Exam Question Practice

Section 2 — Extended Answer Questions for UNIT 1 - DYNAMIC UNIVERSE

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \text{J s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \text{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \text{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \text{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \text{s}^{-1}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 }	Infrared
	10590 }	
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

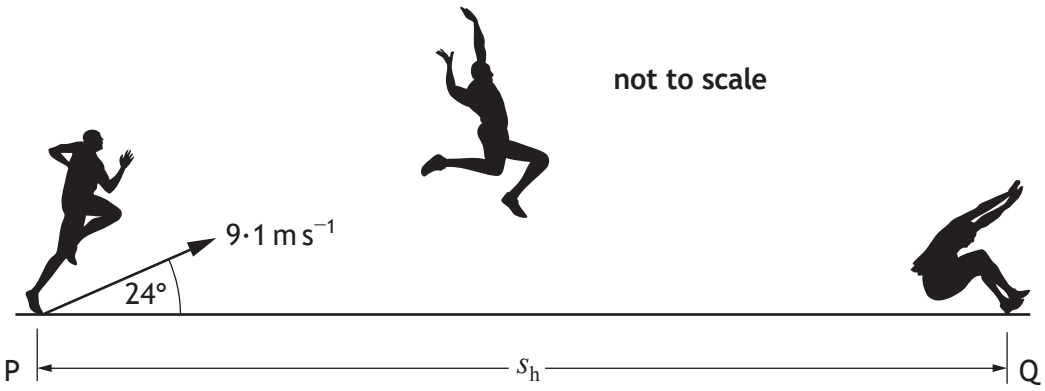
Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION 2 — 110 marks

Attempt ALL questions

1.



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**

Space for working and answer

(ii) the horizontal component of the initial velocity of the athlete. **1**

Space for working and answer

1. continued)

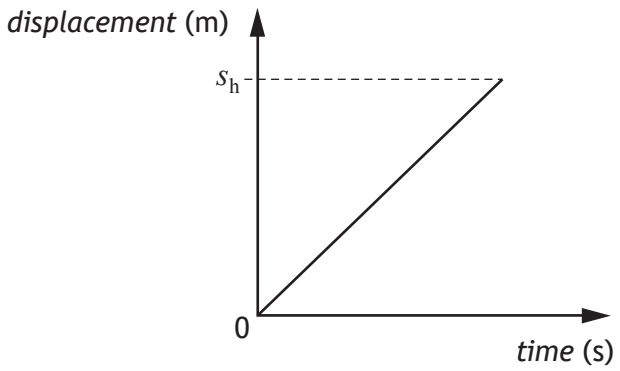
(b) Show that the time taken for the athlete to travel from P to Q is 0·76 s. **2**

Space for working and answer

(c) Calculate the horizontal displacement s_h between points P and Q. **3**

Space for working and answer

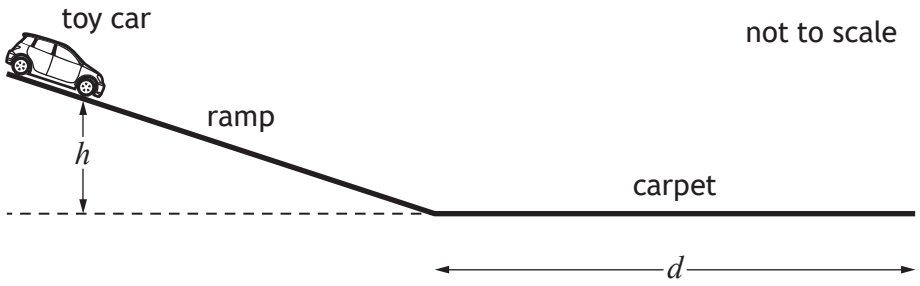
(d) The graph shows how the horizontal displacement of the athlete varies with time for this jump when air resistance is ignored.



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**

(An additional graph, if required can be found on *Page 38*)

2. 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: $(0{\cdot}20 \pm 0{\cdot}01)$ kg

Height, h: $(0{\cdot}40 \pm 0{\cdot}005)$ 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**

Space for working and answer

(ii) Calculate the approximate random uncertainty in this value. **2**

Space for working and answer

2. continued)

(b) Determine which of the quantities; mass m, height h or mean distance d, has the largest percentage uncertainty.

You must justify your answer by calculation. **4**

Space for working and answer

(c) (i) Calculate the potential energy of the toy car at height h.

An uncertainty in this value is not required. **3**

Space for working and answer

2. c) (continued)

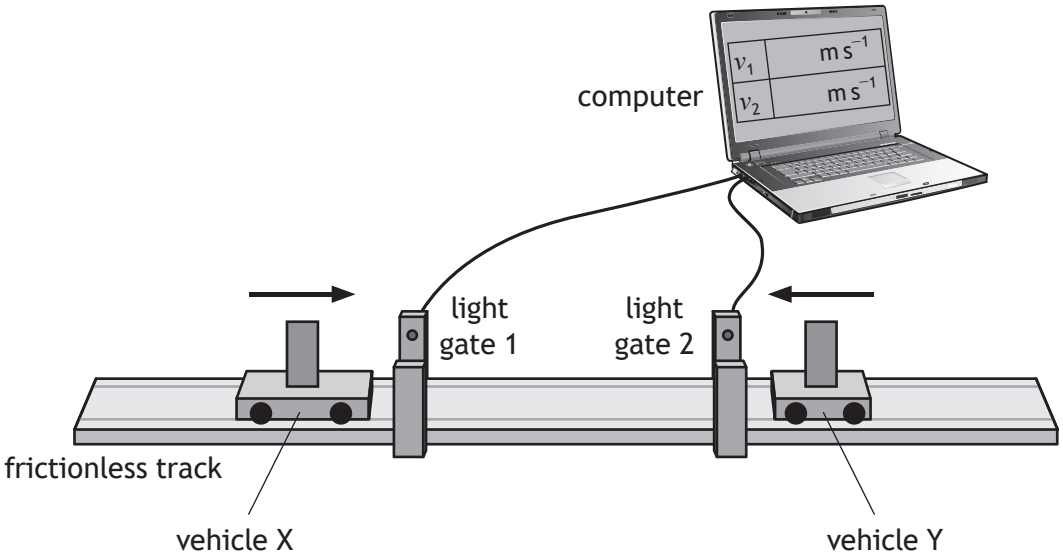
(ii) Calculate the average force of friction acting between the toy car and carpet, as the car comes to rest.

An uncertainty in this value is not required. **3**

Space for working and answer

(iii) State one assumption you have made in (c) (ii). **1**

3. 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**

Space for working and answer

3. continued)

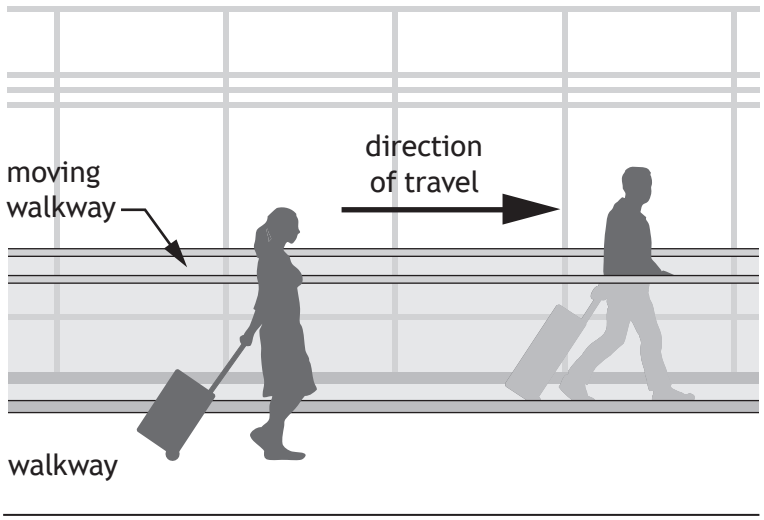
(c) Show by calculation that the collision is inelastic. **4**

Space for working and answer

4. 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 $0{\cdot}83\,\text{m}\,\text{s}^{-1}$ relative to the building. This student walks along the walkway at a speed of $1{\cdot}20\,\text{m}\,\text{s}^{-1}$ relative to the walkway.

The second student walks alongside the walkway at a speed of $1{\cdot}80\,\text{m}\,\text{s}^{-1}$ relative to the building.



