Oxford Cambridge and RSA

Wednesday 24 May 2023 – Afternoon

A Level Physics A

H556/01 Modelling physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number						Candidate number				

First name(s) ______________________________

Last name ______________________________

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **36** pages.

ADVICE
- Read each question carefully before you start your answer.

Section A

You should spend a **maximum** of **30 minutes** on this section.

Write your answer to each question in the box provided.

1 Which row contains **only** scalar quantities?

A Absolute temperature, displacement, moment

B Acceleration, force, momentum

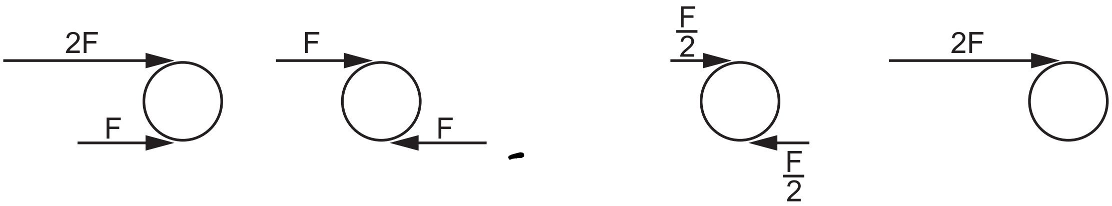
C Gravitational potential, kinetic energy, mass

D Kinetic energy, mass, momentum

Your answer C **[1]**

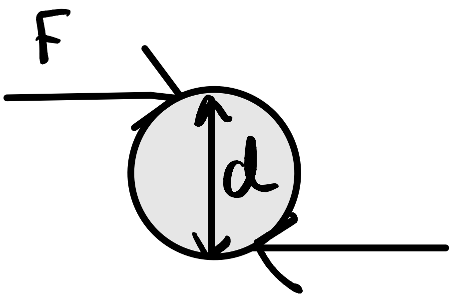
2 Forces are applied to a circular shaft of diameter d.

Which diagram shows a torque of a couple with magnitude Fd?



A **B** **C** **D**

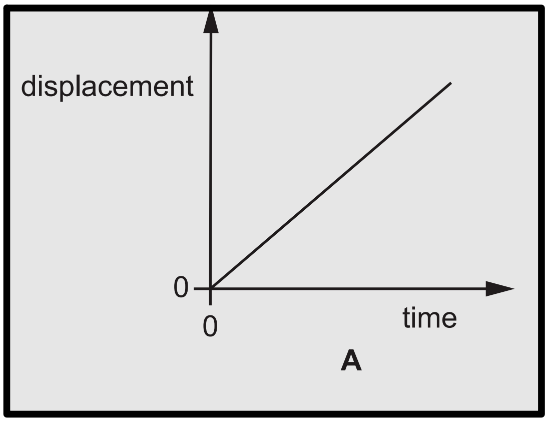
Your answer B **[1]**



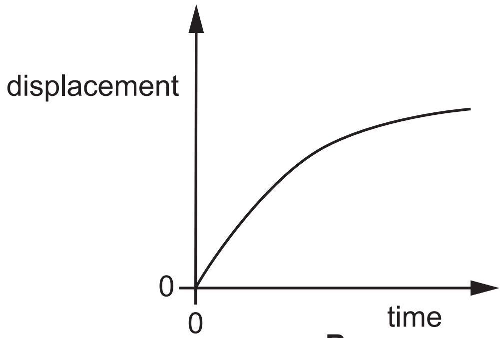
M = F·d

3 The resultant force acting on a moving object is zero.

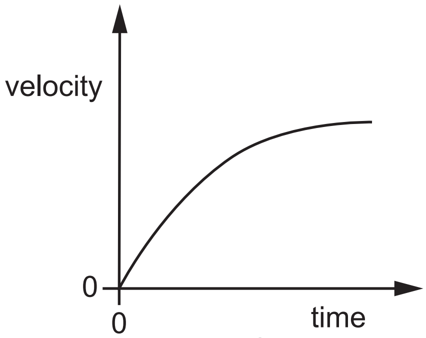
Which graph shows this?



