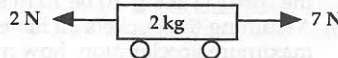
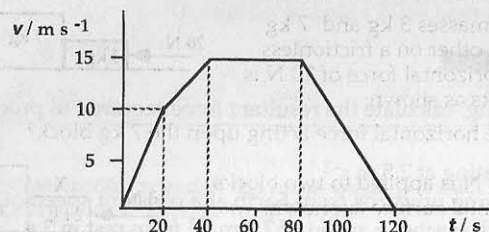


Dynamics

Exercise 2.1 Forces

- For each of the following, calculate the resultant force required to produce the motion described.
 - a 400 kg car accelerating at 2.5 m s^{-2}
 - a 200 kg rocket moving upwards from Earth at a constant speed of 38 m s^{-1}
 - a 750 g toy car which reaches a speed of 7.5 m s^{-1} from rest in 3 s
 - a stationary hot air balloon of mass 300 kg, carrying a total mass of 250 kg
- A block of weight 1500 N is dragged along a horizontal surface at constant speed by a horizontal force of 500 N.
What is the force of friction acting on the block?
- On a certain planet the gravitational force on a mass of 2 kg is 24 N.
If a mass of 4 kg is allowed to fall freely on that planet, what is its acceleration?
- The forces shown act on the trolley of mass 2 kg which is originally at rest on a level surface. After 3 s the 7 N force is removed.
 - Draw an accurate velocity-time graph for the first 3 s of the motion. (Numerical values are required on both axes.)
 - Extend the graph accurately to show the motion of the trolley as it comes to rest.
- A parachutist of mass 50 kg descends towards the Earth at a constant velocity of 2 m s^{-1} .
Calculate the upwards force acting upon him.
- Calculate the force required to lift a mass of 5.6 kg vertically upwards from the surface of the Earth at a constant speed of 4 m s^{-1} .
- A liquid fuelled rocket lifts off vertically upwards. The rocket has an initial mass of 10 000 kg and the engine provides a thrust of 240 kN.
 - Sketch a diagram giving the names and sizes of each force acting on take-off.
 - What is the initial acceleration of the rocket?
 - If the thrust is constant, explain what happens to the acceleration of the rocket as it rises.
- A rocket of mass 1200 kg rises vertically from a planet which has a gravitational field strength of 20 N kg^{-1} . The rocket accelerates upwards from the surface of the planet at 2 m s^{-2} .
What force must the rocket motors produce to give this acceleration?
- A stationary hot air balloon, of total mass 500 kg, is tethered to the ground by a single vertical rope.
 - Sketch the balloon, mark and label all the forces acting on the balloon.
 - When the rope is released, the balloon initially accelerates vertically upwards at 1.5 m s^{-2} . Find the magnitude of the buoyancy force.
 - Calculate the tension in the rope **before** the balloon is released.

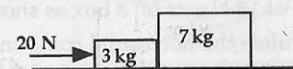
10. The graph shows how the speed of an electric train of mass 2.0×10^5 kg changes as it makes a journey on a horizontal track between two stations.



- a) Draw an accurate acceleration-time graph of the train's motion. (Numerical values are required on both axes.)
 b) Draw an accurate unbalanced force-time graph of the train's motion. (Numerical values are required on both axes.)
11. As part of a competition, a boy is given 1 minute to raise as many buckets of water as he can up 8 m to a window. He has to use a thin cord which breaks if the tension in it is more than 110 N. His team-mates fill the first bucket so that its total mass is 10 kg.
- a) What is the greatest upwards acceleration he can give the bucket without breaking the cord? (Take g to be 10 m s^{-2} .)
 b) Assuming the buckets all have the same mass and are always raised with the maximum acceleration, how many buckets can he lift in the minute?
12. A rocket of mass 2.2×10^6 kg is launched vertically from the surface of the Earth. The rocket engine exerts a constant force of 3.0×10^7 N.
- a) Calculate the resultant force on the rocket at take-off.
 b) Find the initial acceleration of the rocket as it takes off.
 c) The table shows how the speed of the rocket varies at intervals of time after the launch.
- | t / s | 0 | 10 | 20 | 30 | 40 |
|-----------------------|---|----|----|-----|-----|
| $v / \text{m s}^{-1}$ | 0 | 40 | 90 | 150 | 220 |
- i) What does the data in the table indicate about the acceleration of the rocket during the first 40 s of the flight?
 ii) Explain what is happening to the rocket to cause this variation of speed.
13. A lunar landing craft descends vertically towards the surface of the Moon with a constant speed of 2.0 m s^{-1} . The craft and crew have a total mass of 15 000 kg. The gravitational field strength on the Moon is 1.6 N kg^{-1} .
- a) During the first part of the descent the upwards thrust of the rocket is 24 kN. Show by calculation that the craft will move with a constant speed.
 b) The upwards thrust of the engine is increased to 25.5 kN for the last 18 s of the descent.
- i) Calculate the deceleration of the craft during this time.
 ii) What is the speed of the craft just before it lands?
 iii) How far above the surface of the Moon is the landing craft when the engine thrust is increased to 25.5 kN?

