National 5 Physics

Mechanics

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. 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?

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

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

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

5. What was the initial speed of a horse that reaches a speed of 12.3 $m s^{-1}$ after accelerating at a rate of 3.8 $m s^{-2}$ for 2.5 seconds?

6. A car is travelling at 9.0 $m s^{-1}$ 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?

7. 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}?

8. Complete the table below:

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	

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:

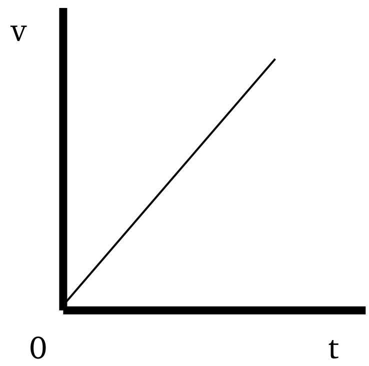
Time (s)	Speed ($m\,s^{-1}$)
0.14	1.4
0.29	2.9
0.36	3.8
0.44	4.2
0.58	5.9
0.61	6.2

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)



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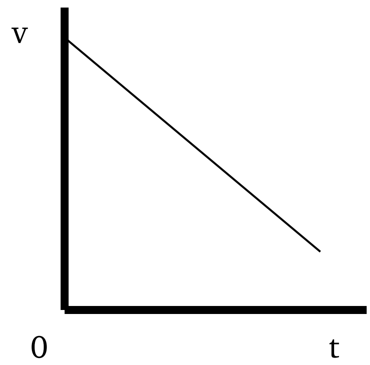

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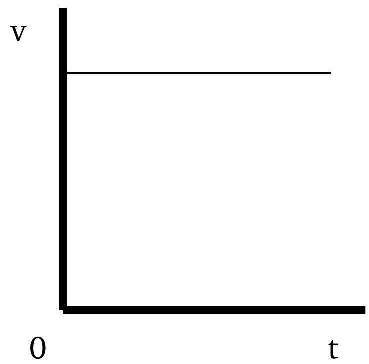

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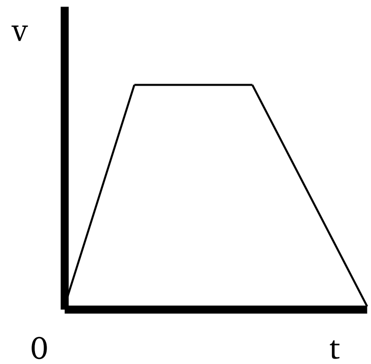
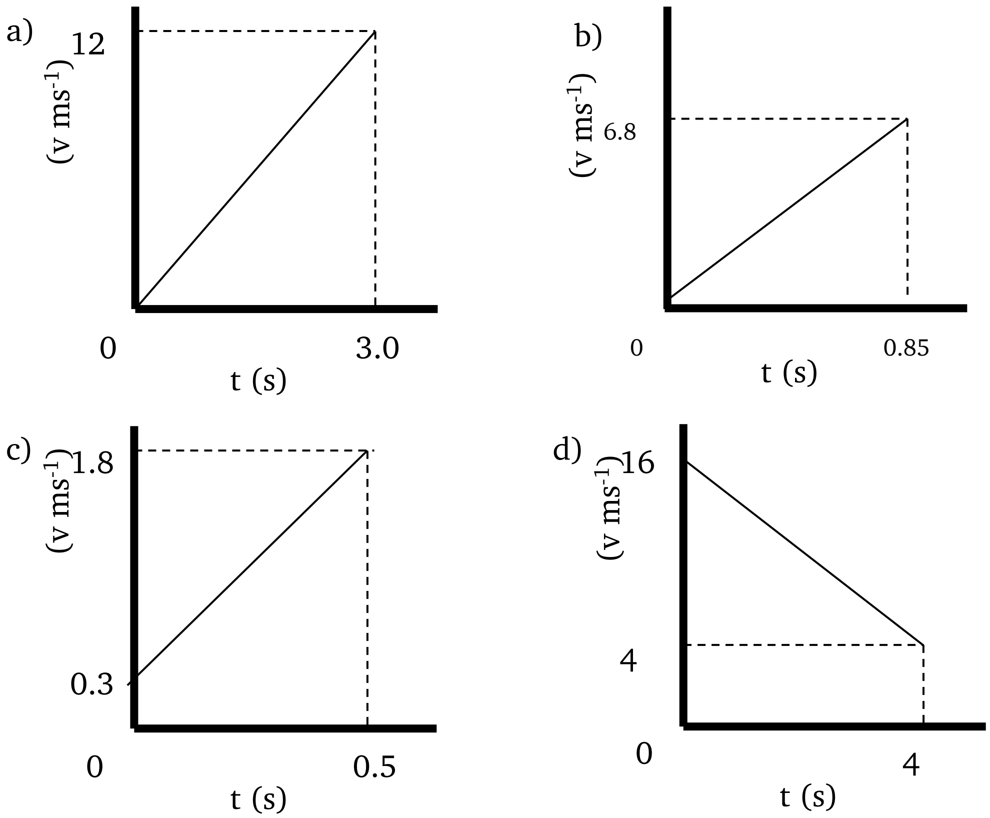
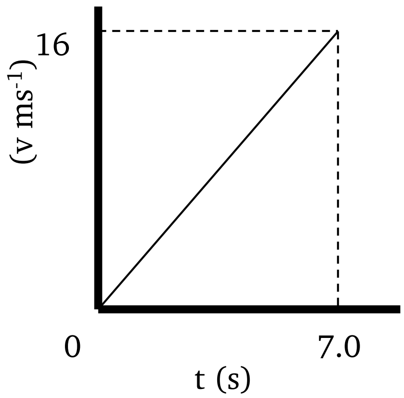