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

Space for working and answer

4. continued)

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

(i) The students consider the plane travelling at $0{\cdot}8c$ 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 $0{\cdot}8c$ as measured by the stationary observer. **3**

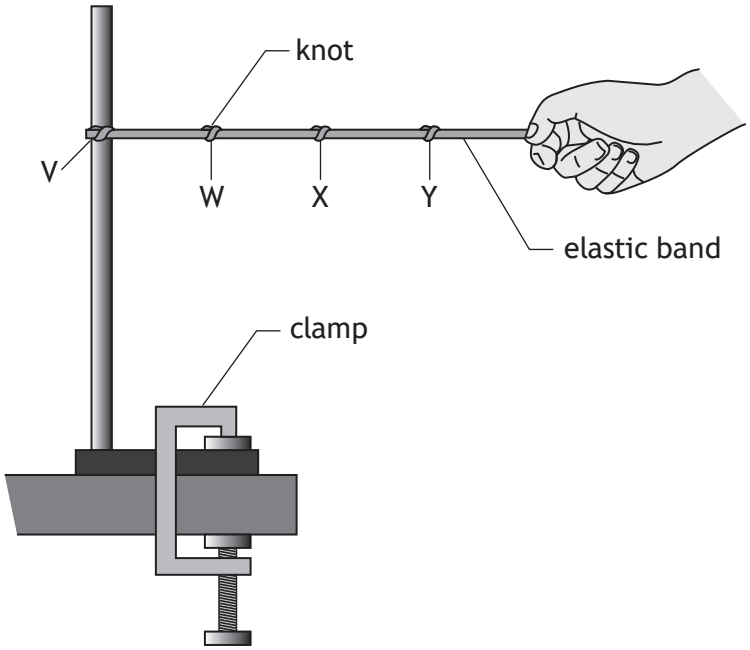
Space for working and answer

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

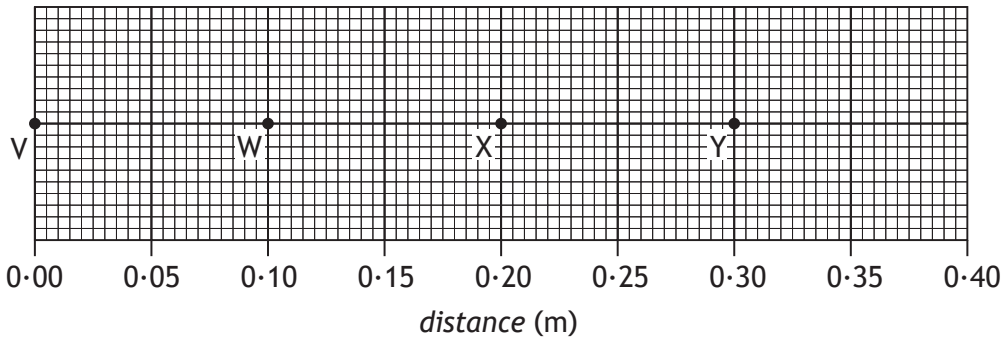
Explain whether or not this statement is correct. **1**

[Turn over

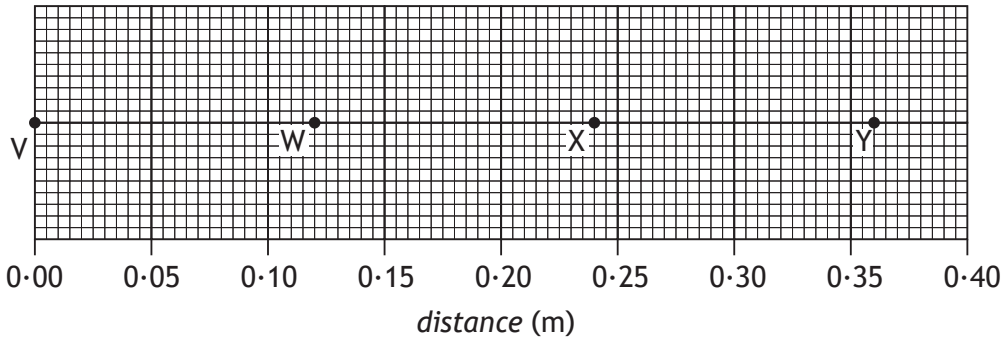
5. (a) A student is using an elastic band to model the expansion of the Universe.



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.



5. (a) continued)

(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	

Space for working

(ii) Explain why this model is a good simulation of the expansion of the Universe. **1**

5. continued)

(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.

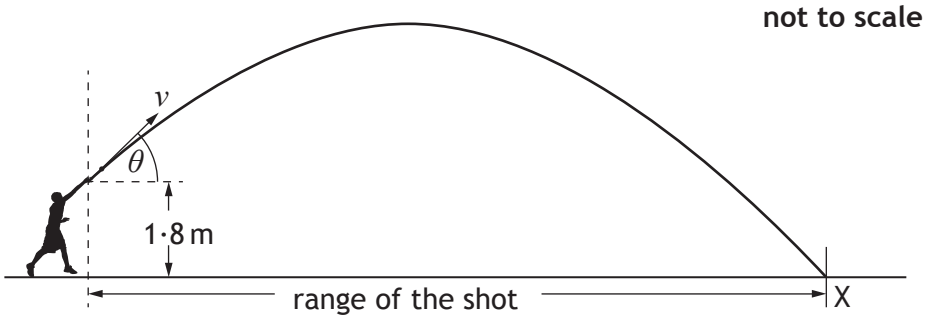
Calculate the redshift of the light from the distant galaxy. **3**

Space for working and answer

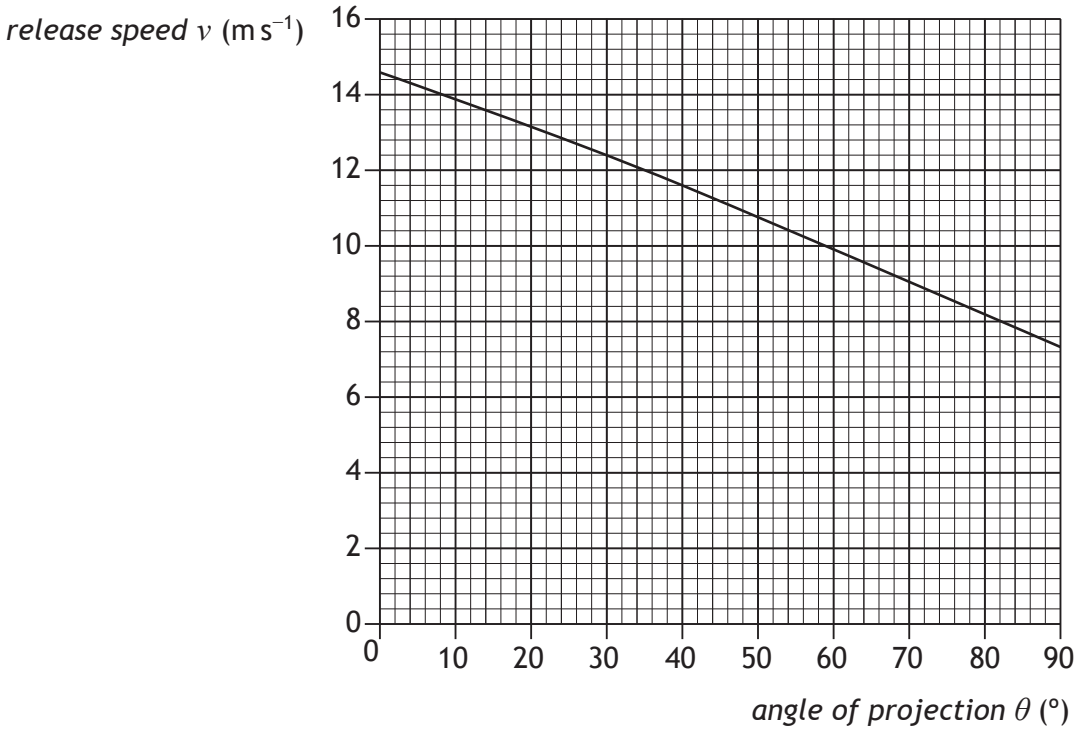
6. A website states "*Atoms are like tiny solar systems with electrons orbiting a nucleus like the planets orbit the Sun*".

Use your knowledge of physics to comment on this statement. **3**

1. 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.