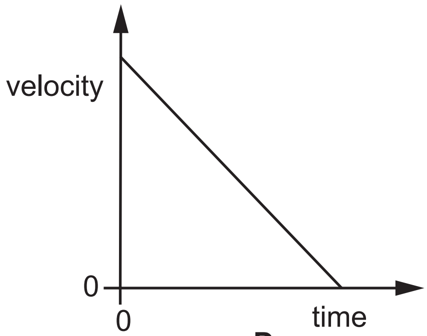
A



B



C



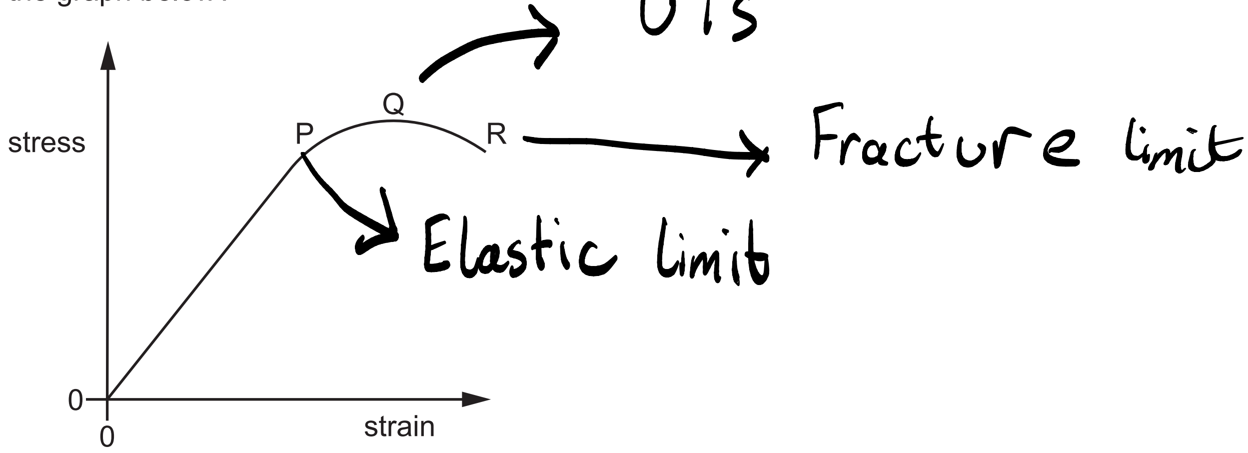
D

Your answer A **[1]**

$v = 0$

$\Delta v = 0$

4 Which row in the table correctly identifies the elastic limit, fracture and ultimate tensile strength in the graph below?



	Elastic limit	Fracture	Ultimate tensile strength
A	P	Q	R
B	P	R	Q
C	P	R	R
D	Q	R	P

Your answer B **[1]**

5 A wire of cross-sectional area $3.9 \times 10^{-6}\,\text{m}^2$ carries a load of 240 N. The strain in the wire is 0.30%.

Which value of the Young modulus, in Pa, is correct and expressed to an appropriate number of significant figures?