3. Calculate the size of the acceleration of the vehicles represented by these velocity-time graphs.



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

a)



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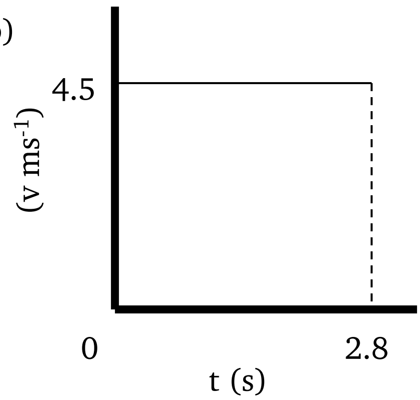

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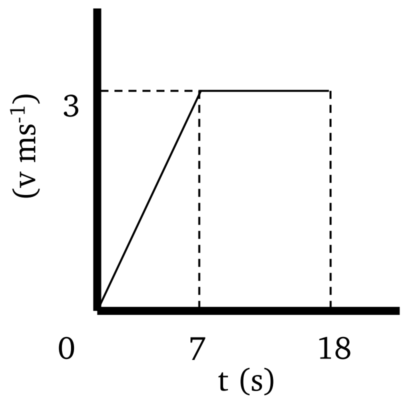

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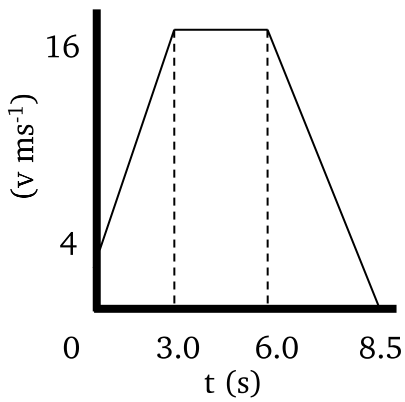
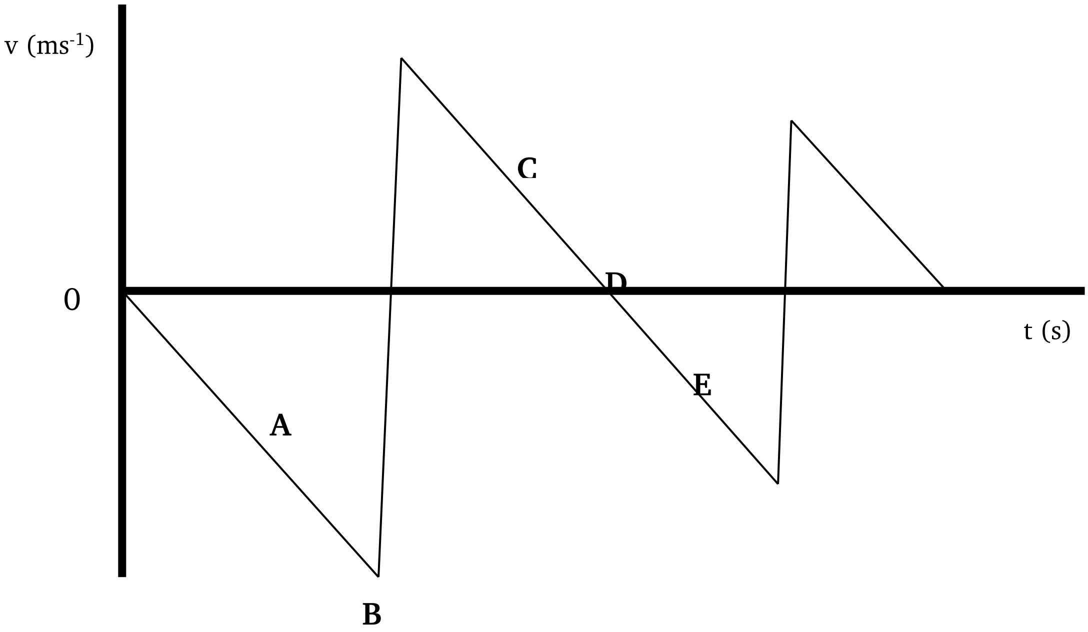


5. A ball is bounced off a surface. The velocity-time graph of the ball is shown.



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

    a) A 3 kg cat.

    b) A 100 g apple.

    c) A 65 kg pupil.

    d) A 1200 kg car.

3. 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.

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

