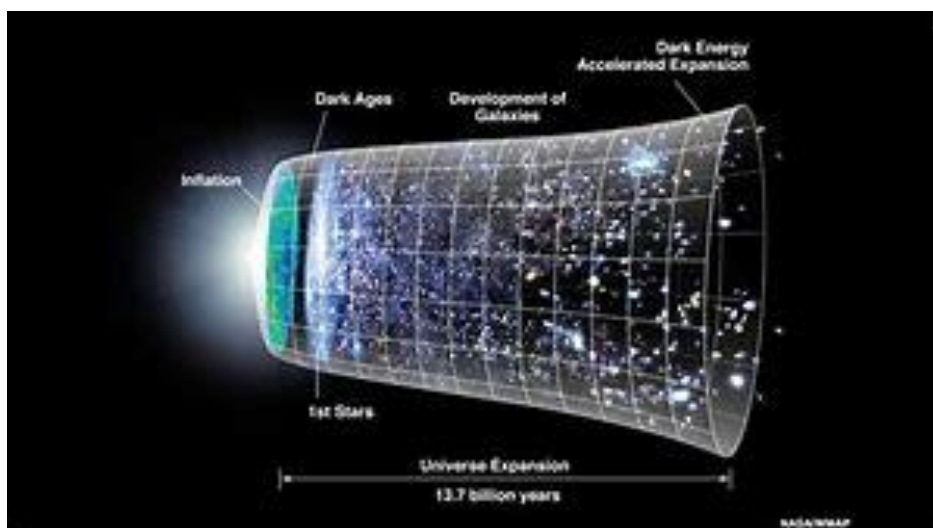


CfE Higher Physics

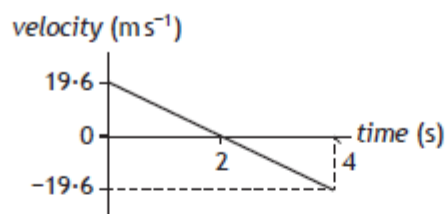
Our Dynamic Universe

2015 to 2018 Past papers

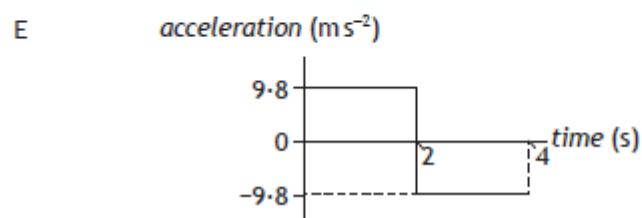
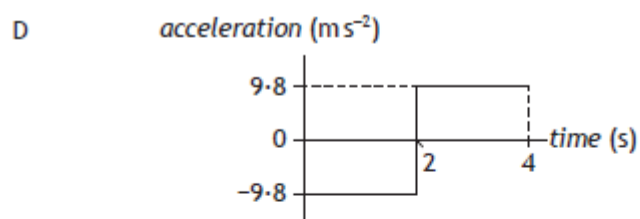
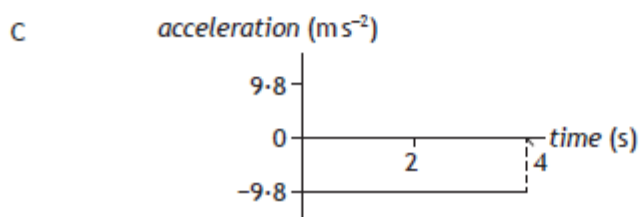
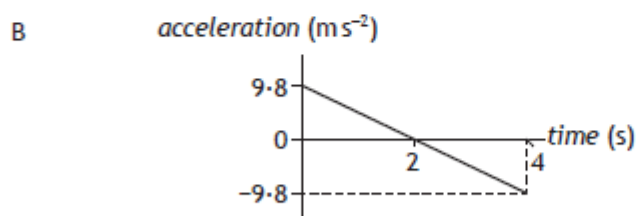
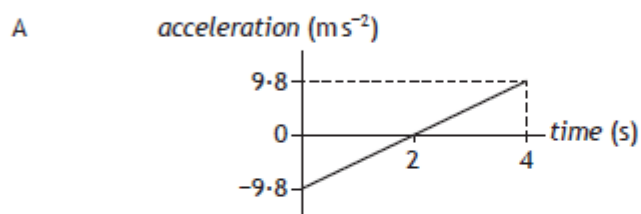


1.

The following velocity-time graph represents the vertical motion of a ball.



Which of the following acceleration-time graphs represents the same motion?



2

A car is travelling at 12 ms^{-1} along a straight road. The car now accelerates uniformly at -1.5 ms^{-2} for 6.0 s .

The distance travelled during this time is

- A 18 m
- B 45 m
- C 68 m
- D 72 m
- E 99 m.

3

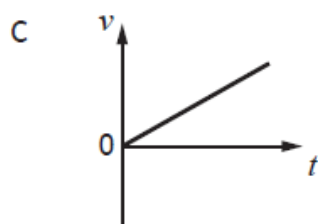
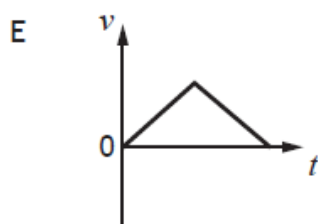
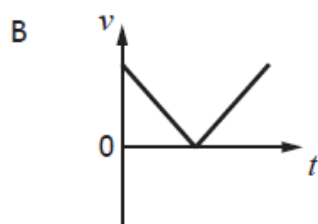
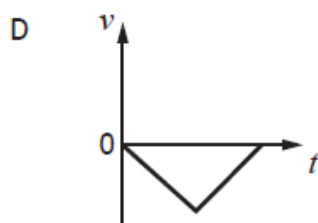
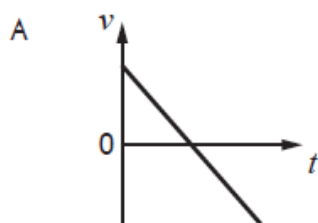
A car accelerates uniformly from rest. The car travels a distance of 60 m in 6.0 s . The acceleration of the car is

- A 0.83 ms^{-2}
- B 3.3 ms^{-2}
- C 5.0 ms^{-2}
- D 10 ms^{-2}
- E 20 ms^{-2} .

4

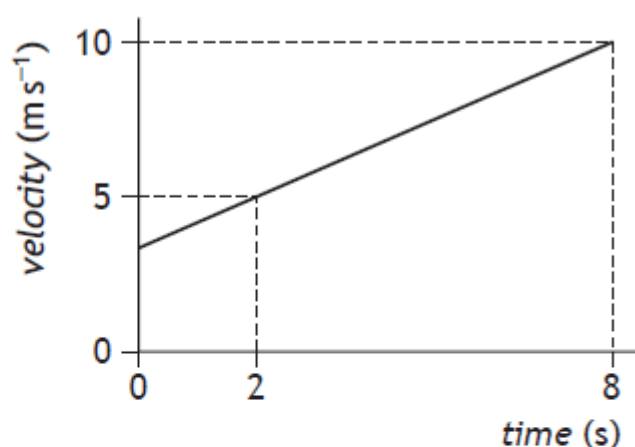
A ball is thrown vertically upwards and falls back to Earth.

Neglecting air resistance, which velocity-time graph represents its motion?



5

The graph shows how the velocity of an object varies with time.



The acceleration of the object is

- A 0.83 m s^{-2}
- B 1.2 m s^{-2}
- C 2.5 m s^{-2}
- D 5.0 m s^{-2}
- E 6.0 m s^{-2} .

6

A car is moving at a speed of 2.0 m s^{-1} .

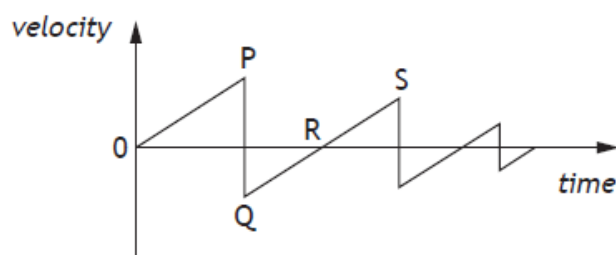
The car now accelerates at 4.0 m s^{-2} until it reaches a speed of 14 m s^{-1} .

The distance travelled by the car during this acceleration is

- A 1.5 m
- B 18 m
- C 24 m
- D 25 m
- E 48 m.

7

A ball is dropped from rest and allowed to bounce several times.
The graph shows how the velocity of the ball varies with time.



A student makes the following statements about the ball.

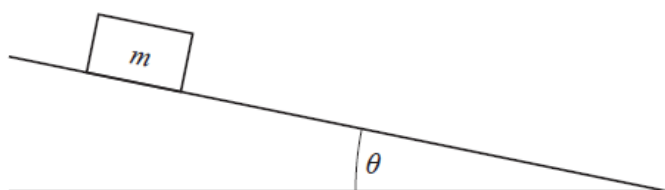
- I The ball hits the ground at P.
- II The ball is moving upwards between Q and R.
- III The ball is moving upwards between R and S.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and II only
- E I and III only

8

A box of mass m rests on a slope as shown.



Which row in the table shows the component of the weight acting down the slope and the component of the weight acting normal to the slope?

	<i>Component of weight acting down the slope</i>	<i>Component of weight acting normal to the slope</i>
A	$mg \sin \theta$	$mg \cos \theta$
B	$mg \tan \theta$	$mg \sin \theta$
C	$mg \cos \theta$	$mg \sin \theta$
D	$mg \cos \theta$	$mg \tan \theta$
E	$mg \sin \theta$	$mg \tan \theta$

9

A person stands on bathroom scales in a lift.

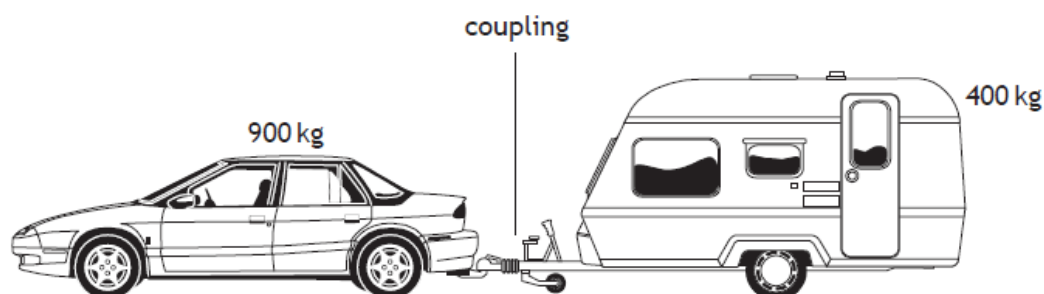
The scales show a reading greater than the person's weight.

The lift is moving

- A upwards with constant speed
- B downwards with constant speed
- C downwards with increasing speed
- D downwards with decreasing speed
- E upwards with decreasing speed.

