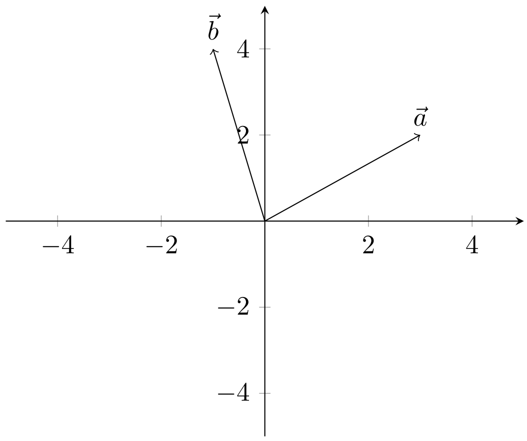
L2 Physics: Problems on mechanics

See the final page for useful formulae and constants.

Sections 2.1-2.2

Main concepts you should understand: vector, displacement, velocity, acceleration

1. Below are drawn vectors $\vec{a}$ and $\vec{b}$. Draw (a) $\vec{a}+\vec{b}$; (b) $\vec{a}-\vec{b}$.



2. A car decelerates from $\vec{v}_0 = 5\,\mathrm{m\,s^{-1}}$ to $\vec{v}_1 = 1\,\mathrm{m\,s^{-1}}$. Draw a vector diagram depicting the two velocity vectors, and the change in velocity.

3. Suppose one starts from point A and walks south 230 m and then walks 350 m west of north to a point B. Find the distance from A to B as the crow flies.

4. A runner runs 3400 m in 10 minutes and 33 seconds; what was her average speed in metres per second?

5. A car moving at $25\,\mathrm{m\,s^{-1}}$ stops suddenly in 14.0 s. What was average acceleration of the car during this time, and how far did the car travel before stopping?

6. A bullet moving at a speed of $150\,\mathrm{m\,s^{-1}}$ travels 3.5 cm into a block of glass before stopping. Find the average acceleration of the bullet, and the time taken for it to stop.

7. A stone is thrown straight upwards from the ground, and goes as high as a nearby building. The stone reaches the ground 3.0 s after it is thrown. How tall is the building?

8. A piano is pushed out of a window that is 8 m above a person sitting below. How fast is it moving when it hits the person, and how long do they have to get out of the way?

9. A train blocks a crossing; it takes 20 s for a carriage to pass through a distance equal to the length of one carriage as the train starts to move. Assuming the length of a carriage is L and the acceleration of the train is constant, how long will it take for the next twenty railway carriages to pass by?

10. A car is moving at $30\,\mathrm{m\,s^{-1}}$. Assuming an average deceleration of $7.0\,\mathrm{m\,s^{-1}\,s^{-1}}$, how long will it take for the car to stop?

11. A ball is thrown straight upwards with a speed v from a point h metres above the ground. Show that the time taken for the ball to strike the ground is

$$\frac{v}{g}\left(1+\sqrt{1+\frac{2hg}{v^2}}\right).$$

Section 2.3

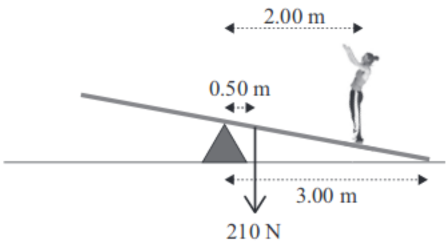
Main concepts you should understand: force, torque, acceleration

1. A 7.0 g bullet is given an acceleration of $40.000\,\mathrm{m\,s^{-1}\,s^{-1}}$ as it is shot from a gun with a 6.0 cm barrel. How large is the average force on the bullet during this process?

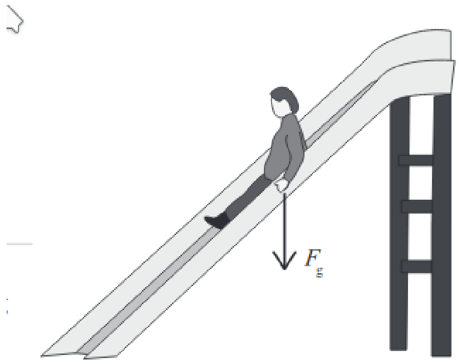
2. How much force does an 70 kg person exert on the earth due to gravity?