5. What is the weight of a 93 kg 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.

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

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

8. 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

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.

a)

b)

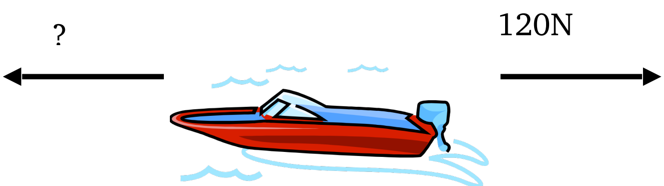
c)

d)

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.

a)



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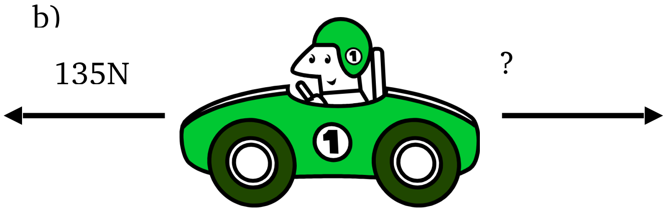

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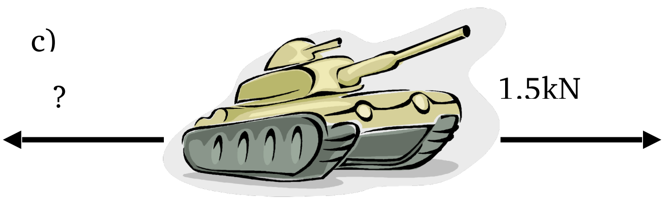


d)

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 5.6 kN 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 5.6 kN, 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____

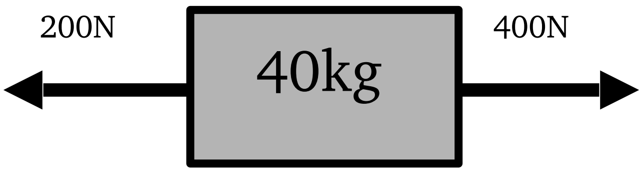
   ____

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.

a)