A 2.05×10^8

B 2.1×10^8

C 2.05×10^{10}

D 2.1×10^{10}

$\sigma = \frac{F}{A} = \frac{240}{3.9 \times 10^{-6}} = 6.154 \times 10^7$

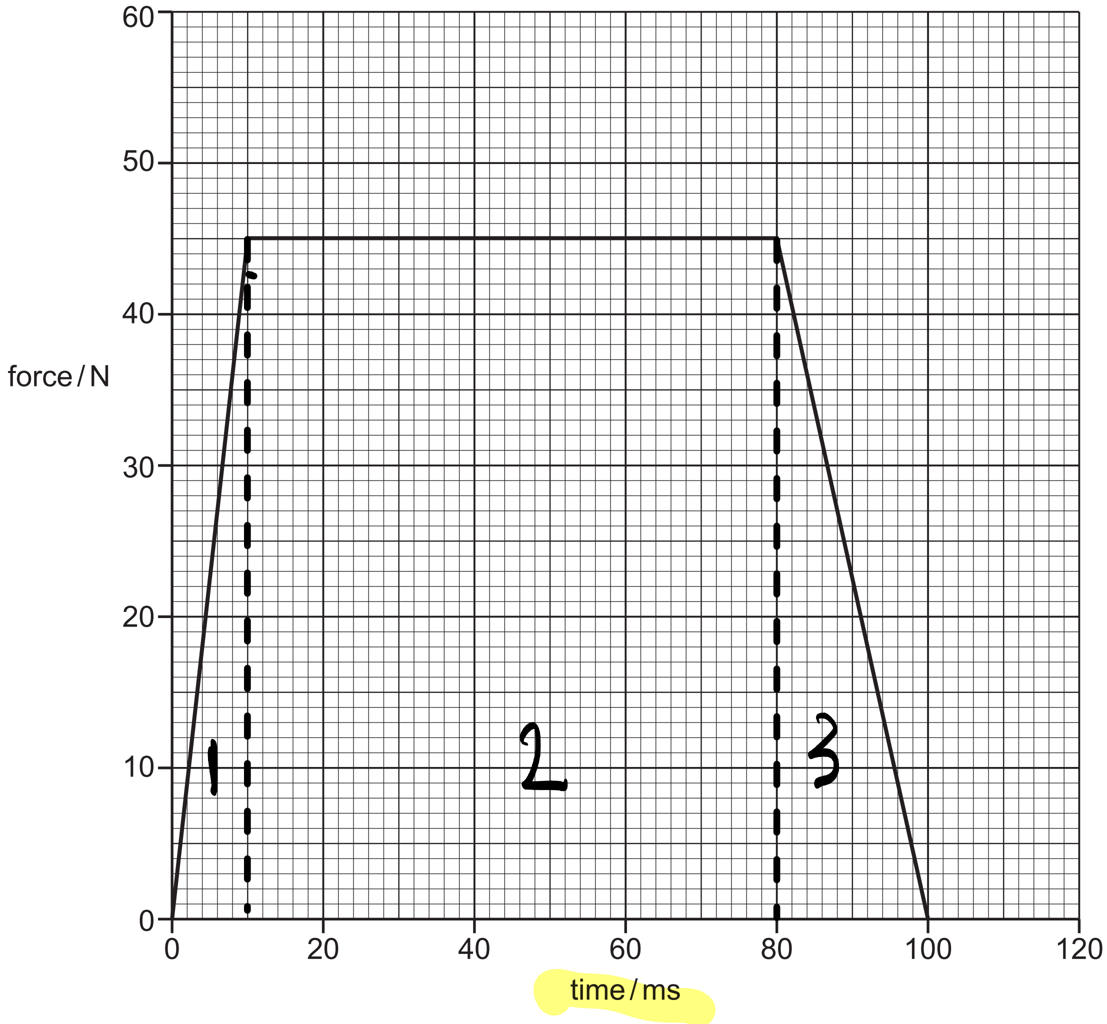
$E = \frac{\sigma}{\varepsilon} = \frac{6.154 \times 10^7}{0.003} = 2.05 \times 10^{10}$

$\varepsilon = 0.3\% \div 100 = 0.003$

2. s.f $\approx 2.1 \times 10^{10}$

Your answer D **[1]**

6 A tennis ball is hit with a racket. The graph shows the force the ball exerts on the racket.



What is the magnitude of the change in momentum of the ball?

A 2.3 kg m s^{-1}

B 3.8 kg m s^{-1}

C 2300 kg m s^{-1}

D 3800 kg m s^{-1}

Your answer: B

$F = \frac{\Delta p}{\Delta t} = \text{Area}$

Area 1 $= \frac{1}{2} \times 10 \times 10^{-3} \times 45$

$= 0.225$

Area 2 $= 45 \times 70 \times 10^{-3}$

$= 3.15$

[1]

7 Two identical spheres, each of mass 8700 kg, have a space of 3.6 m between their centres.

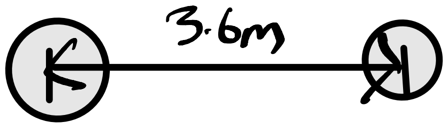
What is the magnitude of the gravitational force they exert on each other?