3. A 1300 kg car must be stpped in a distance of 80 m. The initial speed of the car is $20\,\mathrm{m\,s^{-1}}$. What force needs to be exerted, assuming constant deceleration?

4. (NCEA 2012) Hannah (55 kg) stands on a see-saw. The see-saw has a weight of 210 N. Calculate the size and direction of the force that the floor exerts on the right hand end of the see-saw.

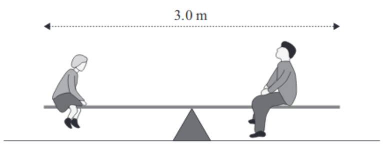


5. (NCEA 2013) Jason is at a fair of some description.
   (a) Jason goes for a ride on a go-kart. Towards the end of the ride, he decelerates at $2.5\,\mathrm{m\,s^{-1}\,s^{-1}}$ and comes to a stop in 4.2 seconds. By calculating Jasons initial velocity, determine the distance he travels while coming to a stop.
   (b) Jason sits on a slide. He is sliding down at constant speed.



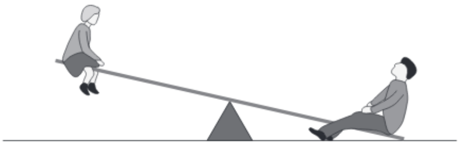
   i. State the size of the net force on Jason. Explain your answer.
   ii. On the diagram on the right, draw the remaining forces (as labelled vectors) acting on Jason.
   iii. Complete and label the vector addition diagram of the forces acting on Jason.

6. (NCEA 2013) The diagram below represents a see-saw on a pivot at its centre with Jane and her dad sitting on opposite sides such that the see-saw is in equilibrium. The mass of the see-saw itself is 60 kg.



   (a) On the diagram above, draw labelled vectors to show all the forces acting on the see-saw.

(b) Jane and her dad move to opposite ends of the see-saw. The diagram below shows what happens when Jane sits at one end of the see-saw while her dad sits at the other end.



If Jane's mass is 30 kg and Jane's dad's mass is 72 kg, calculate the size of the support force from the ground at the end where Jane's dad is sitting. Round your answer to the correct number of significant figures.

7. A box of mass m slides down an incline that makes an angle θ with the vertical, with an acceleration a. A friction force f impedes its motion. (a) Draw a free body (force) diagram; (b) find the acceleration m in terms of θ, m, and f.

8. The weight of an object is defined to be the force exerted on it by gravity; so $W = mg$, where m is the mass of the object. If a three ton (3000 kg) car is travelling at $40\,\mathrm{km\,h^{-1}}$ and the brakes are suddenly applied, and it skids to rest, how far does the car skid given that the friction force experienced by the tires is around 0.7 times the weight of the car?

9. Newton's law of gravity tells us that if we have two objects A and B, with masses m_A and m_b, such that the distance between them is r, then the force that A exerts on B due to gravity is

$$F = \frac{Gm_Am_B}{r^2}.$$

Given that $F = ma$, the units of force are $\mathrm{N} = \mathrm{kg\,m\,s^{-1}\,s^{-1}}$. What are the units of the gravitational constant G?

Sections 2.4-2.5

Main concepts you should understand: momentum, energy (kinetic, gravitational potential, elastic potential), conservation laws of momentum and energy, impulse, elastic/inelastic collision.

1. A 1500 kg car, travelling at 20 metres per second, reduces its speed over 3.0 s to $15\,\mathrm{m\,s^{-1}}$. Calculate the impulse felt by the car. What was the average force causing the deceleration?

2. Find the momentum of an 800 g object after it falls freely from rest a height of 60 cm.

3. A 120 g ball moving at $18\,\mathrm{m\,s^{-1}}$ hits a wall perpendicularly and rebounds with the same speed. After intially touching the wall, the centre of the ball moves an extra 0.27 cm towards it before rebounding. (a) Assuming constant deceleration, show that the total time the ball is in contact with the wall is 2×0.00030s. (b) What is the average force the ball exerts on the wall?

4. A 60 kg astronaut becomes seperated from her ship; she is 15.0 m away and at rest relative to it. She throws a 500 g spanner at a speed of $8.0\,\mathrm{m\,s^{-1}}$ in a direction away from the ship; how long does it take her to get back to the ship?

