Topic: Investigating forces and motion

Investigating acceleration – Lesson 1–2 answers

Lesson concepts

- O A O M The motion of objects can be described and predicted using the laws of physics
- O Questions can be investigated scientifically
- O A O M Conducting investigations requires appropriate methods, assessing risk, and collecting reliable data
- O A O M Data can be collected and recorded systematically and accurately using appropriate equipment
- O A O M Data can be analysed, including describing relationships between variables
- O A O M Knowledge of scientific concepts can be used to draw conclusions that are consistent with evidence
- O A O M Conclusions can be evaluated, sources of uncertainty identified, and ways to improve the quality of data can be described
- O A O M Scientific ideas and information can be communicated using scientific language, conventions and representations

Learning alerts

Be aware of:

- students thinking acceleration is rapidity of motion
- students thinking velocity and acceleration are always positive.

Suggested next steps for learning

- Explain that acceleration is the change in velocity over time.
- Explain that velocity is the change of an object's position over time and thus can be either positive or negative, and acceleration as a change of velocity over time can also be positive or negative.

Prior learning

The activity here reinforces the relationships between the displacement, velocity and acceleration of a moving object. It shows that any one of the graphs (displacement vs time, velocity vs time and acceleration vs time) provides a range of information about the motion of the object.

Government of South Australia
Department for Education

Lesson notes

During this lesson, the student will be determining the acceleration of an object by measuring velocities at more than one point in the motion path of the object. This will require the use of some items from home, including some arrangement to measure velocity.

At this year level, the science inquiry skill expectation includes the ability of a student to select appropriate equipment to systematically collect precise data. The experiment has been designed so that students with access to minimal scientific equipment may still be able to undertake it.

The student may substitute the method if they have access to other equipment that allows the calculation of velocity and acceleration.

Prior learning answers

1. a) i. The displacement–time graph shows that the object is increasing in displacement at different rates so must be accelerating. This is evident because the displacement after 2 seconds is 25 m. During the next two seconds the displacement is 80 m. In the next 2 seconds the displacement has increased to 180 m. This indicates that the velocity must be increasing in the time frames.

   ii. The velocity–time graph shows that the velocity has increased from zero to 60 m/s over the 6 seconds of time shown. This agrees with our statement about the displacement–time graph.

   iii. The acceleration–time graph shows that the acceleration was constant. It had the same value at all times shown in this graph. This agrees with the descriptions for displacement–time and velocity–time graphs.

   b) These graphs can all represent the same object because they show the same changes to motion are occurring. As stated above, the object was accelerating at a constant rate as shown by a flat acceleration graph, the steadily rising velocity graph and the displacement graph that shows an increasing gradient.

2. a) The velocity is not constant. There are different values at different times. Reading the graph as time progresses, the velocity increases for 20 minutes, is constant for the next 20 minutes then decreases in a few stages finishing at zero from 70 to 80 minutes.

   b)

Time (min)	Velocity (km/h)	Change in velocity (km/h)
0	0	
10	20	20
20	40	20
30	40	0
40	40	0
50	15	-25
60	5	-10
70	0	-5
80	0	0

c) The acceleration went from a positive value to zero then to negative values, indicating that the car slowed down, or decelerated.

d) For example: students may have different but appropriate responses.
- They could state that zero (between 20 and 40 minutes, and again between 70 and 80 minutes) was the smallest acceleration.
- They may state that the change of only 5 km/h in velocity in one time interval (between 60 and 70 minutes) was the smallest change that actually involved some acceleration.
- Some students may point out that this 5 km/h change in velocity was negative, and that therefore this acceleration was negative.

e) The two flat level sections of the graph both indicate that no acceleration was occurring; there is no change of velocity. They are different in that the first one, from 20 to 40 minutes, involved travel at a constant velocity that actually involved the car moving. They are different in that in the second one, from 70 to 80 minutes, the car was not actually moving at all.

f) Between 20 and 40 minutes, the car accelerated; it increased its velocity from zero to 40 km/h. The other sections where velocity changed the value decreased, indicating deceleration of the car.