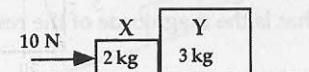
Exercise 2.2 Internal Forces

1. Two wooden blocks of masses 3 kg and 7 kg are in contact with each other on a frictionless horizontal surface. A horizontal force of 20 N is applied to the two blocks as shown.



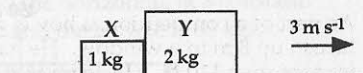
What is the value of the horizontal force acting upon the 7 kg block?

2. A horizontal force of 10 N is applied to two blocks on a frictionless, horizontal surface as shown.



- a) What force does X exert on Y?
 b) If the 10 N force acted on the 3 kg block and in the opposite direction,
 i) explain whether the acceleration would be the same as in part a),
 ii) calculate the horizontal force that block Y would exert on block X.

3. Two blocks, X and Y, move along a frictionless, horizontal surface at a constant velocity of 3 m s^{-1} as shown.

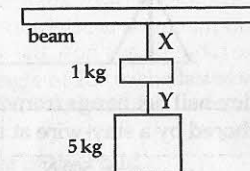


What is the force which X exerts on Y?

4. A tractor of mass 1500 kg pulls a trailer of mass 1000 kg along a horizontal road. The total frictional force has a constant value of 4000 N. One quarter of this frictional force acts on the trailer.

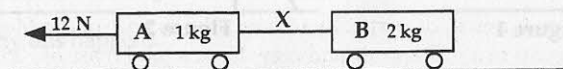
When the acceleration is 2 m s^{-2} , what is the force exerted on the tractor by the tow-bar?

5. Two masses are joined together by string Y and then hung from a beam using string X as shown. String X is burned through using a candle.



Neglecting the mass of each string, calculate the tension in string Y
 a) before string X is burned through,
 b) after string X is burned through.

6. Two trolleys are joined together by a thread and are pulled along a horizontal frictionless bench by a force of 12 N. The thread at X breaks 3 s after starting from rest.



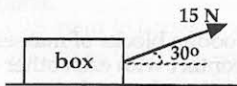
- a) Describe the motion of the two trolleys before the thread breaks.
 b) Describe separately the motion of trolley A and the motion of trolley B after the thread breaks.

7. Two blocks of mass 2 kg and 3 kg are joined by a long piece of elastic and moved apart on a smooth horizontal bench until the elastic is stretched considerably. Both masses are released simultaneously.

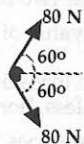
When the 3 kg mass has moved a distance d , how far has the 2 kg mass travelled? (Give your answer in terms of d .)

Exercise 2.3 Components of Forces

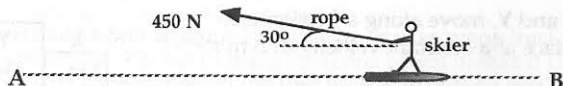
- A force of 15 N acts on a box as shown.
 - Calculate the horizontal component of the force.
 - Calculate the vertical component of the force.



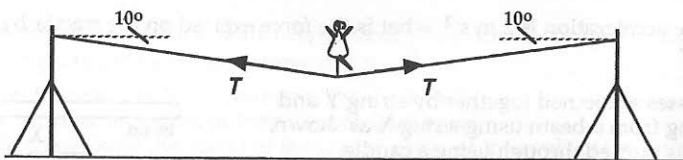
- A stone is about to be fired from a catapult set as shown. What is the magnitude of the resultant force on the stone?



