PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 1: MECHANICS

SCORE	PERCENTAGE
/231	%

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Q1.

Astronomers often use the unit megaparsec (Mpc) for astronomical distances. In a textbook a value for the Hubble constant is given as 72 km s^{-1} Mpc^{-1}.

(a)(i) Show that 72 km s^{-1} Mpc^{-1} is equivalent to a Hubble constant of about 2.3×10^{-18} s^{-1}.

1 Mpc = 3.09×10^{22} m

(2)

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(ii) Determine a value for the age of the universe in years.

1 year = 3.16×10^{7} s

(2)

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Age of universe = ... years

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

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(Total for question = 6 marks)

Q2.

In the 17th century, Kepler proposed his 'law of harmonies' for planetary motion. This law suggested that the ratio of the square of the orbital period T to the cube of the mean radius R has the same value for all the planets that orbit the Sun.

Mathematically his 'law of harmonies' can be written

$$T^2 = KR^3$$

where K is a constant.

(a) The table shows data for Earth and Mars.

Planet	T/s	R/m
Earth	3.16×10^7	1.50×10^{11}
Mars	5.93×10^7	2.28×10^{11}

Show that, for Earth and for Mars, K has a value of about 3.0 ×× 10^{-19} s^2 m^{-3}.

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(b) Kepler's law of harmonies was derived later by Newton. Newton applied his law of gravitation to a planet moving in an approximately circular orbit around the Sun.

Determine a value for K by applying Newton's law of gravitation to a planet of mass m moving in a circular orbit about the Sun.

mass of Sun = 1.99×10^{30} kg

(3)

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K = ... $s^2\ m^{-3}$

(c) Jupiter is the most massive planet in the solar system and has many moons. Kepler's law of harmonies applies to the orbiting moons. However, the value of K for the moons is not the same as the value that applies to planets orbiting the Sun.

Ganymede is Jupiter's largest moon. Ganymede has an orbital radius of 1.07×10^9 m and an orbital period of 172 hours.

Another moon, Io, has an orbital radius of 4.22×10^8 m.

Calculate the orbital period T_I of Io about Jupiter.

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T_I = ...

(Total for question = 8 marks)

Q3.

The astronomer Hertzsprung used parallax to determine the distances to some of the variable stars known as Cepheids.

(a) Using parallax measurements, astronomers can determine distances to all stars with a parallax angle
larger than 2.4×10^{-7} rad.

The variable star Alpha Cephei is 4.6×10^{17} m from the Earth.

Deduce whether the distance to Alpha Cephei could be determined from parallax measurements.

distance from Earth to Sun = 1.5×10^{11} m

(3)

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(b) Cepheids are a type of standard candle.

Describe how standard candles can be used to determine distances to stars.

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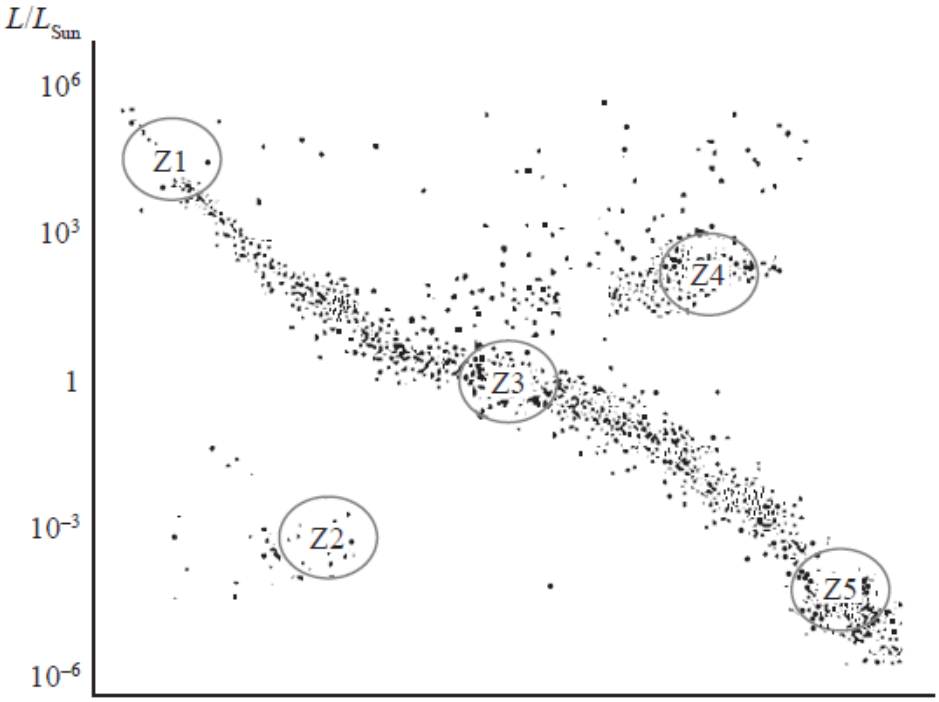
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(c) The Sun is a yellow star with a surface temperature of about 6000 K. In the 20th century, astronomers discovered a large variety of stars in our galaxy. Hertzsprung and Russell developed the Hertzsprung-Russell (HR) diagram as a way of classifying stars.

An HR diagram is shown below.



(i) Label the x-axis of the HR diagram. You should include approximate values.

(3)

(ii) There are five zones, Z1, Z2, Z3, Z4 and Z5, identified on the HR diagram.

Complete the following table. You should match one zone with each description.

(3)

Description	Zone
High mass hot stars	
Low mass cool stars	
Low mass hot stars	

*(iii) The position of a star on the HR diagram changes as the star evolves.

Explain how a star like the Sun evolves as it progresses from zone Z3 to its final position on the HR diagram.

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(Total for question = 18 marks)

Q4.

The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of 1.50×10^{-5} m^3. The pressure of the mercury vapour is 4.25×10^4 Pa.

Calculate the mean kinetic energy of the mercury atoms.

(3)

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Mean kinetic energy of mercury atoms = ...

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm.

The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about 1400 m s^{-1}.

Deduce whether the student's conclusions are correct.

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(c) The surface temperature of Chi Lupi is twice the surface temperature of the Sun.

The radius of Chi Lupi is three times the radius of the Sun.

State where Chi Lupi would be located on the Hertzsprung-Russell diagram.

(1)

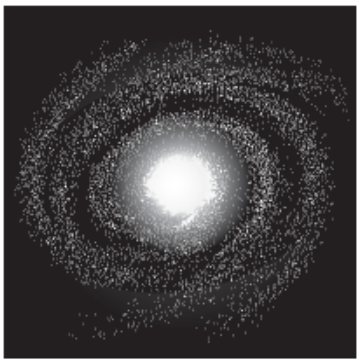
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(Total for question = 8 marks)

Q5.

The image shown is a representation of our galaxy, the Milky Way.



(Source: © daulon/Shutterstock)

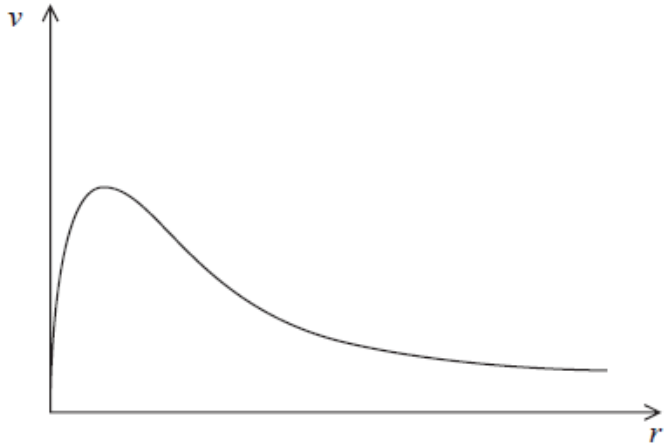
(a) Astronomers think that there is a very large concentration of stars in the central region of the galaxy. Outside this central region the concentration of stars is very much less. All stars in the galaxy are rotating about its centre.

It can be shown that the velocity v of a star a distance r from the centre of the galaxy is given by the expression

$$v = \sqrt{\frac{GM}{r}}$$

where M is the mass of the galaxy contained in a sphere of radius r.

(i) The graph shows how astronomers expect v to vary with r.



Explain how the expression gives the variation of v with r shown in the graph.

(3)

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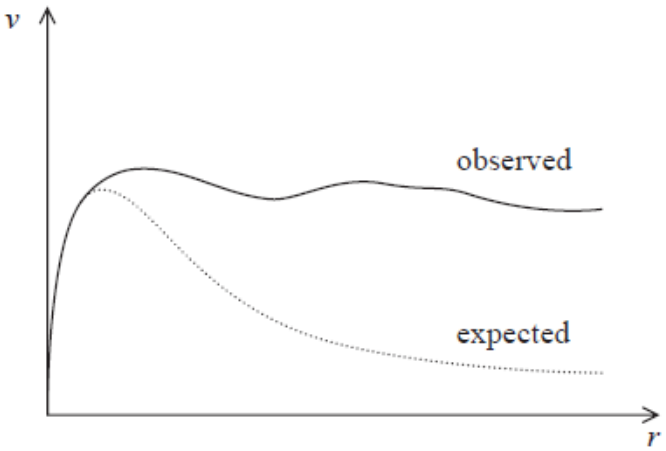
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(ii) The observed variation of v with r has been added to produce the graph below.



Suggest why the 'observed' velocity varies as shown.

(2)

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(b) The ultimate fate of the universe may be a closed universe, but astronomers cannot be sure what their current models predict.

Explain why astronomers cannot be sure that the universe is closed.

(2)

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(Total for question = 7 marks)

Q6.

The planets orbit the Sun in approximately circular orbits. The orbital time *T* of a planet is related to the average distance *r* of the planet from the Sun.

(a)(i) Show that T is related to r by the expression:

$$T^2 \propto r^3$$

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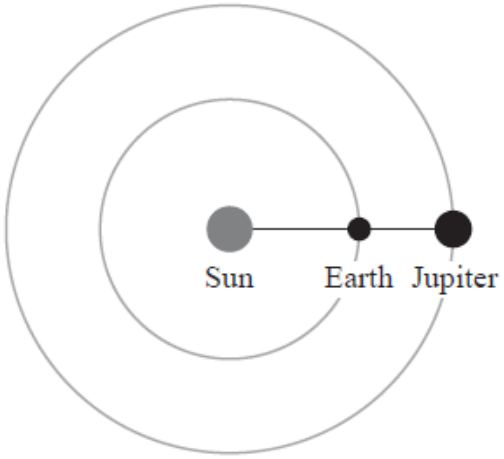
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(ii) When planets align as they orbit the Sun they are said to be 'in opposition'.

The diagram shows the Earth and Jupiter in opposition.



NOT TO SCALE

A website states that the Earth and Jupiter are in opposition every 13 months.

Deduce whether this statement is correct.

mean distance from Earth to Sun = 1.5×10^{11} m
mean distance from Jupiter to Sun = 7.8×10^{11} m
T_{Earth} = 12 months

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(b) The distance of Jupiter from the Sun varies from 7.4×10^{11} m to 8.2×10^{11} m.

Calculate the change in gravitational potential energy of Jupiter as it moves from its closest distance to its furthest distance from the Sun.

mass of Sun = 2.0×10^{30} kg
mass of Jupiter = 1.9×10^{27} kg

(3)

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Change in gravitational potential energy = ...

(Total for question = 11 marks)

Q7.

Wolf 359 is a red dwarf star. The distance of the star from Earth was first determined from parallax measurements made by the astronomer Max Wolf.

(a)(i) The parallax angle was 2.01×10^{-6} rad.

Calculate the distance, in metres, of Wolf 359 from Earth.

mean distance from Earth to Sun = 1.50×10^{11} m

(2)

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Distance of Wolf 359 from Earth = ... m

(ii) Explain why parallax measurements can only be used to determine the distances to a relatively small number of stars.

(2)

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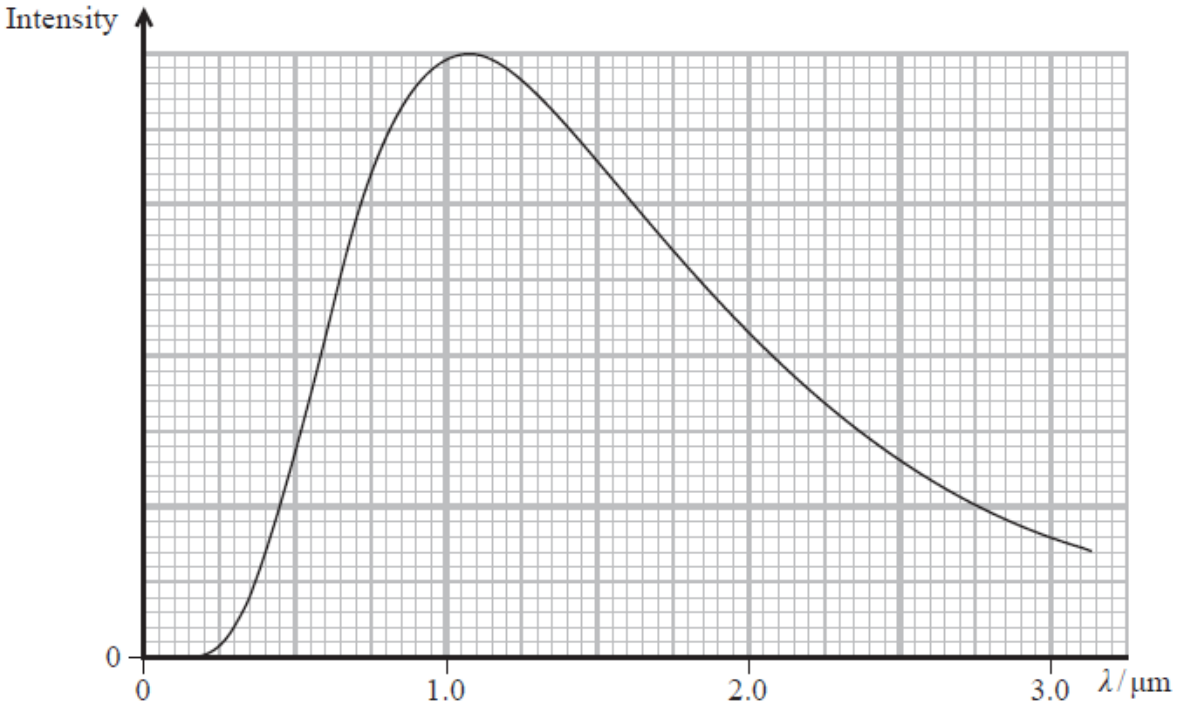
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(b) The graph shows how the intensity of radiation from the star Wolf 359 varies with wavelength.



