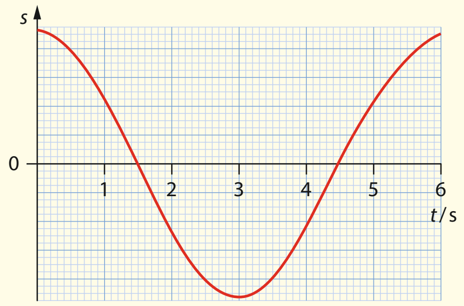
b Find the speed with which it hits the ground.

(Take the acceleration of free fall to be 9.81 m s^{-2}.)

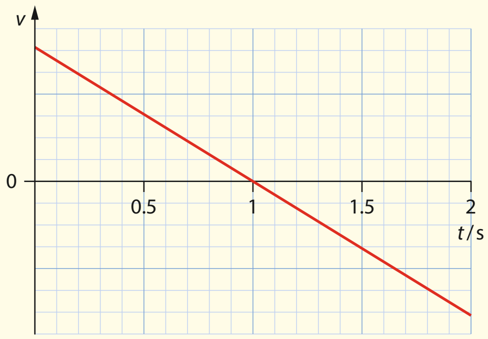
9 A window is 1.50 m high. A stone falling from above passes the top of the window with a speed of 3.00 m s^{-1}. Find the time when it will pass the bottom of the window. (Take the acceleration of free fall to be 9.81 m s^{-2}.)

10 A ball is dropped from rest from a height of 20.0 m. One second later a second ball is thrown vertically downwards. The two balls arrive on the ground at the same time. Determine the initial velocity of the second ball.

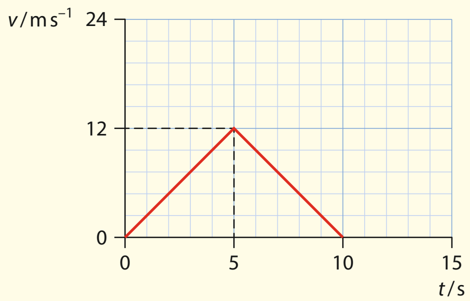
11 The graph shows the variation of the position of a particle with time. Draw the graph showing the variation of the velocity of the object with time.



12 The graph shows the variation of the velocity of a moving object with time. Draw the graph showing the variation of the position of the object with time.



13 The graph shows the variation of the velocity of a moving object with time. Draw the graph showing the variation of the position of the object with time (assuming a zero initial displacement).



14 A hiker starts climbing a mountain at 08:00 in the morning and reaches the top at 12:00 (noon). He spends the night on the mountain and the next day at 08:00 starts on the way down following exactly the same path. He reaches the bottom of the mountain at 12:00 (noon). Show that there must be a time between 08:00 and 12:00 when the hiker was at the same spot along the route on the way up and on the way down.

15 A stone is thrown vertically up from the edge of a cliff 35.0 m from the ground. The initial velocity of the stone is $8.00\,\mathrm{m\,s^{-1}}$.

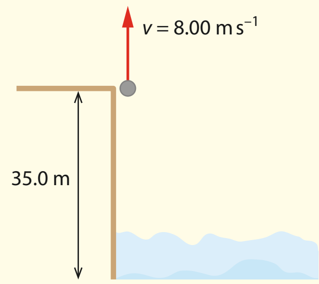
Sketch:

f a graph to show the variation of velocity with time

g a graph to show the variation of position with time.

(Take the acceleration of free fall to be $10.0\,\mathrm{m\,s^{-2}}$.)

16 A rocket accelerates vertically upwards from rest with a constant acceleration of $4.00\,\mathrm{m\,s^{-2}}$. The fuel lasts for 5.00 s.



a Find the maximum height achieved by this rocket.

b Determine the time when the rocket reaches the ground again.

c Sketch a graph to show the variation of the velocity of the rocket with time from the time of launch to the time it falls to the ground.

(Take the acceleration of free fall to be $10.0\,\mathrm{m\,s^{-2}}$.)

Projectile motion

17 A ball is kicked horizontally with a speed of $5.0\,\mathrm{m\,s^{-1}}$ from the roof of a house 3.0 m high.

a Calculate the time when the ball hits the ground.

b Determine the speed of the ball just before hitting the ground.