1. (continue

MArKS

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(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**

Space for working and answer

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

Space for working and answer

(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**

Space for working and answer

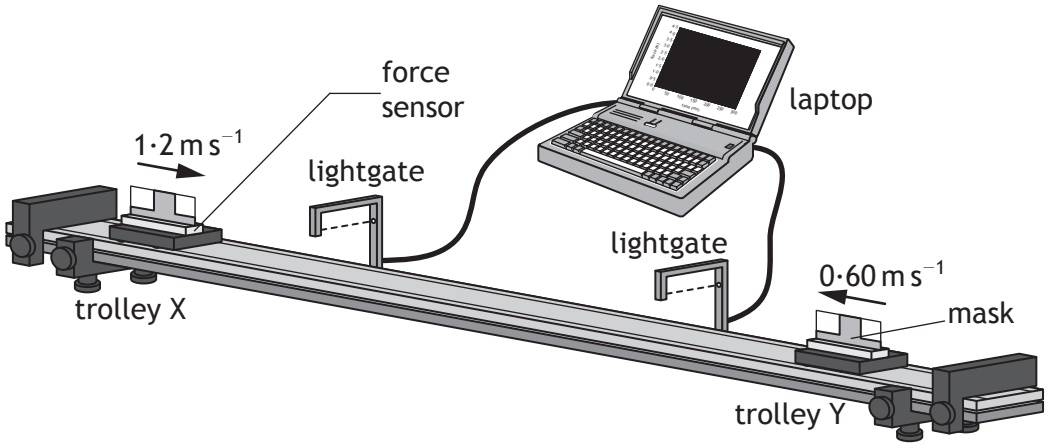
1. (a) (ii) (continued)

(B) Calculate the range of the shot for this throw. **3**

Space for working and answer

(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. 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**

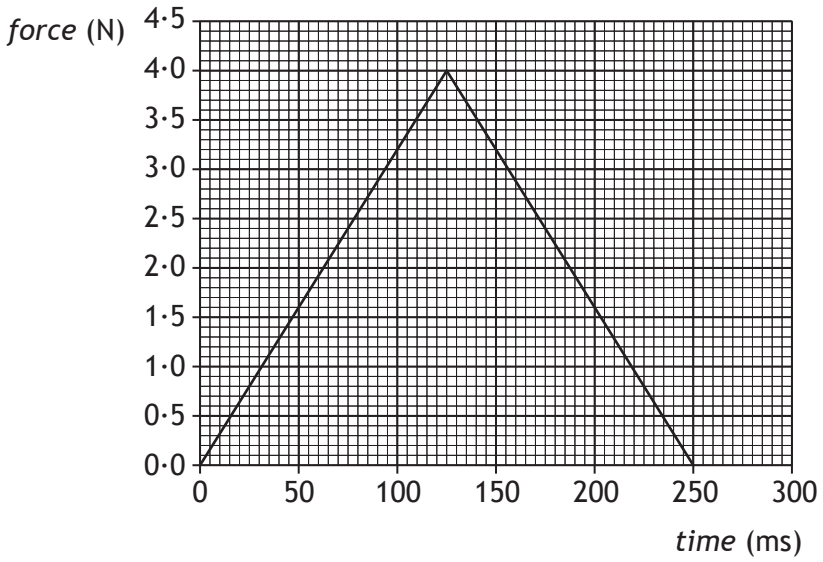
Space for working and answer

[Turn over

2. (continued)

(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**

Space for working and answer

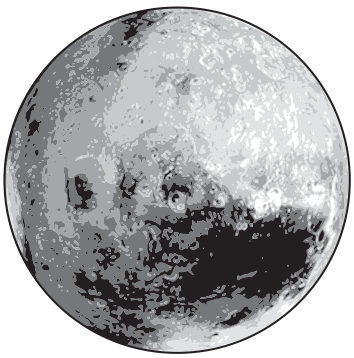
(ii) Determine the magnitude of the change in momentum of trolley X. **1**

2. (b) (continued)

(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.
You may wish to use the square-ruled paper on *Page thirty-six*.

3. A space probe of mass $5{\cdot}60 \times 10^3$ kg is in orbit at a height of $3{\cdot}70 \times 10^6$ m above the surface of Mars.



Mars

space probe

not to scale

The mass of Mars is $6{\cdot}42 \times 10^{23}$ kg.
The radius of Mars is $3{\cdot}39 \times 10^6$ m.

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

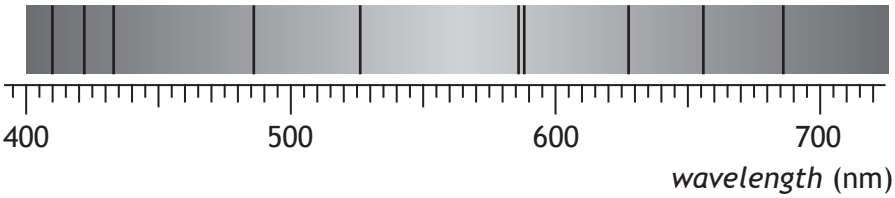
Space for working and answer

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

Space for working and answer

4. Light from the Sun is used to produce a visible spectrum.

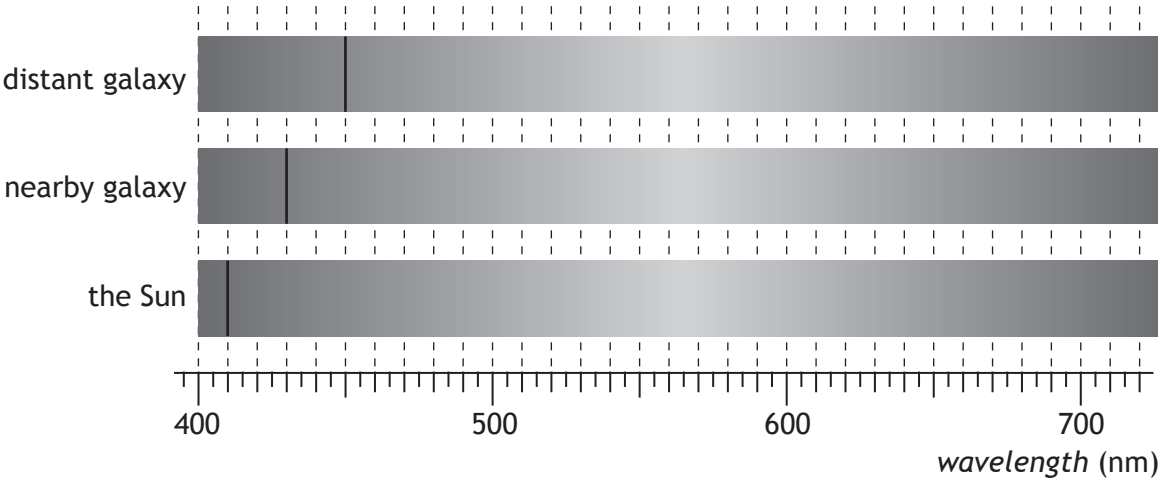
A student views this spectrum and observes a number of dark lines as shown.



(a) Explain how these dark lines in the spectrum of sunlight are produced. **2**

(b) One of the lines is due to hydrogen.

The position of this hydrogen line in the visible spectrum is shown for a distant galaxy, a nearby galaxy and the Sun.



(i) Explain why the position of the line is different in each of the spectra. **2**

4. (b) (continued)

(ii) Show that the redshift of the light from the distant galaxy is 0·098. **2**

Space for working and answer

(iii) Calculate the approximate distance to the distant galaxy. **5**

Space for working and answer

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5. A quote from a well-known science fiction writer states:

"In the beginning there was nothing, which exploded."

Using your knowledge of physics, comment on the above statement. **3**

SECTION 2 — 110 marks

Attempt ALL questions

1. 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 $0{\cdot}32\ m\ s^{-2}$ for 25 seconds.

(i) State what is meant by *an acceleration of $0{\cdot}32\ m\ s^{-2}$*. **1**

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

Space for working and answer

MARKS

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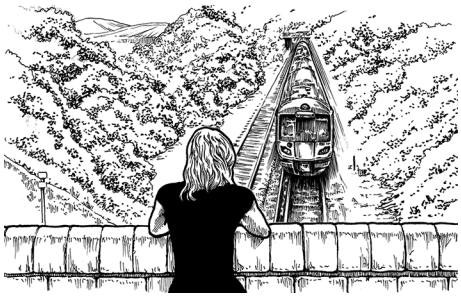
(b) Later in the journey, the train is travelling at a constant speed as it approaches a bridge.



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**

Space for working and answer

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

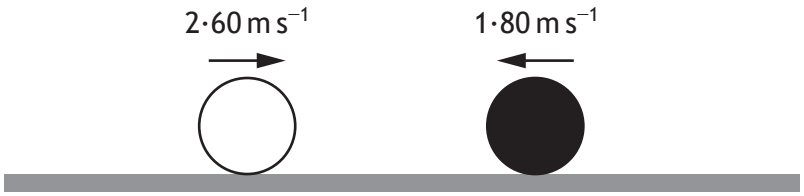
Explain why the frequency of the sound heard by the person standing on the bridge decreases as the train passes under the bridge and then moves away.

You may wish to use a diagram. **1**

2. 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 $2{\cdot}60\,m\,s^{-1}$ to the right and the black ball is travelling at $1{\cdot}80\,m\,s^{-1}$ to the left.



After the collision, the black ball rebounds with a velocity of $2{\cdot}38\,m\,s^{-1}$ to the right.

(a) (i) Determine the velocity of the white ball immediately after the collision. **3**

Space for working and answer

(ii) The collision between the balls is inelastic.

State what is meant by an *inelastic collision*. **1**

MARKS

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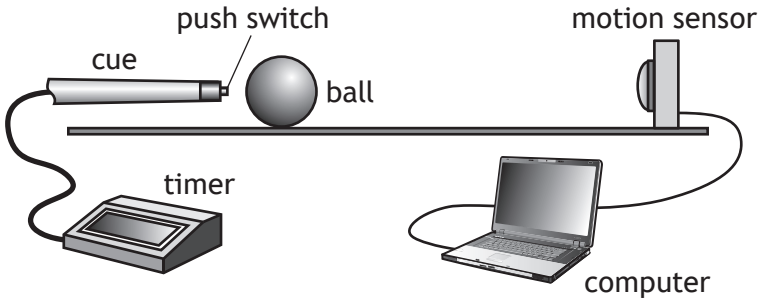
(b) A student carries out an experiment to measure the average force exerted by a cue on a ball.