10

A car of mass 900 kg pulls a caravan of mass 400 kg along a straight, horizontal road with an acceleration of 2.0 m s^{-2} .



Assuming that the frictional forces on the caravan are negligible, the tension in the coupling between the car and the caravan is

- A 400 N
- B 500 N
- C 800 N
- D 1800 N
- E 2600 N.

11

Water flows at a rate of $6.25 \times 10^8 \text{ kg}$ per minute over a waterfall.

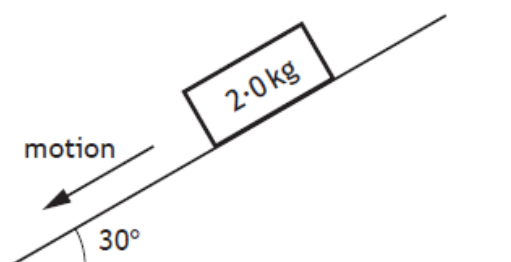
The height of the waterfall is 108 m.

The total power delivered by the water in falling through the 108 m is

- A $1.13 \times 10^9 \text{ W}$
- B $1.10 \times 10^{10} \text{ W}$
- C $6.62 \times 10^{11} \text{ W}$
- D $4.05 \times 10^{12} \text{ W}$
- E $3.97 \times 10^{13} \text{ W}.$

12

A block of wood slides with a constant velocity down a slope. The slope makes an angle of 30° with the horizontal as shown. The mass of the block is 2.0 kg .



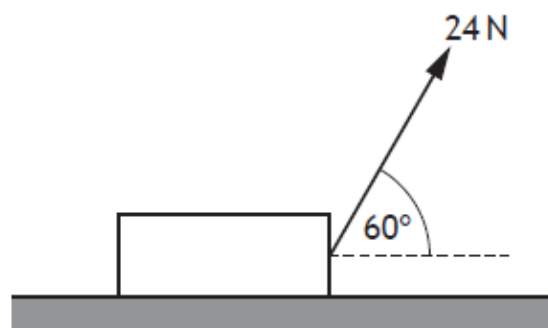
The magnitude of the force of friction acting on the block is

- A 1.0 N
- B 1.7 N
- C 9.8 N
- D 17.0 N
- E 19.6 N .

13

A block is resting on a horizontal surface.

A force of 24 N is now applied as shown and the block slides along the surface.



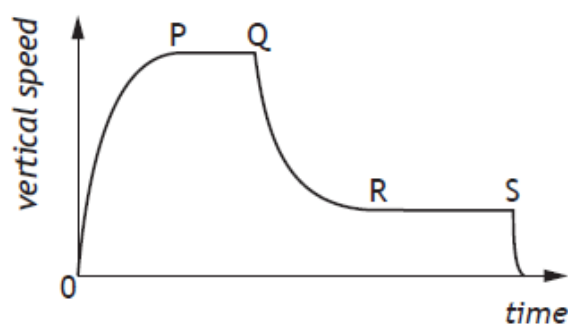
The mass of the block is 20 kg .

The acceleration of the block is 0.20 m s^{-2} .

The force of friction acting on the block is

- A 4.0 N
- B 8.0 N
- C 12 N
- D 16 N
- E 25 N .

The graph shows how the vertical speed of a skydiver varies with time.



A student uses information from the graph to make the following statements.

- I The acceleration of the skydiver is greatest between P and Q.
- II The air resistance acting on the skydiver between Q and R is less than the weight of the skydiver.
- III The forces acting on the skydiver are balanced between R and S.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and II only
- E I, II and III

A block of mass 6.0 kg and a block of mass 8.0 kg are connected by a string.

A force of 32 N is applied to the blocks as shown.



A frictional force of 4.0 N acts on each block.

The acceleration of the 6.0 kg block is

- A 1.7 m s^{-2}
- B 2.0 m s^{-2}
- C 2.3 m s^{-2}
- D 2.9 m s^{-2}
- E 5.3 m s^{-2} .

16

A person stands on a weighing machine in a lift. When the lift is at rest, the reading on the weighing machine is 700 N.

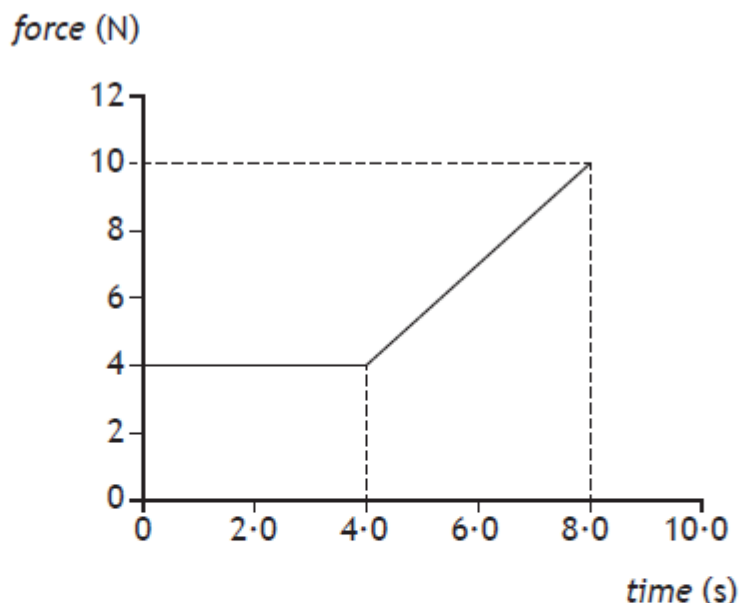
The lift now descends and its speed increases at a constant rate.

The reading on the weighing machine

- A is a constant value higher than 700 N
- B is a constant value lower than 700 N
- C continually increases from 700 N
- D continually decreases from 700 N
- E remains constant at 700 N.

17

The graph shows the force which acts on an object over a time interval of 8.0 seconds.



The momentum gained by the object during this 8.0 seconds is

- A 12 kg m s^{-1}
- B 32 kg m s^{-1}
- C 44 kg m s^{-1}
- D 52 kg m s^{-1}
- E 72 kg m s^{-1} .

18

A planet orbits a star at a distance of 3.0×10^9 m.

The star exerts a gravitational force of 1.6×10^{27} N on the planet.

The mass of the star is 6.0×10^{30} kg.

The mass of the planet is

- A 2.4×10^{14} kg
- B 1.2×10^{16} kg
- C 3.6×10^{25} kg
- D 1.6×10^{26} kg
- E 2.4×10^{37} kg.

19

Enceladus is a moon of Saturn. The mass of Enceladus is 1.08×10^{20} kg.

The mass of Saturn is 5.68×10^{26} kg.

The gravitational force of attraction between Enceladus and Saturn is 7.24×10^{19} N.

The orbital radius of Enceladus around Saturn is

- A 2.38×10^8 m
- B 9.11×10^{13} m
- C 5.65×10^{16} m
- D 8.30×10^{27} m
- E 3.19×10^{33} m.

20

A spacecraft is travelling at a constant speed of $0.60c$ relative to the Moon.

An observer on the Moon measures the length of the moving spacecraft to be 190 m.

The length of the spacecraft as measured by an astronaut on the spacecraft is

- A 120 m
- B 152 m
- C 238 m
- D 297 m
- E 300 m.

21

A spacecraft is travelling at a constant speed of $2.75 \times 10^8 \text{ m s}^{-1}$ relative to a planet. A technician on the spacecraft measures the length of the spacecraft as 125 m. An observer on the planet measures the length of the spacecraft as

- A 36 m
- B 50 m
- C 124 m
- D 314 m
- E 433 m.

22

A galaxy has a recessional velocity of $0.30c$. Hubble's Law predicts that the distance between Earth and this galaxy is

- A $1.3 \times 10^{17} \text{ m}$
- B $3.9 \times 10^{25} \text{ m}$
- C $1.3 \times 10^{26} \text{ m}$
- D $1.4 \times 10^{41} \text{ m}$
- E $4.5 \times 10^{42} \text{ m}$.

23

A spacecraft is travelling at $0.10c$ relative to a star. An observer on the spacecraft measures the speed of light emitted by the star to be

- A $0.90c$
- B $0.99c$
- C $1.00c$
- D $1.01c$
- E $1.10c$.

24

A spacecraft is travelling at a speed of $0.200c$ relative to the Earth.

The spacecraft emits a signal for 20.0 seconds as measured in the frame of reference of the spacecraft.

An observer on Earth measures the duration of the signal as

- A 19.2 s
- B 19.6 s
- C 20.0 s
- D 20.4 s
- E 20.8 s.

25

A siren on an ambulance emits sound at a constant frequency of 750 Hz.

The ambulance is travelling at a constant speed of 25.0 m s^{-1} towards a stationary observer.

The speed of sound in air is 340 m s^{-1} .

The frequency of the sound heard by the observer is

- A 695 Hz
- B 699 Hz
- C 750 Hz
- D 805 Hz
- E 810 Hz.

26

A car horn emits a sound with a constant frequency of 405 Hz.

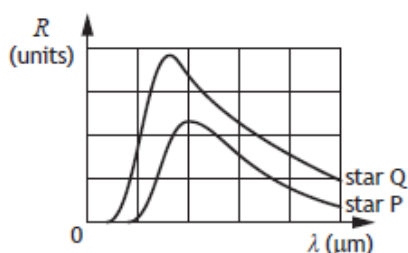
The car is travelling away from a student at 28.0 m s^{-1} .

The speed of sound in air is 335 m s^{-1} .

The frequency of the sound from the horn heard by the student is

- A 371 Hz
- B 374 Hz
- C 405 Hz
- D 439 Hz
- E 442 Hz.

The graphs show how the radiation per unit surface area, R , varies with the wavelength, λ , of the emitted radiation for two stars, P and Q.



A student makes the following conclusions based on the information in the graph.

- I Star P is hotter than star Q.
- II Star P emits more radiation per unit surface area than star Q.
- III The peak intensity of the radiation from star Q is at a shorter wavelength than that from star P.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and II only
- E II and III only

Measurements of the expansion rate of the Universe lead to the conclusion that the rate of expansion is increasing.

Present theory proposes that this is due to

- A redshift
- B dark matter
- C dark energy
- D the gravitational force
- E cosmic microwave background radiation.

A student makes the following statements about the radiation emitted by stellar objects.

- I Stellar objects emit radiation over a wide range of frequencies.
- II The peak wavelength of radiation is longer for hotter objects than for cooler objects.
- III At all frequencies, hotter objects emit more radiation per unit surface area per unit time than cooler objects.

Which of these statements is/are correct?

- A I only
- B III only
- C I and II only
- D I and III only
- E I, II and III

The upward lift force L on the wings of an aircraft is calculated using the relationship

$$L = \frac{1}{2} \rho v^2 A C_L$$

where:

ρ is the density of air

v is the speed of the wings through the air

A is the area of the wings

C_L is the coefficient of lift.