A 2.0×10^{-3} N

B 3.9×10^{-4} N

C 7.5×10^{-4} N

D 4.5×10^{-8} N



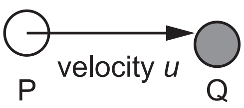
$$F = -\frac{GMm}{r^2} = -\frac{6.67 \times 10^{-11} \times 8700^2}{3.6^2}$$

$$= -3.9 \times 10^{-4} \text{ N}$$

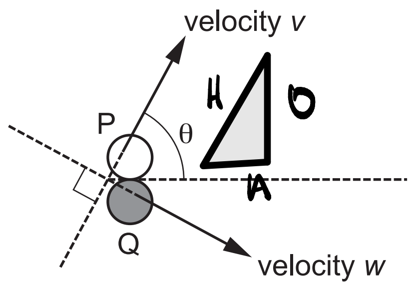
Your answer **B** [1]

8 A particle P of mass m and moving at velocity u collides **elastically** with a stationary particle Q also of mass m.

After the collision particle P moves with velocity v at an acute angle θ to the direction of the original motion. Particle Q moves in a perpendicular direction to P with velocity w. The velocities u, v and w are constant.



Before collision



After collision

$p = mv$

momentum$_x$

$m \cdot u = mv\cos\theta + wm\sin\theta$

$\cos\theta = \sin(90 - \theta)$

$u = v\cos\theta + w\sin\theta$

momentum$_y$

$0 = mv\sin\theta - mw\cos\theta$

$\cancel{m}v\sin\theta = \cancel{m}w\cos\theta$

$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + \frac{1}{2}mw^2$

$u^2 = v^2 + w^2$

Which of the following equations is/are correct?

1. $u = w\cos\theta + v\cos\theta$ ✗
2. $w\cos\theta = v\sin\theta$ ✓
3. $u^2 = w^2 + v^2$

A 1 only

B 1 and 2

C 2 and 3

D 1, 2 and 3

Your answer **C** [1]

9 During cold weather salt is spread on roads causing ice to melt without changing its temperature.

Which statement correctly describes the energy of the water particles during this process?

A Potential and kinetic energies increase

B No energy changes occur

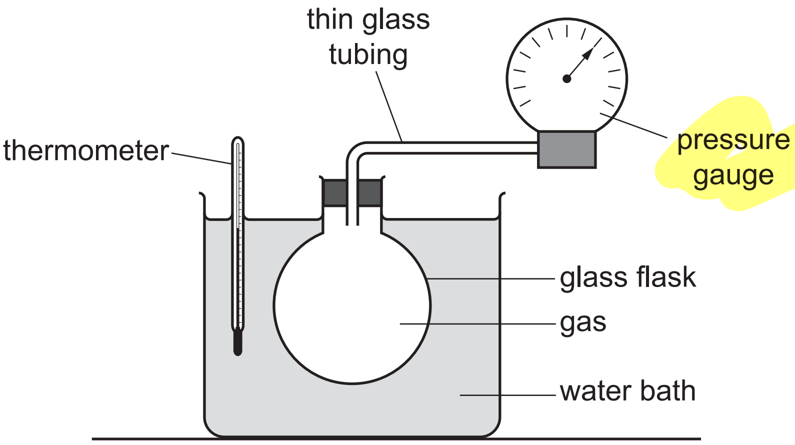
C Only kinetic energy increases

D Only potential energy increases

KE = temp
P.E = Δ state

Your answer D **[1]**

10 An experiment is carried out to estimate the value of absolute zero using the variation of gas pressure with temperature. The apparatus is shown below.



Boyle/charles law

$\frac{PV}{T} = k$

Which variable must be controlled during the experiment?

A Pressure of the gas

B Temperature of the gas

C Volume of the gas

D None of the above

Your answer C **[1]**

11 A satellite is in geostationary orbit 36 000 km above the Earth's surface. The Earth has a radius of 6400 km.

At what speed is the satellite moving relative to the centre of the Earth?

