North Berwick High School

Department of Physics

National 4/5

Unit 1-Dynamics and Space

Section 1 Mechanics

Problems Booklet

DATA SHEET

Speed of light in materials

Material	*Speed* in $m\,s^{-1}$
Air	$3{\cdot}0 \times 10^8$
Carbon dioxide	$3{\cdot}0 \times 10^8$
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	$2{\cdot}1 \times 10^8$
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths

	Gravitational field strength on the surface in $N\,kg^{-1}$
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in $J\,kg^{-1}$
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon Dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Iron	$2{\cdot}67 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in $J\,kg^{-1}$
Alcohol	$11{\cdot}2 \times 10^5$
Carbon Dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials

Material	*Speed* in $m\,s^{-1}$
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	*Specific heat capacity* in $J\,kg^{-1}\,°C^{-1}$
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3

$$s = vt$$

$$d = \overline{v}\,t$$

$$s = \overline{v}\,t$$

$$a = \frac{v-u}{t}$$

$$W = mg$$

$$F = ma$$

$$E_w = Fd$$

$$E_h = ml$$

$$E_h = cm\Delta T$$

$$E_p = mgh$$

$$E_k = \frac{1}{2}mv^2$$

Contents

Speed, distance and time

$$\text{average speed} = \frac{\text{distance}}{\text{time}}$$

where: the average speed of an object is measured in **m s^{-1}**
the distance travelled by an object is measured in **m**
the time taken by an object to travel a distance is measured in **s**

1. A runner completes a 200 m race in 25 s.
   What is his average speed in m/s?

2. A friend asks you to measure his average cycling speed along flat road. Describe which measurements you would take and the measuring instruments you would use.

3. An athlete takes 4 minutes 20 s to complete a 1500 m race. What is the average speed?

4. On a fun run, a competitor runs 10 km in 1 hour. What is her average speed in

   a) km/h b) m/s?

5. Concorde was the fastest passenger aeroplane and could travel at 680 m/s (twice the speed of sound).
   How far would it travel in 25 s at this speed?

6. A girl can walk at an average speed of 2 m/s. How far will she walk in 20 minutes?

7. How long will it take a cyclist to travel 40 km at an average speed of 5 m/s?

8. How long (to the nearest minute) will the Glasgow to London shuttle take if it flies at an average speed of 220 m/s for the 750 km flight?

9. How long, to the nearest minute, will a car take to travel 50 km if its average speed is 20 m/s?

10. Look at this timetable for a train between Glasgow and Edinburgh:

Station	Time	Distance from Glasgow
Glasgow	0800	0 km
Falkirk	0820	34 km
Linlithgow	0828	46 km
Edinburgh	0850	73 km

a) What was the average speed for the whole journey in m/s?
b) What was the average speed in m/s between Glasgow and Falkirk?
c) Explain the difference in average speeds in a) and b).

11. Describe how you would measure the instantaneous speed of a vehicle as it reached the bottom of a slope.

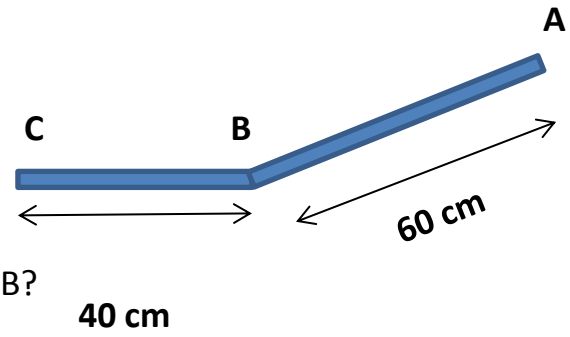
12. In an experiment to measure instantaneous speed, these measurements were obtained:-

Reading on timer = 0.125 s
Length of car = 5 cm

Calculate the instantaneous speed of the vehicle in m/s.

13. A trolley with a 10 cm card attached to it is released from A and runs down the slope, passing through a light gate at B, and stopping at C.