Lesson answers

3. a) The tanker is travelling with constant velocity.

   b) The spaces between the drip marks appear to be constant; therefore the velocity of the truck must be constant. If the tanker was going faster and faster (accelerating), the drips would be getting progressively further apart. If the tanker was going slower and slower (decelerating), the drips would be getting progressively closer together.

4. a) The tanker is accelerating.

   b) The drip marks are getting further and further apart, indicating that the truck must be continually getting faster and faster, which means it is accelerating.

5. If the hammer is going up and down 50 times a second, then each time span between hits will be one-fiftieth of a second 1/50 or 0.02 seconds.

6. No answer required.

7. a) In a five-space section, each space is 0.02 seconds. Five spaces will occur over a 0.10 second time frame, as 5 Å~ 0.02 = 0.10 seconds. To calculate the velocity, displacement is also needed. This can be determined by measuring the length of the five-space section.
   velocity of the section = displacement of the section ÷ time span of the section b-c.

b-c)

Time for each segment (s)	Displacement for each segment (m)	Average velocity over each time span
0	0.0	0.0 m ÷ 0 s = 0 ms^{-1}
0.1	0.045	0.045 m ÷ 0.1 s = 0.45 ms^{-1}
0.1	0.135	0.135 m ÷ 0.1 s = 1.35 ms^{-1}
0.1	0.445	0.445 m ÷0.1 s = 4.45 ms^{-1}
0.1	0.315	0.315 m ÷ 0.1 s = 3.15 ms^{-1}
0.1	0.405	0.405 m ÷ 0.1 s = 4.05 ms^{-1}

d) $a = \frac{v_{(f)} - v_{(t)}}{t}$

$= \frac{4.05\ ms^{-1} - 0.45\ ms^{-1}}{0.4\ s}$

$= 9\ ms^{-2}$

8. a) i. The object is moving with constant velocity — same displacement in equal intervals of time.
   ii. The object is slowing down or decelerating.
   iii. The object is speeding up or accelerating.

9. a) How is the ticker timer similar to the milk truck dropping milk? Various answers acceptable eg. It is moving, milk is dropping at spaced intervals, (the idea of this question is to have students think of similarities and differences and to compare the characteristics of each)
   b) Could you use the drops of milk in the same way as the marks on the ticker tape are used?
   Yes (if many similarities)
   No if too many differences are noted
   c) What are the considerations (or assumptions) you might have to make? Safety issues
   Impact of other variables influencing results eg. Variability in size and regularity of drops falling, source of drops may be limited, etc.

Exploring forces affecting motion – Lesson 3 answers

Lesson concepts

- The motion of bodies can be described and predicted using the laws of physics
- Scientific ideas and information can be communicated using scientific language, conventions and representations

Learning alerts

Be aware of:

- students thinking that an object at rest has no forces acting on it
- students thinking that objects stop moving when the force used to make them move has run out.

Suggested next steps for learning

- Explain that when an object is at rest, the forces acting on it are balanced.
- Explain that moving objects remain in motion until an external force such as gravity, drag, friction, or that exerted by an obstacle, acts against the motion.

Prior learning

The lesson starts with a list of definitions that the student should be familiar with. They should go over these and make a note of any that they do not understand.

Lesson notes

Now that the student is aware of the way in which acceleration is determined by change in velocity, this lesson provides a way to quantify acceleration when observing motion, and to start seeing the ways in which force affects or is affected by acceleration.

The lighthouse activity is to develop the ideas of acceleration in a situation where there is a strong force acting — gravity. This shows the link between acceleration and force acting.

Newton's First Law of Motion is also introduced; students are encouraged to discuss how this law can be seen in everyday situations.

Prior learning answers

1.