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 = $(0{\cdot}040 \pm 0{\cdot}001)$ s

Speed of the ball immediately after contact = $(0{\cdot}84 \pm 0{\cdot}01)$ m s^{-1}

Mass of the ball = $(0{\cdot}180 \pm 0{\cdot}001)$ kg

(i) Calculate the average force exerted on the ball by the cue. An uncertainty in this value is not required. **3**

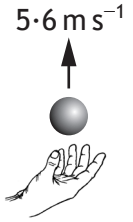
Space for working and answer

(ii) Determine the percentage uncertainty in the value for the average force on the ball. **2**

Space for working and answer

3. A ball is thrown vertically upwards.

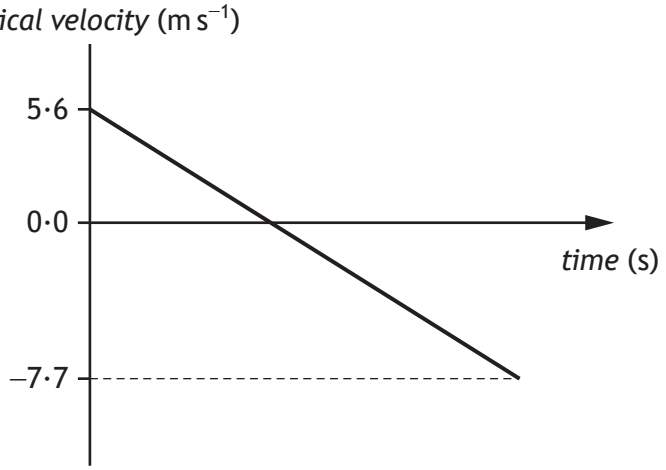
The ball is above the ground when released.



not to scale

ground

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**

Space for working and answer

3. (a) (continued)

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

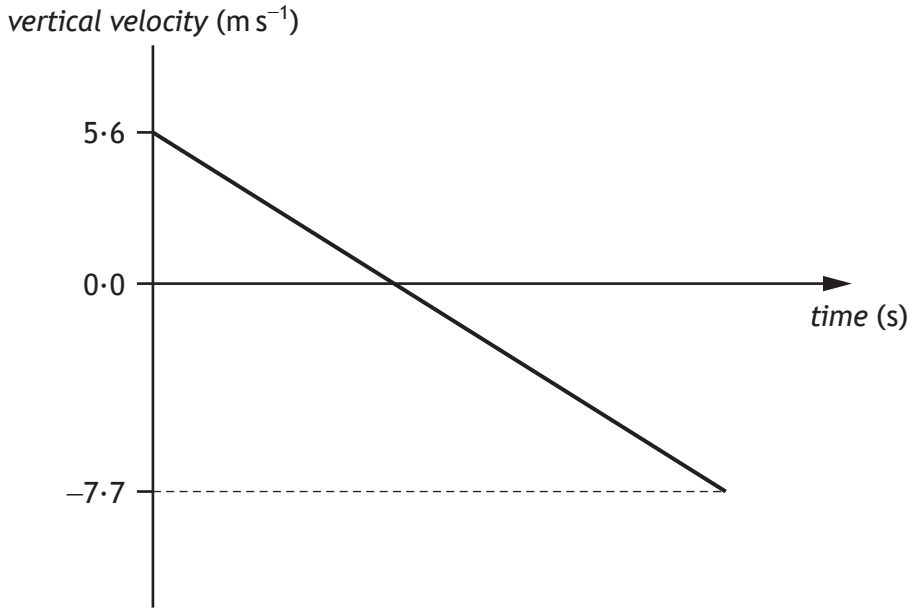
Space for working and answer

(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.

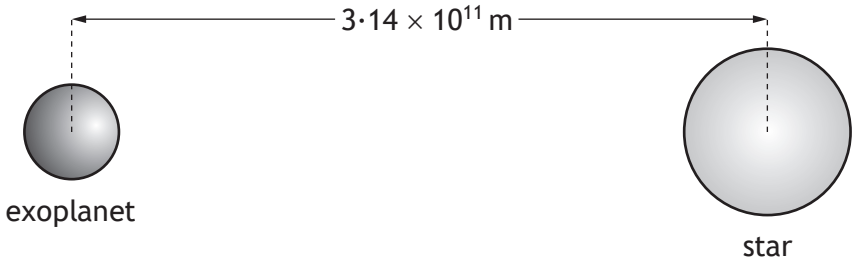
Additional numerical values on the axes are not required. **3**



(An additional graph, if required, can be found on *Page 39*.)

5. Planets outside our solar system are called exoplanets.

An exoplanet of mass $5{\cdot}69 \times 10^{27}$ kg orbits a star of mass $3{\cdot}83 \times 10^{30}$ kg.



not to scale

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

Space for working and answer

(ii) The distance between the exoplanet and the star is $3{\cdot}14 \times 10^{11}$ m.

Calculate the gravitational force between the star and the exoplanet. **3**

Space for working and answer

5. (continued)

(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.

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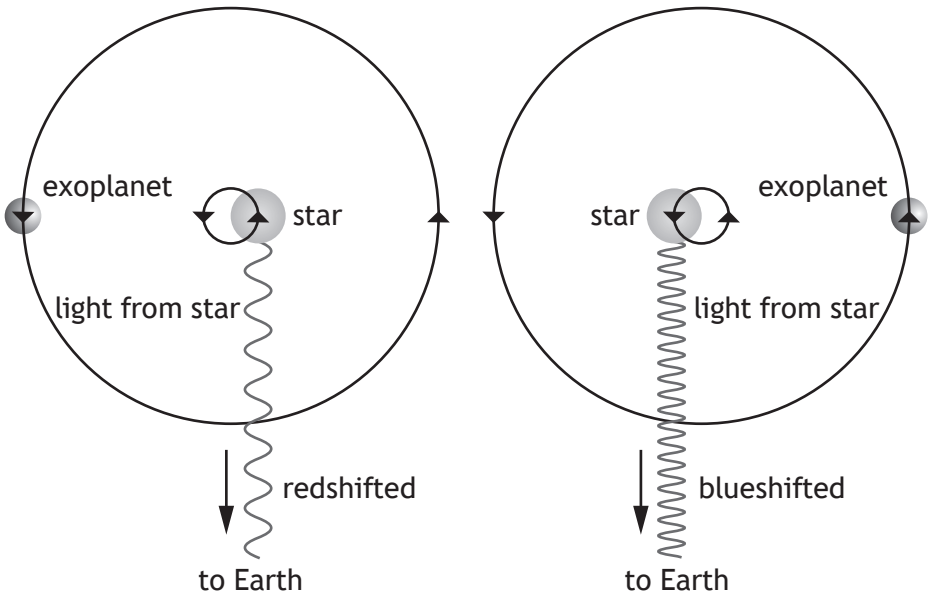


(i) Calculate the redshift of light from the star observed on Earth when the star is moving away from the Earth at $6{\cdot}60 \times 10^3\ m\ s^{-1}$. **3**

Space for working and answer

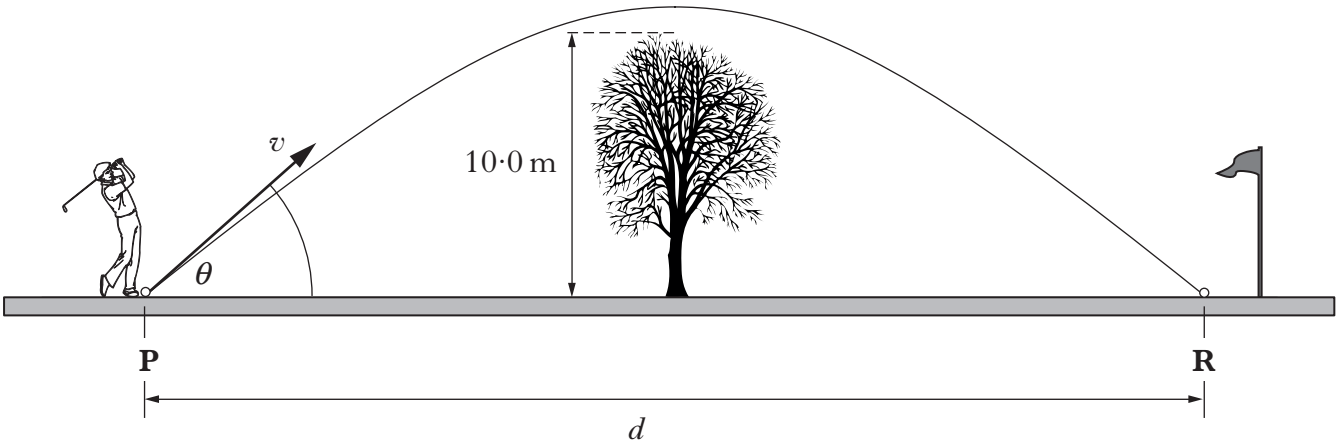
(ii) For an exoplanet of greater mass at the same distance from the star, suggest whether the radius of the circular path followed by the star would be greater than, less than, or the same as that for an exoplanet of smaller mass. **1**

21. A golfer hits a ball from point **P**. The ball leaves the club with a velocity v at an angle of θ to the horizontal.