The weight of a model aircraft is 80.0 N .

The area of the wings on the model aircraft is 3.0 m^2 .

The coefficient of lift for these wings is 1.6 .

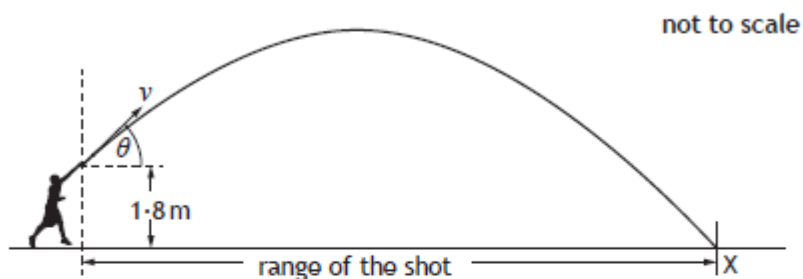
The density of air is 1.29 kg m^{-3}

The speed required for the model aircraft to maintain a level flight is

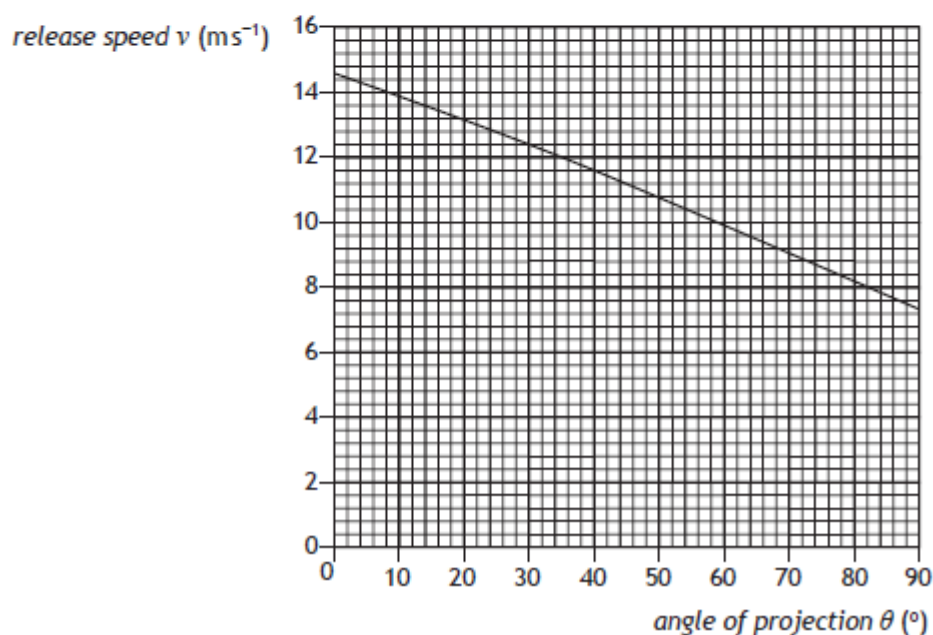
- A 2.5 m s^{-1}
- B 3.6 m s^{-1}
- C 5.1 m s^{-1}
- D 12.9 m s^{-1}
- E 25.8 m s^{-1} .

1	C	11	B	21	B
2	B	12	C	22	B
3	B	13	B	23	C
4	A	14	C	24	D
5	A	15	A	25	E
6	C	16	B	26	B
7	D	17	C	27	C
8	A	18	C	28	C
9	D	19	A	29	D
10	C	20	C	30	C

The shot put is an athletics event in which competitors “throw” a shot as far as possible. The shot is a metal ball of mass 4.0 kg. One of the competitors releases the shot at a height of 1.8 m above the ground and at an angle θ to the horizontal. The shot travels through the air and hits the ground at X. The effects of air resistance are negligible.



The graph shows how the release speed of the shot v varies with the angle of projection θ .



(a) The angle of projection for a particular throw is 40°.

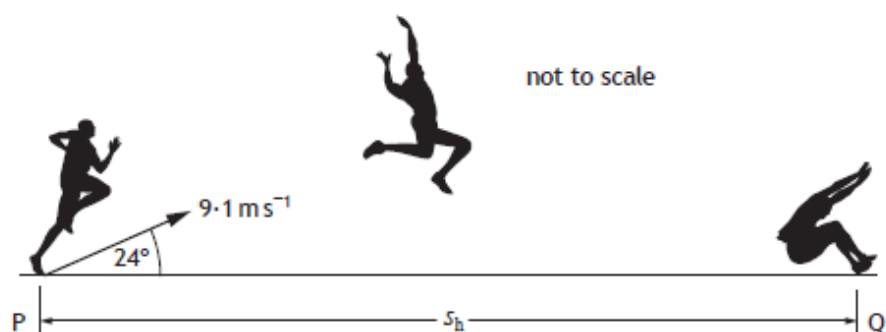
(i) (A) State the release speed of the shot at this angle. 1

(B) Calculate the horizontal component of the initial velocity of the shot. 1

(C) Calculate the vertical component of the initial velocity of the shot. 1

- (ii) The maximum height reached by the shot is 4.7 m above the ground. The time between release and reaching this height is 0.76 s.
- (A) Calculate the total time between the shot being released and hitting the ground at X. 4
- (a) (ii) (continued)
- (B) Calculate the range of the shot for this throw. 3
- (b) Using information from the graph, explain the effect of increasing the angle of projection on the kinetic energy of the shot at release. 2

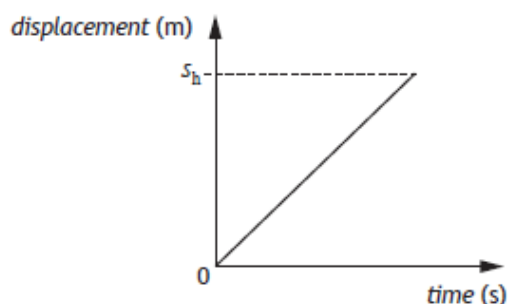
2



An athlete takes part in a long jump competition. The athlete takes off from point P with an initial velocity of 9.1 m s^{-1} at an angle of 24° to the horizontal and lands at point Q.

- (a) Calculate:
- (i) the vertical component of the initial velocity of the athlete; 1
- (ii) the horizontal component of the initial velocity of the athlete. 1
- (b) Show that the time taken for the athlete to travel from P to Q is 0.76 s. 2
- (c) Calculate the horizontal displacement s_h between points P and Q. 3

- (d) The graph shows how the horizontal displacement of the athlete varies with time for this jump when air resistance is ignored.

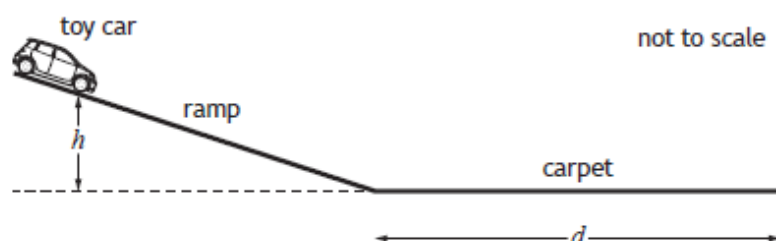


Add a line to the graph to show how the horizontal displacement of the athlete varies with time when air resistance is taken into account.

2

3

A student uses the apparatus shown to investigate the force of friction between the wheels of a toy car and a carpet.



The toy car is released from rest, from a height h . It then travels down the ramp and along the carpet before coming to rest. The student measures the distance d that the car travels along the carpet.

The student repeats the procedure several times and records the following measurements and uncertainties.

Mass of car, m : (0.20 ± 0.01) kg

Height, h : (0.40 ± 0.005) m

Distance, d : 1.31 m 1.40 m 1.38 m 1.41 m 1.35 m

- (a) (i) Calculate the mean distance d travelled by the car. 1
- (ii) Calculate the approximate random uncertainty in this value. 2
- (b) Determine which of the quantities; mass m , height h or mean distance d , has the largest percentage uncertainty. 4
- You must justify your answer by calculation.
- (c) (i) Calculate the potential energy of the toy car at height h . 3
- An uncertainty in this value is not required.
- (ii) Calculate the average force of friction acting between the toy car and carpet, as the car comes to rest. 3
- An uncertainty in this value is not required.
- (iii) State one assumption you have made in (c) (ii). 1

4

During a school funfair, a student throws a wet sponge at a teacher. The sponge is thrown with an initial velocity of 7.4 m s^{-1} at an angle of 30° to the horizontal.

The sponge leaves the student's hand at a height of 1.5 m above the ground.



The sponge hits the teacher.

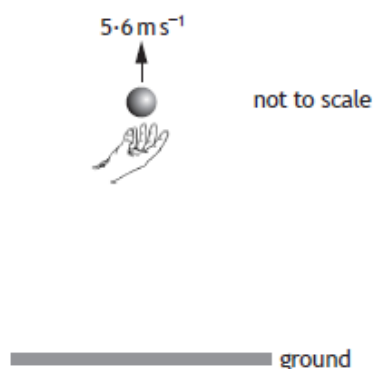
The effects of air resistance can be ignored.

- (a) (i) Calculate:
- (A) the horizontal component of the initial velocity of the sponge; 1
- (B) the vertical component of the initial velocity of the sponge. 1
- (ii) Calculate the time taken for the sponge to reach its maximum height. 3
- (iii) The sponge takes a further 0.45 s to travel from its maximum height until it hits the teacher.
- Determine the height h above the ground at which the sponge hits the teacher. 4
- (b) The student throwing the sponge makes the following statement.
- "If the sponge is thrown with a higher speed at the same angle from the same height then it would take a shorter time to hit the teacher in the same place."*
- Explain why the student's statement is incorrect. 2

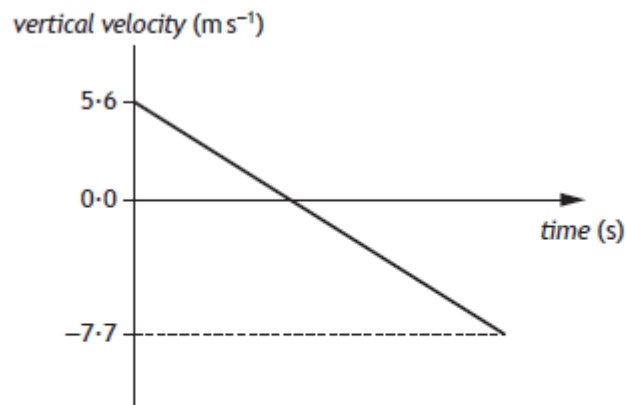
5

A ball is thrown vertically upwards.

The ball is above the ground when released.



The graph shows how the vertical velocity of the ball varies with time from the instant it is released until just before it hits the ground.



The effects of air resistance can be ignored.