5. An object of mass 2.0 kg falls, from rest, through a height h. When it reaches the bottom, its speed is measured as $4\,\mathrm{m\,s^{-1}}$. Calculate h. How long did the object take to fall through the height?

6. A 2000 kg car is travelling at $20\,\mathrm{m\,s^{-1}}$ up a frictionless hill when the motor stops. (a) If the car is a vertical distance of 8 m from the top of the hill at that point, will it be able to reach the top? (b) How far below the top of the hill could the car be to still reach the top?

7. What power does a 60 kg person develop when they lift themselves 12.0 m in 20.0 s using a flight of stairs?

8. A 20.0 kg crate is pushed 6.0 m along the floor at a constant speed by a force inclined 30° below the horizontal. (a) Describe the changes of energy occuring as the crate moves along the floor. (b) If the friction force retarding the motion is 140 N, draw a free body diagram and calculate the net force acting on the crate. (c) How much work is done by the pushing force?

9. (NCEA 2012) A trapeze artist, Hannah, flies through the air and lands on an elastic rope, which is held under tension between two supports.

   (a) Name the main energy changes that occur as Hannah is falling AND as she is coming to a stop.

   (b) Hannah doesnt like the rope to be too tight when she lands on it. State the direction of the force on her from the rope. Explain, in terms of the force acting on Hannah, why the rope should not be too tight when she lands on it.

   (c) An elastic rope is suspended from a beam so that it is hanging vertically down. Hannah hangs vertically down on the elastic rope. The rope is stretched 0.60 m below its normal position when Hannah hangs from it. Calculate the elastic potential energy stored in the elastic rope. (Hannah has a mass of 55 kg.)

10. (NCEA 2013) Jason is still at some kind of fair. Each bumper car in the fair has a rubber bumper all round it.

    (a) The mass of a bumper car is 240 kg. Jason has a mass of 65 kg and is travelling at a speed of $2.4\,\mathrm{m\,s^{-1}}$. Calculate the size of the momentum of Jason and his bumper car.

    (b) The bumper cars are designed to minimise injury. Discuss the reasons for the bumper cars having rubber bumpers all round them. Assume cars with and without bumpers have the same mass. Assume change in velocity is the same with and without bumpers.

    (c) Jason collides head-on with Janet who is in another bumper car. The bumpers dont work properly and after collision both cars lock together. The mass of each bumper car is 240 kg. Jason has a mass of 65 kg and Janet has a mass of 58 kg. They are travelling towards each other in opposite directions, Jason with a speed of $2.4\,\mathrm{m\,s^{-1}}$ to the right and Janet with a speed of $2.7\,\mathrm{m\,s^{-1}}$ to the left. Calculate their combined velocity after collision, as a vector.

    (d) The rubber bumper in Jasons bumper car has a spring constant of $78\,000\,\mathrm{N\,m^{-1}}$. On one occasion he collides with the wall, causing a compression of 15 cm. Calculate the elastic potential energy stored in the rubber bumper, and determine the impulse if the collision lasted for 0.80 s (making sure you include a unit with your answer).

11. A car of mass m rolls from rest down a hill of height h and length L. Show that when the car reaches the bottom it has a speed of
$$v = \sqrt{2gh - \frac{2Lf}{m}}.$$

Formulae

91171 Demonstrate understanding of mechanics

$$v = \frac{\Delta d}{\Delta t} \qquad a = \frac{\Delta v}{\Delta t} \qquad v_f = v_i + at$$

$$d = v_i t + \frac{1}{2}at^2 \qquad d = \frac{v_i + v_f}{2}t \qquad v_f^2 = v_i^2 + 2ad$$

$$a_c = \frac{v^2}{r}$$

$$F = ma \qquad \tau = Fd \qquad F = -kx$$

$$F_c = \frac{mv^2}{r} \qquad p = mv \qquad \Delta p = F\Delta t$$

$$E_p = \frac{1}{2}kx^2 \qquad E_k = \frac{1}{2}mv^2 \qquad \Delta E_p = mg\Delta h$$

$$W = Fd \qquad P = \frac{W}{t}$$

where needed, use $g = 9.8 \text{ m s}^{-2}$