(i) Show that the surface temperature of Wolf 359 is about 2700 K.

(3)

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(ii) The radius of the Sun is R_{Sun}. The radius of Wolf 359 is 0.16 R_{Sun}.

It is claimed that the luminosity of Wolf 359 is less than 0.1% of the luminosity of the Sun, L_{Sun}.

Deduce whether this claim is correct.

$R_{Sun} = 6.96 \times 10^8$ m
$L_{Sun} = 3.83 \times 10^{26}$ W
$T = 2700$ K

(3)

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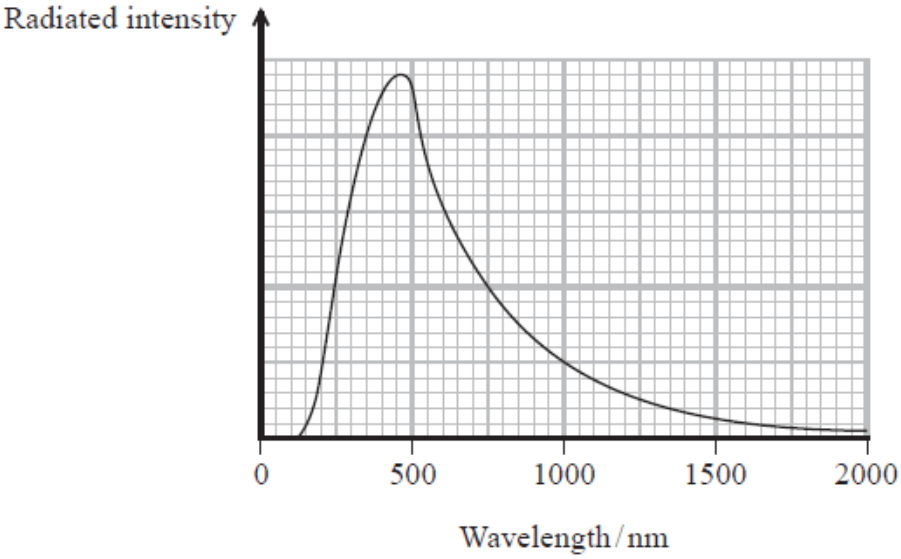
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(Total for question = 10 marks)

Q8.

Procyon is the brightest star in the constellation Canis Minor. The graph shows how the radiated intensity from Procyon varies with wavelength.



A website states that Procyon has twice the diameter of the Sun.

Assess the accuracy of this statement.

luminosity of Procyon = 2.65×10^{27} W
diameter of Sun = 6.96×10^{8} m

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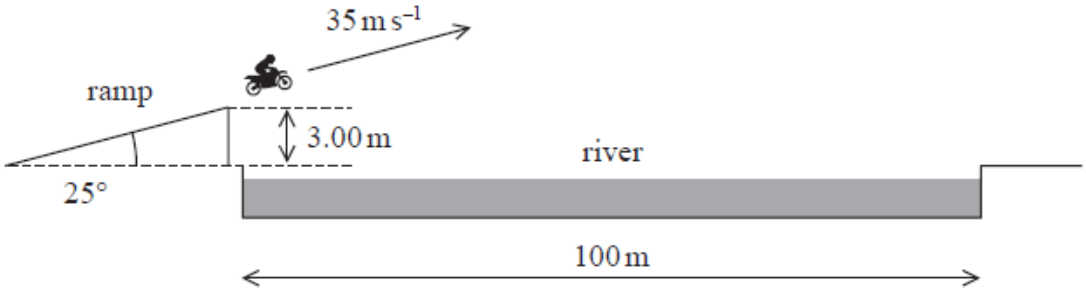
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(Total for question = 5 marks)

Q9.

A stunt motorcyclist wants to jump across a river to land on the other side. The diagram shows the motorcyclist driving off a ramp at the edge of a river.



The ramp is at an angle of 25° to the horizontal and the height at the end of the ramp is 3.0 m. The width of the river is 100 m. The initial velocity of the motorcyclist is 35 m s^{-1}.

(a) Calculate the horizontal and vertical components of the motorcycle's initial velocity as it leaves the ramp.

(2)

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Horizontal component = ...

Vertical component = ...

(b) Deduce whether the rider lands on the other side of the river.

The effects of air resistance can be ignored.

(4)

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(c) Explain how air resistance would affect the jump.

(3)

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(Total for question = 9 marks)

Q10.

A standard candle in the galaxy M81 has a luminosity 14 800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's atmosphere, is 3.64×10^{-17} W m^{-2}.

$L_{Sun} = 3.83 \times 10^{26}$W

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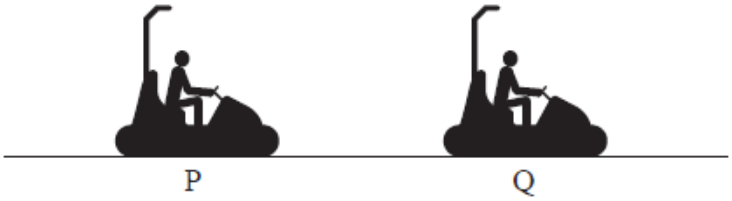
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Distance of M81 from Earth = ...

(Total for question = 3 marks)

Q11.

The diagram shows two bumper cars, P and Q, at an amusement park.



Q was stationary. P was moving at a speed of 2.10 m s^{-1} towards Q.

P collided with Q. After the collision, P and Q moved off in the same direction. P moved with a speed of 1.15 m s^{-1}. Q moved with a speed of 1.57 m s^{-1}.

(a) (i) Show that the total mass of Q was about 150 kg.

total mass of P = 250 kg

(3)

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(ii) State **one** assumption you made in your calculation in (a)(i).

(1)

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(iii) The collision lasted a total time of 1.35 s.

Calculate the average horizontal force on Q during the collision.

(3)

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Average horizontal force = ...

(b) Explain why P decelerates during the collision. Your answer should make reference to Newton's laws of motion.

(3)

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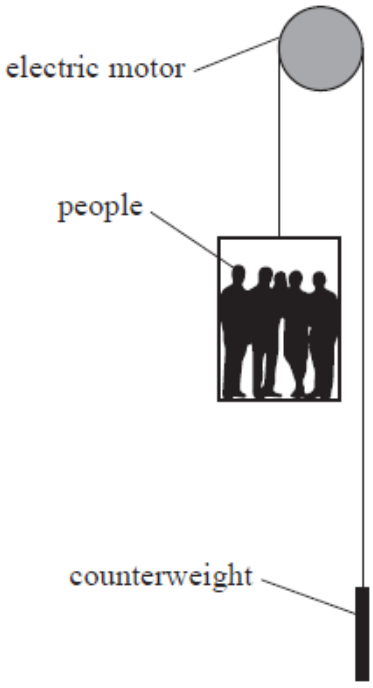
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(Total for question = 10 marks)

Q12.

The diagram shows a lift system for moving people up and down a tall building. There is a counterweight to balance the weight of the lift. An electric motor is used to raise and lower the lift.



(a) Explain how the counterweight affects the amount of work required from the electric motor to raise the lift.

(2)

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(b) The electric motor raises the lift through a height of 40.0 m in a time of 30.0 s.

Show that the output power of the electric motor is about 12 kW.

total mass of lift and people = 2 250 kg
mass of counterweight = 1 300 kg

(4)

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(c) The electric motor dissipates energy to the surroundings at a rate of 3 600 W.

Determine the efficiency of the electric motor.

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Efficiency = ...

(Total for question = 8 marks)

Q13.

A regenerative braking system allows an electric car to use its kinetic energy to charge a battery as the car decelerates.

(a) A car travelling at 13.0 m s^{-1} decelerated to rest.

The energy transferred to the car's battery during the deceleration was 73.9 kJ.

Calculate the efficiency of the regenerative braking system.

mass of car = 1560 kg

(3)

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Efficiency = ...

(b) (i) Drag forces act on the car as it moves through the air.

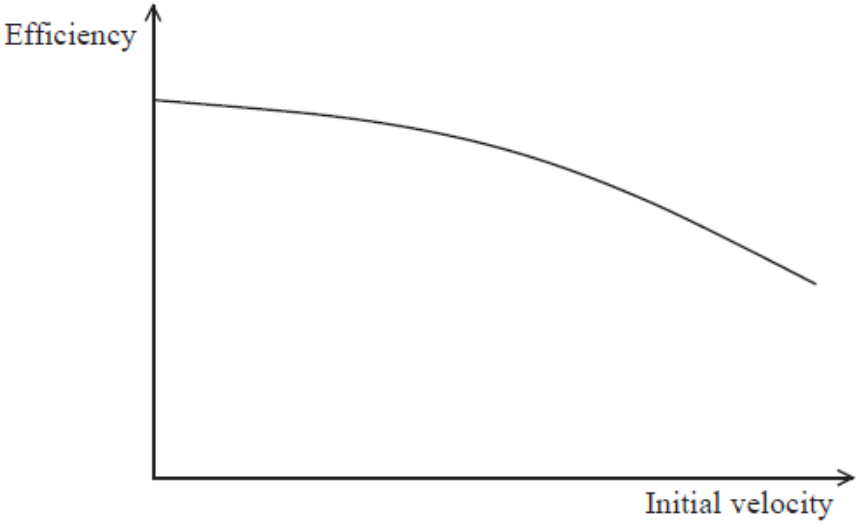
State how the drag forces vary with the velocity of the car.

(1)

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(ii) The graph shows how the efficiency of the regenerative braking system depends upon the initial velocity of the car for initial velocities in the range 20 m s^{-1} to 40 m s^{-1}.



Explain why the efficiency of the regenerative braking system varies as shown in the graph.

(4)

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(Total for question = 8 marks)

Q14.

When an increasing force is applied to a steel cable it will eventually reach its elastic limit.

(a) State what is meant by the elastic limit.

(1)

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(b) The elastic limit of a steel cable was reached when a force of 13.4 × 106 N was applied. The extension of the cable was 0.126 m.

length of cable = 6.00 m cross-sectional area of cable = 9.60 × 10-3 m^2

(i) Calculate the strain of the cable at its elastic limit.

(2)

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Strain = ...

(ii) Calculate the stress in the cable at its elastic limit.

(2)

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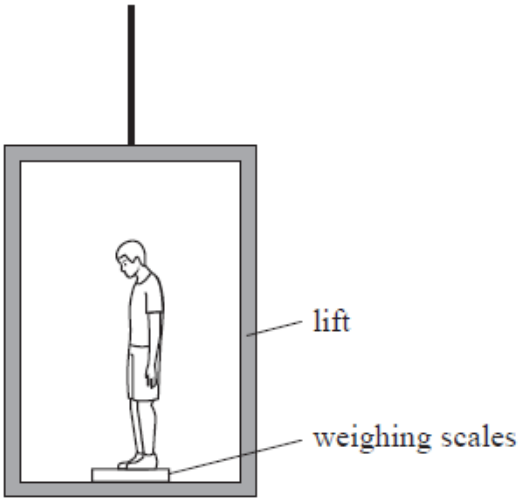
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Stress = ...

(Total for question = 5 marks)

Q15.

* A student of weight 600 N is standing on weighing scales in a lift. The scales are calibrated to give readings in newtons.



The lift moves upwards at constant velocity, then decelerates to rest. As the lift moves, the student looks at the readings on the scales.

Explain the readings on the scales.

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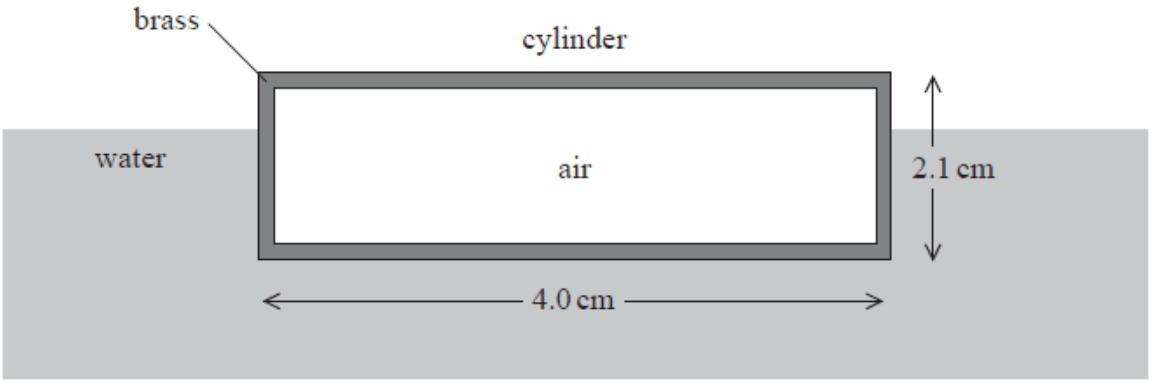
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(Total for question = 6 marks)

Q16.