18 A particle is launched horizontally with a speed of $8.0\,\mathrm{m\,s^{-1}}$ from a point 20 m above the ground.

a Calculate the time when the particle lands on the ground.

b Determine the speed of the particle 1.0 s after launch.

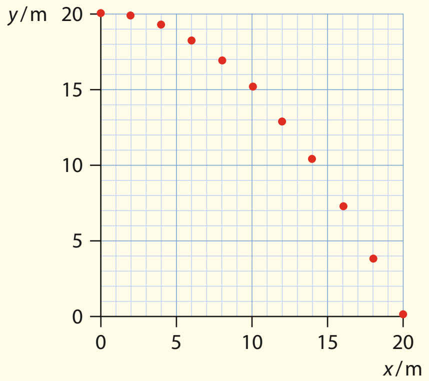
c Find the angle between the velocity and the horizontal 1.0 s after launch.

d Determine the velocity with which the particle hits the ground.

19 A plane flying at a constant speed of $50.0\,\text{m s}^{-1}$ and a constant height of 200 m drops a package of emergency supplies to a group of hikers. The package is released just as the plane flies over a fir tree. Find at what distance from the tree the package will land.

20 A stone is thrown with initial speed $6.0\,\text{m s}^{-1}$ at 35° to the horizontal. Find the direction of the velocity vector 1.0 s later.

21 A ball is launched horizontally from a height of 20 m above ground on Earth and follows the path shown in the diagram. Air resistance and other frictional forces are neglected. The position of the ball is shown every 0.20 s.



a Determine the horizontal component of velocity of the ball.

b The ball is now launched under identical conditions on the surface of a planet where the acceleration of free fall is $20\,\text{m s}^{-2}$. Draw the position of the ball on the diagram at time intervals of 0.20 s.

22 A soccer ball is kicked so that it has a range of 30 m and reaches a maximum height of 12 m. Determine the initial velocity (magnitude and direction) of the ball.

23 A projectile is launched horizontally. The force of air resistance is proportional to speed. Explain why the projectile's velocity is more vertical than it would have been in the absence of air resistance.

2.2 Forces

Equilibrium

24 A block rests on an inclined plane. Draw the forces on the block.

25 Sketch a diagram showing a mass hanging at the end of a vertical spring that is attached to the ceiling. On the diagram, draw the forces on:

a the hanging mass

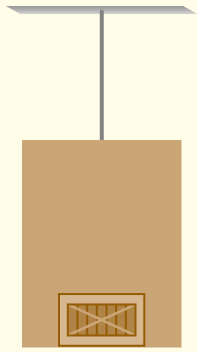
b the ceiling.

26 A force of 125 N is required to extend a spring by 2.8 cm. Estimate the force required to stretch the same spring by 3.2 cm.

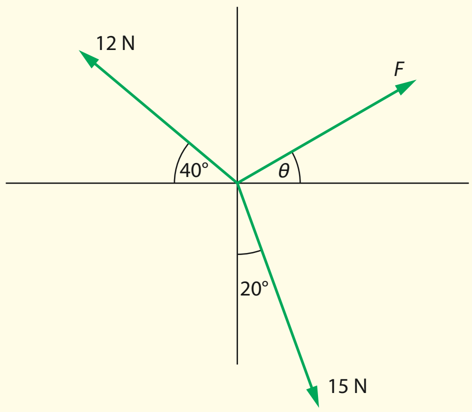
27 A block rests on an elevator floor, as shown in the diagram. The elevator is held in place by a cable attached to the ceiling. On a copy of the diagram, draw the forces on:

a the block

b the elevator.



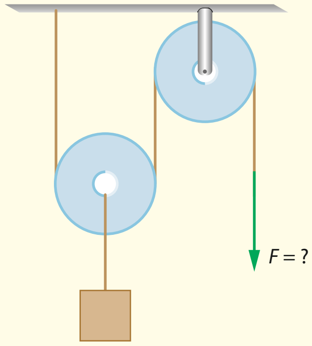
28 Determine F and θ in the diagram such that the net force is zero.



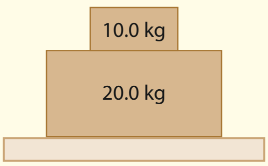
29 A force of 10.0 N is acting along the negative x-axis and a force of 5.00 N at an angle of 20° with the positive x-axis. Find the net force.

