National 5 Physics

Dynamics and Space

Problem Booklet

Contents

Velocity and Displacement

1. What is the difference between a scalar and a vector quantity?

2. Put these quantities in to a table that shows whether they are vector or scalar:

   force, speed, velocity, distance, displacement, acceleration, mass, time, energy

3. Complete this table.

Distance (m)	Time (s)	Speed (ms^{-1})
100	10	
30	2.5	
510		17
72		1.5
	30	12
	0.3	25

4. A person walks 25 metres west along a street before turning back and walking 15 metres east. The journey takes 50 seconds. What is the:

   a) Total distance travelled by the person?

   b) Displacement of the person?

   c) Average speed of the person?

   d) Average velocity of the person?

5. An Olympic runner runs one complete lap around an athletics track in a race. The total length of the track is 400 metres and it takes 45 seconds for the runner to complete the race. Calculate the:

   a) Displacement of the runner at the end of the race.

   b) Average speed of the runner during the race.

   c) Average velocity of the runner during the race.

6. An orienteer starts at point A, walks 300 metres north then 400 metres east until point B is reached in a total time of 900 seconds.

a) What is the total distance walked by the orienteer?

b) What is the displacement of point B relative to point A?

c) What is the average speed of the orienteer?

d) What is the average velocity of the orienteer?

7. A car drives 15 kilometres east for 12 minutes then changes direction and drives 18 kilometres south for 18 minutes.

   a) What is the average speed of the car, in metres per second?

   b) What is the average speed of the car, in kilometres per hour?

   c) What is the average velocity of the car, in metres per second?

8. On a journey, a lorry is driven 120 kilometres west, 20 kilometres north then 30 kilometres east. This journey takes 2 hours to complete.

   a) What is the average speed of the lorry, in km/h?

   b) What is the average velocity of the lorry, in km/h?

Acceleration

1. Complete this table .

Acceleration (ms^{-2})	Change in Speed (ms^{-1})	Time (s)
	12	6
	16.5	5.5
0.5		18
1.2		30
0.125	0.50	
2.70	11.34	

2. What is the magnitude of the acceleration of a dog that starts from rest and reaches a speed of 4.0 metres per second in 2.0 seconds?

3. What is the size of the acceleration of a car that speeds up from 3 metres per second to $15ms^{-1}$ in 7.5 seconds?

4. A motorbike accelerates at a rate of $0.8ms^{-2}$. How long will it take for the motorbike to increase in speed by $18ms^{-1}$?

5. What is the final speed of a sprinter who starts at rest and accelerates at $2.2ms^{-2}$ for 4.5 seconds?

6. What was the initial speed of a horse that reaches a speed of $12.3ms^{-1}$ after accele of $3.8ms^{-2}$ for 2.5 seconds?

7. A car is travelling at $9.0ms^{-1}$ when a cat runs out on to the road. The driver applies the brakes and comes to a stop 0.6 seconds later. What is the magnitude of the deceleration of the car during this time?

8. An aeroplane accelerates from 360km/h to 396km/h in 1 minute and 40 seconds. What is the size of the acceleration of the aeroplane in ms^{-2}?

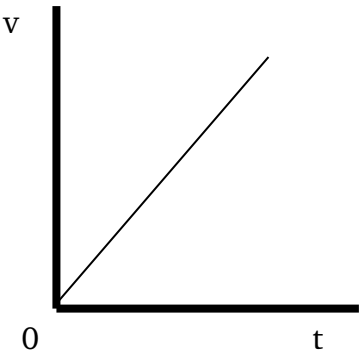
9. In an experiment, the acceleration of a ball is found by dropping it through two light gates connected to a timer. The change in speed of the ball and the time taken for the ball to pass between both light gates are measured. The spacing between the light gates are altered and the experiment is repeated. The results of this entire experiment are shown:

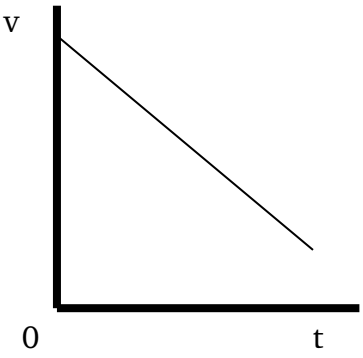
Time (s)	Speed (ms^{-1})
0.14	1.4
0.29	2.9
0.36	3.8
0.44	4.2
0.58	5.9
0.61	6.2

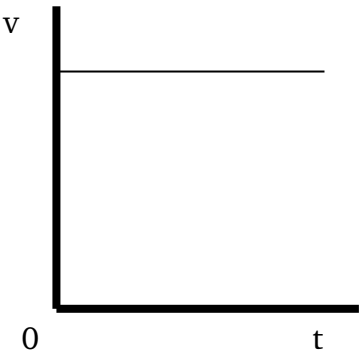
Draw a line graph of these results, and use the gradient of the graph to find the acceleration of the falling ball.