A hollow brass cylinder with closed ends is floating on the surface of water.

The cylinder has a length of 4.0 cm and an external diameter of 2.1 cm as shown.



63% of the volume of the cylinder is submerged. The cylinder contains negligible weight of air.

(a) Explain why the brass cylinder floats.

(2)

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(b) The density of water is 1.0×10^{3} kg m^{-3}

(i) Show that the mass of the cylinder is about 9×10^{-3} kg.

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(ii) Deduce whether an identical hollow cylinder made of gold would also float.

Assume that the volume of gold is the same as the volume of brass.

density of gold = 19.3×10^{3} kg m^{-3}

density of brass = 8.7×10^3 kg m^{-3}

(4)

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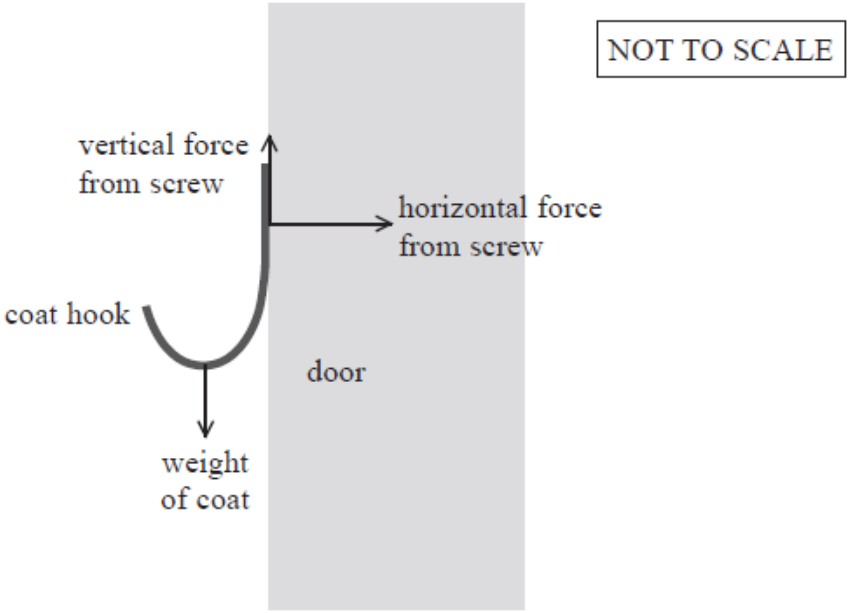
(Total for question = 10 marks)

Q17.

A coat hook is attached to a smooth door by a screw as shown.



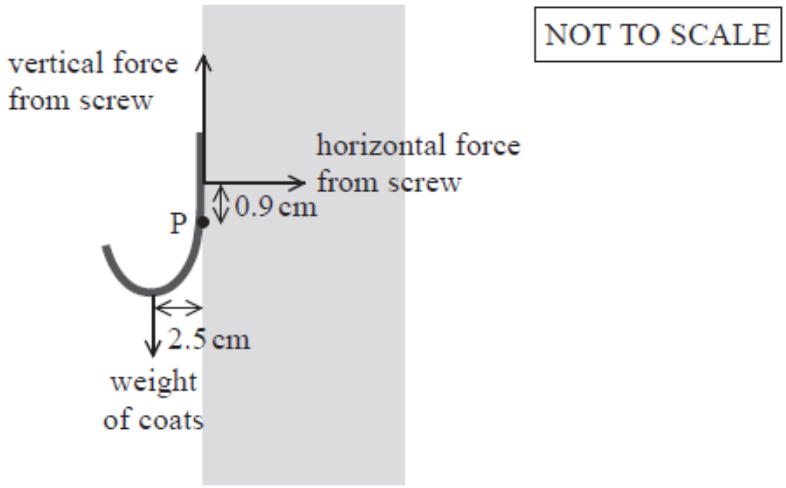
(a) The diagram below shows three of the forces that act on the coat hook when a coat is hung from it. The weight of the coat hook may be neglected.



Add a labelled arrow to the diagram to show the additional force required for the coat hook to be in equilibrium.

(2)

(b) If too many coats are hung on the coat hook, the hook will rotate and pull the screw out of the door. Point P is the position of the pivot as shown.



The maximum horizontal force from the screw is 150 N.

The mass of one coat is 2.6 kg.

Deduce whether a person could hang more than two of these coats from the hook.

(4)

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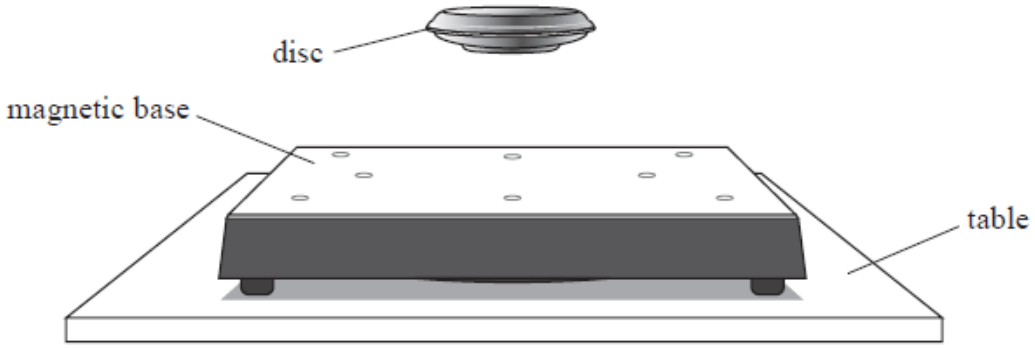
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(Total for question = 6 marks)

Q18.

A disc of mass *m* is held stationary by a force *F* exerted by a magnetic base, as shown.



(a) The free-body force diagram for the disc is shown below.



The two forces shown are equal in magnitude and opposite in direction.

Give two reasons why these forces are **not** a Newton's 3rd law pair.

(2)

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(b) The magnetic base has weight W and rests on a horizontal table.

Complete the free-body force diagram below for the magnetic base.

(2)



(Total for question = 4 marks)

Q19.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following is a scalar quantity?

☒ **A** force

☒ **B** momentum

☒ **C** velocity

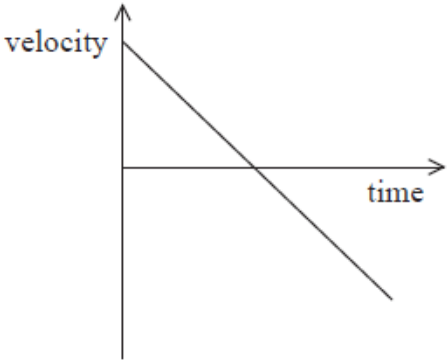
☒ **D** work

(Total for question = 1 mark)

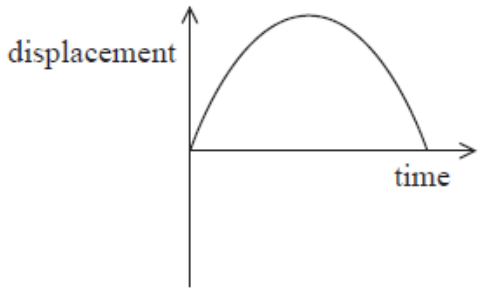
Q20.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

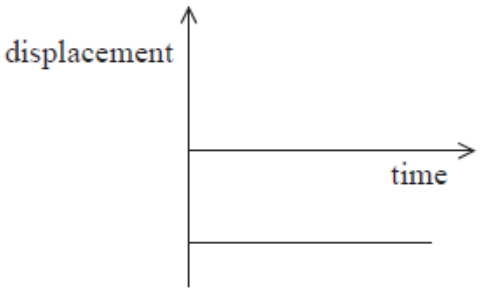
The velocity-time graph for a particle is shown.



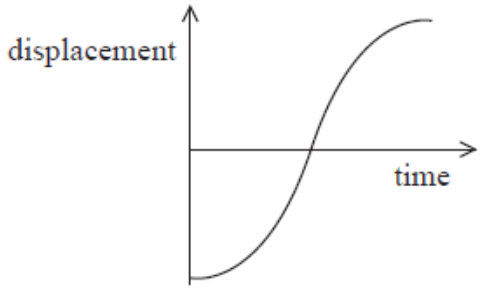
Which of the following is the displacement-time graph for this particle?



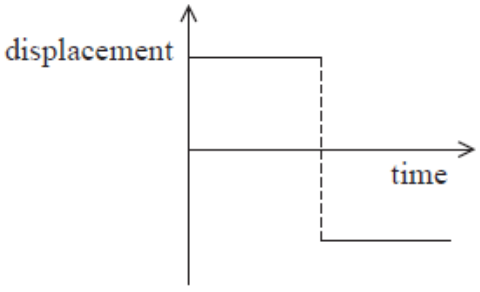
A



B



C



D

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q21.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

A student determined a value for *g* by dropping a metal sphere from rest. The student measured the distance fallen and the time taken for the sphere to fall.

The student obtained a value for *g* of 11.2 m s^{-2}.

Which of the following could explain the difference between the student's value and the accepted value?

☒ **A** The air resistance was not negligible.

☒ **B** The student's measured distance was greater than the actual distance.

☒ **C** The sphere did not fall vertically.

☒ **D** The student's measured time was greater than the actual time taken.

(Total for question = 1 mark)

Q22.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

A machine has a power of 750 W and transfers 150 kJ of energy during a time *t*.

Which of the following expressions gives *t* in seconds?

☒ **A** $\frac{750}{150}$

☒ **B** $\frac{750 \times 150}{1000}$

☒ **C** $\frac{150 \times 1000}{750}$

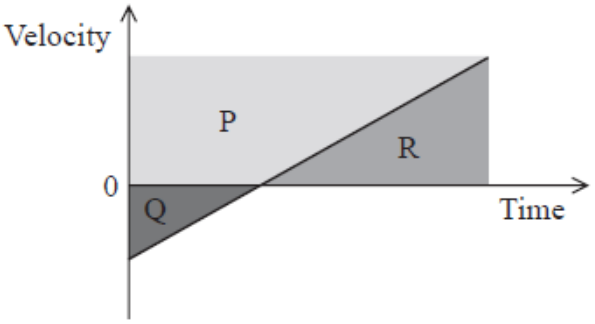
☒ **D** $\frac{750}{150 \times 1000}$

(Total for question = 1 mark)

Q23.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

The velocity-time graph shows the motion of a particle with a constant acceleration. P, Q and R represent the magnitudes of each area shown.



Which of the following expressions gives the total displacement of the particle?

☒ **A** P + Q

☒ **B** P + Q − R

☒ **C** R + Q

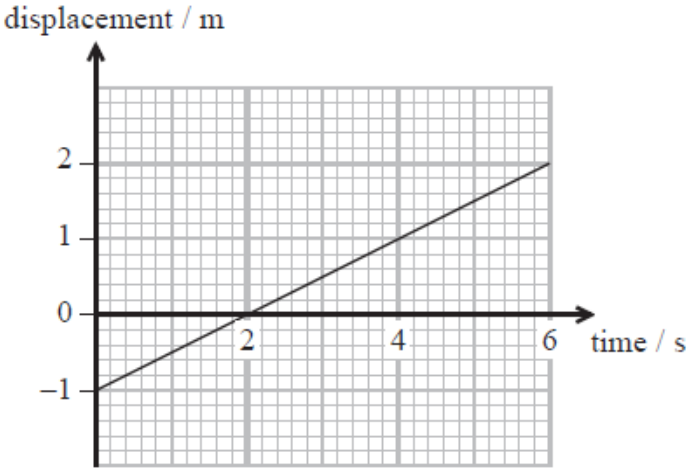
☒ **D** R − Q

(Total for question = 1 mark)

Q24.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A student walks for 6 seconds. The displacement-time graph for the student is shown.



Which row of the table shows the final displacement and velocity of the student?

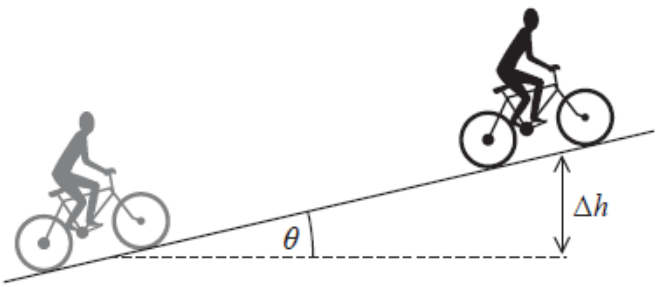
		Displacement / m	Velocity / m s^{-1}
☒	**A**	2.0	0.5
☒	**B**	3.0	0.5
☒	**C**	5.0	2.0
☒	**D**	3.0	2.0

(Total for question = 1 mark)

Q25.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

A cyclist rode along a slope at a constant speed. The increase in vertical height of the cyclist was Δh. The slope was at an angle θ to the horizontal as shown.



The forward force of the road on the bicycle was F and air resistance was negligible.

Which of the following gives the work done by the cyclist?