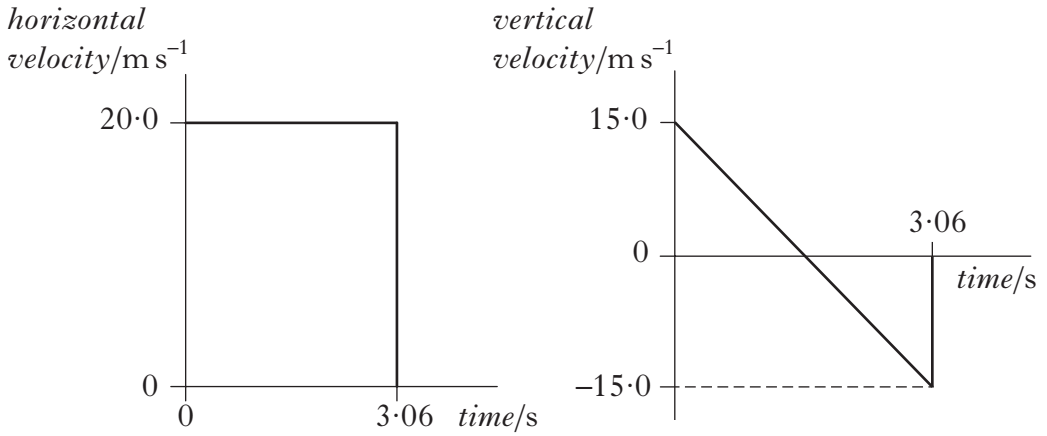
The ball travels through the air and lands at point **R**.

Midway between **P** and **R** there is a tree of height 10·0 m.

not to scale



(*a*) The horizontal and vertical components of the ball's velocity during its flight are shown.



The effects of air resistance can be ignored.

Calculate:

(i) the horizontal distance d; **1**

(ii) the maximum height of the ball above the ground. **2**

(*b*) When the effects of air resistance are **not** ignored, the golf ball follows a different path.

Is the ball more or less likely to hit the tree?

You must justify your answer. **2**

Marks

22. All stars emit radiation with a range of wavelengths. The peak wavelength of radiation, λ_{peak}, emitted from a star is related to the surface temperature, T, of the star.

The table gives the surface temperatures, in kelvin, of four different stars and the peak wavelength radiated from each star.

Surface temperature of star T/K	*Peak wavelength radiated* λ_{peak}/m
4200	$6{\cdot}90 \times 10^{-7}$
5800	$5{\cdot}00 \times 10^{-7}$
7900	$3{\cdot}65 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

(*a*) Use **all** the data in the table to show that the relationship between the surface temperature, T, of a star and the peak wavelength radiated, λ_{peak}, from the star is

$$T = \frac{2{\cdot}9 \times 10^{-3}}{\lambda_{peak}}$$

2

(*b*) The blue supergiant star Eta Carinae is one of the largest and most luminous stars in our galaxy. It emits radiation with a peak wavelength of 76 nm.

Calculate the surface temperature, in kelvin, of this star. **2**

(*c*) Radiation of peak wavelength 1·06 mm can be detected on Earth coming from all directions in space.

(i) What name is given to this radiation? **1**

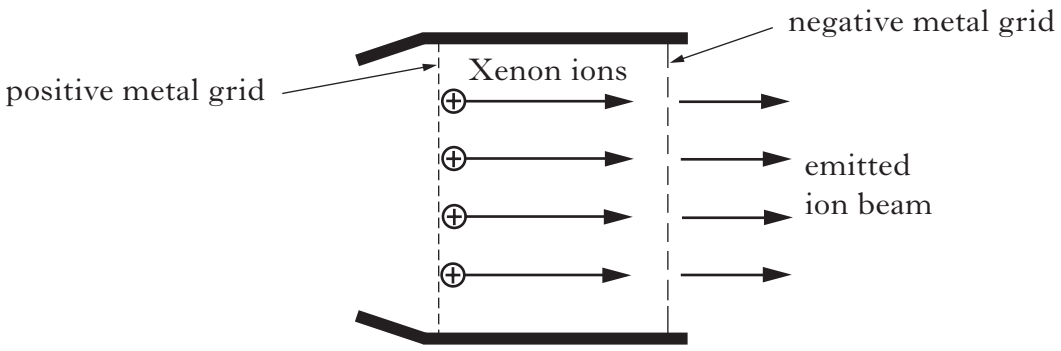
(ii) Give a reason why the existence of this radiation supports the Big Bang Theory. **1**

(6)

Marks

23. An ion propulsion engine can be used to propel spacecraft to areas of deep space.

A simplified diagram of a Xenon ion engine is shown.



The Xenon ions are accelerated as they pass through an electric field between the charged metal grids. The emitted ion beam causes a force on the spacecraft in the opposite direction.

The spacecraft has a total mass of 750 kg.

The mass of a Xenon ion is $2{\cdot}18 \times 10^{-25}$ kg and its charge is $1{\cdot}60 \times 10^{-19}$ C. The potential difference between the charged metal grids is 1·22 kV.

(*a*) (i) Show that the work done on a Xenon ion as it moves through the electric field is $1{\cdot}95 \times 10^{-16}$ J. **1**

(ii) Assuming the ions are accelerated from rest, calculate the speed of a Xenon ion as it leaves the engine. **2**

(*b*) The ion beam exerts a constant force of 0·070 N on the spacecraft. Calculate the change in speed of the spacecraft during a 60 second period of time. **2**

(*c*) A different ion propulsion engine uses Krypton ions which have a smaller mass than Xenon ions. The Krypton engine emits the same number of ions per second at the same speed as the Xenon engine.

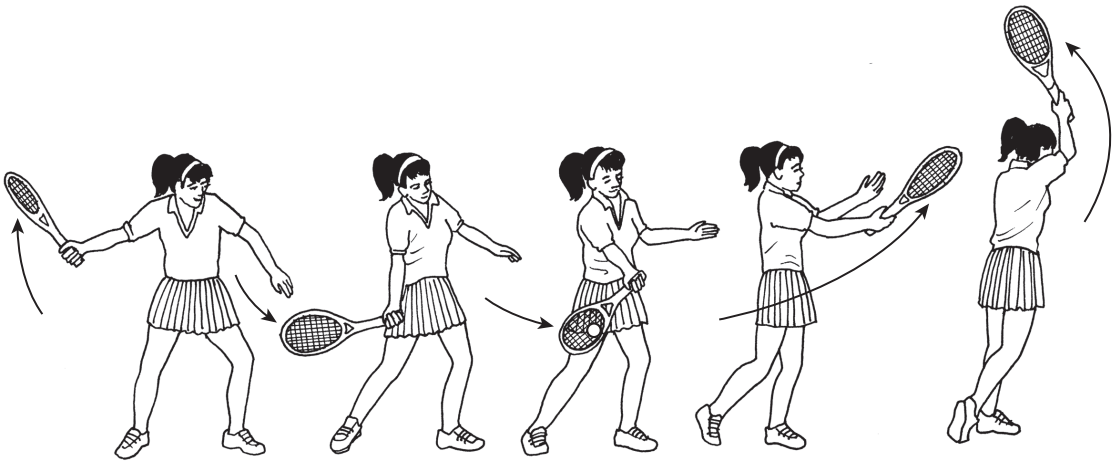
Which of the two engines produces a greater force?

Justify your answer. **2**

(7)

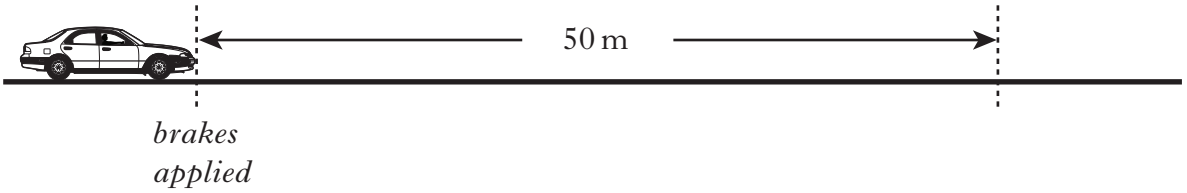
Marks

24. Tennis players are coached to swing "through the ball" when striking it rather than stopping the tennis racquet suddenly.