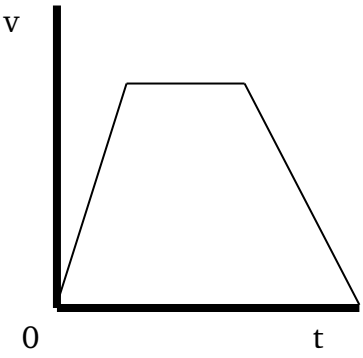
Velocity-Time Graphs

1. For each of these velocity-time graphs, describe the motion of the vehicle.

a) 

b) 

c) 

d) 

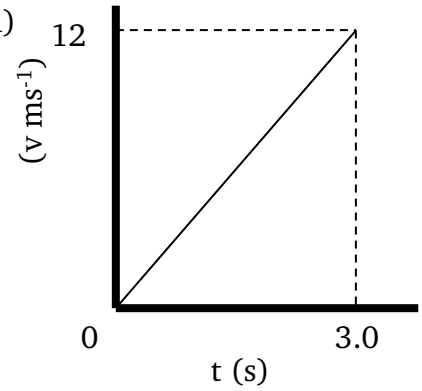
2. Plot a velocity-time graph from each of these sets of data:

Time / s	Speed / m s^{-1}
0	0
1	1.5
2	3.0
3	4.5
4	6.0
5	7.5

Time / s	Speed / m s^{-1}
0	10
0.5	8.75
1	7.5
1.5	6.25
2	5.0
2.5	3.75

3. Calculate the size of the acceleration of the vehicles represented by these velocity-time graphs.

a)



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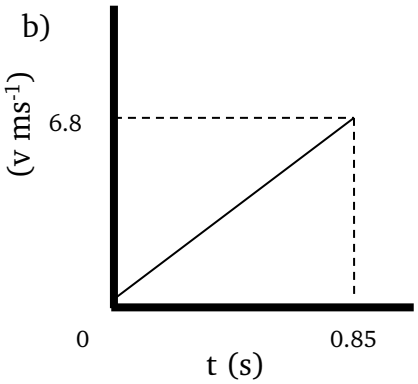

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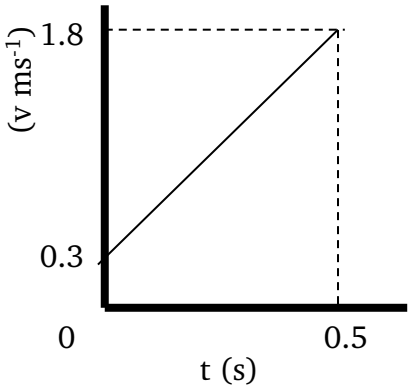

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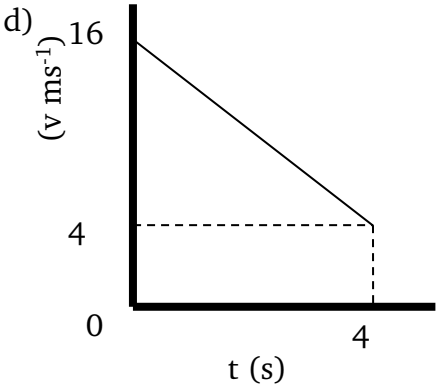
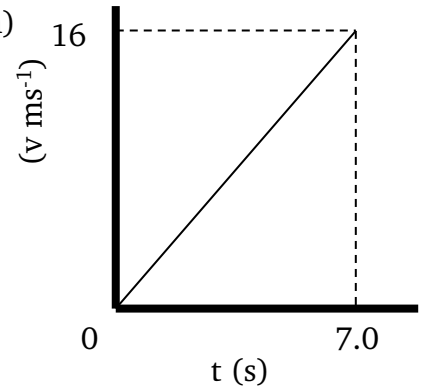


4. Calculate the magnitude of the displacement of the vehicles represented by these velocity-time graphs.

a)



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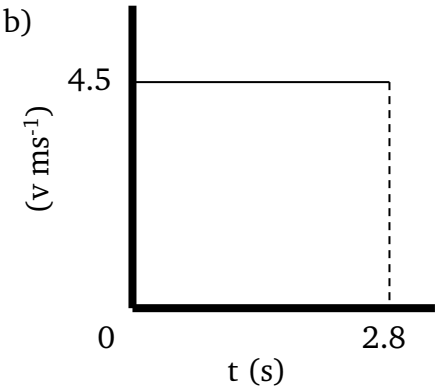

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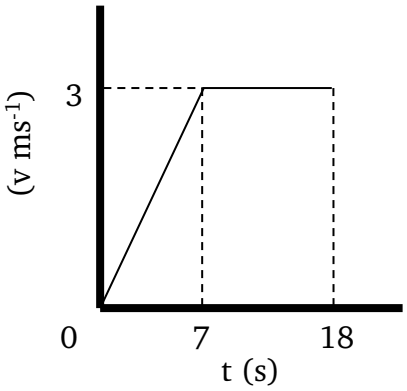