☒ **A** $F \Delta h \cos\theta$

☒ **B** $\frac{F \Delta h}{\cos\theta}$

☒ **C** $F \Delta h \sin\theta$

☒ **D** $\frac{F \Delta h}{\sin\theta}$

(Total for question = 1 mark)

Mark Scheme

Q1.

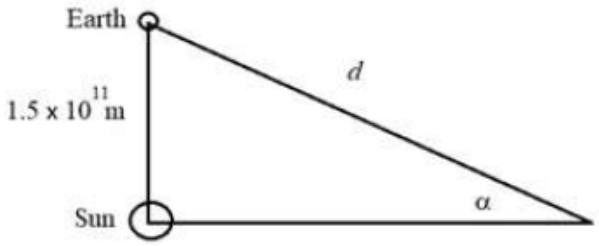
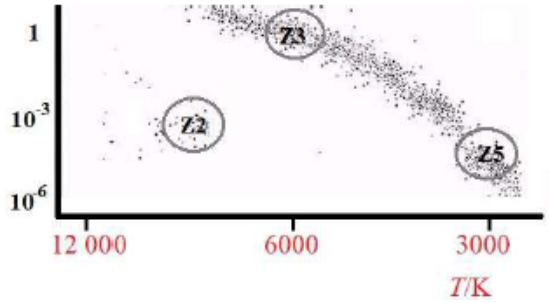
Question Number	Answer		Mark
(a)(i)	Use of $v = H_0 d$	(1)	
	$H_0 = 2.33 \times 10^{-1}$ (s^{-1})	(1)	2
	Example of calculation $H_0 = \frac{72 \times 10^3 \text{ m s}^{-1}}{3.09 \times 10^{22} \text{ m}} = 2.33 \times 10^{-18} \text{ s}^{-1}$		
(a)(ii)	Use of $t = \frac{1}{H_0}$	(1)	
	$t = 1.36 \times 10^{10}$ (years) ecf from (i)	(1)	2
	Example of calculation $t = \frac{1}{2.33 \times 10^{-1} \text{ s}^{-1}} = 4.29 \times 10^{17} \text{ s}$ $t = \frac{4.29 \times 10^{17} \text{ s}}{3.16 \times 10^7 \text{ s year}^{-1}} = 1.36 \times 10^{10} \text{ years}$		
(b)	H_0 is halved (for the same recessional velocity)	(1)	
	So the (calculated) age of the universe doubles (dependent upon MP1)	(1)	
	OR		
	The universe would have taken twice as long to expand to its current size (assuming it expanded at the same rate)	(1)	
	So the age of the universe is double what was previously thought (dependent upon MP1)	(1)	2
	Allow 1 mark max for H_0 is lower so universe is older than previously thought **Or** universe would have taken longer to expand to current size so it is older than previously thought.		
	Total for question		6

Q2.

Question Number	Answer		Mark
(a)	Use of $T^2 = KR^3$	(1)	
	K for Earth = 2.96×10^{-19} ($s^2\ m^{-3}$)	(1)	
	K for Mars = 2.97×10^{-1} ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$K = \frac{T^2}{R^3} = \frac{(3.16 \times 10^7 s)^2}{(1.50 \times 10^{11} m)^3} = 2.959 \times 10^{-19}\ s^2\ m^{-3}$		
	$K = \frac{T^2}{R^3} = \frac{(5.93 \times 10^7 s)^2}{(2.28 \times 10^{11} m)^3} = 2.967 \times 10^{-19}\ s^2\ m^{-3}$		
(b)	**Either**		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	
	Or		
	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$K = \left(\frac{4\pi^2}{6.67 \times 10^{-11}\ N\ m^2\ kg^{-2} \times 1.99 \times 10^{30}\ kg}\right) = 2.97 \times 10^{-1}\ s^2 m^{-3}$		

(c)	Use of $T^2 = KR^3$	(1)	
	T = 43 hours	(1)	**2**
	Example of calculation		
	$\left(\frac{T_I}{T_G}\right)^2 = \left(\frac{R_I}{R_G}\right)^3$		
	$T = \sqrt{\left(\frac{4.22 \times 10^8\ m}{1.07 \times 10^9\ m}\right)^3 \times (172\ hour)^2} = 42.6$ hours		
	Total for question		**8**

Q3.

Question Number	Answer		Mark
(a)	Use of trigonometry to calculate the parallax angle **Or** Use of trigonometry to calculate distance	(1)	
	(Smallest) parallax angle = 3.3×10^{-7} (rad) **Or** max distance = 6.25×10^{17} (m)	(1)	
	Comparison of calculated value with corresponding value in question with valid conclusion	(1)	3
	Example of calculation $\sin\alpha = \dfrac{1.5 \times 10^{11}\ \text{m}}{d}$ $\alpha = \sin^{-1}\left(\dfrac{1.5 \times 10^{11}\ \text{m}}{4.6 \times 10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad **Or** $\alpha = \left(\dfrac{1.5\times10^{11}\ \text{m}}{4.6\times10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad (small angle approximation)		
			
(b)	The intensity (of radiation from the candle) is measured	(1)	
	The luminosity of the standard candle is known	(1)	
	The inverse square law is used to determine the distance [Accept reference to $I=L/4\pi d^2$ with symbols defined]	(1)	3
(c)(i)	Axis labelled with T / K	(1)	
	Reverse logarithmic scale	(1)	
	6000 K in correct position on scale	(1)	3
	Example of graph labelling 		
(c)(ii)			

Description	Zone		
High mass hot stars	Z1	(1)	
Low mass cool stars	Z5	(1)	
Low mass hot stars	Z2	(1)	3

(c)(iii)

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content

IC1 The star is fusing hydrogen in its core

IC2 When fusion ceases (the core of the star cools and) the core collapses/contracts (under gravitational forces)

IC3 The star (moves to Z4 as it expands and) becomes a red giant star

IC4 Temperature (in the core) is high enough for helium fusion to begin

IC5 Helium begins to run out and then fusion ceases

IC6 The star becomes a white dwarf (in Z2)

6

Total for question **18**

Q4.

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Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	3
	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	(1)	
	$\frac{1}{2}m\langle c^2\rangle = 5.8 \times 10^{-20}$ J	(1)	
	Example of calculation $T = \frac{pV}{Nk} = \frac{4.25\times10^{4}\text{ Pa}\times1.50\times10^{-5}\text{ m}^3}{1.65\times10^{19}\times1.38\times10^{-23}\text{ J K}^{-1}} = 2800$ K $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\times 1.38\times10^{-23}\text{ J K}^{-1}\times 2800\text{ K} = 5.80\times10^{-20}$ J		
(b)	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ with wavelength measured on Earth in denominator	(1)	4
	v = 13500 m s^{-1}	(1)	
	The student is correct to say that the star is moving towards the Earth, as the measured wavelength is less than that from the lamp spectrum.	(1)	
	Comparison of calculated velocity with 1400 m s^{-1} and appropriate conclusion.	(1)	
	Example of calculation $v = \frac{\Delta\lambda}{\lambda}c = \frac{(576.933\text{-}576.959)\times10^{-9}\text{m}}{576.959\times10^{-9}\text{ m}}\times3.00\times10^{8}\text{ m s}^{-1} = (-)1.35\times10^{4}\text{ m s}^{-1}$ So the star's velocity is much larger than 1400 m s^{-1}		
(c)	On the main sequence, above the position of the Sun **Or** above and to the left of the position of the Sun	(1)	1
	Total for question		8

Q5.

Question Number	Answer		Mark
(a)(i)	$v \propto \sqrt{\frac{M}{r}}$	(1)	
	Within the central region M changes a lot (so v increases) **Or** Outside the central region M is approximately constant (so v decreases)		
	As r increases v reaches a peak value as shown on the graph	(1)	
	[A bald description of the graph having a peak value can score MP3]	(1)	**3**
(a)(ii)	There must be more mass (than we can observe) [Accept statement that there must be a greater gravitational force]	(1)	
	There is dark matter present (in the galaxy)	(1)	**2**
(b)	(For a closed universe) the density of the universe must be greater than the critical density	(1)	
	And the (average) density of the universe is uncertain **Or** the amount of dark matter is uncertain	(1)	**2**
	Total for question		7

Q6.

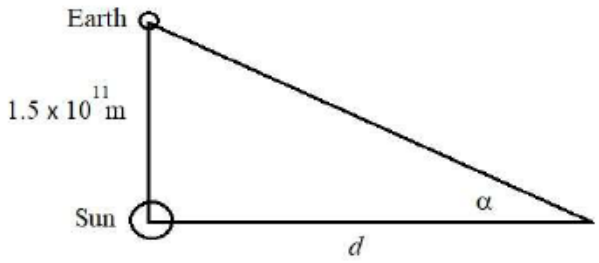
Question Number	Answer		Mark
(a)(i)	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	
	OR		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	3
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$\therefore T^2 \propto r^3$		

(a)(ii)	Use of $T^2 \propto r^3$	(1)	
	T_J = 142 months (11.9 years)	(1)	
	Use of $\omega = \frac{\theta}{t}$ and $\omega = \frac{2\pi}{T}$	(1)	
	Calculation of time elapsed for planets to be in opposition	(1)	
	Time between opposition is 13.1 months, with an appropriate conclusion (dependent upon MP4)	(1)	5
	Example of calculation		
	$\left(\frac{T_J}{T_E}\right)^2 = \left(\frac{r_J}{r_E}\right)^3$		
	$\left(\frac{T_J}{1\text{ year}}\right)^2 = \left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3$		
	$T_J = 12\text{ months} \times \sqrt{\left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3} = 142\text{ months}$		
	At the next opposition Earth will have done one more orbit than Jupiter plus whatever fraction of an orbit Jupiter has completed.		
	If t is the time to next opposition, both planets will have the same angular displacement, so equating $\theta = 2\pi\, t/T$ for both planets where for Earth the time is $(t - 12)$.		
	$\frac{2\pi\text{ rad }(t-12)\text{ month}}{12\text{ month}} = \frac{2\pi\text{ rad }t}{142\text{ month}} \therefore t = 13.1\text{ month}$		

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(b)	Use of $V = (-)\frac{GM}{r}$	(1)	
	Use of $\Delta V \times m$	(1)	
	$\Delta E_{grav} = 3.3 \times 10^{34}$ J	(1)	**3**
	<u>Example of calculation</u> $\Delta V = -GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ $\Delta V = -6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 2.0 \times 10^{30}\text{kg} \times \left(\frac{1}{8.2 \times 10^{11}\ \text{m}} - \frac{1}{7.4 \times 10^{11}\ \text{m}}\right)$ $\Delta V = 1.76 \times 10^{7}\ \text{J kg}^{-1}$ $\therefore \Delta E_{grav} = 1.76 \times 10^{7}\ \text{J kg}^{-1} \times 1.9 \times 10^{27}\ \text{kg} = 3.34 \times 10^{34}\ \text{J}$		
	Total for question		**11**

Q7.

Question Number	Answer		Mark
(a)(i)	Use of trigonometry to calculate distance **Or** use of small angle approximation to calculate distance	(1)	
	Distance to Wolf 359 = 7.5×10^{16} (m)	(1)	**2**
	<u>Example of calculation</u>  $\tan(2.01 \times 10^{-6}) = \frac{1.50 \times 10^{11}\ \text{m}}{d}$ $\therefore d = \frac{1.50 \times 10^{11}\ \text{m}}{2.01 \times 10^{-6}} = 7.46 \times 10^{16}\ \text{m}$		
(a)(ii)	Parallax angle decreases as distance from the Earth increases **Or** parallax is only suitable for (relatively) close stars	(1)	
	As parallax angle is too small to measure for distant stars	(1)	**2**

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(b)(i)	λ_{max} read from graph	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	$T = 2680$ (K) [accept 2635 K → 2760 K]	(1)	**3**
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{1.08 \times 10^{-6}\ \text{m}} = 2683\ \text{K}$		
(b)(ii)	Use of $L = \sigma A T^4$	(1)	
	$L = 4.70 \times 10^{23}$ W (allow ecf from (b)(i))	(1)	
	Comparison of calculated value of L with L_{Sun} and appropriate conclusion **Or** comparison of calculated L/L_{Sun} percentage with 0.1% and appropriate conclusion	(1)	**3**
	Example of calculation $L = 4\pi\,(0.16 \times 6.96 \times 10^8\ \text{m})^2 \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}\ (2700\ \text{K})^4$ $L = 4.70 \times 10^{23}\ W$ $\frac{L}{L_{Sun}} \times 100\% = \frac{4.70 \times 10^{23}\ W}{3.83 \times 10^{26}\ W} \times 100\% = 0.12\%$		
	Total for question		**10**

Q8.

Question Number	Answer		Mark
	λ_{max} read from graph [450 nm → 500 nm]	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	Use of $L = \sigma AT^4$	(1)	
	Use of $A = 4\pi r^2$	(1)	
	$D_P = 4.6 \times D_{Sun}$ so statement is incorrect Or $D_P = 3.2 \times 10^9$ m, which is more than twice Sun's diameter, so statement is incorrect	(1)	5
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{470 \times 10^{-9}\ \text{nm}} = 6170\ \text{K}$ $A = \frac{2.65 \times 10^{27}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^4 \times (6170\ \text{K})^4} = 3.22 \times 10^{19}\ \text{m}^2$ $r = \sqrt{\frac{3.22 \times 10^{19}\ \text{m}^2}{4\pi}} = 1.60 \times 10^9\ \text{m}$ $\frac{D_P}{D_{Sun}} = \frac{2 \times 1.60 \times 10^9\ \text{m}}{6.96 \times 10^8\ \text{m}} = 4.6$		
	Total for question		5

Q9.