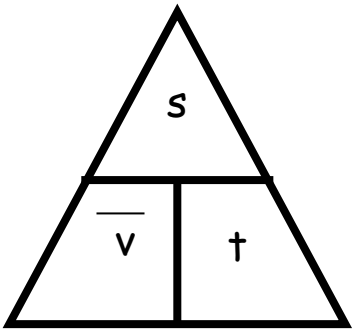
Time from A to B = 0.8 s.
Time on light gate timer = 0.067 s



a) What is the average speed between A and B?
b) What is the instantaneous speed at B?
c) Explain the difference between the two speeds

Velocity and Displacement

$$\bar{v} = \frac{s}{t}$$



where: v is the average velocity of an object (m s^{-1})
s is displacement travelled by an object (m)
t is the time taken by an object to travel a distance (s)

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. Copy and complete this table.

	***Distance* / m**	***Time* / s**	***Speed* / m s^{-1}**
(a)	100	10	
(b)	30	2.5	
(c)	510		17
(d)	72		1.5
(e)		30	12
(f)		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?

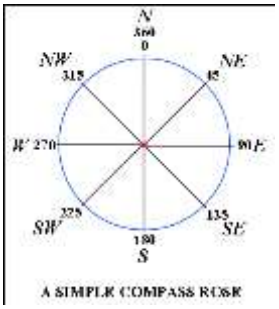
5. An Olympic runner runs one complete lap around an athletics track in a race. The total length of the track is 400 metres and it takes 45 seconds for the runner to complete the race. Calculate the:

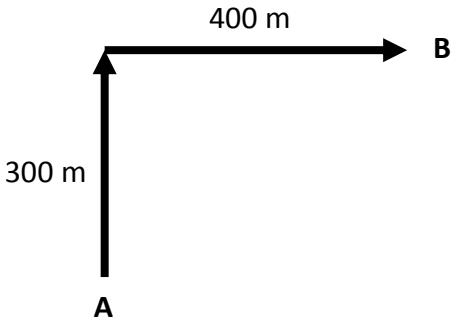
(a) Displacement of the runner at the end of the race.

(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, as shown.





(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 m/s?

(b) What is the average speed of the car, in km/h?

(c) What is the average velocity of the car, in m/s?

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.

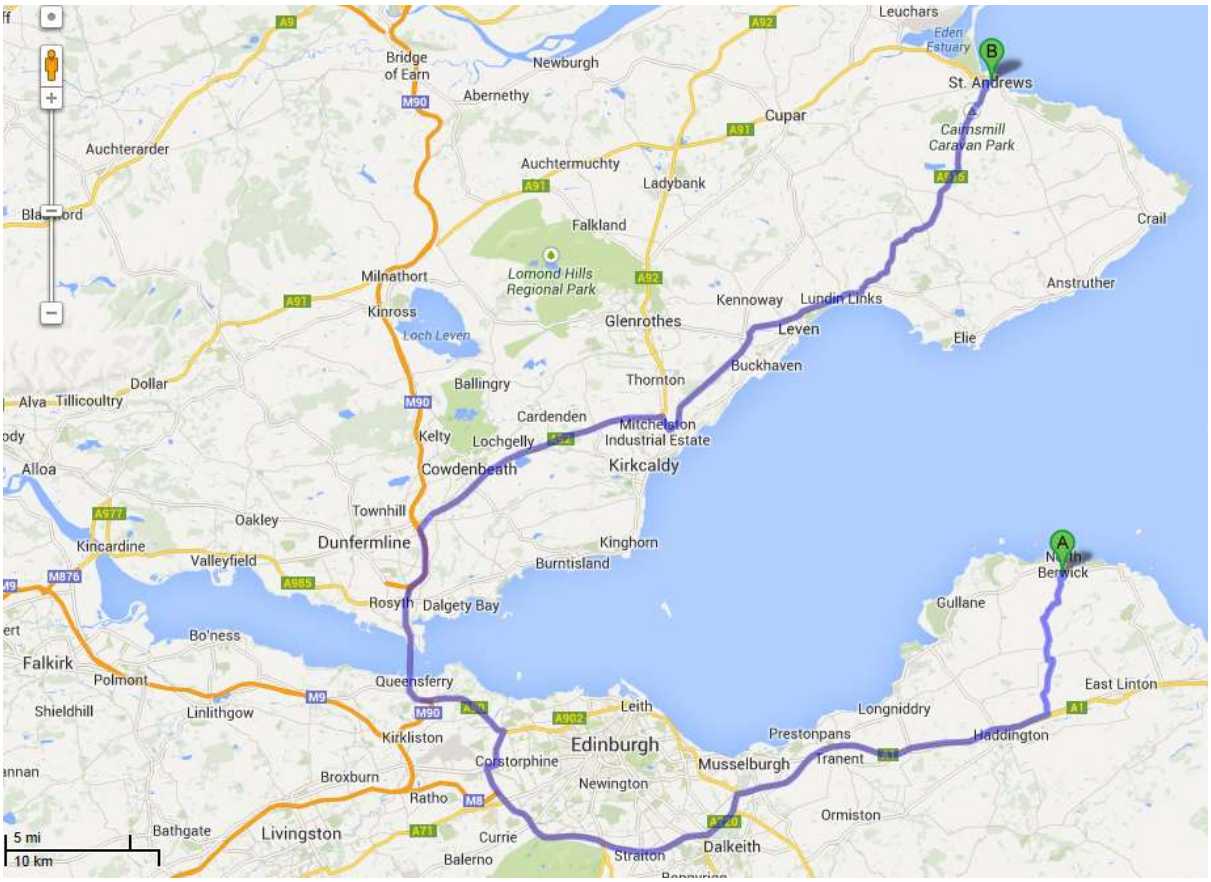
(a) What is the average speed of the lorry, in km/h?