- (a) (i) Calculate the time taken for the ball to reach its maximum height. 3

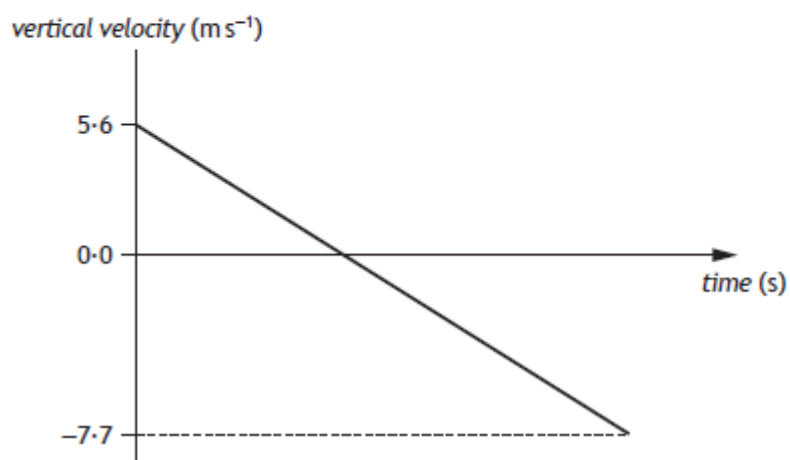
- (ii) Calculate the distance the ball falls from its maximum height to the ground. 3

- (b) The ball is now thrown vertically upwards from the same height with a greater initial vertical velocity.

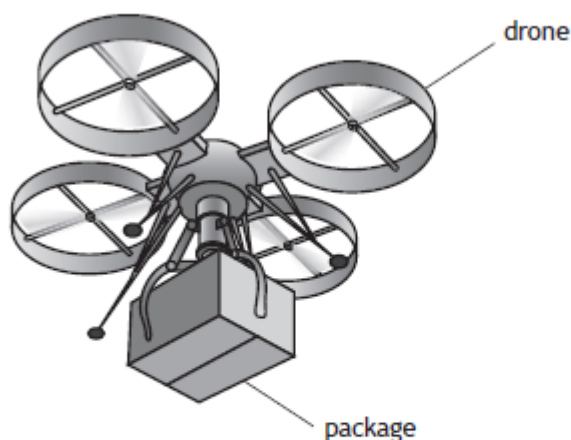
Add a line to the graph below to show how the vertical velocity of the ball varies with time from the instant it is released until just before it hits the ground.

The effects of air resistance can be ignored.

Additional numerical values on the axes are not required. 3



An internet shopping company is planning to use drones to deliver packages.



- (a) During a test the drone is hovering at a constant height above the ground.

The mass of the drone is 5.50 kg .

The mass of the package is 1.25 kg .

- (i) Determine the upward force produced by the drone.

3

- (ii) The package is now lowered using a motor and a cable.

A battery supplies 12 V across the motor. The resistance of the motor is $9.6\ \Omega$.

Calculate the power dissipated by the motor.

3

- (iii) While the package is being lowered the cable breaks.

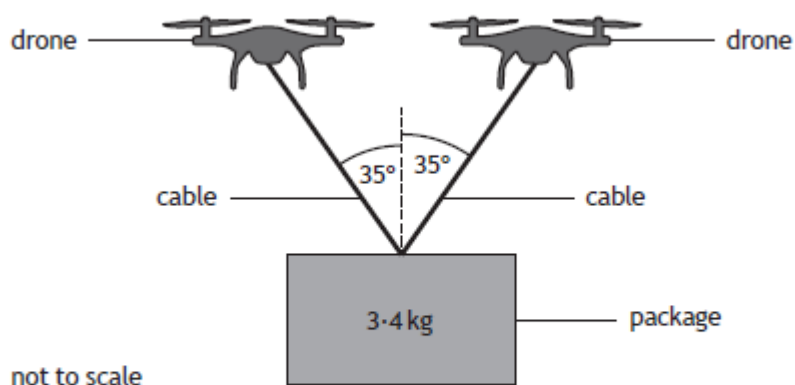
The upward force produced by the drone remains constant.

Describe the vertical motion of the drone immediately after the cable breaks.

2

Justify your answer.

(b) To carry a package with a greater mass two drones are used as shown.

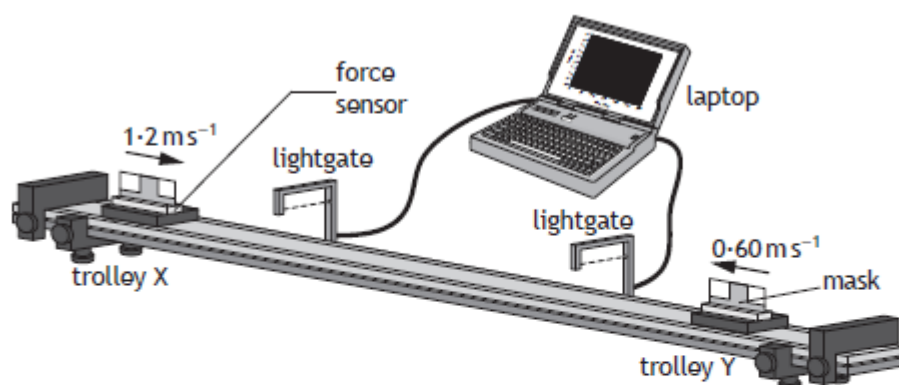


The drones are hovering at a constant height above the ground.
The mass of the package suspended from the two drones is 3.4 kg .
Determine the tension in each cable.

4

7

A student sets up an experiment to investigate collisions between two trolleys on a long, horizontal track.



The mass of trolley X is 0.25 kg and the mass of trolley Y is 0.45 kg .

The effects of friction are negligible.

In one experiment, trolley X is moving at 1.2 m s^{-1} to the right and trolley Y is moving at 0.60 m s^{-1} to the left.

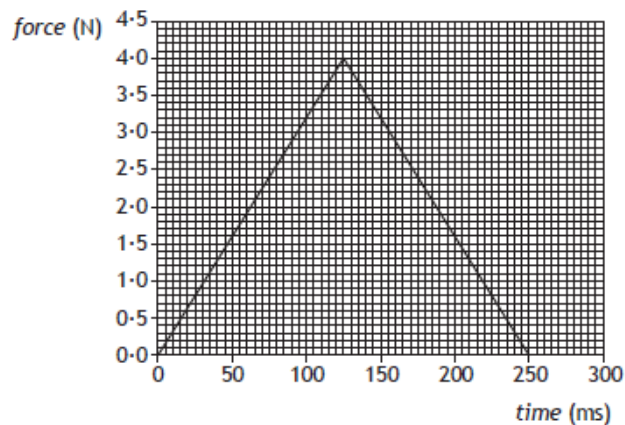
The trolleys collide and do not stick together. After the collision, trolley X rebounds with a velocity of 0.80 m s^{-1} to the left.

(a) Determine the velocity of trolley Y after the collision.

3

- (b) The force sensor measures the force acting on trolley Y during the collision.

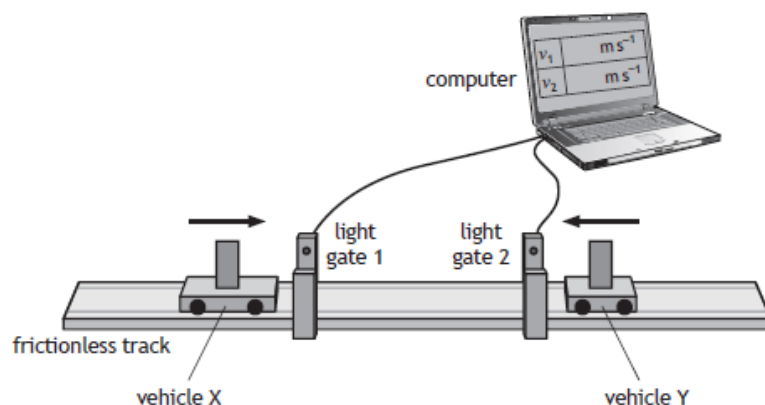
The laptop displays the following force-time graph for the collision.



- (i) Determine the magnitude of the impulse on trolley Y. 3
- (ii) Determine the magnitude of the change in momentum of trolley X. 1
- (iii) Sketch a velocity-time graph to show how the velocity of trolley X varies from 0.50 s before the collision to 0.50 s after the collision. 3
- Numerical values are required on both axes.

8

The following apparatus is set up to investigate the law of conservation of linear momentum.



In one experiment, vehicle X is travelling to the right along the track and vehicle Y is travelling to the left along the track.

The vehicles collide and stick together.

The computer displays the speeds of each vehicle before the collision.

The following data are recorded:

Mass of vehicle X = 0.85 kg

Mass of vehicle Y = 0.25 kg

Speed of vehicle X before the collision = 0.55 m s⁻¹

Speed of vehicle Y before the collision = 0.30 m s⁻¹

- (a) State the law of conservation of linear momentum. 1
- (b) Calculate the velocity of the vehicles immediately after the collision. 3
- (c) Show by calculation that the collision is inelastic. 4

A white snooker ball and a black snooker ball travel towards each other in a straight line.

The white ball and the black ball each have a mass of 0.180 kg .

Just before the balls collide head-on, the white ball is travelling at 2.60 m s^{-1} to the right and the black ball is travelling at 1.80 m s^{-1} to the left.



After the collision, the black ball rebounds with a velocity of 2.38 m s^{-1} to the right.

- (a) (i) Determine the velocity of the white ball immediately after the collision.

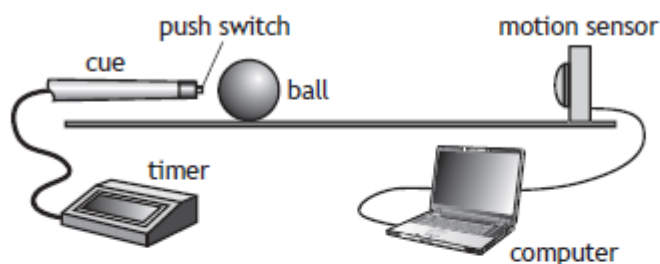
3

- (ii) The collision between the balls is inelastic.

State what is meant by an *inelastic collision*.

1

- (b) A student carries out an experiment to measure the average force exerted by a cue on a ball.



The cue hits the stationary ball.

The timer records the time the cue is in contact with the ball.

The computer displays the speed of the ball.

The results are shown.