Question Number	Answer		Mark
(a)	Use of appropriate trigonometry	(1)	
	v_x =32 m s^{-1} **and** v_y =15 m s^{-1}	(1)	2
	Example of calculation v_x =35 m s^{-1} × cos 25° = 31.7 m s^{-1} v_y =35 m s^{-1} × sin 25° = 14.8 m s^{-1}		

(b)	Use of $s = u_x t$ to find time taken to travel 100 m horizontally	**(1)**	
	Use of $s = u_y t + ½ a t^2$ with $a = -g$ to find distance fallen in time t Accept other correct SUVAT methods	**(1)**	
	Distance fallen = 2.1 m	**(1)**	
	Conclusion consistent with comparison of student's values, e.g. 2.1 m < 3.0 m so rider lands on other side of river	**(1)**	
	Or		
	Use of correct SUVAT method with $a = -g$ to find time to descend by 3 m.	**(1)**	
	Use of $s = u_x t$ to find horizontal distance travelled in time t.	**(1)**	
	Distance travelled = 102 m	**(1)**	
	Conclusion consistent with comparison of student's values	**(1)**	
	Or		
	Use of $s = u_x t$ to find time taken to travel 100 m horizontally	**(1)**	
	Use of correct SUVAT method with $a = -g$ to find time to descend by 3 m.	**(1)**	
	Time = 3.21 s	**(1)**	
	Conclusion consistent with comparison of student's values, e.g. 3.15 s < 3.21 s so rider lands on other side of river	**(1)**	**4**
	<u>Example of calculation</u> time taken to travel 100 m = 100 m ÷ 31.7 m s^{-1} = 3.15 s vertical displacent = 14.8 × 3.15 − 0.5 × 9.81 × 3.15^2 = − 2.12 m 2.1 m < 3.0 m, so rider lands on other side of river		

(c)	Air resistance act to oppose the motion of the motorcyclist	**(1)**	
	So it decreases the time for which the motorcyclist is in the air **Or** There is deceleration in the horizontal direction **Or** Speed in horizontal direction is reduced **Or** The (maximum) height reached by the motorcyclist is reduced	**(1)**	
	Horizontal distance travelled is reduced (dependent on MP1 or MP2)	**(1)**	**3**
	Total for question		**9**

Q10.

Question Number	Answer		Mark
	Use of $L = 14800\ L_{Sun}$	(1)	
	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	$d = 1.1 \times 10^{23}$ m	(1)	3
	<u>Example of calculation</u> $L_{candle} = 14\ 800 \times 3.83 \times 10^{26}\ W = 5.67 \times 10^{30}\ W$ $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{5.67 \times 10^{30} W}{4\pi \times 3.64 \times 10^{-17} W\ m^{-2}}} = 1.11 \times 10^{23}$ m		
	Total for question		**3**

Q11.

Question Number	Answer		Mark
(a)(i)	Use of $p = m\ v$	**(1)**	
	Use of conservation of momentum	**(1)**	
	$m = 151$ (kg)	**(1)**	**3**
	Use of $F = \Delta p / \Delta t$ scores MP1 and MP2 <u>Example of calculation</u> $p = 250\ kg \times 2.10\ m\ s^{-1} = 250\ kg \times 1.15\ m\ s^{-1} + m \times 1.57\ m\ s^{-1} = 525.0\ kg\ m\ s^{-1}$ $m = (525.0 - 287.5\ N\ s)\ kg\ m\ s^{-1} \div 1.57\ m\ s^{-1}$ $= 237.5\ kg\ m\ s^{-1} \div 1.57\ m\ s^{-1} = 151.3\ kg$		
(a)(ii)	No external horizontal forces acted on either car during the collision.	**(1)**	**1**
(a)(iii)	Use of $a = \Delta v / \Delta t$	**(1)**	
	Use of $\Sigma F = ma$	**(1)**	
	$\Sigma F = 1.76 \times 10^2$ N (ecf from (a)(i))	**(1)**	**3**
	<u>Example of calculation</u> average acceleration $= 1.57\ m\ s^{-1} \div 1.35\ s = 1.16\ m\ s^{-2}$ $\Sigma F = 151.3\ kg \times 1.16\ m\ s^{-2} = 1.76 \times 10^2$ N		
(b)	P exerts a force on Q so Q exerts a force on P	**(1)**	
	Due to N3 forces are equal and opposite in direction	**(1)**	
	Resultant force on P opposite to direction of motion so according to N2, P decelerates	**(1)**	**3**
	Total for question		**10**

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Q12.

Question Number	Answer	Mark
(a)	Amount of work from the electric motor is reduced **(1)** Because there is energy transfer between the counterweight and the lift **Or** Because counterweight contributes to total work done (on lift cage) **Or** Because the counterweight reduces the force required from the motor **Or** Because total work done (on lift cage) is sum of work done by counterweight/gravity and by the motor. **(1)**	**2**
(b)	Use of $\Delta W = F\Delta x$ **or** $\Delta E_{grav} = mg\Delta h$ **(1)** Use of conservation of energy **(1)** Use of P = W / t **(1)** P = 12.4 (kW) **(1)** **Or** Calculates resultant force **(1)** Use of $\Delta W = F\Delta x$ **(1)** Use of P = W / t **(1)** P = 12.4 (kW) **(1)** <u>Example of calculation</u> For counterweight $\Delta E_{grav} = mg\Delta h$ $= 1300\ kg \times 9.81\ ms^{-2} \times 40.0\ m = 5.101 \times 10^5\ J$ For lift $\Delta E_{grav} = mg\Delta h$ $= 2250\ kg \times 9.81\ ms^{-2} \times 40.0\ m = 8.829 \times 10^5\ J$ Energy required = $8.829 \times 10^5\ J - 5.101 \times 10^5\ J = 3.728 \times 10^5\ J$ $P = 3.728 \times 10^5\ J \div 30\ s = 1.243 \times 10^4\ W$	**4**
(c)	Use of efficiency = useful power output ÷ total power input **(1)** Efficiency = 0.78 (ecf from (b) **(1)** <u>Example of calculation</u> Efficiency = 12.4 kW÷ (12.4 + 3.6) kW = 0.775	**2**
	Total for question	**8**

Q13.

Question Number	Answer		Mark
(a)	Use $E_K = ½ m v^2$	(1)	
	Use of efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$	(1)	
	Efficiency = 0.56 **Or** 56%	(1)	3
	Example of calculation $E_K = 0.5 \times 1\,560\ \text{kg} \times (13\ \text{m s}^{-1})^2 = 1.32 \times 10^5\ \text{J}$ efficiency = $73.9 \times 10^4\ \text{J} \div 1.32 \times 10^5\ \text{J} = 0.56$		
(b)(i)	As the velocity increases the drag forces increase.	(1)	1
(b)(ii)	At higher speeds more work done against air resistance. So more energy dissipated. So a smaller proportion of energy is available to charge battery. (Hence) the efficiency of the system is lower.	(1) (1) (1) (1)	4
	Total for question		8

Q14.

Question Number	Answer		Mark
(a)	It's the force / stress beyond which the cable does not return to its original length when the force / stress is removed	(1)	1
(b)(i)	Use of $\varepsilon = \Delta x/x$ $\varepsilon = 0.021$ Example of calculation $\varepsilon = 0.126\ \text{m} \div 6\ \text{m} = 0.021$	(1) (1)	2
(b)(ii)	Use of $\sigma = F/A$ $\sigma = 1.4 \times 10^9\ \text{Pa}$ Example of calculation $\sigma = 1.34 \times 10^6\ \text{N} \div 9.6 \times 10^{-3}\ \text{m}^2 = 1.40 \times 10^9\ \text{Pa}$	(1) (1)	2
	Total for question		5

Q15.

Question Number	Answer	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content and lines of reasoning.	**6**

IC points	IC mark	Max linkage mark available	Max final mark
6 or more	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

	Marks
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

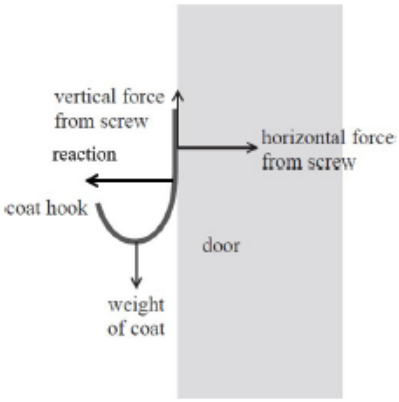
	Indicative content: IC1 The force of the lift/scales on the student is the reading on the scales **Or** The reaction/contact force is the reading on the scales IC2 At constant speed, the resultant force on the student is zero **Or** Weight/W = Reaction/R IC3 At constant speed the reading on the scales would be 600 N. **Or** At rest the reading on the scales would be 600 N IC4 As lift decelerates reaction is less than weight IC5 As the lift decelerates there is a resultant downward force (on the student). IC6 As the lift decelerates the reading on the scales will be less than 600 N (because the upward force on the student is less than his weight)	
	Total for question	**6**

Q16.

Question Number	Answer	Mark
(a)	There is an upthrust which is equal to the weight of water displaced **(1)** The upthrust is equal to the weight of the cylinder (when it's partially submerged) **(1)** **OR** The (overall) density (of the cylinder) is less than the density of the water. **(1)** The weight of water displaced is equal to the weight of the cylinder **(1)**	**2**
(b)(i)	Use of Volume = $\pi r^2 l$ **(1)** Use of 63% with their volume **(1)** Use of $\rho = m / V$ **(1)** $m = 8.8 \times 10^{-3}$ (kg) **(1)** Example of calculation volume of cylinder= $\pi \times (1.05\text{ cm})^2 \times 4\text{ cm} = 1.39 \times 10^{-5}\text{ m}^3$ volume submerged = $0.63 \times$ volume of cylinder $= 0.63 \times 1.39 \times 10^{-5}\text{ m}^3 = 8.76 \times 10^{-6}\text{ m}^3$ mass of cylinder = mass of water displaced $= 1\,000\text{ kg m}^{-3} \times 8.76 \times 10^{-6}\text{ m}^3 = 8.76 \times 10^{-3}\text{ kg}$	**4**

(b)(ii)	Use of $\rho = m / V$ to calculate the volume of brass **(1)** Use of $\rho = m / V$ to calculate the mass of the same volume of gold (not volume of whole cylinder) **(1)** Use of $\rho = m / V$ to calculate the volume of water needed to float the cylinder **Or** Use of $\rho = m / V$ to calculate the maximum mass/weight of water that could be displaced **(1)** Correct conclusion from comparison of displaced volume of water required to float gold ($1.9 \times 10^{-5}\text{ m}^3$) with volume of cylinder ($1.4 \times 10^{-5}\text{ m}^3$) **Or** Correct conclusion from comparison of weight of gold cylinder (0.19 N) with max weight of water that could be displaced (0.14 N) (ecf from (b)(i)) **Or** Correct conclusion from comparison of mass of gold cylinder (0.019 kg) with max mass/weight of water that could be displaced (0.014 kg) (ecf from (b)(i)) **(1)** Example of calculation volume of gold = volume of brass $= 8.73 \times 10^{-3}\text{ kg} \div 8.7 \times 10^{3}\text{ kg m}^{-3} = 1.00 \times 10^{-6}\text{ m}^3$ mass of gold = $1.00 \times 10^{-6}\text{ m}^3 \times 19.3 \times 10^{3}\text{ kg m}^{-3} = 0.019\,3\text{ kg}$ volume of water required = $0.019\,3\text{ kg} \div (1.00 \times 10^{3}\text{ kg m}^{-3}) = 1.93 \times 10^{-5}\text{ m}^3$ $1.93 \times 10^{-5}\text{ m}^3 > 1.39 \times 10^{-5}\text{ m}^3$ ∴ sinks	**4**
	Total for question	**10**

Q17.

Question Number	Answer		Mark
(a)			
	Horizontal arrow pointing to the left labelled "reaction (force from the wall on the hook)"	(1)	
	Arrow drawn below screw and not lower than last point of contact between hook and wall	(1)	2
	MP2 depends upon MP1		
(b)	Use of moment of force = $F x$	(1)	
	Use of principle of moments	(1)	
	Use of $W = m g$	(1)	
	Correct calculation leading to conclusion no (as maximum is two coats)	(1)	4
	Example of calculation 150 N × 0.009 m = W × 0.025 m W = 1.35 N m ÷ 0.025 m = 54.0 N m = 54.0 N ÷ 9.81 N kg^{-1} = 5.50 kg 5.50 kg ÷ 2.6 kg = 2.12 ∴ two coats max, so no.		
	Total for question		**6**

Q18.

Question Number	Answer	Mark
(a)	The forces act on the same object. **(1)** They are different types of force. **(1)**	**2**
(b)	Downward arrow labelled magnetic force (from disc) **Or** Downward arrow labelled *F*. **(1)** Upward arrow labelled (normal) reaction / contact / *R* / *N* / **and** arrow length approximately equal to *F* + *W*. **(1)** 	**2**
	Total for question	**4**

Q19.

Question Number	Answer	Mark
	The correct answer is **D** A is incorrect because force is a vector B is incorrect because momentum is a vector C is incorrect because velocity is a vector	**1**

Q20.

Question Number	Answer	Mark
	A is the only correct answer B is incorrect because the velocity is always zero C is incorrect because the velocity is always positive D in incorrect because velocity is zero except for a very short time.	**1**

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Q21.