A $0\,\text{m}\,\text{s}^{-1}$

B $490\,\text{m}\,\text{s}^{-1}$

C $2.6\,\text{km}\,\text{s}^{-1}$

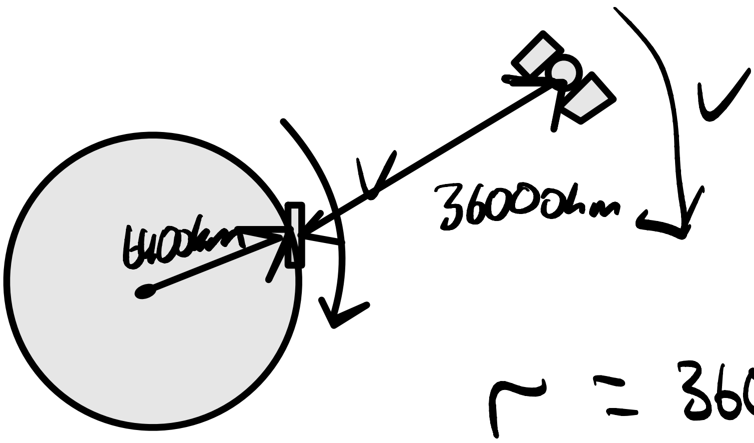
D $3.1\,\text{km}\,\text{s}^{-1}$

$s = vt$

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

$\frac{2\pi r}{T} = \frac{2\pi \times 42400}{86400} = 3.08$

Your answer D **[1]**

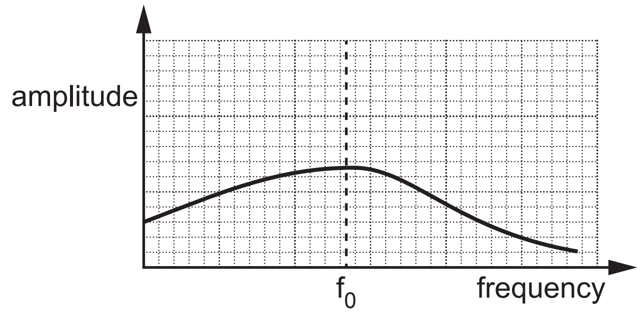
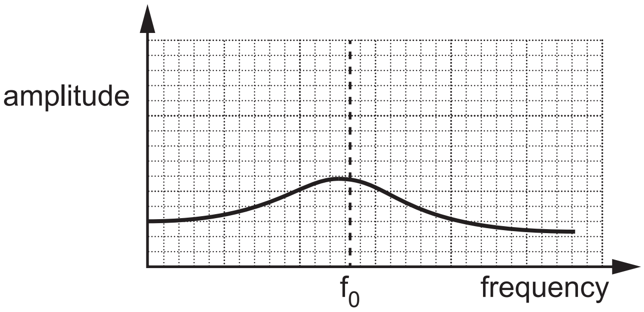
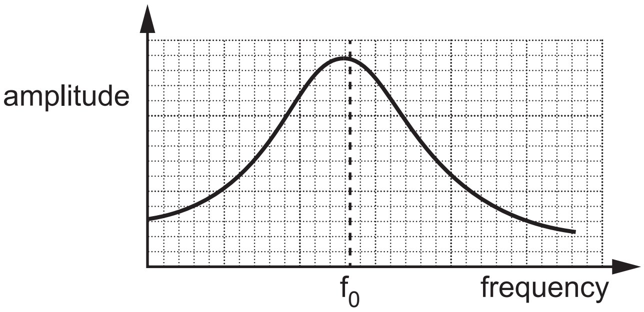
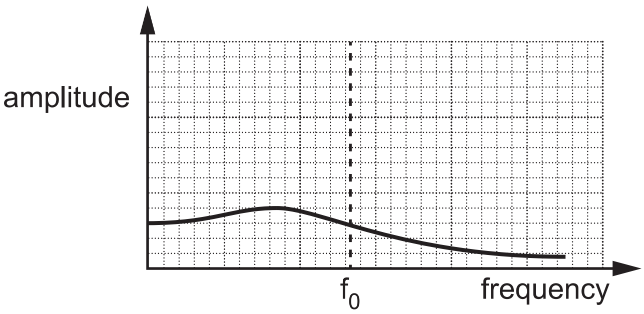


$r = 36000 + 6400\,\text{km}$

$= 42400\,\text{km}$

12 Four different oscillator systems are forced to oscillate at various frequencies. The graphs show the amplitude of oscillation for each frequency. f_0 is the undamped resonant frequency for each oscillator. The vertical axes on the graphs are all to the same scale.

Which of the oscillators, **A** to **D**, is the most heavily damped?

A	
B	
C	
D	

Amplitude ↓
Frequency ↓

Your answer D

[1]

13 During the evolution of the universe there was a period of inflation.

Which forms of matter, if any, existed 10^{-10} s after the big bang?