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

9. A car makes a journey from North Berwick to St. Andrews along the route shown. The journey takes 1 hour and 50 minutes. Use the map below to estimate the:

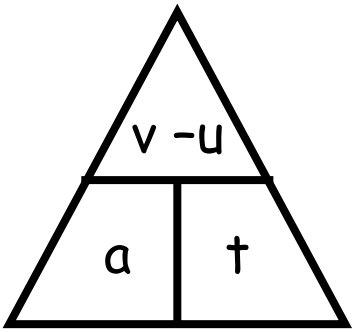
(a) Average speed of the car during the journey.

(b) Average velocity of the car during the journey.



Acceleration

$$a = \frac{v - u}{t}$$



where: a is the acceleration of an object (m s^{-2})
v is the final velocity of an object (m s^{-1})
u is the initial velocity of an object (m s^{-1})
t is the time that an object accelerates for (s)

1. Copy and complete this table .

	***Acceleration* / m s^{-2}**	***Change in Speed* / m s^{-1}**	***Time* / s**
(a)		12	6
(b)		16.5	5.5
(c)	0.5		18
(d)	1.2		30
(e)	0.125	0.50	
(f)	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 15 m s^{-1} in 7.5 seconds?

4. 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}?

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

6. 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?

7. 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?

8. An aeroplane accelerates from 360 km h^{-1} to 396 km h^{-1} in 1 minute and 40 seconds. What is the size of the acceleration of the aeroplane in m s^{-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 is altered and the experiment is repeated. The results of this entire experiment are shown:

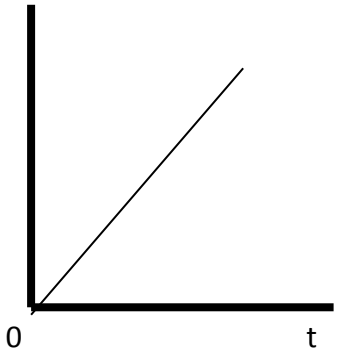
***Time* / s**	***Speed* / m s^{-1}**
0.14	***1.5***
0.29	***3***
0.36	***3.7***
0.44	***4.5***
0.58	***5.8***
0.61	***6.2***

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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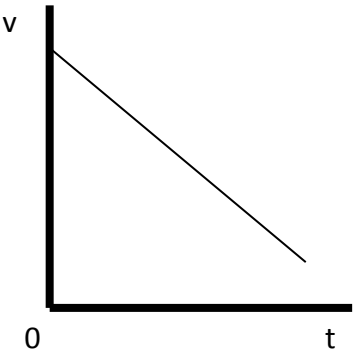