30 A force has components 2.45 N and 4.23 N along two perpendicular axes. Determine the magnitude of the force.

31 A block of mass 12.5 kg hangs from very light, smooth pulleys as shown in the diagram. Determine the magnitude of the force that must be applied to the rope so the system is in equilibrium.



32 A block of mass 10.0 kg rests on top of a bigger block of mass 20.0 kg, which in turn rests on a horizontal table (see the diagram).

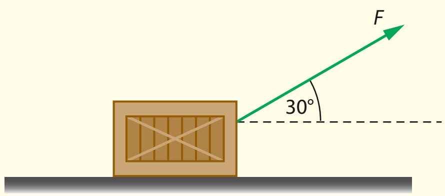


a Find the individual forces acting on each block.

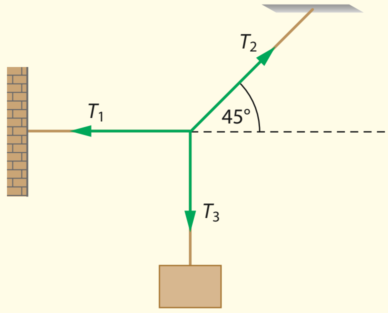
b Identify force pairs according to Newton's third law.

c A vertical downward force of 50.0 N acts on the top block. Calculate the forces on each block now.

33 A 460 kg crate is being pulled at constant velocity by a force directed at 30° to the horizontal as shown in the diagram. The coefficient of dynamic friction between the crate and the floor is 0.24. Calculate **a** the magnitude of the pulling force and **b** the reaction force from the floor on the crate.



34 A block of mass 5.00 kg hangs attached to three strings as shown in the diagram. Find the tension in each string. (Hint: Consider the equilibrium of the point where the strings join.)



Accelerated motion

35 A mass of 2.00 kg is acted upon by two forces of 4.00 N and 10.0 N. What is the smallest and largest acceleration these two forces can produce on the mass?

36 A bird is in a glass cage that hangs from a spring scale. Compare the readings of the scale in the following cases.

a The bird is sitting in the cage.

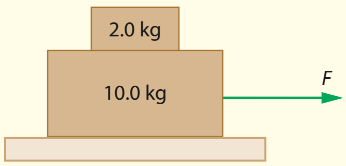
b The bird is hovering in the cage.

c The bird is moving upward with acceleration.

d The bird is accelerating downward.

e The bird is moving upward with constant velocity.

37 A block of mass 2.0 kg rests on top of another block of mass 10.0 kg that itself rests on a frictionless table (see diagram). The coefficient of static friction between the two blocks is 0.80. Calculate the largest force with which the bottom block can be pulled so that both blocks move together without sliding on each other.

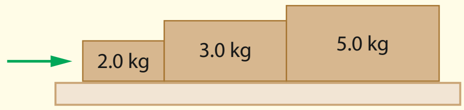


38 A small passenger car and a fully loaded truck collide head-on.

a State and explain which vehicle experiences the greater force.

b If you had to be in one of the vehicles, which one would you rather be in? Explain your answer.

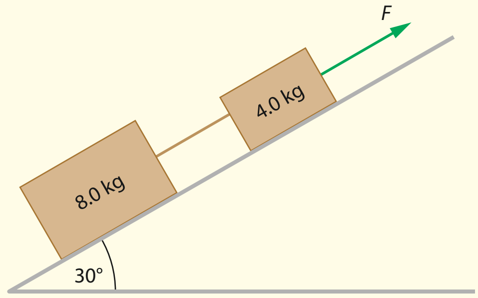
39 Three blocks rest on a horizontal frictionless surface, as shown in the diagram. A force of 20.0 N is applied horizontally to the right on the block of mass 2.0 kg.



a Find the individual forces acting on each mass.

b Identify force pairs according to Newton's third law.

40 Two bodies are joined by a string and are pulled up an inclined plane that makes an angle of 30° to the horizontal, as shown in the diagram.



a Calculate the tension in the string when:

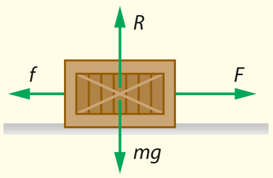
i the bodies move with constant speed

ii the bodies move up the plane with an acceleration of 2.0 m s^{-2}.

b What is the value of F in each case?