TERM	MEANING
Distance	the length of the path taken between two objects or points
Displacement	shortest distance and direction between two points
Velocity	the rate of change of displacement of an object over time, measured in metres per second, m/s or m/s^{-1}
Acceleration	rate of change of velocity over time, measured in metres per second per second, m/s/s or m/s^{-2}
Average velocity	the overall rate of change of displacement over time
Instantaneous velocity	the rate of change of displacement at a point in time of an object in motion
Average acceleration	the overall rate of change of velocity over time
Instantaneous acceleration	the rate of change of velocity at a point in time of an object in motion
Constant acceleration	is a value that does not change over some period of time (can be zero). Velocity is changing constantly
Motion path	a set of points through which an object moves

2. No answer required
3. The slideshow provides a set of still images that advance in one-second intervals to give a realistic impression of the displacement each second and how it increases.
4. Sheet 1 — Analysing the motion of a ball dropped from a lighthouse (see answers on page 7).
5. a) given
   b) Friction forces oppose the robot's applied force. This is shown as F_f in the free-body diagram.
   c) The force applied by the robot must be greater than the force of friction to start the object moving. Watch carefully to see the friction force change just when the object starts to move.

d) $F_{(gravity)}$ and $F_{(normal)}$ do not change at any point during the movement of the object. These forces are balanced to keep the object on the surface. $F_{(friction)}$ increases to a maximum value until the crate just begins to slide, then it decreases a little and remains constant during the motion of the object. The applied force increases to a maximum value, at which point it becomes constant. The force of friction was about 490 to 500 N to get the crate moving.

e) When the robot stops applying the force, the object continues moving and its velocity decreases until it stops. The $F_{(gravity)}$ and $F_{(normal)}$ remain constant. The $F_{(applied)}$ drops to zero almost instantly. The $F_{(friction)}$, which opposes the motion, remains constant and causes the velocity of the object to decrease until it is stationary.

f) The motion will follow the same pattern. $F_{(applied)}$ must be larger than $F_{(friction)}$ for the object to start to move. $F_{(applied)}$ and $F_{(friction)}$ reach maximum values and motion continues. When $F_{(applied)}$ reduces to zero, $F_{(friction)}$ will cause the object to slow and stop. If the object has a greater mass, a larger force needs to be applied in order for the object to move and overcome the opposing force of friction. If the object has less mass, then the object requires a lesser force to put it in motion.

g) A change of surface changes the amount of force required to cause the object to start moving. The greater the friction, the greater the force needed.

6. The video is a simple demonstration of inertia and the first law of motion. There are many other demonstrations of this law that can be performed.

   a) For example:
   - the student's own movement in a car when the inertia leaves them moving forward when the brakes are applied
   - someone jumping off a moving skateboard and having to take a few steps to slow themselves while the skateboard continued moving
   - the feel of the seat pushing on you as the car takes a corner. Similar forces acting when on a ride at a carnival or local show
   - the function of a spinning top is subject to inertia
   - the function of a yo-yo is subject to inertia, most evident when the yo-yo has unwound down the string and winds itself nearly all the way up again
   - the spin of a bowling ball being opposite to its motion towards the pins. Its inertia is set by the throw to move forward toward the pins and even though it rotates the opposite way it still keeps moving forward.

7. a) The pineapple is initially stationary (at rest) and according to Newton's first law will want to remain at rest, hence, when the car moves off rapidly, the pineapple will remain behind, sliding off the back of the car. This is just like the coin, which did not move with the card.

   b) The only way the pineapple could remain on the roof of the car is if the force of friction is large enough to overcome the inertia of the pineapple as the car accelerates. In practical terms, this would mean the car would have to accelerate very slowly.

   c) According to Newton's first law, the pineapple would want to continue in its current state of motion which is in a straight line. Hence, when the car does a rapid right turn the pineapple will continue in a straight line, sliding off the car sideways. Once again, the force of friction would not be large enough to keep the pineapple in place going around the turn.