Question Number	Answer	Mark
	The correct answer is **B** A is incorrect because air resistance would reduce the acceleration C is incorrect because drop time is unaffected by horizontal motion D is incorrect because a greater time would give a lower acceleration	**1**

Q22.

Question Number	Answer	Mark
	The correct answer is **C** A is incorrect because the numerator and denominator are the wrong way around, and a factor of 1 000 is missing in the numerator B is incorrect because the factor 750 should be in the denominator and the 1 000 in the numerator D is incorrect because the numerator and denominator are the wrong way around.	**1**

Q23.

Question Number	Answer	**Mark**
	The correct answer is **D** because the area below the *t* axis represents negative displacement A is incorrect because P is above the line and Q should be subtracted B is incorrect because P is above the line C is incorrect because Q should be subtracted	**1**

Q24.

Question Number	Answer	Mark
	A is the only correct answer B is incorrect because final displacement is measured from 0, not −1 C is incorrect because displacement is not the area between the line and the *t* axis, and velocity is 3 m ÷ 6 s, not 6 m ÷ 3 s D in incorrect because velocity is 3 m ÷ 6 s, not 6 m ÷ 3 s	**1**

Q25.

Question Number	Answer	Mark
	The correct answer is **D** A is incorrect because the distance moved by the force is not $\Delta h \cos \theta$ B is incorrect because the distance moved by the force is not $\Delta h / \cos \theta$ C is incorrect because the distance moved by the force is not $\Delta h \sin \theta$	**1**

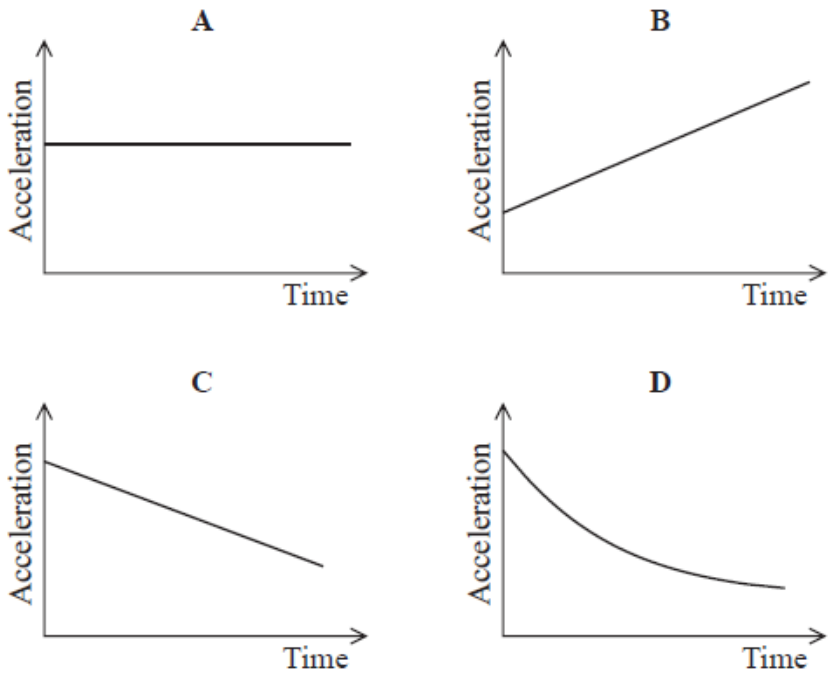
Q1.

Answer the question with a cross in the box you think is correct (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

A rocket is accelerating horizontally due to a constant resultant force.

The mass of the rocket decreases steadily as it uses up its fuel.

Which graph shows how the acceleration of the rocket could change?



☐ **A**

☐ **B**

☐ **C**

☐ **D**

(Total for question = 1 mark)

Q2.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The gravitational field strength at the surface of the Earth is *g*.

Another planet has the same density as the Earth, but twice the radius of the Earth.

What is the gravitational field strength at the surface of this planet?

☒ **A** $4g$

☒ **B** $2g$

☒ **C** $\frac{g}{2}$

☒ **D** $\frac{g}{4}$

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A communications satellite has a mass of 935 kg. The satellite has an orbital radius four times the radius of the Earth.

☒ **A** 0 N

☒ **B** 570 N

☒ **C** 2300 N

☒ **D** 9200 N

(Total for question = 1 mark)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following does **not** have the base unit s^{-1}?

☒ **A** angular velocity

☒ **B** frequency

☒ **C** redshift

☒ **D** rate of decay

(Total for question = 1 mark)

Q5.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

An object on the Moon falls a vertical distance of 0.32 m, from rest, in a time of 0.63 s.

Which of the following expressions gives the acceleration due to gravity on the Moon in m s^{-2}?

☒ **A** $\frac{0.32}{2 \times 0.63}$

☒ **B** $\frac{0.32}{2 \times 0.63^2}$

☒ **C** $\frac{2 \times 0.32}{0.63^2}$

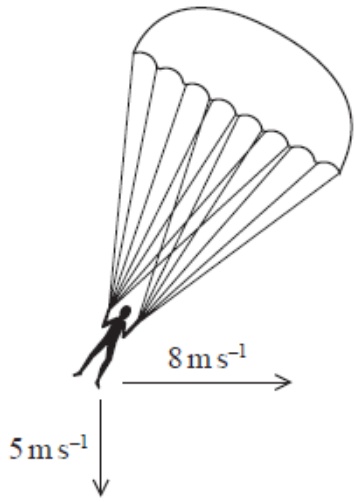
☒ **D** $\frac{2 \times 0.32}{0.63}$

(Total for question = 1 mark)

Q6.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The diagram shows a student during a parachute jump on a windy day. The vertical component of her velocity is 5.0 m s^{-1}. The horizontal component of her velocity is 8.0 m s^{-1}. She descends at an angle θ to the vertical.



Which row of the table gives expressions for the magnitude and angle of the student's resultant velocity?

	Magnitude / m s^{-1}	θ / °
☒ A	$\sqrt{8^2 - 5^2}$	$\tan^{-1}\frac{8}{5}$
☒ B	$\sqrt{8^2 - 5^2}$	$\sin^{-1}\frac{5}{8}$
☒ C	$\sqrt{8^2 + 5^2}$	$\tan^{-1}\frac{8}{5}$
☒ D	$\sqrt{8^2 + 5^2}$	$\sin^{-1}\frac{5}{8}$

(Total for question = 1 mark)

Q7.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The spectrum of electromagnetic radiation from a galaxy is observed to have a redshift.

Which of the following is a correct statement about lines in this spectrum?

☒ **A** All the lines are in the red part of the spectrum.

☒ **B** All the lines are observed to have longer wavelengths than expected.

☒ **C** Lines with wavelengths at the red end of the spectrum are the most intense.

☒ **D** Light for all the lines was emitted with longer wavelengths than expected.

(Total for question = 1 mark)

Q8.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sirius and α-Centauri are two of our closest stars. Sirius has a luminosity about 16 times greater than the luminosity of α-Centauri. Sirius is twice as far away from the Earth as α-Centauri.

The intensity of light from Sirius is I_s and the intensity of light from α-Centauri is I_α.

Which of the following is the value of $\frac{I_s}{I_\alpha}$?

☒ **A** $\frac{1}{4}$

☒ **B** 4

☒ **C** 8

☒ **D** 16

(Total for question = 1 mark)

Q9.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Current theory suggests that the universe is expanding.

Which of the following is evidence to support this theory?

☒ **A** All galaxies appear to be rotating in space.

☒ **B** Dark matter has been detected in the universe.

☒ **C** All distant stars are observed to be increasing in size.

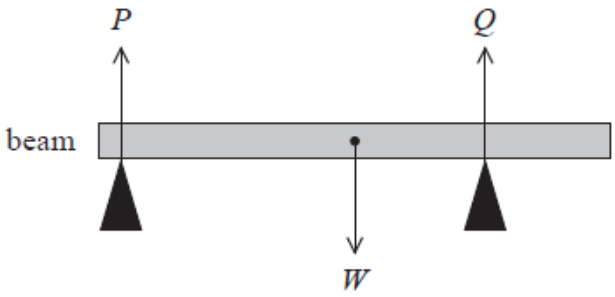
☒ **D** The further a galaxy is from the Earth, the faster it recedes.

(Total for question = 1 mark)

Q10.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A beam is balanced on two supports as shown.



The beam has a weight W and the reaction forces at the two supports are P and Q.

Which of the following statements about the magnitudes of the forces is correct?

☒ **A** $P > Q$

☒ **B** $Q > W$

☒ **C** $Q > P$

☒ **D** $(P + Q) > W$

(Total for question = 1 mark)

Q11.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A person is pushing a trolley at a constant velocity.

The floor exerts a force *P* on the person, the person exerts a force *Q* on the trolley.

The trolley exerts a force *R* on the person and the total drag force on the trolley is *S*.



(Source: Andy Dossett/Alamy Stock Photo)

Which pair of forces is a Newton's Third Law pair?

☒ **A** *P* and *R*

☒ **B** *Q* and *R*

☒ **C** *Q* and *S*

☒ **D** *P* and *S*

(Total for question = 1 mark)

Q12.

Select one answer from A to D and put a cross in the box ☒. If you change your mind

about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Physical quantities may be vectors or scalars.

Which row of the table is correct?

		Force	Mass	Acceleration
☒	**A**	scalar	vector	scalar
☒	**B**	scalar	scalar	vector
☒	**C**	vector	vector	scalar
☒	**D**	vector	scalar	vector

(Total for question = 1 mark)

Q13.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The luminosity axis of a Hertzsprung-Russell diagram has a logarithmic scale.

Which of the following is the reason for this?

☒ **A** Stars all have very large luminosities.

☒ **B** The range of luminosities of stars is very large.

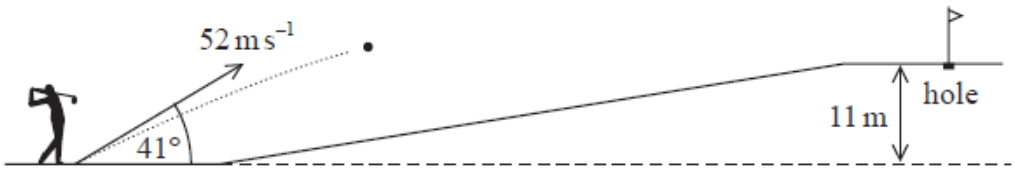
☒ **C** The range of distances to stars is very large.

☒ **D** The temperature axis has a logarithmic scale.

(Total for question = 1 mark)

Q14.

A golfer hit a golf ball into the air at a speed of 52 m s^{-1} and an angle of 41° to the horizontal, as shown.



The ball landed on the ground near a hole. The ground was 11 m higher than the starting point of the ball.

(a) Show that the vertical component of the ball's initial velocity was about 30 m s^{-1}.

(2)

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(b) Show that the time taken by the ball to reach the ground was about 7 s. You should ignore the effects of air resistance.

(3)

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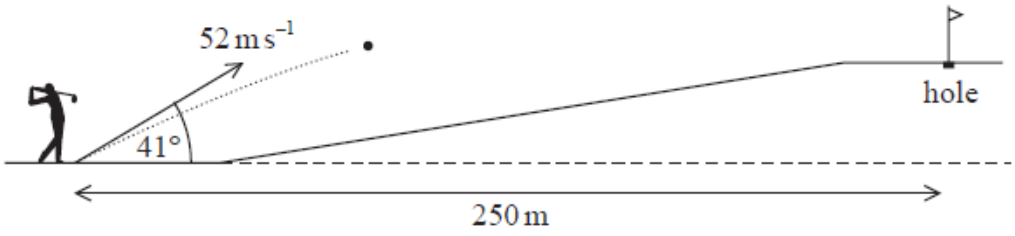
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(c) The hole is a horizontal distance of 250 m from the starting point of the ball, as shown.



Deduce whether the ball landed within 5.0 m of the hole. You should ignore the effects of air resistance.

(3)

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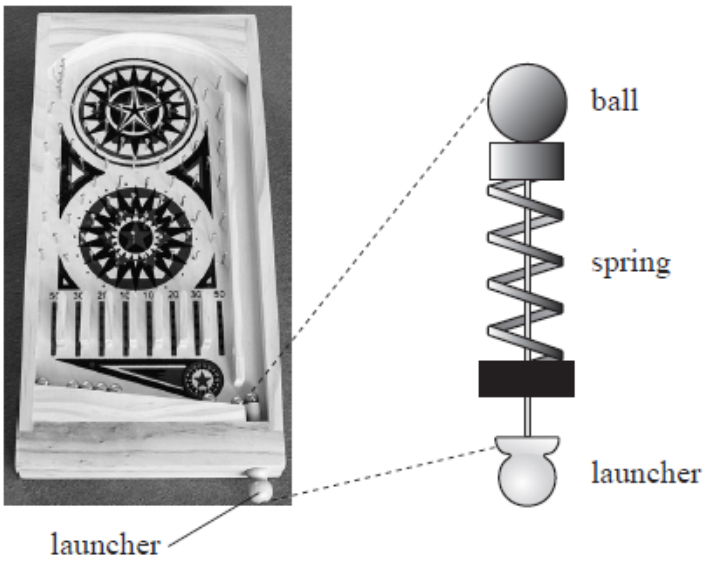
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(Total for question = 8 marks)

Q15.

The photograph shows a toy pinball machine. The launcher is pulled back, compressing a spring. The spring obeys Hooke's law. When the launcher is released, the spring returns to its original length and a small ball is launched horizontally into the machine.



(Source: © Valery Voennyy/Alamy Stock Photo)

When the launcher is pulled back, the spring is compressed by 5.0 cm. When the spring is released, the ball is launched at a speed of 8.0 cm s^{-1}.