2.3 Work, energy and power

41 A block of mass 4.0 kg is pushed to the right by a force F = 20.0 N. A frictional force of 14.0 N is acting on the block while it is moved a distance of 12.0 m along a horizontal floor. The forces acting on the mass are shown in the diagram.



a Calculate the work done by each of the **four** forces acting on the mass.

b Hence find the net work done.

c State by how much the kinetic energy of the mass changes.

42 A weightlifter slowly lifts a 100 kg mass from the floor up a vertical distance of 1.90 m and then slowly lets it down to the floor again.

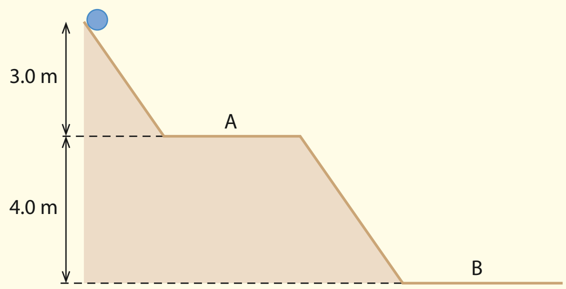
a Find the work done by the weight of the mass on the way up.

b Find the work done by the force exerted by the weightlifter when lifting the weight up.

c Find the total work done by the weight on the way up and the way down.

43 A spring of spring constant k = 150 N m^{-1} is compressed by 4.0 cm. The spring is horizontal and a block of mass of 1.0 kg is held against the right end of the spring. The mass is released. Calculate the speed with which the block moves away.

44 A ball is released from rest from the position shown in the diagram. What will its speed be as it goes past positions A and B?



45 A 25.0 kg block is very slowly raised up a vertical distance of 10.0 m by a rope attached to an electric motor in a time of 8.2 s. Calculate the power developed in the motor.

46 For cars having the same shape but different size engines the maximum power developed by the car's engine is proportional to the third power of the car's maximum speed. Predict the dependence on speed of the wind resistance force.

47 Describe the energy transformations taking place when a body of mass 5.0 kg:

a falls from a height of 50 m without air resistance

b falls from a height of 50 m with constant speed

c is being pushed up an incline of 30° to the horizontal with constant speed.

48 A car of mass 1200 kg starts from rest, accelerates uniformly to a speed of 4.0 m s^{-1} in 2.0 s and continues moving at this constant speed in a horizontal straight line for an additional 10 s. The brakes are then applied and the car is brought to rest in 4.0 s. A constant resistance force of 500 N is acting on the car during its entire motion.

a Calculate the force accelerating the car in the first 2.0 s of the motion.

b Calculate the average power developed by the engine in the first 2.0 s of the motion.

c Calculate the force pushing the car forward in the next 10 s.

d Calculate the power developed by the engine in those 10 s.

e Calculate the braking force in the last 4.0 s of the motion.

f Describe the energy transformations that have taken place in the 16 s of the motion of this car.

49 A bungee jumper of mass 60 kg jumps from a bridge 24 m above the surface of the water. The rope is 12 m long and is assumed to obey Hooke's law.

a Estimate the spring constant of the rope so that the jumper just reaches the water surface.

b The same rope is used by a man whose mass is more than 60 kg. Explain why the man will not stop before reaching the water. (Treat the jumper as a point and ignore any resistance to motion.)

50 For the bungee jumper of mass 60 kg in question **49**, calculate:

a the speed of the jumper after falling 12 m

b the maximum speed attained by the jumper during their fall.

c Explain why the maximum speed is reached after falling more than a distance of 12 m (the unstretched length of the rope).

d Sketch a graph to show the variation of the speed of the jumper with distance fallen.

2.4 Momentum and impulse

51 Two bodies of mass 2.00 kg and 4.00 kg are kept on a frictionless horizontal table with a compressed spring between them. The masses are released. The heavier body moves away with velocity 3.50 m s^{-1}. Find the velocity of the other body.

52 A body of mass 0.500 kg moving at 6.00 m s^{-1} strikes a wall normally and bounces back with a speed of 4.00 m s^{-1}. The mass was in contact with the wall for 0.200 s. Find:

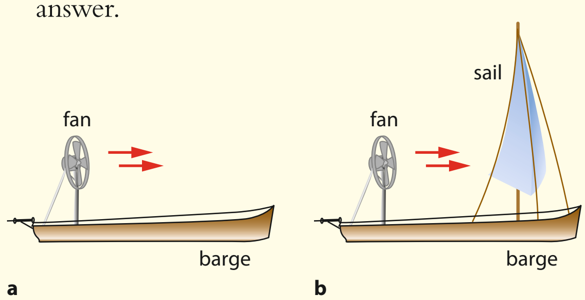
a the change of momentum of the mass

b the average force the wall exerted on the mass.