Use your knowledge of physics to comment on why this causes the ball to leave the racquet with a greater speed. **(3)**

25. A car is travelling along a straight, level road. The brakes are then applied and the car comes to rest in a distance of 50 m.



The work done in stopping the car is 75 kJ and the average external frictional force exerted on the car is 300 N.

The total mass of the car and driver is 1100 kg.

(*a*) Calculate the average force exerted by the brakes on the car. **3**

(*b*) A second car of smaller total mass is travelling at the same speed along the same road. Its brakes are applied and it stops in the same distance of 50 m.

The same average external frictional force is exerted on this car.

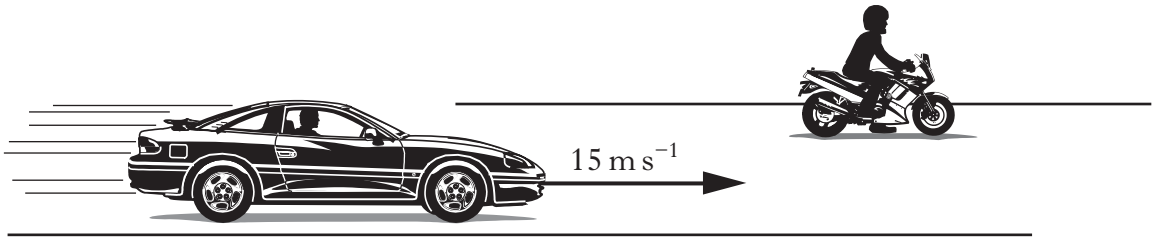
How does the value of the average braking force on this car compare to that of the original car?

You must justify your answer. **2**

(5)

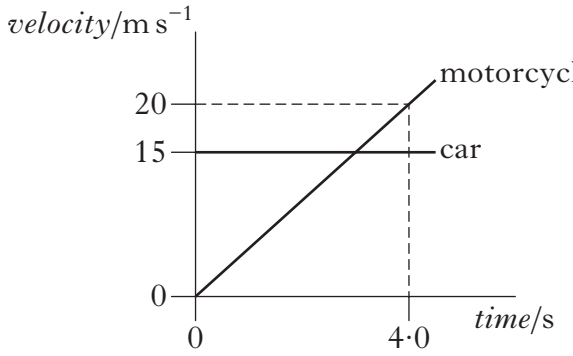
21. A car is travelling at a constant speed of $15\,m\,s^{-1}$ along a straight, level road.

It passes a motorcycle which is stationary at the roadside.



At the instant the car passes, the motorcycle starts to move in the same direction as the car.

The graph shows the motion of each vehicle from the instant the car passes the motorcycle.



(*a*) Show that the initial acceleration of the motorcycle is $5{\cdot}0\,m\,s^{-2}$. **1**

(*b*) Calculate the distance between the car and the motorcycle at 4·0 s. **2**

(*c*) The total mass of the motorcycle and rider is 290 kg. At a time of 2·0 s the driving force on the motorcycle is 1800 N.

(i) Calculate the frictional force acting on the motorcycle at this time. **2**

(ii) Explain why the driving force must be increased with time to maintain a constant acceleration. **1**

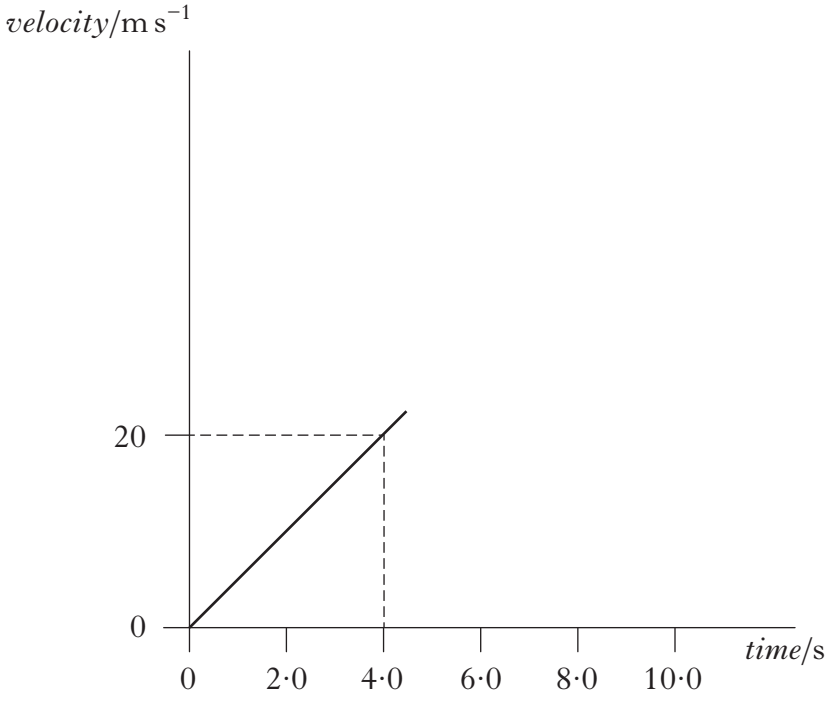
Marks

21. (continued)

(*d*) The driving force on the motorcycle reaches its maximum value at 5·0 s and then remains constant.

Sketch the velocity-time graph shown below and extend the graph to show how the velocity of the motorcycle varies with time between 4·0 s and 10·0 s.

Additional numerical values on the velocity axis are **not** required.



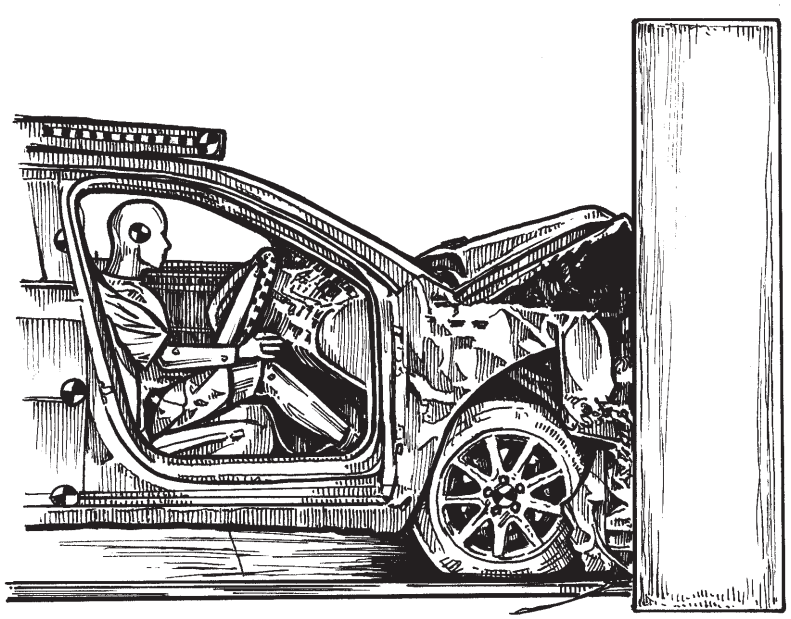
1

(7)

Marks

22. The force applied by a seat belt on a crash test dummy is being investigated. The crash test dummy is placed in a car.

The car then travels along a test track at a speed of $13{\cdot}4\ \text{m s}^{-1}$, collides with a wall and comes to rest.



(*a*) State the law of conservation of linear momentum. **1**

(*b*) The total mass of the car and dummy is 1200 kg.

Calculate the change in momentum of the car and dummy in the collision. **2**

(*c*) The crash test dummy has a mass of 75 kg and is wearing a seat belt. During the collision the dummy travels a distance of 0·48 m while coming to rest.

Calculate the average force exerted on the dummy by the seat belt. **3**

(*d*) This seatbelt is designed to stretch slightly during the collision.