Time of contact between the cue and the ball = $(0.040 \pm 0.001) \text{ s}$

Speed of the ball immediately after contact = $(0.84 \pm 0.01) \text{ m s}^{-1}$

Mass of the ball = $(0.180 \pm 0.001) \text{ kg}$

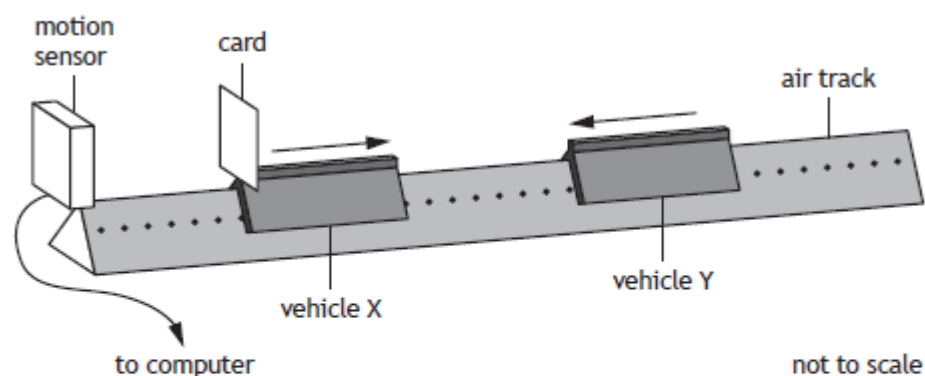
- (i) Calculate the average force exerted on the ball by the cue.
An uncertainty in this value is not required.

3

- (ii) Determine the percentage uncertainty in the value for the average force on the ball.

2

A student sets up an experiment to investigate a collision between two vehicles on a frictionless air track.

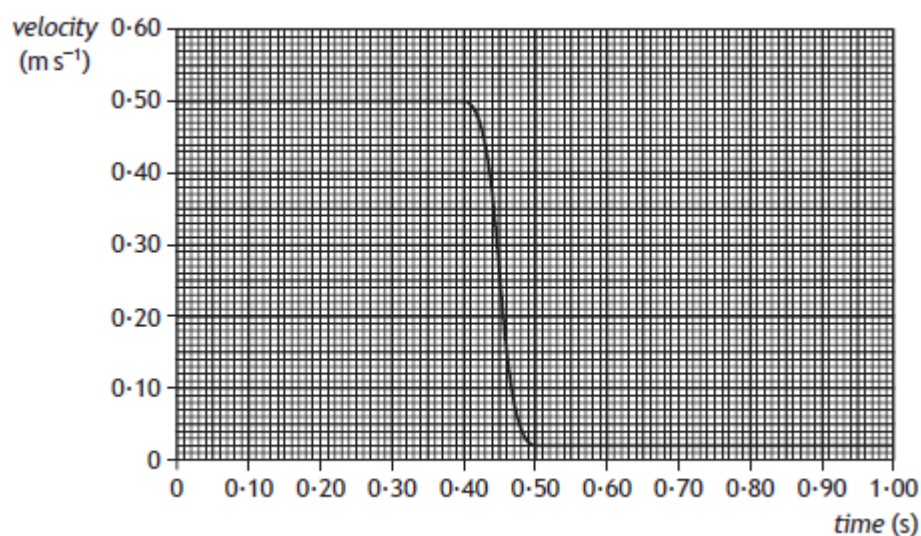


Vehicle X of mass 0.75 kg is travelling to the right along the track.

Vehicle Y of mass 0.50 kg is travelling to the left along the track with a speed of 0.30 m s^{-1} .

The vehicles collide and move off separately.

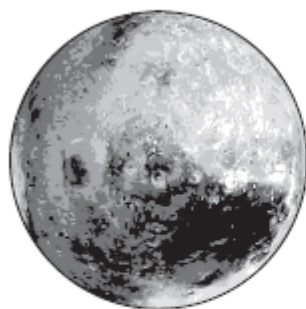
A computer displays a graph showing the velocity of vehicle X from just before the collision to just after the collision.



- (a) Show that the velocity of vehicle Y after the collision is 0.42 m s^{-1} . 2
- (b) Determine the impulse on vehicle Y during the collision. 3
- (c) Explain how the student would determine whether the collision was elastic or inelastic. 2

11

A space probe of mass $5.60 \times 10^3 \text{ kg}$ is in orbit at a height of $3.70 \times 10^6 \text{ m}$ above the surface of Mars.



Mars



space probe

not to scale

The mass of Mars is $6.42 \times 10^{23} \text{ kg}$.

The radius of Mars is $3.39 \times 10^6 \text{ m}$.

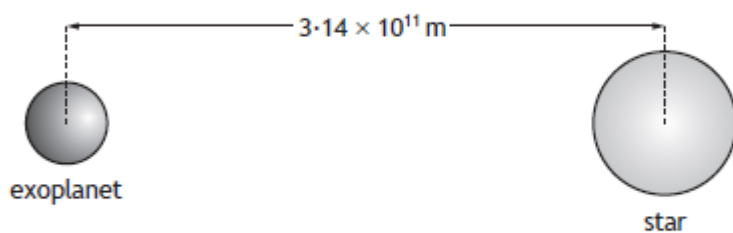
(a) Calculate the gravitational force between the probe and Mars. 3

(b) Calculate the gravitational field strength of Mars at this height. 3

12

Planets outside our solar system are called exoplanets.

An exoplanet of mass $5.69 \times 10^{27} \text{ kg}$ orbits a star of mass $3.83 \times 10^{30} \text{ kg}$.

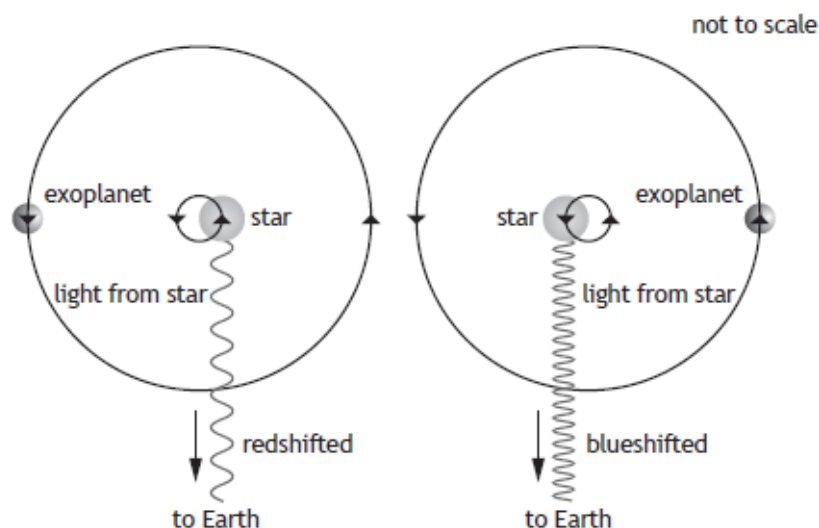


(a) (i) Compare the mass of the star with the mass of the exoplanet in terms of orders of magnitude. 2

(ii) The distance between the exoplanet and the star is $3.14 \times 10^{11} \text{ m}$.
Calculate the gravitational force between the star and the exoplanet. 3

- (b) The gravitational force between the star and the exoplanet causes the star to follow a circular path as the exoplanet orbits the star. Small differences in the wavelength of the light from the star are observed on Earth.

Light from the star is redshifted when the star moves away from the Earth and blueshifted when the star moves towards the Earth.



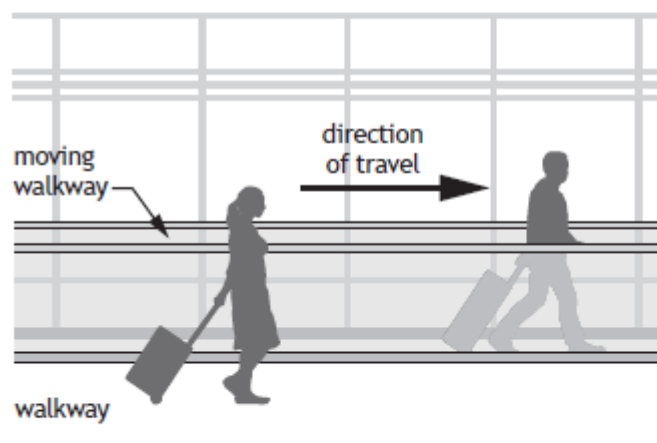
- (i) Calculate the redshift of light from the star observed on Earth when the star is moving away from the Earth at $6.60 \times 10^3 \text{ m s}^{-1}$. 3
- (ii) For an exoplanet of greater mass at the same distance from the star, suggest whether the radius of the circular path followed by the star would be greater than, less than, or the same as that for an exoplanet of smaller mass. 1

13

Two physics students are in an airport building on their way to visit CERN.

- (a) The first student steps onto a moving walkway, which is travelling at 0.83 m s^{-1} relative to the building. This student walks along the walkway at a speed of 1.20 m s^{-1} relative to the walkway.

The second student walks alongside the walkway at a speed of 1.80 m s^{-1} relative to the building.



Determine the speed of the first student relative to the second student. 2

(b) On the plane, the students discuss the possibility of travelling at relativistic speeds.

- (i) The students consider the plane travelling at $0.8c$ relative to a stationary observer. The plane emits a beam of light towards the observer.

State the speed of the emitted light as measured by the observer.

Justify your answer.

2

- (ii) According to the manufacturer, the length of the plane is 71 m.

Calculate the length of the plane travelling at $0.8c$ as measured by the stationary observer.

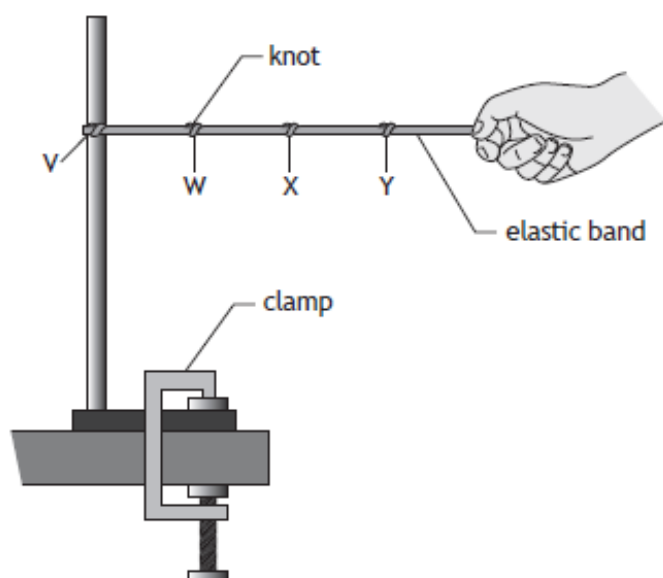
3

- (iii) One of the students states that the clocks on board the plane will run slower when the plane is travelling at relativistic speeds.

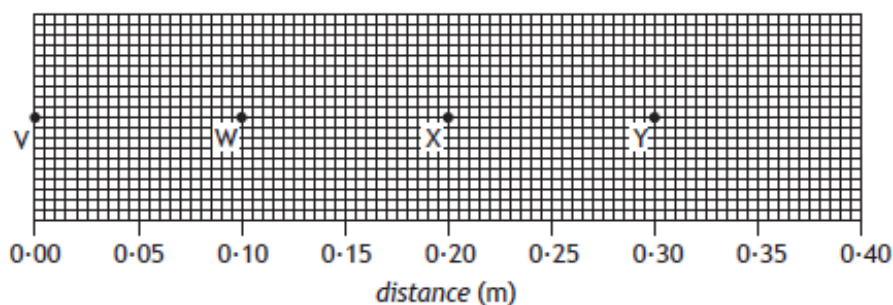
Explain whether or not this statement is correct.