53 A person holds a book stationary in his hand and then releases it. As the book falls, state and explain whether the momentum of the book is conserved.

54 **a** A fan on a floating barge blows air at high speed toward the right, as shown in the diagram. State and explain whether the barge will move.

b A sail is now put up on the barge so that the fan blows air toward the sail, as shown in the diagram. Will the barge move? Explain your answer.



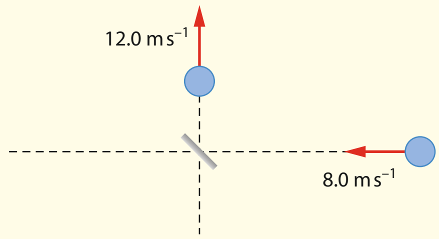
55 You jump from a height of 1.0 m from the surface of the Earth. The Earth will actually move up a bit as you fall.

a Explain why.

b Estimate the distance the Earth moves, listing any assumptions you make.

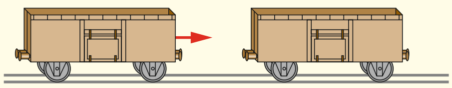
c State and explain whether the Earth would move more, less or the same if a heavier person jumped.

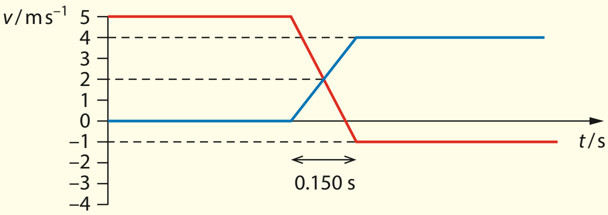
56 A 0.350 kg mass is approaching a moving plate with speed 8.00 m s^{-1}. The ball leaves the plate at right angles with a speed of 12.0 m s^{-1} as shown in the diagram. What impulse has been imparted to the ball?



57 A body of mass M, initially at rest, explodes and splits into two pieces of mass $\frac{M}{3}$ and $\frac{2M}{3}$, respectively. Find the ratio of the kinetic energies of the two pieces.

58 A wagon of mass 800 kg moving at 5.0 m s^{-1} collides with another wagon of mass 1200 kg that is initially at rest. Both wagons are equipped with buffers. The graph shows the velocities of the two wagons before, during and after the collision.





Use the graph to:

a show that the collision has been elastic

b calculate the average force on each wagon during the collision

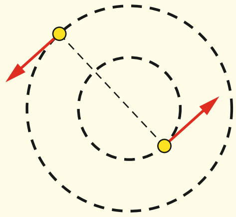
c calculate the impulse given to the heavy wagon.

d If the buffers on the two wagons had been stiffer, the time of contact would have been less but the final velocities would be unchanged. Predict how your answers to **b** and **c** would change (if at all).

e Calculate the kinetic energy of the two wagons at the time during the collision when both have the same velocity and compare your answer with the final kinetic energy of the wagons. How do you account for the difference?

59 A mass of 6.0 kg moving at 4.0 m s^{-1} collides with a mass of 8.0 kg at rest on a frictionless surface and sticks to it. How much kinetic energy was lost in the collision?

60 A binary star system consists of two stars that are orbiting a common centre, as shown in the diagram. The only force acting on the stars is the gravitational force of attraction in a direction along the line joining the stars.



a Explain carefully why the total momentum of the binary star is constant.

b Explain why the two stars are always in diametrically opposite positions.

c Hence explain why the two stars have a common period of rotation and why the inner star is the more massive of the two.

61 You have a mass of 60 kg and are floating weightless in space. You are carrying 100 coins each of mass 0.10 kg.

a If you throw all the coins at once with a speed of 5.0 m s^{-1} (relative to you) in the same direction, calculate the velocity with which you will recoil.

b If instead you throw the coins one at a time with a speed of 5.0 m s^{-1} relative to you, discuss whether your final speed will be different from before. (Use your graphics display calculator to calculate the speed in this case.)