Explain, in terms of forces, an advantage of this design. **2**

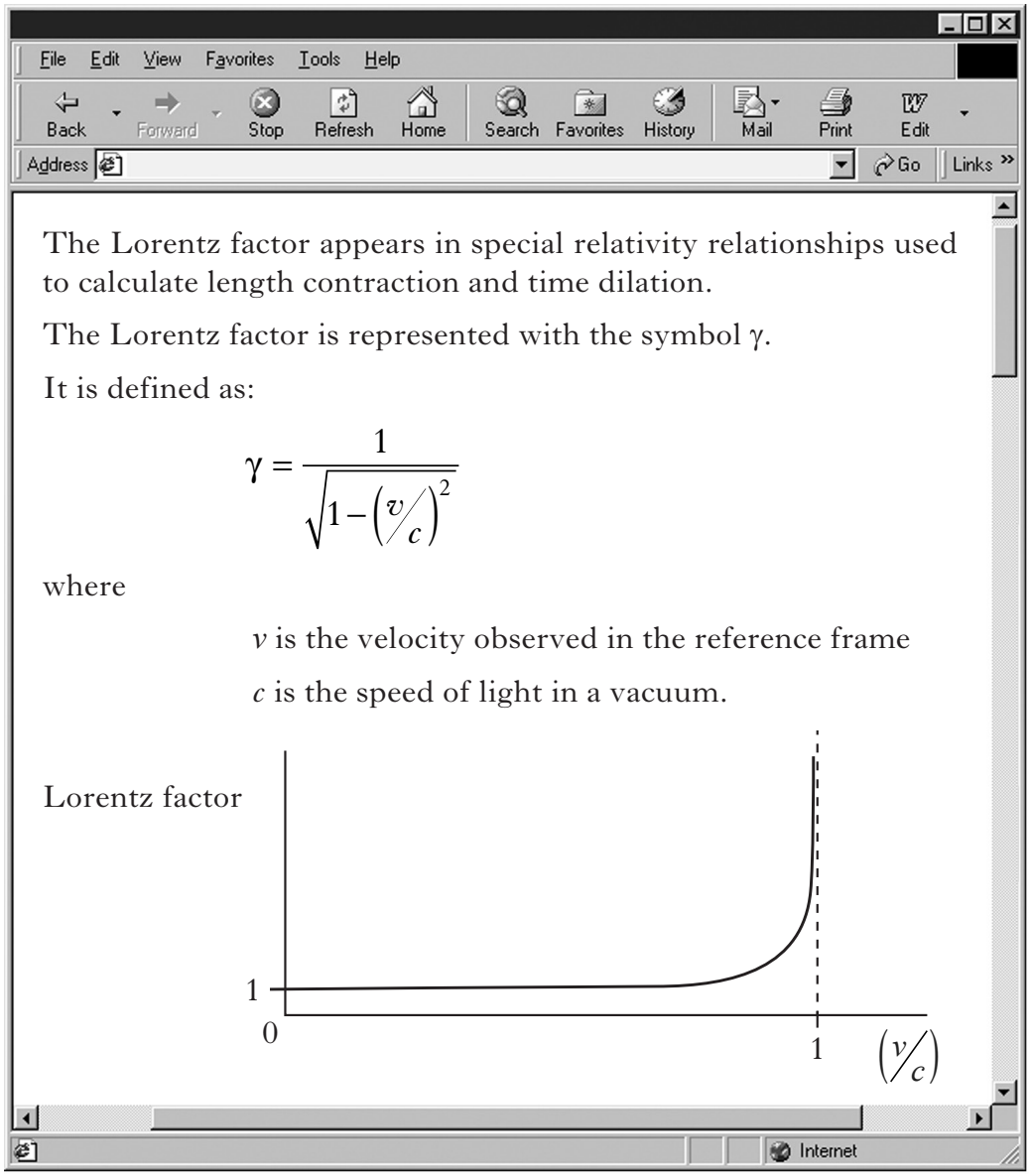
(8)

23. Estimate the gravitational force of attraction between two students sitting beside each other.

Clearly show your working for the calculation and any estimates you have made. **(3)**

Marks

24. A page from a website on special relativity is shown.



(*a*) Explain what is meant by the term *length contraction*. **1**

(*b*) Calculate the Lorentz factor when the ratio $\left(v/c\right) = 0{\cdot}80$. **1**

(*c*) Length contraction calculations use the relationship

$$l' = l\sqrt{1-\left(v/c\right)^2}$$

where the symbols have their usual meanings.

State this relationship in terms of l', l and γ. **1**

(*d*) Explain, in terms of the Lorentz factor, why an observer can ignore relativistic effects for an object which is moving with a velocity much less than *c*. **2**

(5)

Marks

25. (*a*) Experimental work at CERN has been described as "*recreating the conditions that occurred just after the Big Bang*".

Describe what scientists mean by the *Big Bang theory* and give **one** piece of evidence which supports this theory. **2**

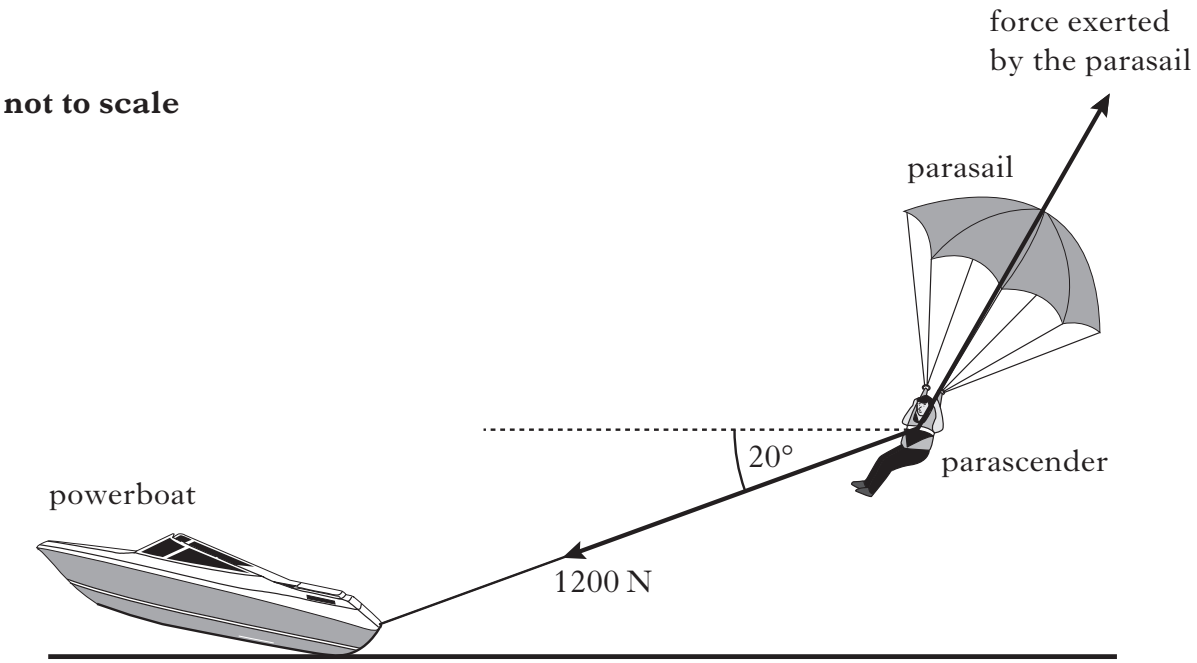
(*b*) During a television programme the presenter states, "*Looking through a telescope at the night sky is like looking back in time*".

Use physics principles to comment on this statement. **3**

(5)

Marks

21. A powerboat is used to pull a parascender at a constant speed and height.



The weight of the parascender is 900 N.

A rope exerts a force of 1200 N on the parascender at an angle of 20° to the horizontal.

Another force is exerted on the parascender by the parasail.

(*a*) The resultant force acting on the parascender is 0 N.

(i) State what is meant by the *resultant of a number of forces*. **1**

(ii) By scale drawing or otherwise, determine the magnitude and direction of the force exerted on the parascender by the parasail. **3**

(*b*) The parascender releases the rope and initially rises higher.

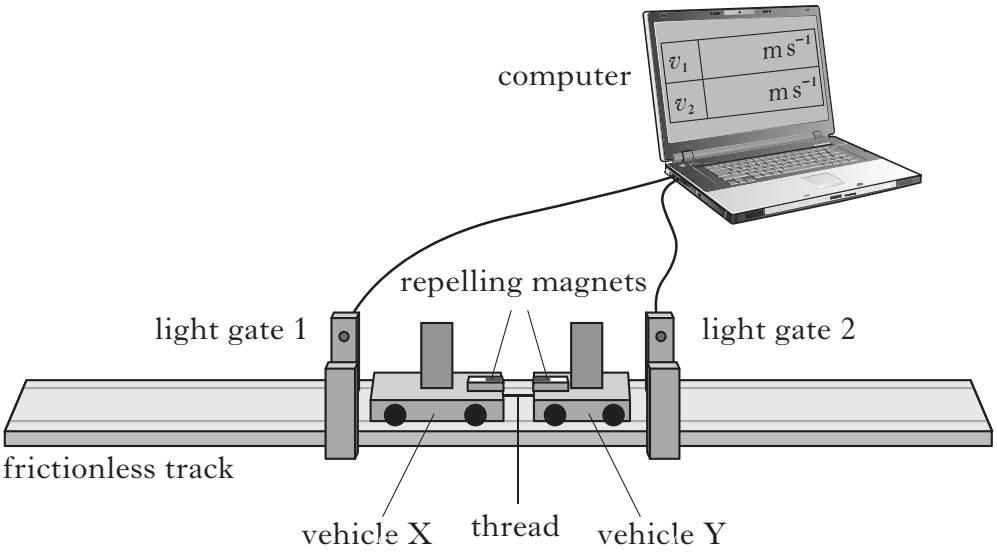
Explain, in terms of the forces acting, why the parascender rises. **2**

(6)

Marks

22. Interactions between objects can be analysed using the law of conservation of momentum.

(*a*) An experiment is set up to verify that momentum is conserved when two vehicles explode apart.