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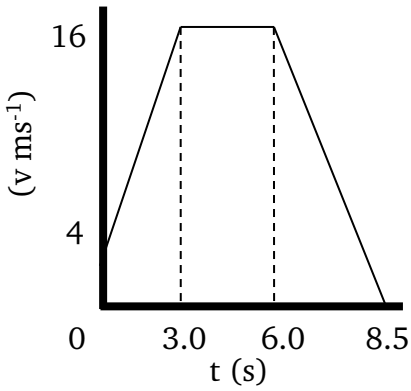
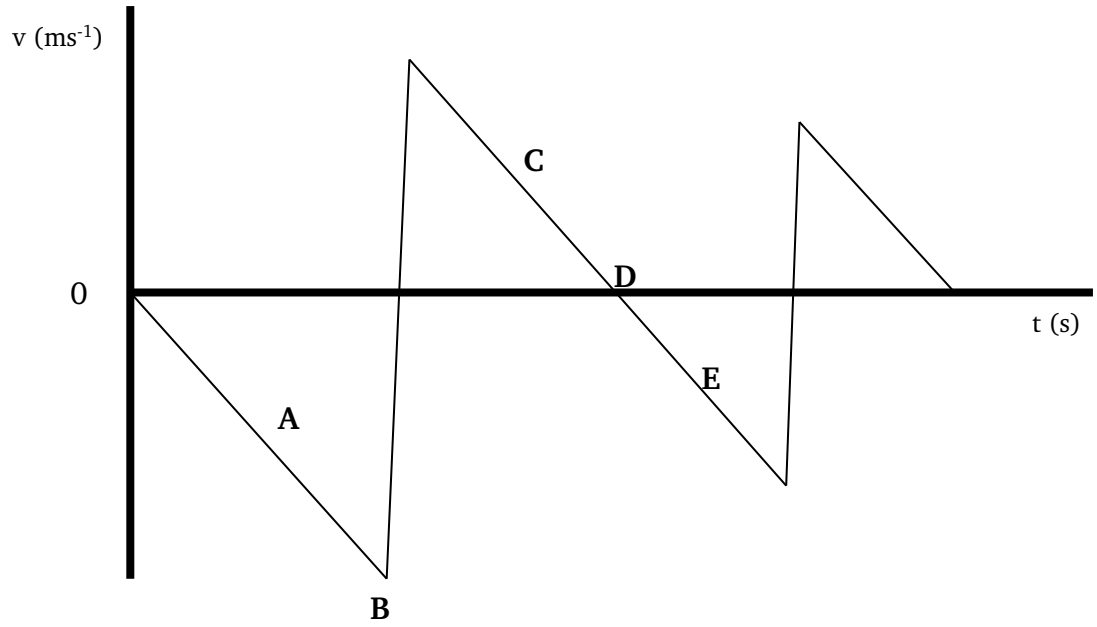


5. A ball is bounced off a surface. The velocity-time graph of the ball is shown.



a) Describe the motion of the ball at each point indicated on the graph.

b) Explain why the 'spikes' on the velocity graph are getting smaller as time increases.

c) Sketch the speed-time graph of the ball during this time.

Weight

1. What is the difference between weight and mass?

2. Complete this table:

Weight (N)	Mass (kg)	Gravitational Field Strength (Nkg^{-1})
	3	10
	0.25	9
300		10
210		7
520	65	
3640	140	

3. What is the weight of these objects on the surface of the Earth?

   a) A 3kg cat.

   b) A 100g apple.

   c) A 65kg pupil.

   d) A 1200kg car.

4. What happens to the weight of a space shuttle as it gets further away from the surface of the Earth? Give two reasons for your answer.

5. The mass of an astronaut is found to be 85kg on Earth. What is the mass of the astronaut on the moon?

6. What is the weight of a 93kg astronaut in the following places in the solar system?

   a) The surface of Mars.

   b) The surface of Jupiter.

   c) The surface of Mercury.

   d) Drifting in space on an 'EVA' — a space walk.

7. What is the mass of an astronaut who has a weight of 675N on the surface of Venus?

8. An astronaut of mass 82kg is standing on the surface of a planet in our solar system and measures his weight to be 902N. Which planet is the astronaut standing on?

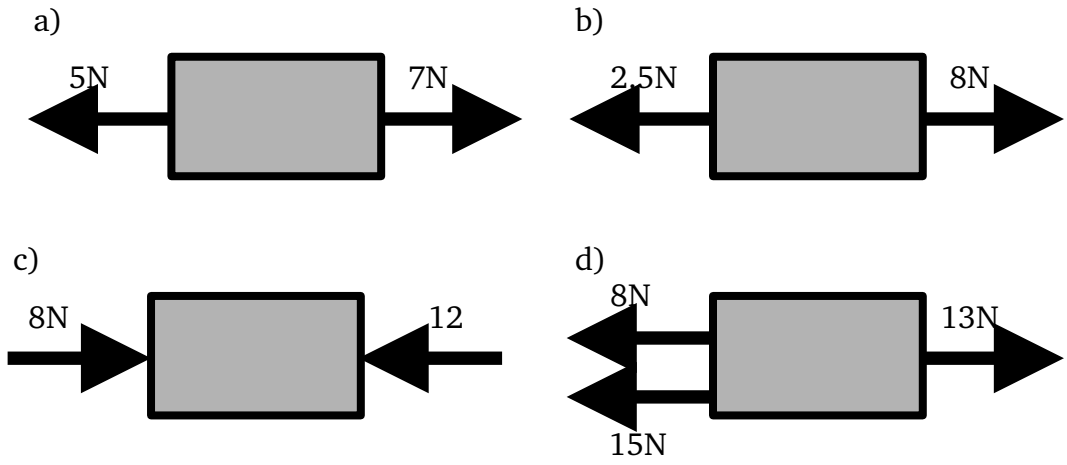
9. In a set of experiments being carried out on a far away planet, an alien measures the mass and weight of different objects. The results are shown.