1

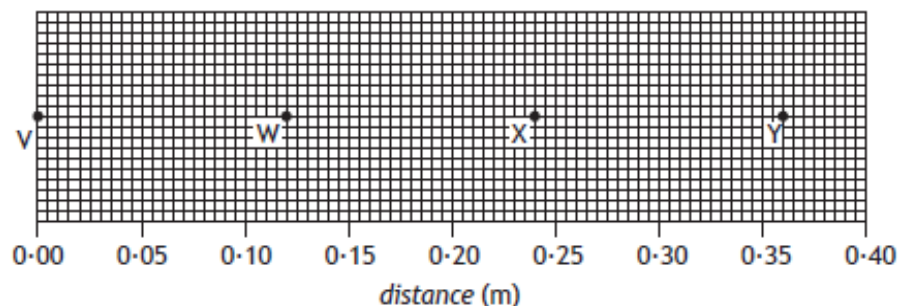
- (a) A student is using an elastic band to model the expansion of the Universe.



One end of the band is fixed in a clamp stand at V. Knots are tied in the band to represent galaxies. The knots are at regular intervals of 0.10 m, at points W, X and Y as shown.



The other end of the elastic band is pulled slowly for 2.5 seconds, so that the band stretches. The knots are now in the positions shown below.



- (i) Complete the table to show the average speeds of the knots X and Y. 2

Knot	Average speed (m s^{-1})
W	0.008
X	
Y	

- (ii) Explain why this model is a good simulation of the expansion of the Universe.

1

- (b) When viewed from the Earth, the continuous emission spectrum from the Sun has a number of dark lines. One of these lines is at a wavelength of 656 nm.



In the spectrum of light from a distant galaxy, the corresponding dark line is observed at 667 nm.

Calculate the redshift of the light from the distant galaxy.

3

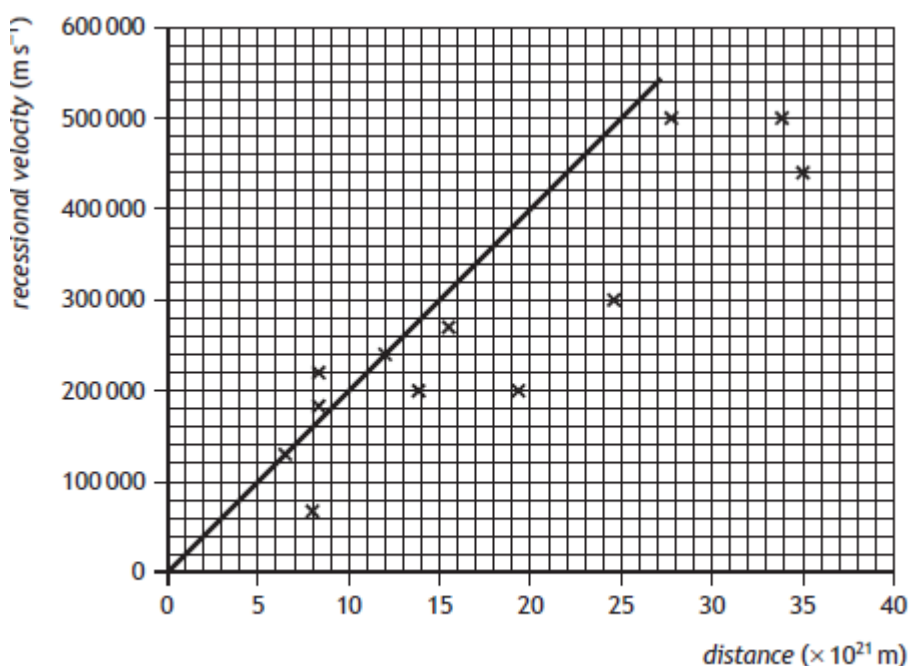
15

Hubble's Law states that the universe is expanding. The expanding universe is one piece of evidence that supports the Big Bang theory.

- (a) State one other piece of evidence that supports the Big Bang theory.

1

- (b) A student plots some of the original data from the 1929 paper by Edwin Hubble and adds the line shown in order to determine a value for the Hubble constant H_0 .



The student calculates the gradient of their line and obtains a value for the Hubble constant of $2.0 \times 10^{-17} \text{ s}^{-1}$.

The age of the universe can be calculated using the relationship

$$\text{age of universe} = \frac{1}{H_0}$$

- (i) Calculate the age of the universe, in years, obtained when using the student's value for the Hubble constant. 2

- (ii) The current estimate for the age of the universe is 13.8×10^9 years.

- (A) State why the value obtained in (b)(i) is different from the current estimate for the age of the universe. 1

- (B) Suggest a change that the student could make to their graph to obtain a value closer to the current estimate for the age of the universe. 1

- (c) It has been discovered that the rate of expansion of the universe is increasing.

State what physicists think is responsible for this increase. 1

16

A student is on a stationary train.

The train now accelerates along a straight level track.

The student uses an app on a phone to measure the acceleration of the train.



- (a) The train accelerates uniformly at 0.32 m s^{-2} for 25 seconds.

- (i) State what is meant by an *acceleration of 0.32 m s^{-2}* . 1

- (ii) Calculate the distance travelled by the train in the 25 seconds. 3

- (b) Later in the journey, the train is travelling at a constant speed as it approaches a bridge.



A horn on the train emits sound of frequency 270 Hz.

The frequency of the sound heard by a person standing on the bridge is 290 Hz.

The speed of sound in air is 340 m s^{-1} .

- (i) Calculate the speed of the train.

3

- (ii) The train continues to sound its horn as it passes under the bridge.

Explain why the frequency of the sound heard by the person standing on the bridge decreases as the train passes under the bridge and then moves away.

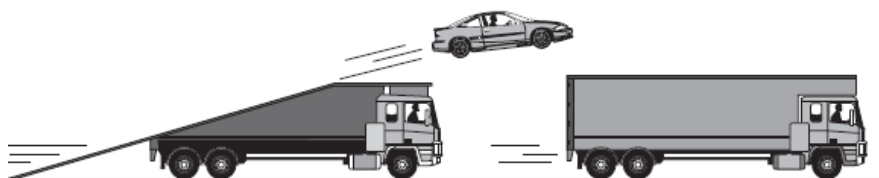
You may wish to use a diagram.

1

17.

A stunt is being carried out during the making of a film.

A car is to be driven up a ramp on a moving lorry, who will attempt to land the car safely on the roof of a second moving lorry. The car is to stop on the roof of the second lorry while this lorry is still moving.



Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully.

3

18.

Some motorways have variable speed limits, with overhead information boards displaying the maximum speed allowed. This system is designed to keep the traffic flowing and to avoid congestion.

Editorial Credit: Flik47 / Shutterstock.com



In this system, the flow of traffic is observed and the maximum speed to be displayed is determined using

$$\text{speed} = \text{frequency} \times \text{wavelength}$$

Use your knowledge of physics to comment on this system for determining the maximum speed to be displayed.

3

Question			Answer	Max Mark	Additional Guidance
1.	(a)	(i)	A $v = 11.6 \text{ m s}^{-1}$ (1)	1	Unit required - incorrect or missing unit award 0 Accept m/s No other value accepted.
			B $v_h = 11.6 \cos 40$ $= 8.9 \text{ m s}^{-1}$ (1)	1	Or consistent with A Accept 8.886, 8.89, 9 but <u>not</u> 9.0 0 marks for mixing up B and C
			C $v_v = 11.6 \sin 40$ $= 7.5 \text{ m s}^{-1}$ (1)	1	Or consistent with A Accept 7.456, 7.46, 7 but <u>not</u> 7.0
		(ii)	A $s = ut + \frac{1}{2}at^2$ (1) $4.7 = 0 + \frac{1}{2} \times 9.8 \times t^2$ (1) $t = 0.979 \text{ (s)}$ (1) Total Time = $0.98 + 0.76$ $= 1.7 \text{ s}$ (1)	4	s and a must have the same sign $v^2 = u^2 + 2as$ $= 0 + 2 \times 9.8 \times 4.7$ $v = 9.6$ $v = u + at$ $9.6 = 0 + 9.8t$ $t = 0.979$
			B $v = \frac{d}{t}$ (1) $8.9 = \frac{d}{1.7}$ (1) $d = 15\text{m}$ (1)	3	$s = ut + \frac{1}{2}at^2$ or $s = \frac{1}{2}(u+v)t$ (1) Or consistent with (a)(ii)(A) and (a)(i)(B) Accept 20, 15.1, 15.13 If $t = 1.74$ accept 15, 15.5, 15.49
	(b)		kinetic energy is less (1) (as θ increases) speed decreases (1)	2	This statement is required before any marks awarded. If there is wrong physics in the answer then award 0 marks

(a)	(i)	$u_v = 9.1 \sin 24^\circ$ $u_v = 3.7 \text{ m s}^{-1}$ (1)	1	Sig figs: Accept 4, 3.70, 3.701 OR Accept m/s
	(ii)	$u_h = 9.1 \cos 24^\circ$ $u_h = 8.3 \text{ m s}^{-1}$ (1)	1	Sig figs: Accept 8, 8.31, 8.313
(b)		$v = u + at$ (1) $0 = 3.7 + (-9.8)t$ $t = 0.378 \text{ (s)}$ (total) $t = 0.378 \times 2$ (1) (total) $t = 0.76 \text{ s}$ OR $v = u + at$ (1) $-3.7 = 3.7 + (-9.8) \times t$ (1) (total) $t = 0.76 \text{ s}$	2	SHOW question. Sign convention must be correct. Accept $0 = 3.7 - 9.8t$ If final line not shown then a maximum of 1 mark can be awarded. Guidance on alternatives $s = ut + \frac{1}{2}at^2$ (1) $0 = 3.7t + \frac{1}{2}(-9.8)t^2$ (1) (total) $t = 0.76 \text{ s}$
(c)		$s = v_h \times t$ (1) $s = 8.3 \times 0.76$ (1) $s = 6.3 \text{ m}$ (1)	3	Or consistent with (a)(ii) Sig figs: Accept 6, 6.31, 6.308 Accept $s = \frac{1}{2}(u+v)t$ Accept $s = ut + \frac{1}{2}at^2$ Accept $s = ut$ $v_h = 8.31 \text{ m s}^{-1}$ gives $s = 6.32 \text{ m}$ is acceptable
(d)		Smaller displacement (1) curve with decreasing gradient (1)	2	Ignore any change in time Any part of the curve drawn above the original line - award 0 marks These marks are independent.