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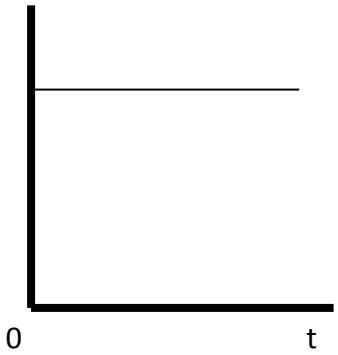

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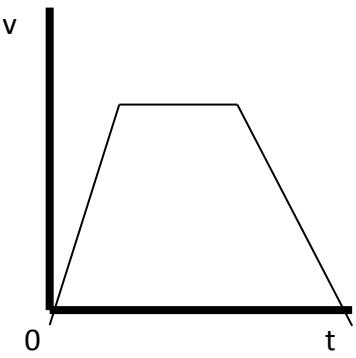


2. Plot a velocity-time graph from each of these sets of data.

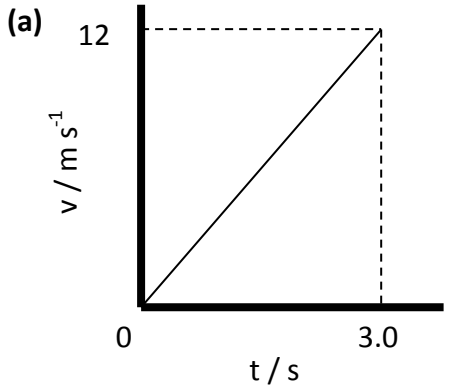
(a)

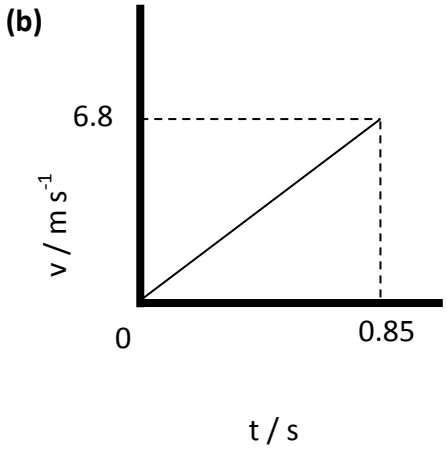
Time / s	*Speed / m s^{-1}*
0	0
1	1.5
2	3.0
3	4.5
4	6.0
5	7.5

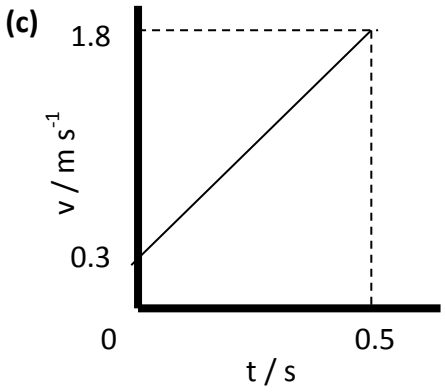
(b)

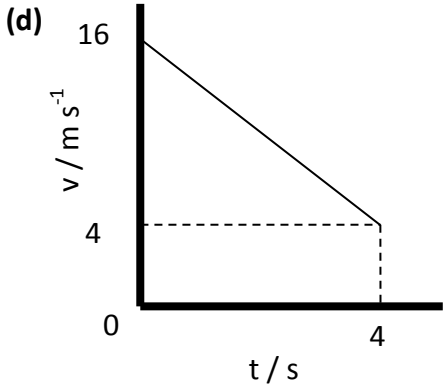
Time / s	*Speed / m s^{-1}*
0	10
0.5	8.75
1	7.5
1.5	6.25
2	5.0
2.5	3.75