Initially both vehicles are stationary on the horizontal track and are held together by a thread.

The thread is cut and the force between the magnets pushes the vehicles apart.

The computer then displays the speed of each vehicle as it passes through a light gate.

The following data is recorded:

Mass of vehicle X = 0·70 kg
Mass of vehicle Y = 0·30 kg
Speed of vehicle X through light gate 1 = 0·51 m s^{-1}
Speed of vehicle Y through light gate 2 = 1·19 m s^{-1}

Use this data to show that momentum is conserved in this interaction. **2**

22. (continued)

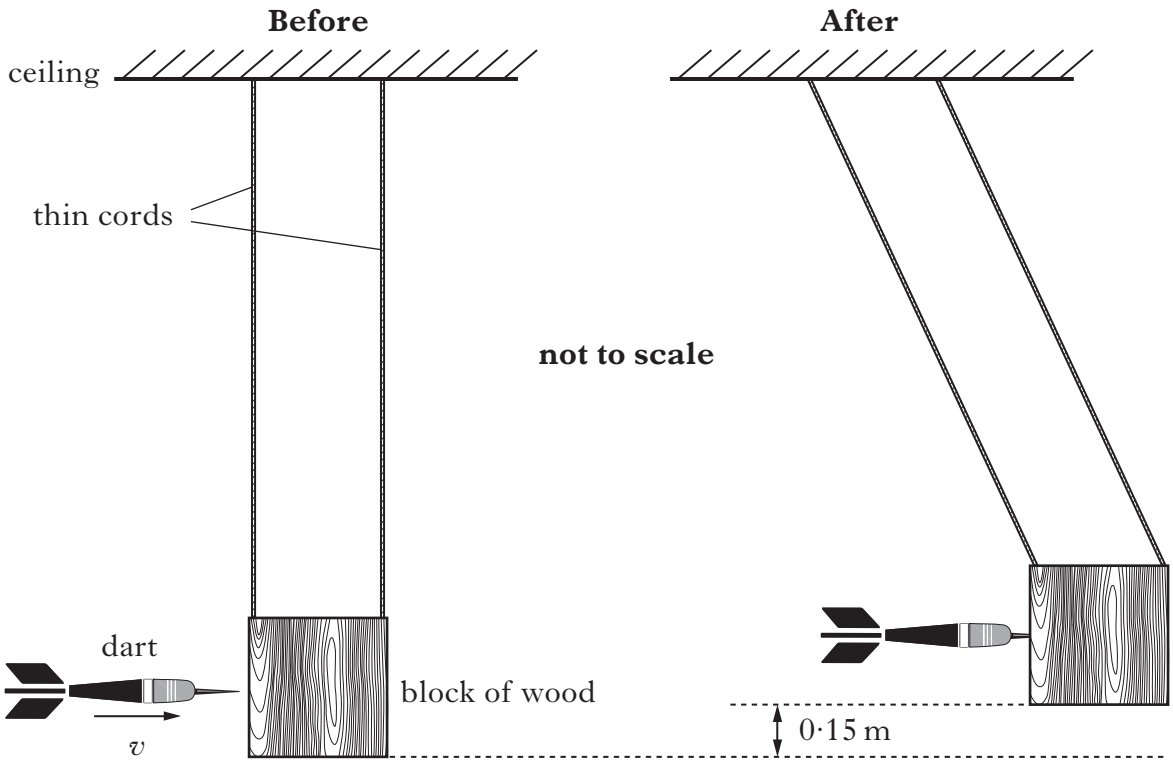
(*b*) In a second experiment, a block of wood of mass 0·20 kg is suspended from the ceiling by thin cords of negligible mass.

A dart of mass 0·050 kg is thrown at the stationary block of wood.

Just before the dart hits the block it is travelling horizontally at a velocity v.

The dart sticks into the block.

The dart and block then swing to a maximum height of 0·15 m as shown.



(i) Use conservation of energy to show that the velocity of the dart and block just after the collision is 1·7 m s^{-1}. **1**

(ii) Calculate the velocity v of the dart just before it hits the block. **2**

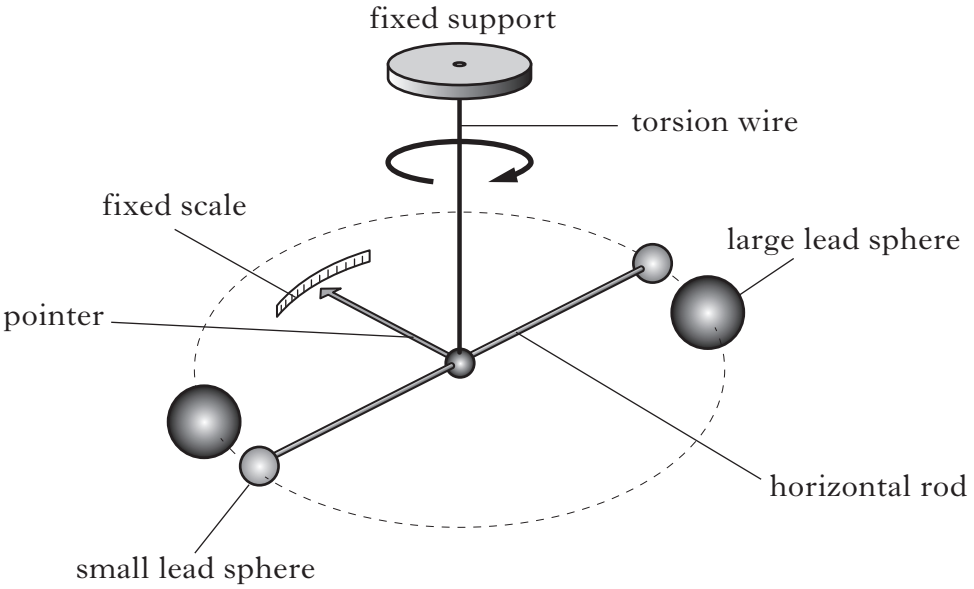
(5)

[Turn over

Marks

23. A student carries out an experiment to measure the Universal Constant of Gravitation.

The apparatus consists of a horizontal rod with small lead spheres at each end. The rod is suspended from its centre by a thin torsion wire. The student places a large lead sphere near each of the small spheres. The gravitational attraction between each pair of large and small spheres causes the torsion wire to twist. The angle of twist is indicated on a fixed scale by the position of a pointer attached to the rod.



The torsion wire twists by one degree when each small lead sphere experiences a force of $1{\cdot}56 \times 10^{-9}$ N.

(*a*) (i) The student measures the angle of twist to be 0·45°.

Show that the gravitational force between one pair of large and small spheres is $7{\cdot}0 \times 10^{-10}$ N. **1**

(ii) The small lead spheres each have a mass of 0·0148 kg.

The large lead spheres each have a mass of 1·52 kg.

The student measures the distance from the centre of mass of each of the large spheres to the centre of mass of its adjacent small sphere to be 46·5mm.

What value does the student determine for the Universal Constant of Gravitation from these results? **2**

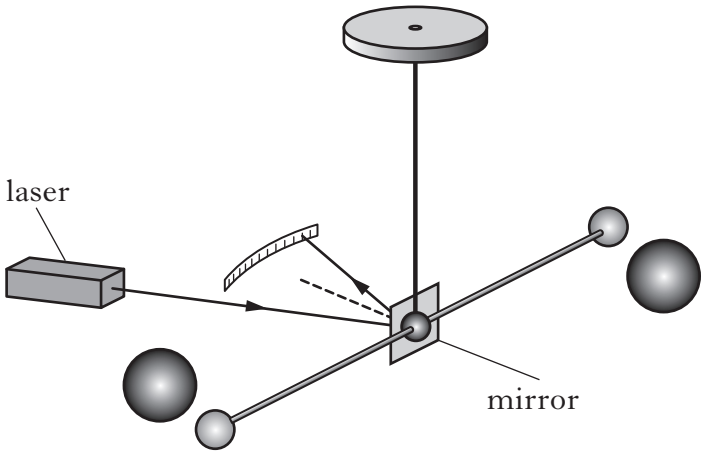
23. (continued)

(*b*) The manufacturer of the apparatus claims that this experiment can achieve an accuracy to within ±2·5% of the accepted value for the Universal Constant of Gravitation.

Does the student's value for the Universal Constant of Gravitation agree with this claim?

You must justify your answer by calculation. **2**

(*c*) The student now decides to replace the pointer on the horizontal rod with a small mirror. A laser beam is then directed at the mirror in such a way that the beam is reflected onto the scale as shown.



Explain how this modification improves the accuracy of the experiment. **2**

(7)

24. According to the lyrics of a popular comedy song:

The universe itself keeps on expanding and expanding in all of the directions it can whizz.

As fast as it can go, at the speed of light, you know, twelve million miles a minute, and that's the fastest speed there is.

Use your knowledge of physics to comment on these lyrics. **(3)**