(a)	(i)	$\bar{d} = \frac{1.31+1.40+1.38+1.41+1.35}{5}$ $\bar{d} = 1.37 \text{ m}$ (1)	1	Sig figs: Accept 1.4, 1.370
	(ii)	$\Delta \bar{d} = \frac{1.41-1.31}{5}$ (1) $\Delta \bar{d} = 0.02 \text{ m}$ (1)	2	Sig figs: Accept 0.020 Accept $(1.37 \pm 0.02) \text{ m}$
(b)		$\% \Delta m = \frac{0.01}{0.20} \times 100 = 5\%$ (1) $\% \Delta h = \frac{0.0005}{0.40} \times 100 = 1.3\%$ (1) $\% \Delta \bar{d} = \frac{0.02}{1.37} \times 100 = 1.5\%$ (1) Mass (has largest percentage uncertainty). (1)	4	Or consistent with (a)(i) and (a)(ii). Each correct calculation with correct substitution is awarded 1 mark Each calculation is independent but must have all three calculations shown to access the final mark for the conclusion. Accept percentage sign missing. Wrong substitution - maximum of 2 marks. Sig figs: for $\% \Delta m$ Accept 5.0, 5.00 for $\% \Delta h$ Accept 1, 1.25, 1.250 for $\% \Delta \bar{d}$ Accept 1, 1.46, 1.460
(c)	(i)	$E_p = mgh$ (1) $E_p = 0.20 \times 9.8 \times 0.40$ (1) $E_p = 0.78 \text{ J}$ (1)	3	Sig figs: Accept 0.8, 0.784 Treat -9.8 as wrong substitution unless h is also negative.

(c)	(ii)	$E_w = Fd$ (1) $0.78 = F \times 1.37$ (1) $F = 0.57 \text{ N}$ (1)	3	Or consistent with (a)(i) and (c)(i) Sig figs: Accept 0.6, 0.569, 0.5693 Candidates can arrive at this answer by alternative methods eg equating loss in E_p to gain in E_k etc. If alternative methods used, can also accept 0.572, 0.5723 1 for ALL equations 1 for ALL substitutions 1 for correct answer
	(iii)	All E_p converted to E_k All E_p converted to E_w Air resistance is negligible Ramp is frictionless Bearings in the wheels are frictionless The carpet is horizontal No energy/heat loss on the ramp etc	1	Only one correct statement required Note the \pm rule applies Energy is conserved on its own OR No energy/ heat loss on its own - 0 marks

(a)	(i) (A)	$u_h = 7.4 \cos 30$ $u_h = 6.4 \text{ m s}^{-1}$ (1)	1	Accept: 6, 6.41, 6.409
	(i) (B)	$u_v = 7.4 \sin 30$ $u_v = 3.7 \text{ m s}^{-1}$ (1)	1	Accept: 4, 3.70, 3.700
	(ii)	$v = u + at$ $0 = 3.7 + (-9.8)t$ $t = 0.38 \text{ s}$ (1) (1) (1)	3	OR consistent with (a)(i)(B) u and a must have opposite signs Accept: 0.4, 0.378, 0.3776
	(iii)	$s = ut + \frac{1}{2}at^2$ $s = (3.7 \times 0.83) + (0.5 \times -9.8 \times 0.83^2)$ $h = 1.5 + ((3.7 \times 0.83) \times (0.5 \times -9.8 \times 0.83^2))$ $h = 1.2 \text{ m}$ (1) (1) (1) (1)	4	OR consistent with (a)(i)(B) and (a)(ii) Accept: 1, 1.20, 1.195 For alternative methods 1 mark for ALL relationships 1 mark for ALL substitutions 1 mark for addition relative to 1.5m 1 mark for final answer
(b)		(Initial) vertical/horizontal speed is greater. (1) Sponge is higher than the teacher when it has travelled the same horizontal distance. OR Sponge has travelled further horizontally when it is at the same height as the teacher. (1)	2	Look for this statement first - if incorrect or missing then 0 marks.

(a)	(i)	$v = u + at$ $0 = 5.6 + (-9.8)t$ $t = 0.57 \text{ s}$ 1 1 1	3	u and a must have opposite signs Accept $0 = 5.6 - 9.8t$ Accept 0.6, 0.571, 0.5714
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(a)	(ii)	$v^2 = u^2 + 2as$ $(-7.7)^2 = 0^2 + 2 \times (-9.8)s$ $s = -3.0 \text{ m}$ (Distance = 3.0 m)	1 1 1	3 Accept 3, 3.03, 3.025 Alternative method: $mgh = \frac{1}{2}mv^2$ $gh = \frac{1}{2}v^2$ $9.8 \times h = \frac{1}{2} \times 7.7^2$ $h = 3.0 \text{ m}$ If an alternative method is used, 1 mark for ALL equations 1 mark for ALL substitutions 1 mark for correct answer
(b)		Starting point greater than 5.6 Final point beyond -7.7 Acceptably parallel line	1 1 1	3 Independent marks Must be <u>one</u> continuous acceptably <u>straight</u> line for third mark.

6

(a)	(i)	$W = mg$ $W = (5.50 + 1.25) \times 9.8$ $W = 66 \text{ N}$	(1) (1) (1)	3 Accept: 70, 66.2, 66.15 In this question, ignore negative signs in both the substitution and final answer for weight. Do not accept: $F = ma$
	(ii)	$P = \frac{V^2}{R}$ $P = \frac{12^2}{9.6}$ $P = 15 \text{ W}$	(1) (1) (1)	3 Accept: 20, 15.0, 15.00 For alternative methods 1 mark for ALL relationships 1 mark for ALL substitutions 1 mark for final answer
	(iii)	Drone <u>accelerates upwards</u> Upward force is greater than weight OR (Upward force remains constant but) weight decreases therefore forces are no longer balanced. OR (Upward force remains constant but) weight decreases therefore there is an unbalanced force (upwards).	(1) (1)	2 Look for correct statement of effect first - if incorrect or missing then 0 marks. Accept free-body diagram to aid description of relative size and direction of forces acting on the drone.

(b)	$W = mg$ $W = 3.4 \times 9.8$ $W = 33.32 \text{ (N)}$ (1) Each cord supports $33.32/2 = 16.66 \text{ (N)}$ (1) $F \cos 35 = 16.66$ (1) $F = 20 \text{ N}$ (1)	4	Accept: 20.3, 20.34 Accept: $F \sin 55 = 16.66$ $F = 20 \text{ N}$ Alternative methods: Each cord supports $3.4/2 = 1.7 \text{ (kg)}$ (1) $W = mg$ $W = 1.7 \times 9.8$ $W = 16.66 \text{ (N)}$ (1) $F \cos 35 = 16.66$ (1) $F = 20 \text{ N}$ (1)
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7

(a)	(Total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ (1) $(0.25 \times 1.20) + (0.45 \times -0.60)$ $= (0.25 \times -0.80) + (0.45 \times v_y)$ (1) $0.30 - 0.27 = -0.20 + 0.45 \times v_y$ $0.45 \times v_y = 0.23$ $v_y = 0.51 \text{ ms}^{-1}$ (1) (to the right)	3	If sign convention not applied then max (1) for formula. Answer must be consistent with sign convention in substitution line. 0.5, 0.511, 0.5111 Where candidates calculate the momentum of each trolley individually both before and after, no marks are awarded unless correct addition (including sign convention) and equating takes place.
(b) (i)	$\text{impulse} = \text{area under graph}$ $\left(= \frac{1}{2} b \times h \right)$ (1) $= \frac{1}{2} \times 0.25 \times 4.0$ (1) $= 0.50 \text{ N s}$ (1) Accept 0.5, 0.500, 0.5000	3	$\text{Impulse} = mv - mu$ $= (0.45 \times 0.51) - (0.45 \times -0.60)$ $= 0.50 \text{ N s}$ For alternative method accept: 0.5, 0.500, 0.4995 Accept kg m s^{-1}
(ii)	0.50 kg m s^{-1} (1)	1	Or consistent with (i) Accept N s Accept 0.5

(iii)	<p>Constant velocity at correct values and signs before and after collision (1)</p> <p>Velocity change from initial to final in 0.25 s. (1)</p> <p>Shape of change of velocity correct ie initially gradual, increasing steepness then levelling out to constant velocity. (1)</p>	3	The origin and at least one axis must be labelled with quantity or unit or both otherwise maximum 2 marks.
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8

(a)	<p>Total momentum before (a collision) is equal to the <u>total</u> momentum after (a collision) in the absence of external forces (1)</p>	1	<p>Not: TMB = TMA</p> <p>An isolated system is equivalent to the absence of external forces</p>
(b)	$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v \quad (1)$ $(0.85 \times 0.55) + (0.25 \times -0.3) \quad (1)$ $= (0.25 + 0.85) v \quad (1)$ $v = 0.36 \text{ m s}^{-1} \quad (1)$	3	<p>Sign of the answer must be consistent with the substitution of + and - velocities.</p> <p>Sig figs: Accept 0.4, 0.357, 0.3568</p> <p>If candidate then goes on to state a direction which is not consistent with their substitution then maximum two marks can be awarded.</p> <p>Where candidates calculate the momentum of each trolley individually both before and after, no marks are awarded unless correct addition (including sign convention) <u>and</u> equating takes place.</p>
(c)	$E_k = \frac{1}{2} m v^2 \quad \text{ANYWHERE} \quad (1)$ <p>Before $E_k = \frac{1}{2} m_X v_X^2 + \frac{1}{2} m_Y v_Y^2$</p> $= (\frac{1}{2} \times 0.85 \times 0.55^2) + (\frac{1}{2} \times 0.25 \times 0.3^2) \quad (1)$ $= 0.14 \text{ (J)} \quad (1)$ <p>After $E_k = \frac{1}{2} m v^2$</p> $= \frac{1}{2} \times 1.1 \times 0.36^2 = 0.071 \text{ (J)} \quad (1)$ <p>Kinetic energy is lost. (Therefore inelastic.) (1)</p>	4	<p>Or consistent with (b)</p> <p>1 mark for both substitutions</p> <p>If candidate answers 0.49 in (b), this gives 0.13 J for E_k after.</p> <p>$E_{k \text{ before}} \neq E_{k \text{ after}}$ is insufficient</p>