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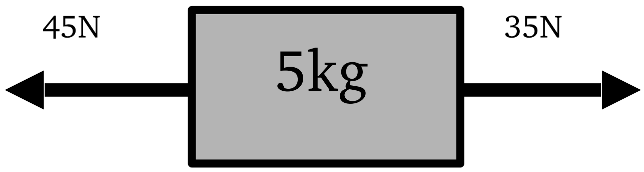

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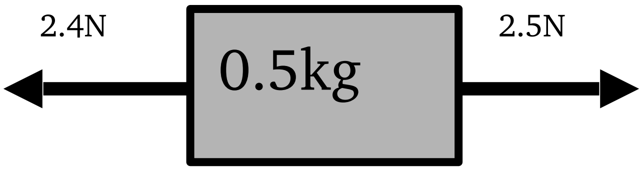

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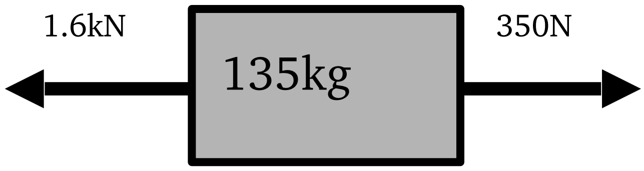


11. What is the unbalanced force acting on a 1200 kg car accelerating at 1.2 $m\,s^{-2}$?

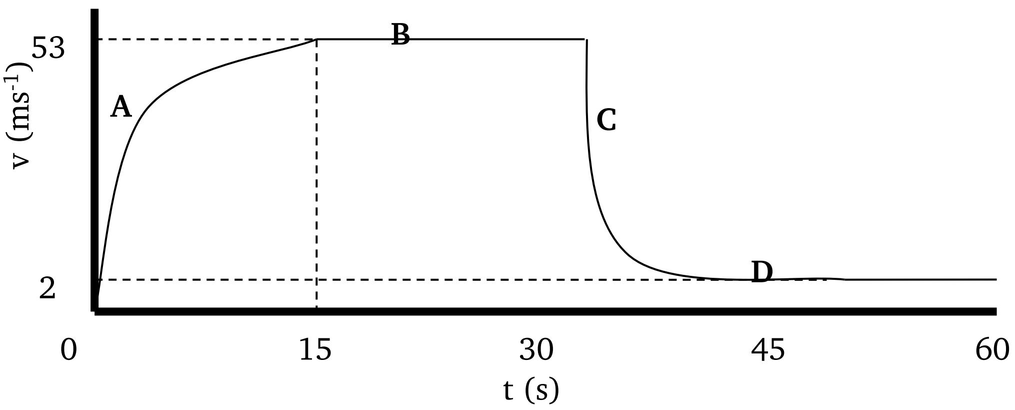
12. Describe and explain, using Newton's Laws, how the following safety features of a car could save your life:

    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.

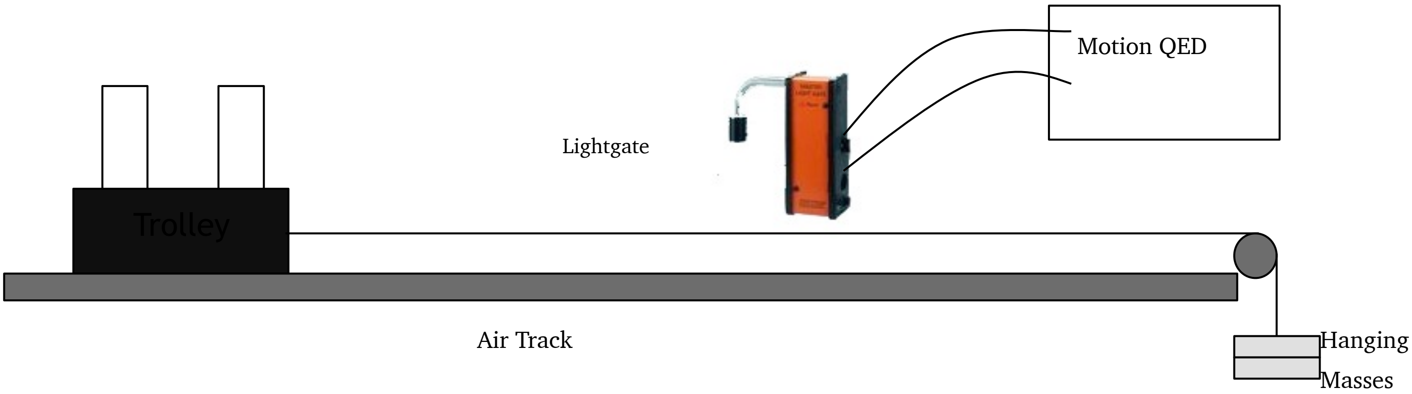
14. Explain the results of these experiments:

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 $18\ \mathrm{m\,s^{-2}}$?

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

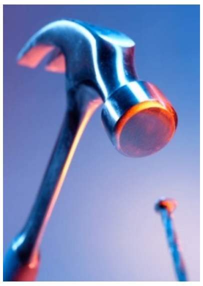
Draw a line graph of these results, and use the gradient of the straight line to calculate the mass of the trolley.

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. Make a diagram showing all of the forces acting in the following situations:

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.

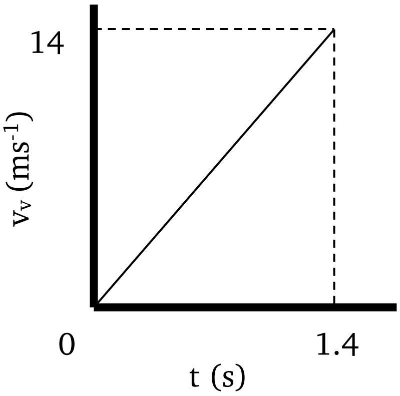
Projectile Motion

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.

a)



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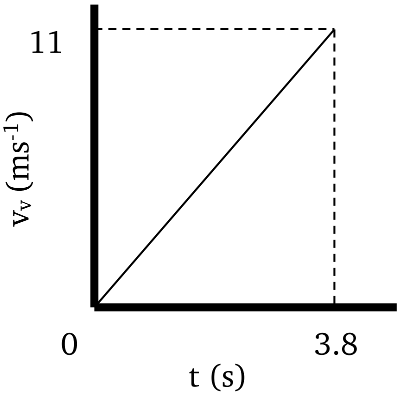
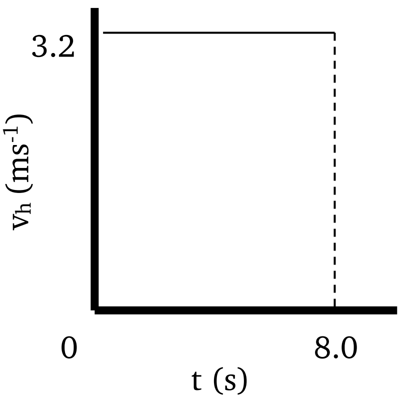


4. These graphs show how horizontal velocity of an object changes with time. In each case, calculate the horizontal displacement of the object.

a)



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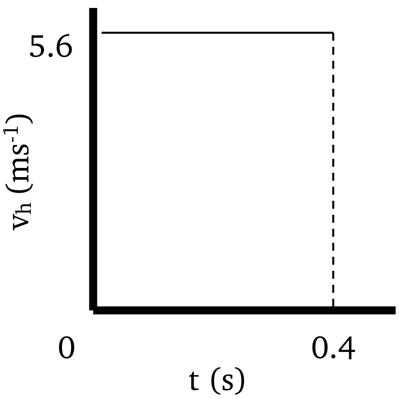

5. A monkey is relaxing in a tree when it sees a hunter climb a nearby tree and take aim with a bow and arrow. The hunter is aiming directly at the head of the monkey. The monkey is smart though. It decides to jump out of the tree at the exact moment the arrow is released from the hunter's bow. Assuming 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 35 $m\,s^{-1}$. 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 75 $m\,s^{-1}$ 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 55 $m\,s^{-1}$ 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.