Mass (kg)	Weight (N)
0.3	3.9
0.5	6.5
0.7	9.1
1.4	18.2
1.8	23.4
2.1	27.3

10. Draw a line graph of these results and use the gradient of the graph to calculate the gravitational field strength of the far away planet.

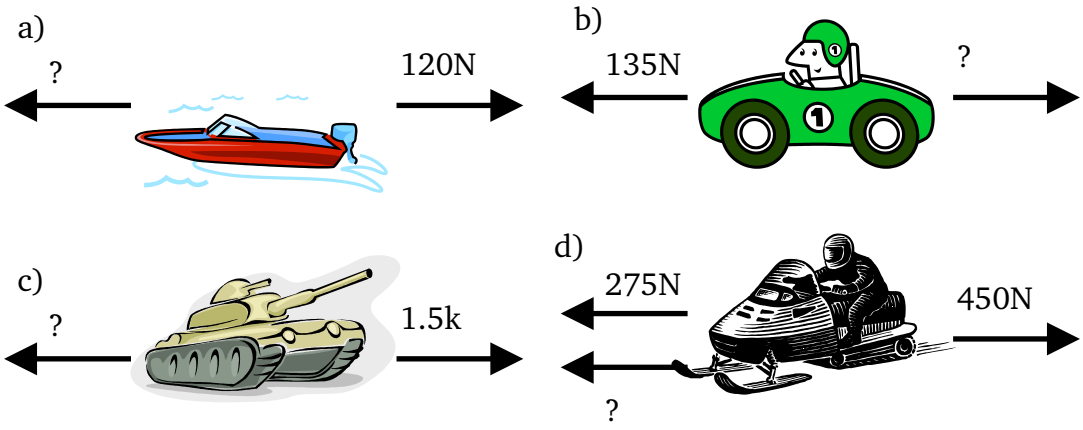
Newton's Laws

1. State the unbalanced force acting on each of these objects. Remember to include magnitude and direction.



2. Complete this sentence: When the forces acting on an object are balanced, the object will move with a constant _____. In other words, the object will have zero _____.

3. Each of these vehicles is travelling at a constant speed. Calculate the value of the missing force in each of the situations.



4. In a tug of war competition, two teams of eight people are competing against each other. The teams start at rest, then each team exerts a total of 5.6kN of force on the rope.

   a) Describe and explain the motion of the teams.

   b) What is the average force exerted by each person taking part?

   c) One person leaves the competition. Assuming that the opposing team still pulls with a force of 5.6kN, what is the average force per person required to keep to stop the other team from winning?

5. What is friction?

6. Give two examples of situations where it is a good idea to increase friction.

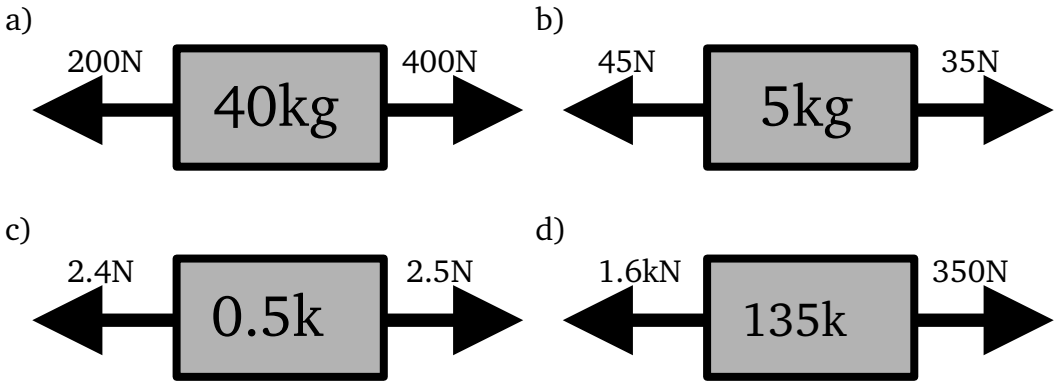
7. Give two examples of situations where it is a good idea to decrease friction.