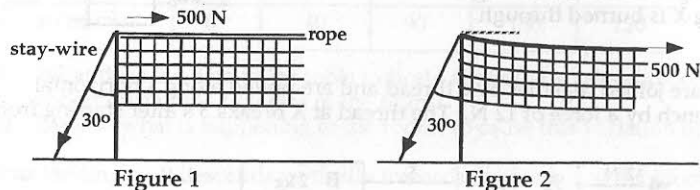
- A water skier is being towed by a rope from a boat travelling at constant speed. If the tension in the rope is 450 N as shown, calculate the force acting along the line AB opposing the forward motion of the skier.



- An acrobat is stationary at the centre of a tightrope. The angle between the rope and the horizontal is 10° as shown. If the acrobat weighs 600 N, calculate the tension T in the rope.



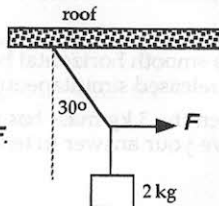
- A volley-ball net hangs from a horizontal rope, supported by vertical poles. Each pole is anchored by a stay-wire at an angle of 30° as shown in figure 1.



- If the tension in the rope is 500 N, what is the tension in the stay-wire?
- In practice the rope will not be horizontal but will sag as shown in figure 2. What effect will this have on the value of the tension in the stay-wire as calculated in part a)?

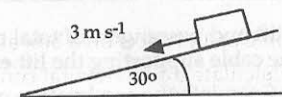
- A 2 kg mass is hanging by a string from the roof. A horizontal force F is applied to hold the string in the position shown. The 2 kg mass and the string are stationary.

By drawing a scale diagram or otherwise, find the value of F .

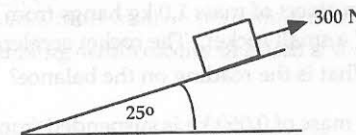


Exercise 2.4 Force on a Slope

- A block of wood of mass 2.0 kg slides down a 30° slope at 3 m s^{-1} as shown. What is the value of the force of friction acting on the block?

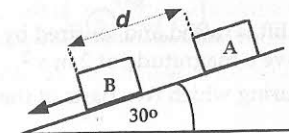


- A mass of 10 kg is moving up an incline with a constant acceleration of 10 m s^{-2} . An applied force of 300 N acts up the incline as shown.



- Calculate the component of the weight acting down the slope.
 - Calculate the value of the friction force acting down the slope.
- A cyclist free-wheels down a slope inclined at 15° to the horizontal, at a constant velocity of 3 m s^{-1} . The combined mass of the rider and the bicycle is 85 kg. What is the force of friction acting on the bicycle and rider?

- A block of mass 3 kg is held at rest at A on a frictionless surface inclined at 30° to the horizontal as shown. The block is then released and it takes 2 s to travel to position B.



- Calculate the component of the weight acting down the slope.
 - Calculate the acceleration of the block down the slope.
 - Find the distance d travelled in the 2 s.
- A child on a sledge slides down a slope which is at an angle of 20° to the horizontal. The combined weight of the child and the sledge is 400 N. The frictional force acting on the sledge and child at the start of the slide is 20 N.
 - Calculate the component of the combined weight of the child and sledge down the slope.
 - Calculate the initial acceleration of the child and sledge.
 - The child decides to start the slide further up the slope. Explain whether or not this has any effect on the initial acceleration.
 - During the slide, the sledge does not continue to accelerate but reaches a constant speed. Explain why this happens.