(a) Show that the kinetic energy of the ball just after launching is about 4×10^{-5} J.

mass of ball = 12 g

(2)

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(b) Determine the force on the ball when the spring is released.

(2)

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Force = ...

(c) Determine the stiffness of the spring.

(2)

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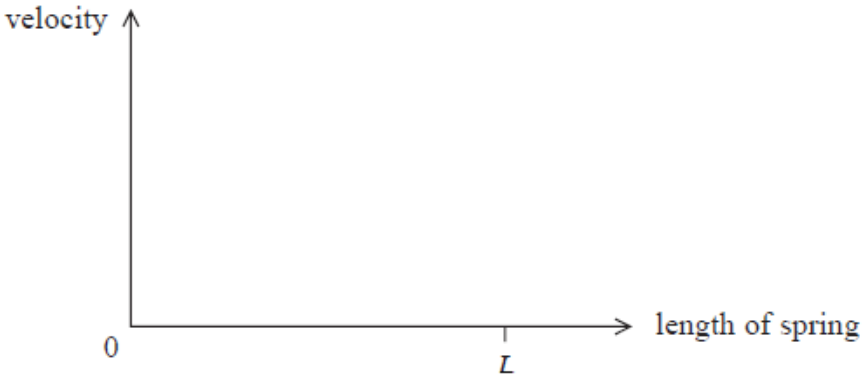
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Stiffness = ...

(d) The spring returns to its original length *L*.

Sketch a graph, on the axes below, to show how the velocity of the ball varies with the length of the spring.

(4)



(Total for question = 10 marks)

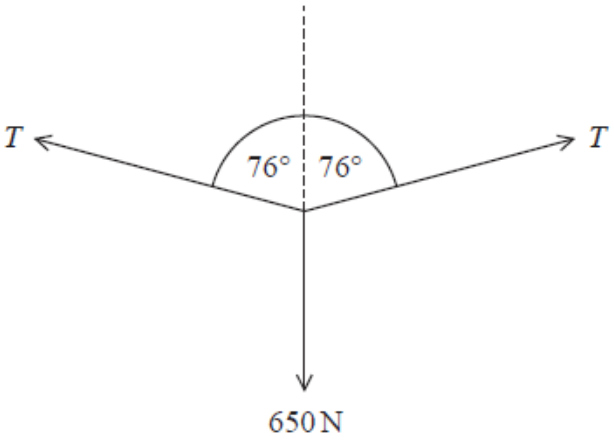
Q16.

The Tyrolean traverse is a technique for crossing a deep valley. The photograph shows a climber crossing a river using this technique. The climber moves along a rope suspended from the bank on either side of the river.



(Source: © Folio Images/Alamy Stock Photo)

(a) The free-body force diagram for the climber is shown below. The weight of the climber is 650 N.



Show that the tension T in the rope is about 1.3×10^3 N.

(3)

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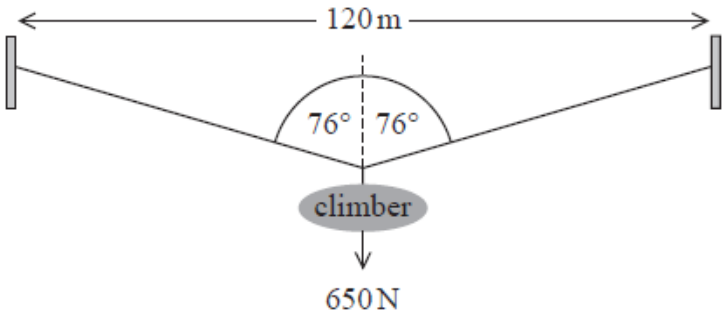
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(b) The rope has an unstretched length of 120 m as shown below.



(i) Determine the strain in the rope while it is supporting the weight of the climber.

You may ignore the weight of the rope.

(3)

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Strain = ...

(ii) The rope has a cross-sectional area of 3.14×10^{-4} m^2.

Determine the Young modulus of the rope material.

(3)

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Young modulus = ...

(Total for question = 9 marks)

Q17.

A small sphere is moving horizontally through a viscous liquid.

(a) Stokes' law can be used to calculate the drag force on an object.

State the conditions that must apply for Stokes' law to be valid.

(2)

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(b) There is a constant force of 2.3×10^{-5} N acting horizontally on the sphere.

diameter of sphere = 4.5×10^{-3} m
viscosity of liquid = 7.1×10^{-2} Pa s

(i) At one instant, the speed of the sphere is 5.2×10^{-3} m s^{-1}.

Calculate the resultant horizontal force on the sphere.

(3)

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Resultant horizontal force = ...

(ii) Calculate the maximum speed of the sphere in the horizontal direction.

(2)

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Maximum horizontal speed = ...

(c) A larger diameter sphere in the same liquid is acted upon by the same constant force as in (b). The liquid is at a lower temperature.

Explain the effect these changes have on the maximum speed of this sphere.

(4)

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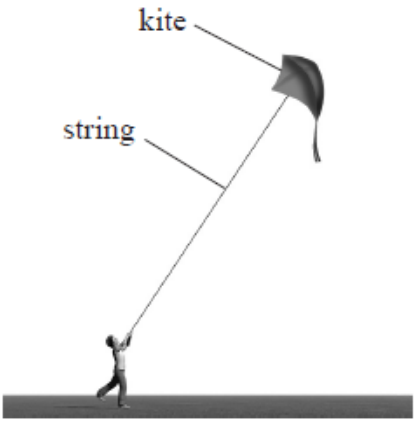
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(Total for question = 11 marks)

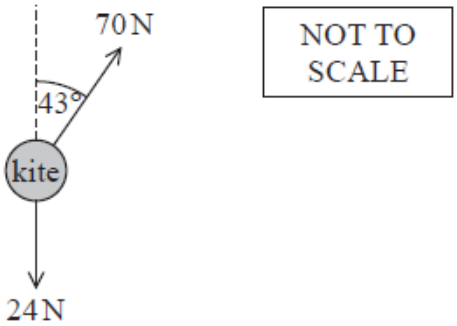
Q18.

A student is flying a kite. The kite is held in equilibrium by a string as shown.



(Source: © CAROL & MIKE WERNER/SCIENCE PHOTO LIBRARY)

The weight of the kite is 24 N, and the wind exerts a force of 70 N at an angle of 43° to the vertical, as shown below.

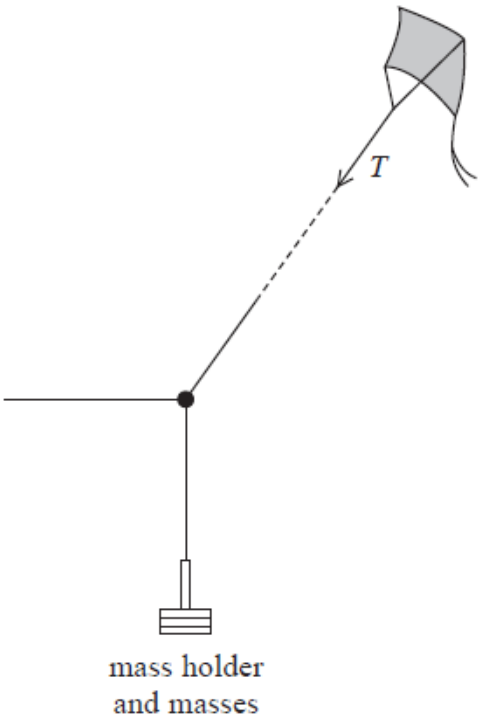


(a) Determine the magnitude of the tension in the string by using a scaled vector diagram.

(4)

Tension = ...

(b) The student wants to determine the tension *T* in the string. She attaches a mass holder to the string. The student adds known masses to the mass holder until the kite is in equilibrium and part of the string becomes horizontal, as shown.



The student takes a photograph of the arrangement.

Describe how the student can use the photograph to determine *T*.

(5)

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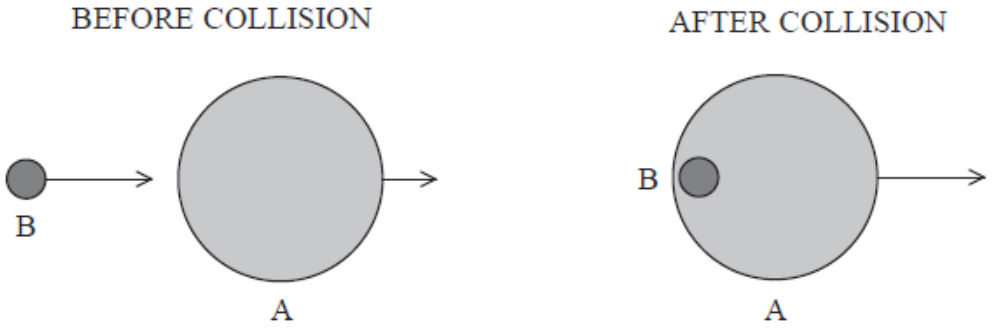
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(Total for question = 9 marks)

Q19.

A slow moving asteroid A was hit by a faster asteroid B. Asteroid B was absorbed by asteroid A as shown.



(a) State the principle of conservation of linear momentum.

(2)

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(b) Before the collision, asteroid A had a velocity of 2.19×10^3 m s^{-1} and a momentum of 1.80×10^{17} kg m s^{-1}.

(i) Show that the mass of asteroid A was about 8.2×10^{13} kg.

(2)

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(ii) Calculate the velocity of the asteroids after the collision.

mass of asteroid B = 5.90×10^{12} kg
velocity of asteroid B before the collision = 15.0×10^3 m s^{-1}

(3)

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Velocity of asteroids = ...

(Total for question = 7 marks)

Q20.

A falling sphere viscometer is a device used to determine the viscosity of a liquid. A sphere falls through a cylinder containing a liquid, and the terminal velocity of the sphere is measured.

(a) State why the temperature of the liquid should **not** increase during the measurement.

(1)

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(b) A scientist measured the terminal velocity of an aluminium sphere as it fell through glycerol.

(i) Show that the weight of the sphere is about 4.8×10^{-3} N.

density of aluminium = 2.70×103 kg m^{-3}

diameter of sphere = 7.00×10^{-3} m

(4)

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(ii) The terminal velocity of the sphere was 4.05×10^{-2} m s^{-1}.

Deduce whether Stokes' law applied to the falling sphere.

density of glycerol = 1.26×103 kg m^{-3}

viscosity of glycerol = 9.50×10^{-1} Pa s

(3)

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(iii) State **one** condition that must be met for Stokes' law to apply.

(1)

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(c) A scientist used the viscometer to measure the viscosity of blood. The viscosity of blood is typically in the range 3×10^{-3} Pa s to 4×10^{-3} Pa s.

Explain why the scientist should use an aluminium sphere with a much smaller diameter than the sphere used with the glycerol. Do not include calculations in your answer.

viscosity of glycerol = 9.50×10^{-1} Pa s

(5)

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(Total for question = 14 marks)

Q21.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which row of the table contains two units that are **not** equivalent?

		Unit 1	Unit 2
☒	**A**	Js^{-1}	W
☒	**B**	$kgms^{-2}$	Ns
☒	**C**	Nkg^{-1}	ms^{-2}
☒	**D**	Nm	J

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer	Mark
	The correct answer is B because for a constant resultant force acceleration increases if mass decreases A is incorrect because a constant acceleration for a decreasing mass would require a decreasing resultant force C is incorrect because a decreasing acceleration for a decreasing mass would require a decreasing resultant force D is incorrect because a decreasing acceleration for a decreasing mass would require a decreasing resultant force	1

Q2.

Question Number	Answer	Mark
	B is the correct answer, as $g = \frac{GM}{r^2}$ and $M = \frac{4}{3}\pi\rho r^3$	**(1)**

Q3.

Question Number	Answer	Mark
	B is the correct answer, as $F = \frac{GMm}{r^2}$	**(1)**

Q4.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer, as angular velocity has units (rad) s^{-1} B is not the correct answer, as frequency has units Hz = s^{-1} D is not the correct answer, as rate of decay has units Bq = s^{-1}	**(1)**

Q5.

Question Number	Answer	Mark
	C is the only correct answer A is incorrect because the 2 should be above the line, and the 0.63 should be squared B is incorrect because the 2 should be above the line D is incorrect because he 0.63 should be squared	**1**

Q6.

Question Number	Answer	Mark
	C is the only correct answer A is incorrect because the magnitude is the sum of the squares not the difference B is incorrect because the magnitude is the sum of the squares not the difference and a tangent is required for the angle, not a sine. D is incorrect because a tangent is required for the angle, not a sine.	**1**

Q7.

Question Number	Answer	Mark
	B is the correct answer A is incorrect, as the lines may be shifted into any region of the spectrum C is incorrect, as the intensity of the lines is not related to the redshift D is incorrect, as the wavelengths of the emitted lines is not affected	(1)

Q8.

Question Number	Answer	Mark
	B is the correct answer, as $I = \frac{L}{4\pi d^2}$	(1)

Q9.

Question Number	Answer	Mark
	D is the correct answer, as this is a statement of Hubble's law	(1)

Q10.

Question Number	Answer	Mark
	C is the only correct answer A is incorrect because moments must balance about the centre of mass. B is incorrect because moments must balance about the left support. D is incorrect because the total reaction must be equal to the weight.	1

Q11.

Question Number	Answer	Mark
	B is the only correct answer A is incorrect because force P and R act on the same object C is incorrect because force Q and S act on the same object D is incorrect because forces P and S are not the same type of force.	**1**

Q12.