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

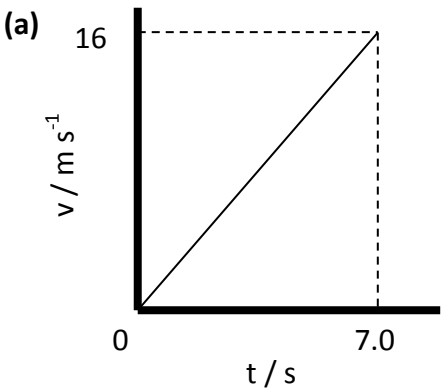


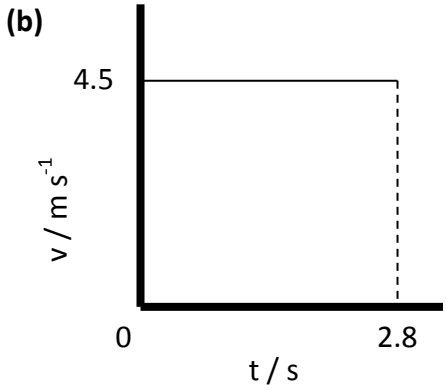




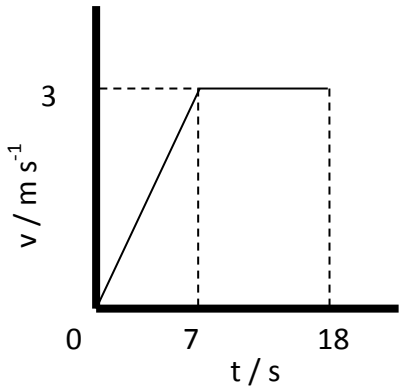


4. Calculate the magnitude of the displacement of the vehicles represented by these velocity-time graphs.





(c)



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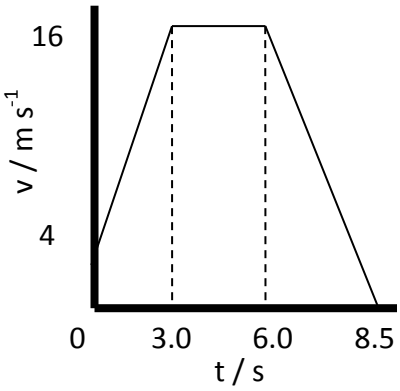
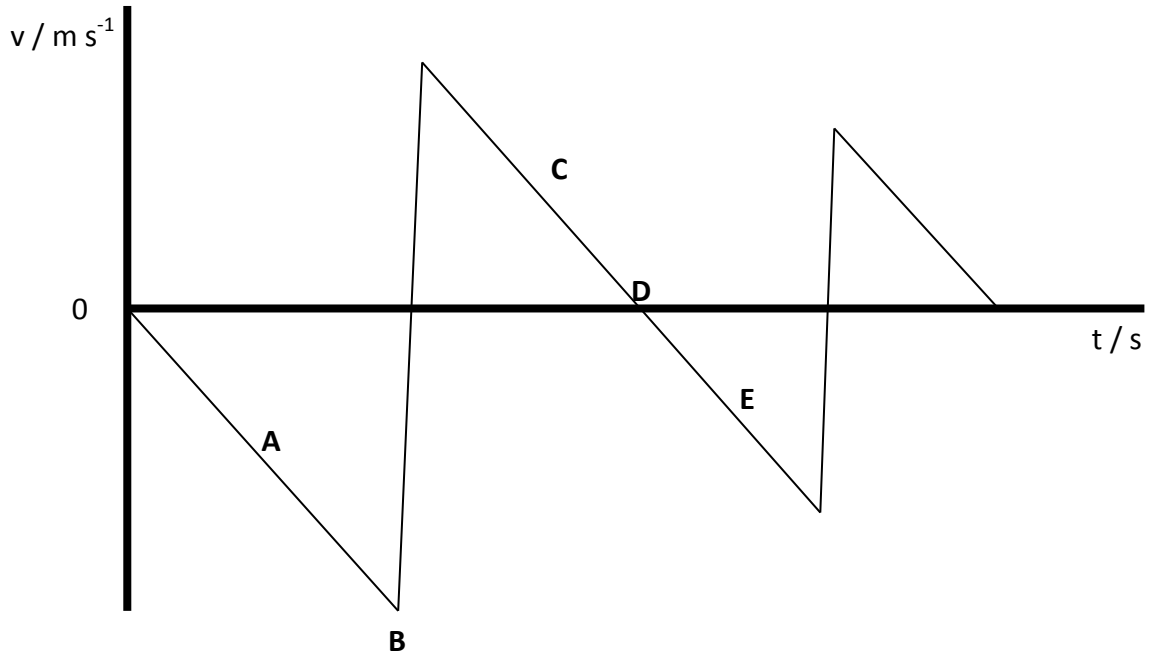


5. A ball is bounced off a surface. The velocity-time graph of the ball is shown.



(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.