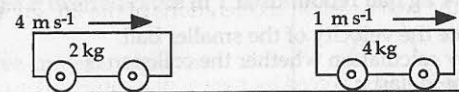
Exercise 2.5 Lifts

- A lift and passengers of total mass 2000 kg is travelling upwards at 3.9 m s^{-1} . The cable supporting the lift exerts an upwards force of 17 000 N.
 - Calculate the acceleration of the lift.
 - Calculate the time taken for the lift to stop if this acceleration continues.
- An object of mass 1.0 kg hangs from a spring balance which is suspended on the inside of a small rocket. The rocket accelerates upwards from the Earth's surface at 2.0 m s^{-2} . What is the reading on the balance?
- A mass of 0.060 kg is suspended from a spring balance inside a lift. The lift accelerates down at 4.0 m s^{-2} . What is the reading on the spring balance?
- A man weighs 800 N and stands on an accurate weighing machine in a lift. The reading on this weighing machine is 820 N. Calculate the two possible accelerations of the lift, giving the directions of the acceleration.
- A lift is raised and lowered by means of a cable. All accelerations and decelerations have a magnitude of 2 m s^{-2} . During which two parts of the lift's journey is the tension in the cable at a maximum?
- A mass of 1.0 kg hangs from a spring balance which is attached to the roof of a lift. The balance has a scale marked from 0 to 25 N. Calculate the reading which the balance will show
 - when the lift is at rest,
 - when the lift is moving up at 4 m s^{-1} ,
 - when the lift is accelerating up at 3 m s^{-2} ,
 - when the lift is accelerating down at 2 m s^{-2} ,
 - when the lift is decelerating at 4 m s^{-2} while moving down.
- A man is standing in a lift which is initially at rest. F is the force which is exerted by the man's feet on the floor of the lift and R is the force exerted by the floor of the lift on the man's feet. For each of the following, describe how the magnitudes of F and R compare.
 - The lift accelerates upwards.
 - The lift travels upwards at a constant velocity.
 - The lift decelerates while travelling upwards.
 - The lift accelerates downwards.
 - The lift decelerates while travelling downwards.
- A student of mass 70 kg investigates the motion of a lift. He stands on a weighing machine in a lift on its downward journey. For 2 s immediately after the lift starts the weighing machine reads 560 N, then for a further 6 s it reads 700 N and for the final 2 s it reads 840 N.
 - Describe the motion of the lift during its journey.
 - Calculate the magnitude and direction of the resultant force at each stage.
 - Draw an accurate acceleration-time graph for the journey. (Numerical values are required on both axes.)

Exercise 2.6 Momentum

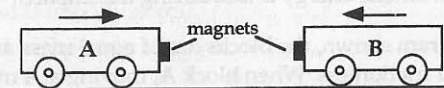
- Calculate the momentum of each of the following.
 - a 700 kg van travelling to the right at 17 m s^{-1}
 - a 1.8 kg toy bus travelling to the left at 85 cm s^{-1}
 - a 450 g ball travelling to the left at 2.8 m s^{-1}
 - a 1500 kg rocket travelling to the right at 8 km s^{-1}
- A field-gun of mass 1000 kg fires a shell of mass 10 kg with velocity of 100 m s^{-1} . Calculate the recoil velocity of the field-gun.
- A shell of mass 5 kg is travelling horizontally with a speed of 200 m s^{-1} when it explodes into two parts. One part of mass 3 kg continues in the original direction at 100 m s^{-1} . Calculate the velocity of the other part.

- Two trolleys are moving in the same direction as shown. The trolleys collide, coupling together on impact.



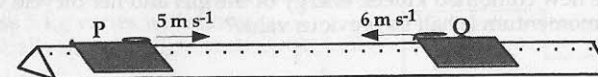
What is their common velocity after impact?

- Two trolleys fitted with magnets collide as shown.



For each of the following, calculate the velocity of the two trolleys after the collision.

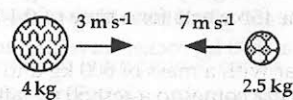
- Trolley A has a mass of 2 kg and is moving at 1 m s^{-1} . Trolley B has a mass of 2 kg and is moving at 2 m s^{-1} . (The magnets stick together.)
 - Trolley A has a mass of 2 kg and is moving at 3 m s^{-1} . Trolley B has a mass of 1.5 kg and is moving at 4 m s^{-1} . (The magnets stick together.)
 - Trolley A has a mass of 1.5 kg and is moving at 5 m s^{-1} . Trolley B has a mass of 2 kg and is moving at 2 m s^{-1} . Trolley A rebounds at 3 m s^{-1} . (The magnets repel.)
- Two linear air track vehicles, P and Q, are projected towards each other as shown. The masses of P and Q are 0.4 kg and 0.2 kg respectively.



- Vehicle Q rebounds to the right with a velocity of 2 m s^{-1} . Calculate the velocity of vehicle P.
- Vehicle P rebounds to the left with a velocity of 2 m s^{-1} . Calculate the velocity of vehicle Q.