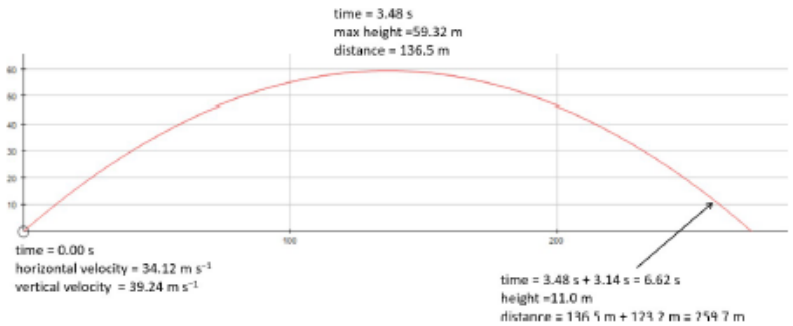
Question Number	Answer	Mark
	D is the only correct answer A is not the correct answer because mass is a scalar and force and acceleration are vectors B is not the correct answer because force is a vector C is not the correct answer because mass is a scalar and acceleration is a vector	**1**

Q13.

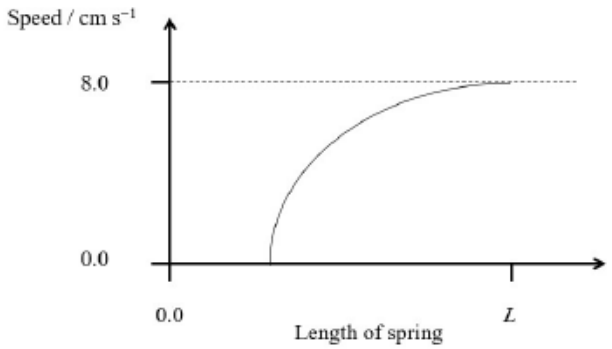
Question Number	Answer	Mark
	B is the correct answer A is not the correct answer, as large values could fit on a linear scale C is not the correct answer, as distance from the star only affects the intensity D is not the correct answer, as the temperature and luminosity scales are independent	**(1)**

Q14.

Question Number	Answer		Mark
(a)	Use of trigonometry Vertical component = 34 (m s^{-1}) Example of calculation 52 m s^{-1} × sin 41° = 34.1 m s^{-1}	(1) (1)	2
(b)	Method 1: Use of $s = u t + ½ a t^2$ with s = 11 m and a = − 9.81 m s^{-2} Use of quadratic formula t = 6.62 (s) [Allow ecf from (a)] Method 2: Use of $v = u + at$, with $v = 0$ to find time to max height [3.48 s] Use of $s = ½(u + v) t$, or other correct *suvat* equation, to find max height [59.3 m] **And** Use of $s = u t + ½ a t^2$ to find time to fall to 11 m [3.14 s] t = 6.62 (s) depending on rounding of (a) [Allow ecf from (a)] (allow ecf from (a)) [Allow any valid *suvat* method] Example of calculation Let time to max height = t 11 m = 34.1 m s^{-1} × t − ½ × 9.81 m s^{-2} × t^2 4.91 × t^2 − 34.1 m s^{-1} × t + 11 m = 0 t = (34.1 ± √(34.1^2 − 4 × 11 × 4.91) m s^{-1} ÷ 9.81 m s^{-2} = 6.62 s (or 0.34 s)	(1) (1) (1) (1) (1) (1)	3

(c)	Resolves for horizontal component of velocity Use of $s = v t$ 260 m so no (Allow ecf from (b) with correct conclusion based on student's value) Example of calculation Horizontal component of velocity = 52 m s^{-1} × cos 41° = 39.2 m s^{-1} s = 39.2 m s^{-1} × 6.62 s = 260 m Distance required 245 m to 255 m and 260 m > 255 m so no.  	(1) (1) (1)	3
	Total for question		8

Q15.

Question Number	Answer	Mark
(a)	Use of $E_k = ½ m v^2$ (1) $E_k = 3.8 \times 10^{-5}$ (J) (1) Example of calculation $E_k = 0.5 \times 12 \times 10^{-3}$ kg $\times (8.0 \times 10^{-2}$ m s$^{-1})^2 = 3.84 \times 10^{-5}$ J	2
(b)	Use of $\Delta E_{el} = ½ F \Delta x$ (1) $F = 1.5 \times 10^{-3}$ N (allow ecf from (a)) (1) Example of calculation $\Delta E_{el} = E_k = 3.84 \times 10^{-5}$ J $= 0.5 \times F \times 0.05$ m $F = 3.84 \times 10^{-5}$ J $\div 0.025$ m $= 1.54 \times 10^{-3}$ N	2
(c)	Use of $F = k \Delta x$ (1) $k = 0.03$ N m^{-1} (allow ecf from (b)) (1) Example of calculation 1.54×10^{-3} N $= k \times 0.05$ m $k = 1.54 \times 10^{-3}$ N $\div 0.05$ m $= 0.031$ N m^{-1}	2
(d)	Line has initially decreasing positive gradient (1) Line starts at $v = 0$ and a non-zero value of length (1) Line levels off to horizontal at length = L (1) Final velocity marked as 8.0 cm s^{-1} **Or** (1) Original compressed length marked as "$L - 5$" in cm  	4
	Total for question	**10**

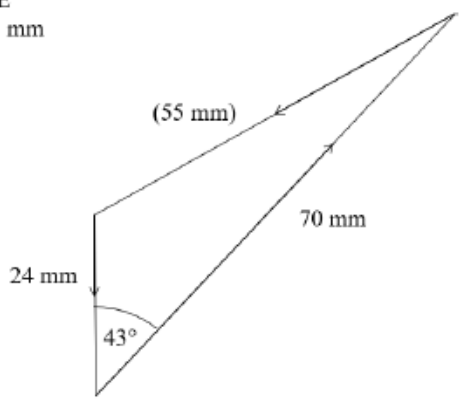
Q16.

Question Number	Answer		Mark
(a)	Vertical component of tension = $T \cos 76°$	**(1)**	**3**
	Use of 650 N = 2 × vertical component of tension	**(1)**	
	$T = 1.34 \times 10^3$ (N)	**(1)**	
	Example of calculation 650 N = 2 T cos 76° T = ½ × 650 N ÷ cos 76° = 1 343 N		
(b)(i)	Use of sin76° or cos 14° to find new length of cord	**(1)**	**3**
	Use of $\varepsilon = \Delta x \div x$	**(1)**	
	ε = 0.03 or 3%	**(1)**	
	Example of calculation $(x + \Delta x) \div 2$ = 60 m ÷ sin 76° = 61.8 m Δx = (61.8 × 2) m − 120.0 m = 3.7 m ε = 3.7 m ÷ 120 m = 0.031		
(b)(ii)	Use of $\sigma = F \div A$ with F = tension from (a)	**(1)**	**3**
	Use of $E = \sigma \div \varepsilon$	**(1)**	
	$E = 1.4 \times 10^8$ Pa (ecf from (a) and (b)(i))	**(1)**	
	Example of calculation $\sigma = 1.34 \times 10^3$ N ÷ 3.14×10^{-4} m^2 = 4.28 MPa E = 4.28×10^6 Pa ÷ 0.031 = 1.38×10^8 Pa		
	Total for question		**9**

Q17.

Question Number	Answer		Mark
(a)	**Max 2** Object must be a sphere Low speed/velocity Laminar flow	**(1)** **(1)** **(1)**	**2**
(b)(i)	Use of $F = 6\pi \eta r v$ Subtraction of two forces Resultant force = 7×10^{-6} N <u>Example of calculation</u> drag force = $6\pi \times 7.1 \times 10^{-2}$ Pa s $\times$ 2.25×10^{-3} m $\times$ 5.2×10^{-3} m s^{-1} = 1.6×10^{-5} N Resultant force = 2.3×10^{-5} N $- 1.6 \times 10^{-5}$ N = 0.7×10^{-5} N	**(1)** **(1)** **(1)**	**3**
(b)(ii)	Use of $F = 6\pi \eta r v$ with $F = 2.3 \times 10^{-5}$ N $v = 7.6 \times 10^{-3}$ m s^{-1} <u>Example of calculation</u> 2.30×10^{-5} N = $6\pi \times 7.10 \times 10^{-2}$ Pa s $\times$ 2.25×10^{-3} m $\times$ v $v = 2.30 \times 10^{-5}$ N $\div$ ($6\pi \times 7.10 \times 10^{-2}$ Pa s $\times$ 2.25×10^{-3} m) = 7.64×10^{-3} m s^{-1}	**(1)** **(1)**	**2**
(c)	Larger diameter gives larger drag force (at given speed) **Or** Larger diameter gives a lower speed (for the same constant force) Lower temperature so viscosity is greater Greater viscosity gives larger drag force (at given speed) **Or** Greater viscosity gives lower speed (for the same constant force) Maximum speed will decrease (dependent on MP1 and MP3)	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question		**11**

Q18.

Question Number	Answer		Mark
(a)	Two arrowed lines for 70 N and 24 N with correct orientation [use template for angle] Lines labelled with name/force/scaled length Tension drawn in correctly i.e. correct vector diagram with correct direction Answer in range 55 ± 2 N [Correct answer from trigonometry scores MP4 only] <u>Example of calculation</u> SCALE 1 N : 1 mm  	(1) (1) (1) (1)	4
(b)	Measure angle of string to vertical Using a protractor Calculate weight of mass holder and masses using $W = mg$ Vertical component of T is equal to W Vertical component is $T \cos \theta$, so T can be calculated	(1) (1) (1) (1) (1)	5
	Total for question		**9**

Q19.

Question Number	Answer	Mark
(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** Total momentum before (a collision) = total momentum after (a collision) **Or** Total momentum remains constant **Or** The momentum of a system remains constant **(1)** Provided no external/unbalanced/resultant force acts **Or** in a closed/isolated system **(1)**	**2**
(b)(i)	Use of $p = m\,v$ **(1)** $m = 8.22 \times 10^{13}$ (kg) **(1)** Example of calculation 1.80×10^{17} N s = $m \times 2.19 \times 10^{3}$ m s^{-1} $m = 1.80 \times 10^{17}$ N s ÷ 2.19×10^{3} m s^{-1} = 8.219×10^{13} kg	**2**
(b)(ii)	Use of $p = m\,v$ with combined final mass **(1)** Use of momentum conservation **(1)** $v = 3.05 \times 10^{3}$ m s^{-1} (ecf from (i)) **(1)** Example of calculation 1.80×10^{17} N s + (5.90×10^{12} kg × 15.0×10^{3} m s^{-1}) = (8.219×10^{13} kg + 5.90×10^{12} kg) × v $v = 2.685 \times 10^{17}$ N s ÷ 8.81×10^{13} kg = 3.048×10^{3} m s^{-1}	**3**
	Total for question	**7**

Q20.

Question Number	Answer		Mark
(a)	The viscosity decreases (with temperature)	(1)	1
(b)(i)	Use of $V = (4/3)\pi r^3$ Use of $\rho = m / V$ Use of $W = m g$ $W = 4.76 \times 10^{-3}$ N Example of calculation volume = $(4/3)\pi \times (3.5 \times 10^{-3}\ \text{m})^3 = 1.80 \times 10^{-7}\ \text{m}^3$ $m = 1.80 \times 10^{-7}\ \text{m}^3 \times 2.70 \times 10^3\ \text{kg m}^{-3} = 4.85 \times 10^{-4}$ kg $W = 4.85 \times 10^{-4}\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 4.76 \times 10^{-3}$ N	(1) (1) (1) (1)	4
(b)(ii)	Use of $F = 6\pi \eta r v$ Use of U = weight of fluid displaced Comparison of F with $W - U$ and conclusion consistent with student's values Example of calculation $D = 6\pi \times 0.95\ \text{Pa s} \times 0.003\ 5\ \text{m} \times 0.040\ 5\ \text{m} = 2.54 \times 10^{-3}$ N $U = 1.80 \times 10^{-7}\ \text{m}^3 \times 1.26 \times 10^3\ \text{kg m}^{-3} \times 9.81\ \text{N kg}^{-1} = 2.22 \times 10^{-3}$ N $W - U = 4.76 \times 10^{-3}\ \text{N} - 2.22 \times 10^{-3}\ \text{N} = 2.54 \times 10^{-3}$ N $2.54 \times 10^{-3}\ \text{N} = D$ ∴ Stokes law obeyed	(1) (1) (1)	3
(b)(iii)	Low speed **Or** Laminar flow **Or** Small sphere [Accept reference to wide cylinder]	(1)	1

(c)	Viscosity of blood is much lower	(1)	
	Drag will be lower for given velocity (proportional to diameter)	(1)	
	Reducing diameter gives less weight (proportional to cube of diameter)	(1)	
	Forces balance at lower speed **Or** Terminal velocity lower	(1)	
	Laminar flow needs low speed	(1)	5
	Viscosity of blood much lower (1) (For the original sphere) drag would be (much) lower at same velocity (1) So terminal velocity would be (much) too large for Stokes' law (1) Reducing r reduces W much more than D OR W proportional to r3 but D proportional to r (1) (With smaller sphere) forces will still balance at low speed (1)		
	Total for question		14

Q21.

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Question Number	Answer	Mark
	B is the only correct answer A is incorrect because one watt is defined as one joule per second C is incorrect because a 1 N = 1 kg m s^{-2} D is incorrect because a joule is the unit for work, and work = force × distance	**1**