8. Complete this sentence: When the forces acting on an object are unbalanced, the_____
   _____

9. Complete this table.

Unbalanced Force (N)	Mass (kg)	Acceleration (ms^{-2})
	15	1.5
	0.8	0.25
0.6		1.5
2.0		0.05
15	10	
350	140	

10. Calculate the acceleration of these objects.



11. What is the unbalanced force acting on a 1200kg car accelerating at $1.2ms^{-2}$?

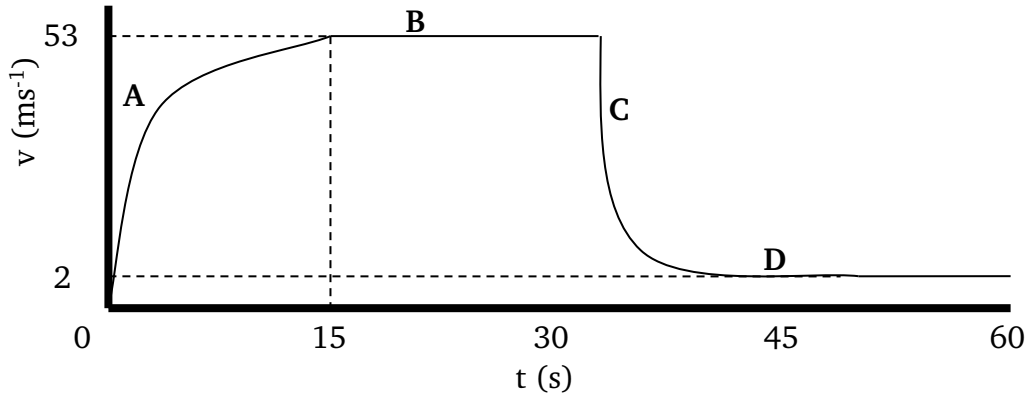
12. Describe and explain, using Newton's Laws, how the following safety features of a car could save your life:

    a) Seat belts

    b) Air bags

    c) Bumpers

13. A sky diver jumps out of an aeroplane. The graph shows the vertical speed of the sky diver for the first 60 seconds of the jump.



a) What are the two vertical forces acting on the sky diver during the jump?

b) What is meant by the term 'terminal velocity'?

c) What is the terminal velocity of the sky diver in this example?

d) Explain, in terms of vertical forces, the motion of the sky diver at each of the points indicated on the graph.

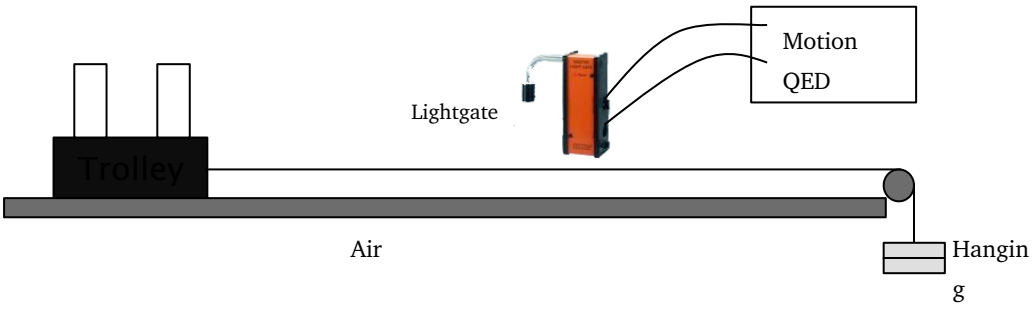
14. Explain the results of these experiments:

a) When released from the same height on Earth, a hammer will hit the ground before a feather.

b) When released from the same height on the moon, a hammer and feather will hit the ground at the same time.

c) A space shuttle has a mass of 2.4×10^{5}kg. What is the engine force required at launch to make the shuttle accelerate upwards at a rate of $18ms^{-2}$?

15. In an experiment, a trolley is connected to hanging masses and placed on to an air track as shown.



The acceleration of the trolley is measured. The value of the hanging masses is then changed thus altering the force pulling the trolley. The results of the experiment are shown.

Force (N)	Acceleration (ms^{-2})
0	0.0
0.1	0.5
0.2	1.0
0.3	1.5
0.4	2.0
0.5	2.5

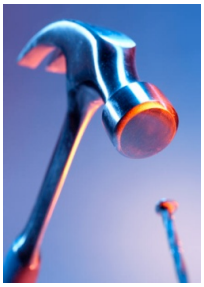
Draw a line graph of these results, and use the gradient of the straight line to calculate the mass of the trolley.

16. Complete these sentences:

a) If object A applies a force on to object B, then object B applies an _____ but _____ force back on to object A.

b) Every action has an _____ but _____ reaction.

17. Identify the Newton pairs being represented in these examples:

a) 

b) 

c) 

18. Explain, using Newton's Third Law, how a space shuttle is able to take off from the surface of the Earth.

Work Done

1. What is meant by the term ‘work done’?

2. Complete this table:

Work Done (J)	Force (N)	Distance (m)
	100	30
	25	6.2
300,000		150
40		2
1250	125	
144,000	3200	

3. What is the work done by a shopper pushing a shopping trolley with an average force of 480N over a distance of 35 metres?

4. What is the average force applied by a mother pushing a pram for a distance of 500 metres if her total work is 150,000J?

5. What is the distance that a boy pushes his bike if he does 240,000J of work and applies a constant force of 6000N?

6. What is the work done by a truck if it drives 20km with an average engine force of 1.5kN?

7. A group of 6 snow dogs pull a sledge with an average force of 600N each. What is the distance that the sledge has been pulled when the total work done by all of the dogs is 90MJ?

8. The Formula 1 Australian Grand Prix is a race where the winning car drives 308km. The work done by a car that completes the full race is 2.43×10^{9}J. What is the average engine force of the car?