Answers

Speed, distance & time

1. 8 ms^{-1}

3. 5.8 ms^{-1}

4. **(a)** 10 km/h
(b) 2.8 ms^{-1}

5. 17 000 m

6. 2400 m

7. 8000 s
(2 h 13 min)

9

8. 57 min

9. 42 min

10. **(a)** 24.3 ms^{-1}
(b) 28.3 ms^{-1}

12. 0.4 m/s

13. **(a)** 0.75 ms^{-1}
(b) 1.5 ms^{-1}

Velocity & Displacement

1. *Scalar* quantities have a magnitude only.
Vector quantities have a magnitude and direction.

2. *Scalars*: Speed, Distance, Mass, Time, Energy.
Vectors: Force, Velocity, Displacement, Acceleration

3. **(a)** 10 m s^{-1}
(b) 12 m s^{-1}
(c) 30 s
(d) 48 s
(e) 360 m
(f) 7.5 m

4. **(a)** 40 m
(b) 10m west
(a) 0.8 m s^{-1}
(b) 0.2 m s^{-1} west

5. **(a)** 0 m
(b) 8.89 m s^{-1}
(c) 0 m s^{-1}

6. **(a)** 700 m
(b) 500 m (053°)
(c) 0.78 m s^{-1}
(d) 0.56 m s^{-1} (053°)

7. **(a)** 18.3 m s^{-1}
(b) 66 km h^{-1}
(c) 13.0 m s^{-1} (140°)

8. **(a)** 85.0 km h^{-1}
(b) 46.1 km h^{-1} (283°)

9. **(a)** 20 m s^{-1}
(b) 5 m s^{-1} (350°)

Acceleration

1. (a) 2 m s^{-2}
(b) 3 m s^{-2}
(c) 9 m s^{-1}
(d) 36 m s^{-1}
(e) 4 s
(f) 4.2 s

2. 2 m s^{-2}

3. 1.6 m s^{-2}

4. 22.5 s

5. 9.9 m s^{-1}

6. 2.8 m s^{-1}

7. -15 m s^{-2}

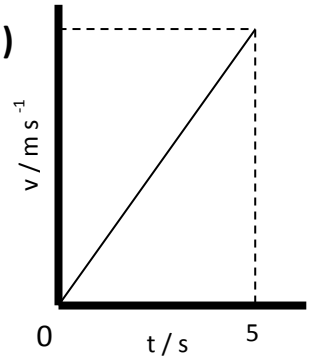
8. 0.36 m s^{-2}

9. 9.8 m s^{-2}

Velocity-Time Graphs

1. (a) Uniform acceleration
(b) Uniform deceleration
(c) Constant speed / zero acceleration
(d) Accelerates uniformly from rest. Stays at a constant speed. Decelerates uniformly until it has stopped.

2. (a)



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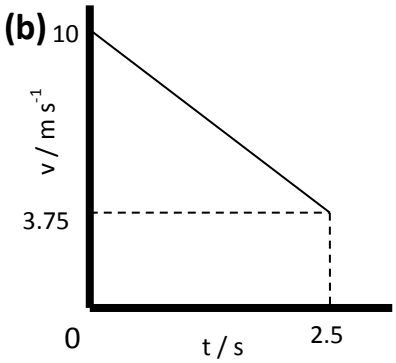

3. (a) 4 m s^{-2}
(b) 8 m s^{-2}
(c) 3 m s^{-2}
(d) -3 m s^{-2}

4. (a) 56 m
(b) 12.6 m
(c) 43.5 m
(d) 118 m

5. (a) A – ball is accelerating down towards ground.
B – ball is bouncing on ground.
C – ball is decelerating upwards.
D – ball reaches highest point.
E – ball is accelerating down towards ground.

(b) The ball is losing energy

(c)