(a)	(i)	<p>(total momentum before = total momentum after)</p> $m_x u_x + m_y u_y = m_x v_x + m_y v_y \quad (1)$ $(0.180 \times 2.60) + (0.180 \times -1.80)$ $= (0.180 v_x + 0.180 \times 2.38) \quad (1)$ $0.468 - 0.324 = 0.180 v_x + 0.4284$ $v_x = -1.58 \text{ m s}^{-1} \quad (1)$ <p>(Accept '1.58 ms⁻¹ to the left' or an indication of direction eg arrow left)</p>	3	<p>1 mark for equating the momentums before and after. 1 mark for the substitutions. 1 mark for answer including unit.</p> <p>Signs must be consistent.</p> <p>Allow cancellation of masses throughout the relationship.</p> <p>Accept $v_x = -1.58 \text{ ms}^{-1}$ to the left as "loose" use of direction.</p> <p>Sig fig 1.6, 1.580, 1.5800</p>
	(ii)	kinetic energy is lost/greater before the collision than after.	1	<p>Do not accept: E_k before $\neq E_k$ after. E_k is not conserved.</p>
(b)	(i)	$Ft = mv - mu \quad (1)$ $F \times 0.040 = (0.180 \times 0.84) - (0.180 \times 0) \quad (1)$ $F = 3.8 \text{ N} \quad (1)$	3	<p>Accept:</p> $a = \frac{v-u}{t}$ $a = \frac{0.84(-0)}{0.040}$ $a = 21 \text{ (m s}^{-2}\text{)}$ $F = ma$ $F = 0.180 \times 21$ $F = 3.8 \text{ N}$
	(ii)	$\left(\frac{0.01}{0.84} \times 100 = 1.2 \right)$ $\left(\frac{0.001}{0.180} \times 100 = 0.56 \right)$ $\frac{0.001}{0.040} \times 100 (=2.5) \quad (1)$ <p>(Uncertainty in F is) 2.5% (1)</p>	2	<p>1 mark for correct or implied working for % uncertainty in t.</p> <p>1 mark for indicating 2.5% as the largest.</p> <p>Must have % in final answer - equivalent to 'unit'.</p> <p>Accept: 3%</p>

(a)		<p>(Total momentum before = Total momentum after)</p> $p = mv$ <p>OR</p> $(m_x u_x + m_y u_y) = (m_x v_x + m_y v_y)$ $(0.75 \times 0.50) + (0.50 \times -0.30) = (0.75 \times 0.02) + (0.50 v_y) \quad (1)$ $v_y = 0.42 \text{ m s}^{-1} \quad (1)$	2	<p>"SHOW" question</p> <p>If sign convention is not applied then max 1 mark for formula.</p>
(b)		$Ft = mv - mu \quad (1)$ $Ft = (0.50 \times 0.42) - (0.50 \times -0.30) \quad (1)$ $Ft = 0.36 \text{ N s} \quad (1)$	3	<p>Accept: 0.4</p> <p>Accept: Impulse = $mv - mu$</p> <p>v and u must have opposite sign.</p> <p>Accept: kg m s^{-1}</p>
(c)		<p>Calculate the <u>total</u> kinetic energy before and (<u>total</u> kinetic energy) after. (1)</p> <p>If E_k before is equal to E_k after the collision, is elastic.</p> <p>OR</p> <p>If E_k before is greater than E_k after, the collision is inelastic. (1)</p>	2	<p>Look for a statement relating to calculating/finding the <u>total</u> E_k before and after first, otherwise 0 marks.</p> <p>There must be an indication of total kinetic energy or equivalent term.</p>

(a)	$F = \frac{GMm}{r^2} \quad (1)$ $F = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23} \times 5.60 \times 10^3}{(3.39 \times 10^6 + 3.70 \times 10^6)^2} \quad (1)$ $F = 4.77 \times 10^3 \text{ N} \quad (1)$	3	Accept 4.8, 4.770, 4.7704
(b)	$g = \frac{W}{m} \quad (1)$ $g = \frac{4770}{5600} \quad (1)$ $g = 0.852 \text{ N kg}^{-1} \quad (1)$	3	<p>Or consistent with (a) $F = ma$ is acceptable If candidate uses</p> $g = \frac{GM}{r^2}$ <p>and has already lost marks in (a) for not adding the radius to the height, do not penalise for a second time. (Gives 3.13) if r is consistent with (a).</p> <p>Accept m s^{-2}</p>

(a)	<p>(i)</p> $\left(\frac{3.83 \times 10^{30}}{5.69 \times 10^{27}} \right) = 673 \quad 1$ <p>(Star is) 3 (orders of magnitude) <u>greater</u> 1 OR <u>Exoplanet</u> is 3 (orders of magnitude) <u>smaller</u></p>	2	<p>Sig figs: accept 670, 673.1, 673.11</p> <p>Or</p> $\left(\frac{10^{30}}{10^{27}} \right) = 1000 \text{ or } 10^3$ <p>Or</p> $(30-27) = 3 \quad 1$ <p>'3 greater' on its own is worth 2 marks.</p> <p>Care should be taken where candidates answer by the reciprocal method - 2 marks are still available.</p> $\left(\frac{5.69 \times 10^{27}}{3.83 \times 10^{30}} \right) = 1.49 \times 10^{-3} \quad 1$ <p>Comparison statement 1</p> <p>'Greater' on its own - 0 marks</p>
	<p>(ii)</p> $F = G \frac{m_1 m_2}{r^2} \quad 1$ $F = 6.67 \times 10^{-11} \frac{5.69 \times 10^{27} \times 3.83 \times 10^{30}}{(3.14 \times 10^{11})^2} \quad 1$ $F = 1.47 \times 10^{25} \text{ N} \quad 1$	3	<p>Sig figs: Accept 1.5, 1.474, 1.4743</p>

(b)	(i)	$z = \frac{v}{c}$ 1 $z = \frac{6 \cdot 60 \times 10^3}{3 \cdot 00 \times 10^8}$ 1 $z = 2 \cdot 20 \times 10^{-5}$ 1	3	Sig figs: Accept 2·2, 2·200, 2·2000
	(ii)	Greater (than)	1	Accept any word synonymous with 'greater'. Any correct suggestion followed by wrong physics 0 marks.

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(a)		$(0 \cdot 83 + 1 \cdot 20) - 1 \cdot 80$ (1) $0 \cdot 23 \text{ m s}^{-1}$ (1)	2	
(b)	(i)	$3 \times 10^8 \text{ m s}^{-1}$ or c (1) Speed of light is the same for all observers / all (inertial) frames of reference or equivalent (1)	2	Look for this statement first - if incorrect then 0 marks. $3 \times 10^8 \text{ m s}^{-1}$ or c on its own is worth 1 mark If the numerical value for speed is given, then unit is required - otherwise 0 marks Any wrong physics in justification then maximum 1 mark for the statement
	(ii)	$l' = l \sqrt{1 - \left(\frac{v}{c}\right)^2}$ (1) $l = 71 \sqrt{1 - 0 \cdot 8^2}$ (1) $l = 43 \text{ m}$ (1)	3	Sig figs: Accept 40, 42·6, 42·60
	(iii)	Correct - from the perspective of the stationary observer there will be time dilation Incorrect - from the perspective of the students they are in the same frame of reference as the clock Not possible to say/could be both correct and incorrect - frame of reference has not been defined	1	The response must involve a statement referring to, or implying, a frame of reference

(a)	(i)	$\Delta X = 0.04 \text{ (m)}$ $X = 0.016 \text{ (m s}^{-1}\text{)} \quad (1)$ $\Delta Y = 0.06 \text{ (m)}$ $Y = 0.024 \text{ (m s}^{-1}\text{)} \quad (1)$	2	If values are not entered in the table, then X and Y must be identified <u>and</u> units required.
	(ii)	More distant <u>galaxies</u> are moving <u>away</u> at a greater velocity/ have a greater recessional velocity Or equivalent	1	The (average) speed (of the knots) is (directly) <u>proportional</u> to the distance (from V) Any reference to planets or stars alone - 0 marks
(b)		$z = \frac{\lambda_{\text{observed}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}} \quad (1)$ $z = \frac{667 \times 10^{-9} - 656 \times 10^{-9}}{656 \times 10^{-9}} \quad (1)$ $z = 0.0168 \quad (1)$	3	Sig figs: Accept 0.017, 0.01677, 0.016768 Accept $z = \frac{667 - 656}{656}$

(a)		Cosmic Microwave Background Radiation OR Olber's Paradox OR Abundance of Hydrogen and Helium in the Universe	1	Present temperature of the universe 2.7K (Blackbody radiation graph) Accept: Abundance of Light elements in the Universe Do not accept: the abbreviation "CMBR" on its own. Do not accept any further evidence based on redshift alone.
(b)	(i)	$\left(\text{Age} = \frac{1}{H_0} \right)$ $\text{Age} = \frac{1}{2.0 \times 10^{-17}} \quad (1)$ $(\text{Age} = 5.0 \times 10^{16} \text{ (s)})$ $\text{Age} = 1.6 \times 10^9 \text{ (years)} \quad (1)$	2	Accept: 2, 1.58, 1.584 Accept: 2, 1.59, 1.585 (365 days has been used - this does not need to be shown explicitly.) Years in brackets as question asks for age "in years".

(ii)	(A)	(Student's) value for H_0 is incorrect/too large/not accurate (enough). OR Incorrect line (of best fit) drawn. OR The (student's) gradient (which is H_0) is too large. OR New/more data is available/more accurate. OR Not enough data at large distances.	1	Accept: H_0 varies/decreases as age of the universe increases Do not accept: H_0 is different
	(B)	The student could draw the (correct) line of best fit. OR Student could use a larger sample/all of the 1929 Hubble data.	1	Accept: The student could use current data. Do not accept " <u>different</u> line of best fit" alone.
(c)		Dark energy	1	

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(a)	(i)	The velocity increases by 0.32 m s^{-1} each/per second	1	Accept: Speed increases by ... Rate of change of velocity/speed is ... Train gets faster by ... Velocity/speed changes by ...
	(ii)	$s = ut + \frac{1}{2}at^2$ (1) $s = ((0 \times 25)) + (0.5 \times 0.32 \times 25^2)$ (1) $s = 100 \text{ m}$ (1)	3	Accept: $v = u + at$ $v = (0) + 0.32 \times 25$ $v = 8(\text{ms}^{-1})$ $v^2 = u^2 + 2as$ $8^2 = (0^2) + (2 \times 0.32 \times s)$ $s = 100 \text{ m}$

(b)	(i)	$f_o = f_s \left(\frac{v}{v \pm v_s} \right) \quad (1)$ $290 = 270 \left(\frac{340}{340 - v_s} \right) \quad (1)$ $v_s = 23 \text{ m s}^{-1} \quad (1)$	3	$f_o = f_s \left(\frac{v}{v - v_s} \right)$ is also acceptable Accept 20, 23.4, 23.45
	(ii)	Statement that there are fewer wavefronts per second. OR The wavefronts are further apart OR The wavelength increases OR diagram showing wavefronts closer together ahead of the train and further apart behind it. or any similar response	1	In a diagram, there must be an implication of direction of travel. Do Not Accept Any answer that implies that the frequency/wavelength of the horn itself is changing.

Q17 & Q18. Open ended questions.

No standard marking instructions. Try to respond with as much Higher Physics knowledge as you can, and attempt to answer by referring back to the question posed.