9. In a P.E. lesson, a pupil of mass 58kg climbs 12 metres up a rope. What is the work done by the pupil during this climb?

10. In an experiment, a pupil measures the distance travelled and the work done by a battery powered toy car (using E = Pt). The results are shown:

Distance / m	Work Done / J
0.0	0.00
2.5	11.25
5.0	18.00
7.5	33.75
10.0	45.00
12.5	56.25

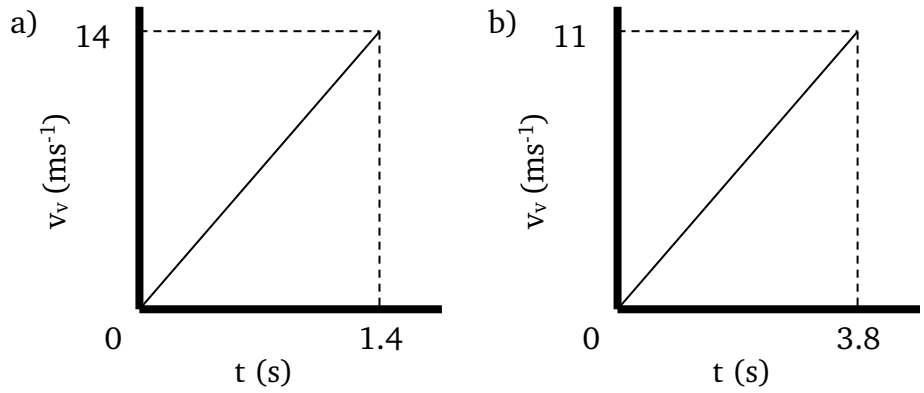
Draw a line graph of these results and use the gradient of the straight line to find the average force of the motor of the toy car.

Projectile Motion

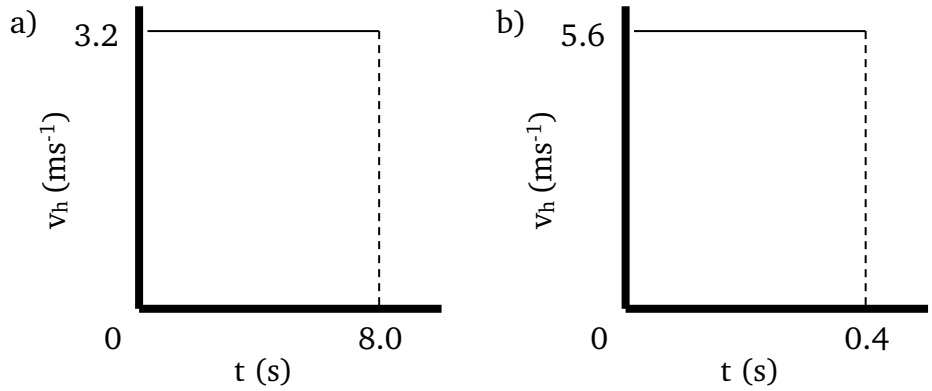
1. Describe what is meant by ‘projectile motion’.

2. A rock is dropped from the top of a cliff. It lands in the sea 2.7 seconds after being dropped. What is the vertical velocity of the rock when it reaches the sea?

3. These graphs show how vertical velocity of an object changes with time. In each case, calculate the vertical displacement of the object.



4. These graphs show how horizontal velocity of an object changes with time. In each case, calculate the horizontal displacement of the object.



5. A monkey is relaxing in a tree when it sees a hunter climb a nearby tree and take aim with a bow and arrow. The hunter is aiming directly at the head of the monkey. The monkey is smart though. It decides to jump out of the tree at the exact moment the arrow is released from the hunter's bow. Assuming that the hunter has perfect aim, the monkey has zero reaction time and that air resistance is negligible, explain whether the monkey will avoid being struck by the arrow.

6. A cowboy uses a gun to fire a bullet horizontally. He drops his gun at exactly the same time as the bullet leaves. Which will hit the ground first — the bullet, the gun or will they land at the same time? Explain your answer (The effects of air resistance should be ignored).

7. A golfer hits a golf ball from the top of a hill with a horizontal velocity of $35ms^{-1}$. The ball takes 3.0 seconds to hit the ground.

   a) What is the horizontal displacement of the ball when it lands?

   b) What is the vertical velocity of the ball when it hits the ground?

8. A plane is travelling at a constant horizontal velocity of $75ms^{-1}$ when a box is dropped out of it. The box lands on the ground after a time of 15.5 seconds.

   a) What is the horizontal distance travelled by the box during the drop to the ground?

   b) What is the horizontal displacement of the box, relative to the plane when it hits the ground?

   c) What is the vertical velocity of the box when it hits the ground?

   d) In reality, the vertical velocity of the box is around $55ms^{-1}$ when it hits the ground. Explain the difference between this value and your answer to (c).