   d) The current state of motion of the boat was reversing at speed. According to Newton's first law, the boat will continue to move in this straight line as the towing car stops. The rollers would definitely not have enough friction to prevent this happening, hence the boat would slide off the trailer, probably hitting the ramp as it slid off the trailer, or it may launch into the water after hitting the ramp.

e) i. The state of motion of the bag of shopping was in a straight line at speed. Newton's First Law of Motion states the bag will continue moving in a straight line with speed until it impacts with the car dash.

ii. If the driver was not wearing a seat belt, their movement will be the same as for the bag of shopping.

f) When the car reaches the speed bump, there is a force making the car and all in it move upwards. The liquid in a cup moves upwards also. The car then moves downwards on the other side of the speed bump due to gravity, but the liquid now has an upwards movement that makes it leave the cup. We get a spill of liquid as a result.

Sheet 1 – Analysing the motion of a ball dropped from a lighthouse answers

Displacement vs time

Total time elapsed (s)	Total no. of bands travelled	Displacement (m)
0	0	0
1	1	5
2	4	20
3	9	45
4	16	80
5	25	125

Velocity vs time

Elapsed time (s)	Velocity (m/s) at the end of each second
0	0
1	10
2	20
3	30
4	40
5	50

Note: Students may calculate the velocity at 5 s to be 0 (as the ball appears to have stopped in the image). Acknowledge that it refers to the velocity at the beginning of the second, and that a ball could not lose all velocity that quickly.

1. What happens to the displacement of the ball from the starting point as it falls?
   As the ball falls, the displacement changes by an increasing amount per second.

2. What happens to the velocity of the ball as it falls? Suggest a reason for this.
   As the ball falls, its velocity increases. A force must be acting to increase the velocity of the ball.

3. Determine the acceleration value for at least three time intervals. Are they all the same value?

   $a = \frac{v_{(f)} - v_{(t)}}{t}$

   Between 1 and 2 seconds, the velocity changed from 10 m/s $v_{(i)}$ to 20 m/s $v_{(f)}$ in 1 second

   a = (20 m/s – 10 m/s) ÷ 1s
   = 10 ms_{-2}

   Between 3 and 4 seconds, the velocity changed from 30 m/s $v_{(i)}$ to 40 m/s $v_{(f)}$ in 1 second

   a = (40 m/s – 30 m/s) ÷ 1s
   = 10 ms_{-2}

   Between 2 and 5 seconds, the velocity changed from 20 m/s $v_{(i)}$ to 50 m/s $v_{(f)}$ in 3 seconds

   a = (50 m/s – 20 m/s) ÷ 3s
   = 10 ms_{-2}

   These values of acceleration are all the same. This indicates a constant force.

4. Calculate the average velocity of the ball over the 5s.

   t = 5s

   s = 125 m

   $$\text{average velocity} = \frac{\text{displacement}}{\text{time}} = \frac{125\text{ m}}{5\text{ s}} = 25\text{ m/s}$$

5. Describe the relationship between the velocity of the falling object just before it hits the ground and the average velocity.

   The average velocity is a measure of the velocity over the ball's entire fall. However, it will have a greater velocity in the last second of its fall because it travels 45m in that last one second.

   The velocity as it hits the ground is the maximum velocity.

6. Describe how the forces acting on the ball change its motion as it falls.

   Initially, the force pushing upwards from the tower acting on the ball is balanced by the force exerted by gravity pulling downwards and so the ball is stationary. Here the forces are balanced in direction and size. As the ball falls, the force exerted by gravity is not balanced by the force of air resistance (drag) opposing it. This means that the ball's velocity increases the longer the forces are acting, so it has the greatest velocity just before impact.

   After impact, the ball rebounds but eventually the force of gravity is balanced by the force of resistance from the ground, so the ball finally ends up being stationary.