Exercise 2.7 Elastic and Inelastic Collisions

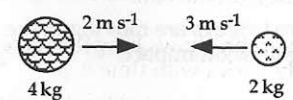
- What is meant by a perfectly elastic collision?
 - What is meant by an inelastic collision?
- Two balls collide head-on as shown. The larger 4 kg ball rebounds at 1.5 m s^{-1} .



 - Calculate the velocity of the smaller ball.
 - Show by calculation whether the collision is elastic or inelastic.

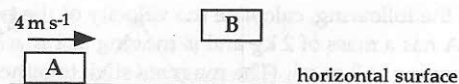
- A ball X of mass 1 kg travelling at 5 m s^{-1} strikes a stationary ball Y of mass 2 kg. Ball X rebounds along its original path at 1 m s^{-1} .
 - Calculate the velocity of ball Y
 - Show by calculation whether the collision is elastic or inelastic.

- Two balls collide head-on as shown. The larger 4 kg ball rebounds at 1 m s^{-1} .



 - Calculate the velocity of the smaller ball.
 - Show by calculation whether the collision is elastic or inelastic.

- A trolley of mass 2 kg moving at 2 m s^{-1} collides inelastically with an identical stationary trolley. After the collision, they move off coupled together. How much kinetic energy is lost during the impact?
- In the diagram shown, the blocks are of equal mass and the horizontal surface can be considered frictionless. When block A, moving at 4 m s^{-1} , moves under block B, block B is dropped onto and sticks to block A.

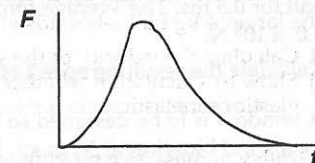


- Is the total momentum affected by block B falling on block A?
 - Calculate the velocity of the combined masses after block B falls on block A.
 - How is the total kinetic energy affected by block B falling on block A?
- A girl on a bicycle is cycling at a constant speed. The combined kinetic energy of the girl and her bicycle is 1600 J. She then slows down. What is the new combined kinetic energy of the girl and her bicycle when their combined momentum is half its previous value?

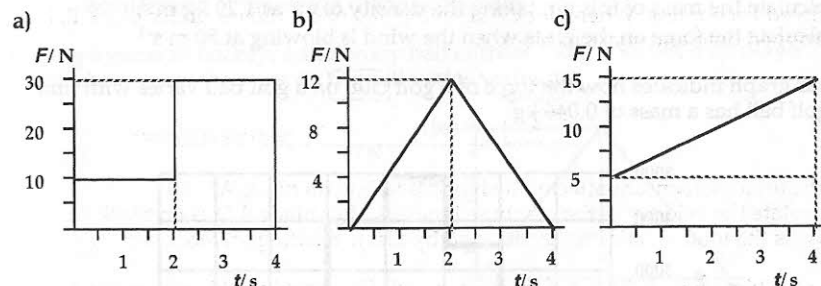
Exercise 2.8 Impulse

- Give two formulae for impulse and state the units for impulse in each case.
- An unbalanced force of 60 N acts on a mass of 3.0 kg. If the force acts for a time of 0.10 s, calculate the impulse given to the mass.
- A car with a mass of 600 kg and a velocity of 40 m s^{-1} skids and crashes into a wall. The car comes to a rest 50 ms after hitting the wall.
 - Calculate the change in momentum of the car.
 - Calculate the average force on the car during the crash.
- A ball of mass 1 kg is initially at rest. The ball is kicked and moves off with a velocity of 10 m s^{-1} . If the impact between the boot and the ball lasts for 125 ms, calculate the average force exerted on the ball.

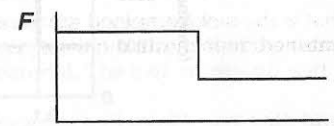
- The graph shows how the force F exerted on a body varies with time t . What is represented by the area under the graph?



- The graphs show how the force exerted on a body varies with time. The body has a mass of 2 kg and is initially at rest. In each case, calculate the speed of the body after 4 s.



- The graph shows how the force applied to an object of mass 5 kg varies with time. The object is initially at rest.
 - Sketch the matching acceleration-time graph.
 - Sketch the matching velocity-time graph.



- A motorcycle safety helmet has a soft inner lining which is compressed on impact during an accident. Explain how the design protects the skull.