9. Using Newton's Thought Experiment (Newton's Cannon), explain how satellites stay in orbit around a planet.

Specific Heat Capacity

1. What is meant by the following statement: "The specific heat capacity of water is 4180$Jkg^{-1}°C^{-1}$."

2. Complete this table:

Heat Energy (J)	Specific Heat Capacity ($Jkg^{-1}°C^{-1}$)	Mass (kg)	Change in Temperature (°C)
	2,350	2.0	10
	902	5.0	25
36,900		4.5	2
6,885		0.75	34
10,080	2,100		12
105,600	480		40
2400	128	2.5	
27,690	2,130	3.25	

3. What is the heat energy required to heat 3kg of water from 20°C to 80°C?

4. A 2.4kg lump of brass is heated up by a Bunsen burner. When 9120J of heat energy has been absorbed, the temperature of the brass increases by 10°C. What is the specific heat capacity of the brass?

5. A pane of glass has a mass of 800g. What is the temperature change of the glass if it is heated by 1000J of heat energy?

6. A block of lead is heated from 24°C to 28°C by a heat source that gives off 6144J of heat energy. What is the mass of the lead block?

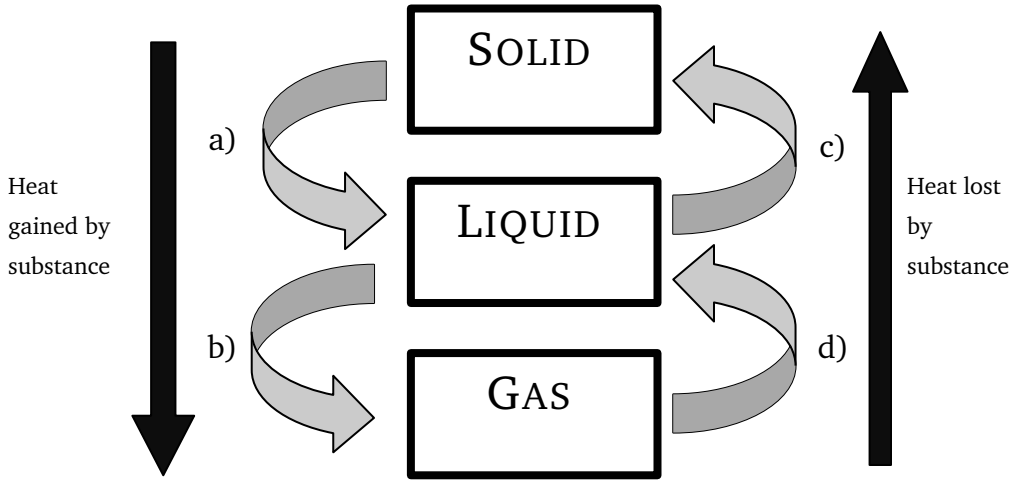
Specific Latent Heat

1. What is the meaning of the following terms:

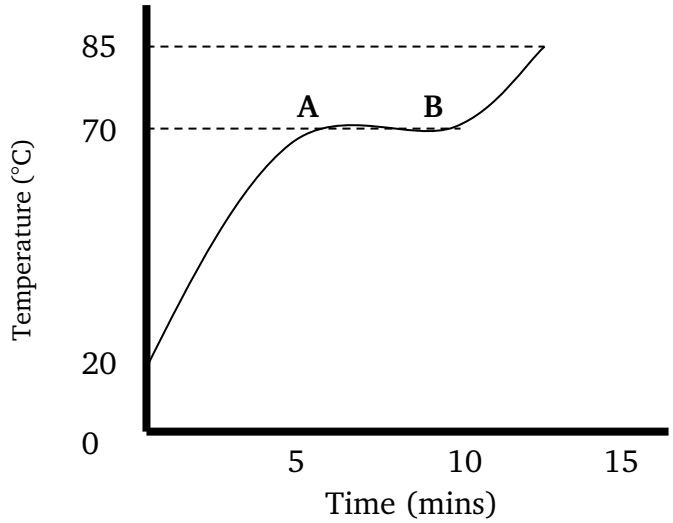
    a) Specific Latent Heat of Vaporisation?

    b) Specific Latent Heat of Fusion?

2. Complete this flow diagram to show the name given to each change of state.



3. Stearic acid is a solid at room temperature. 100g of stearic acid is heated in a water bath until it reaches a temperature of 85°C. A graph of how the temperature changes with time is shown.



Describe and explain what happens to the stearic acid between points A & B.

4. Complete this table:

Heat Energy (J)	Mass (kg)	Specific Latent Heat of Fusion (Jkg^{-1})
	1.5	0.99×10^5
	0.6	3.95×10^5
144,000		1.80×10^5
266,500		2.05×10^5
60,000	2.4	
48,060	0.18	

5. How much heat energy is required to:

    a) Turn 400g of ice in to 400g of water?

    b) Turn 400g of water in to 400g of steam?

6. How much heat energy is given out by:

    a) 700g of steam turning in to 700g of water?

    b) 700g of water turning in to 700g of ice?

7. What is the mass of alcohol if 1.008MJ of energy is required to change all of the alcohol from a liquid to a gas?

8. A 50g substance is a gas at room temperature. It is cooled to a very low temperature and it becomes 50g of liquid. If the substance releases 18,850J of heat energy as it changes state:

    a) What is the specific latent heat of vaporisation of the substance?

    b) What is the name of the substance?

9. In a laboratory, 150g of water is found to have a temperature of 20°C. It is heated to a temperature of 100°C and it is all converted in to steam. How much heat energy is required to do heat 150g of water at 20°C in to 150g of steam at 100°C?

10. During an experiment, a 1.5kW kettle is filled with 400g of water and switched on. After 30 seconds, the heat energy given to the water is calculated (using E = Pt), the mass of the water is measured with digital scales and the mass loss of the water is worked out. The results of the experiments are shown.

Heat Energy (J)	Mass Loss of Water (g)
0	0
750	0.14
1500	0.27
2250	0.41
3000	0.55
3750	0.68

a) Using this data, draw a line graph and use the gradient of the straight line to find the specific latent heat of vaporisation of water.

b) Is this experimental value for the specific latent heat of vaporisation of water larger, smaller or the same as the actual value? Explain any difference.

Space Exploration

1. A space shuttle is about to be launched from the surface of the Earth. It has a mass of 7.9×10^4kg.

   a) What is the weight of the space shuttle at launch?

   b) Describe and explain what happens to the weight of the space shuttle as it gets further away from the surface of the Earth.

2. A space rocket has a mass of 9.0×10^4kg. What engine thrust is required to make the rocket accelerate at 25ms^{-2} at take off?

3. A spacecraft of mass 9000kg is to re-enter Earth's atmosphere. Just before re-entry it has a speed of 7500ms^{-1}. At a point during re-entry, the speed of the spacecraft drops to 700ms^{-1}. What is the heat energy gained by the spacecraft up to this point in re-entry?

4. A pupil in a physics class makes the following statement: "The material used to protect space shuttles during re-entry needs to have a low specific heat capacity". Do you agree or disagree with this statement? Give a reason for your opinion.

5. A 50kg piece of space junk orbits the Earth with a speed of 1200ms^{-1}. It re-enters the Earth's atmosphere and its speed drops to 400ms^{-1}. The specific heat capacity of the piece of space junk is 850Jkg^{-1}°C^{-1}. What is the temperature change of the space junk during re-entry?

6. A NASA scientist has to choose a suitable material to construct heat tiles on the outside of a space shuttle. The possible materials are shown in the table below:

Material	Density (gcm^{-3})	Specific Heat Capacity (Jkg^{-1}°C^{-1})	Melting Point (°C)
Aluminium	2.700	897	660
Copper	8.960	385	1085
Iron	7.874	450	1538
Silica	2.448	703	1725
Titanium	4.506	523	1668

   Which material is best suited to protect a space shuttle during re-entry to the Earth's atmosphere? Give reasons for your answer.

7. Voyager 2 is a spacecraft that was launched on the 20th of August 1977. It took many photographs of Jupiter, Saturn, Uranus and Neptune in the 1980's and is still in contact with the Earth despite now being over 1.50×10^{13} metres away. Why is it useful to have explored these planets using spacecraft, such as Voyager 2, and telescopes?

8. Satellites which orbit the Earth are of great use to society. Give some examples of everyday use of satellites.

9. The Hubble Space Telescope orbits the Earth and is used to look at far away stars and galaxies. Why does the Hubble Space Telescope get clearer images of space than telescopes on the surface of the Earth?

10. How far is a light year, in metres?

11. Complete this table.

Celestial Body	Average distance from the Sun (m)	Time taken for light from the sun to travel to body
Earth		8 minutes
Neptune	4.503×10^{12}	
Proxima Centauri		4.3 years
Betelgeuse	6.079×10^{18}	
		434 years

12. On average, Jupiter is around 7.78×10^{11} metres from the Sun. How long does it take for light from the Sun to reach Jupiter?

13. By using detailed analysis of the stars and galaxies that surround us, astronomers have made some theories about the observable universe, all of which have been backed up by experimental evidence.

14. Why are there parts of the universe that can't be observed from Earth?

15. Explain the 'Big Bang' theory regarding the origin of the universe.

16. How old is the universe believed to be? Explain how astronomers came to this estimate.

17. Complete this sequence to show the electromagnetic spectrum in order of increasing wavelength.

a)	X-Ray	b)	Visible	c)	Micro wave	(d)

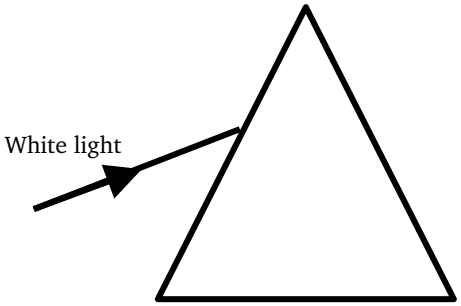
18. Why is it useful to study electromagnetic radiation from stars and galaxies which have wavelengths outside of the visible spectrum?

19. Why are radio telescopes often found in large groups called ‘arrays’?

20. COBE (Cosmic Background Explorer) is a satellite that detects infrared and microwave ‘background’ radiation in space. Why is COBE collecting this data?

21. SETI (Search for Extra-Terrestrial Intelligence) is a group of organisations that study electromagnetic radiation, in particular radio waves, from space. Why are the SETI organisations analysing this data?

A beam of white light is shone through a Perspex prism as represented in the diagram.



Complete the diagram to show what happens to the light as it passes through the prism.