A Atoms ✗

B Leptons ✗

C None

D Quarks ✗

10^{-35} s = Inflation

10^{-6} s = First fundamental particles

Leptons particles

Quark + Quark = Hadron

Your answer C

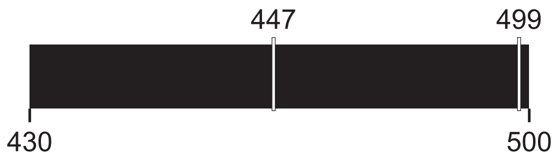
[1]

14 Part of the emission spectrum for hydrogen in a laboratory is shown. All wavelengths are given in nm.

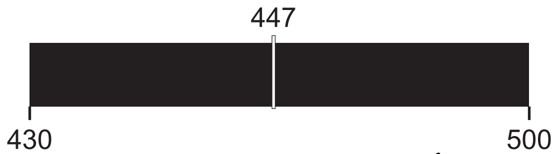
Which diagram shows the corresponding part of the absorption spectrum observed from Earth emitted from a galaxy moving away with a velocity of 0.031 c?

Emission

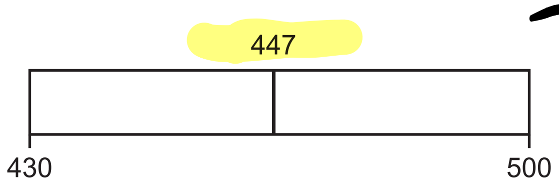
A



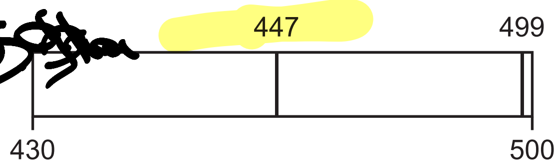
B



C



D



Doppler effect

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$\lambda_{initial} = 434$

$\Delta\lambda = 434 \times 0.031$

$= 13 \quad \lambda_{new} = 447$

$486 + 486 \times 0.031$

$= 501$

Your answer C

[1]

15 An early estimate for the Hubble constant was $500\,km\,s^{-1}\,Mpc^{-1}$.

What is the value of this estimate in units of s^{-1}?

1 parsec = 3.1×10^{16} m

A 2.3×10^{-18}

B 1.6×10^{-17}

C 1.6×10^{-5}

D 0.5

Your answer B **[1]**

$v = H_0 d$

$H_0 = \frac{v}{d}$ $\frac{1}{H_0} = \text{time}$

$s = vt$

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

$$\frac{500 \times 1000}{(3.1 \times 10^{16}) \times 1 \times 10^{6}} = 1.6 \times 10^{-17}$$

Section B

16 The diagram shows a road where vehicles travel at high speeds.

Markings painted on the road surface are spaced 40 m apart.

Drivers are advised to keep at least two markings visible on the road between them and the vehicle in front.

(not to scale)

The maximum speed vehicles travel at on the road is 110 km/hr. The table shows data from a driving manual for a vehicle travelling on a straight, horizontal road.

Speed (km/hr)	Braking distance (m)	Stopping distance (m)
110	75	96

(a) **(i)** Calculate the maximum speed v of vehicles on the road in S.I. units.

$110\ kmh^{-1}$

$\frac{110 \times 1000}{60^2} = 30.56$

v = 31 .... Unit = ms^{-1} .... **[2]**

(ii) A vehicle passes over one of the markings.

Calculate time taken to travel the 40 m distance between the two markings.

$s = v \times t$

$t = \frac{s}{v} = \frac{40}{30.56} = 1.31s$

t = ... 1.31 .... s **[1]**

(iii) Using the table, explain why having markings 40 m apart helps prevent collisions.

- Braking − stopping = thinking = 21m
- 21m < 40m ∴ driver enough time to react
- 75 (for braking) < 80m

[3]

(b) A vehicle with mass 1600 kg is travelling at 110 km / hr.
The driver sees an obstruction and applies the brakes to bring the vehicle to rest in 5.6 s.

(i) Estimate the magnitude of the average resultant force *F* required to bring the vehicle to rest.

s = ?, u = 30.56 v = 0 a = ? t = 5.6

$v = u + at \quad a = \frac{v - u}{t} = \frac{0 - 30.56}{5.6} = -5.46$

$F = ma$
$= 1600 \times 5.46 = 8736\,N$

F = 8700 N **[2]**

(ii) Explain the effect on the distance required to bring the vehicle to rest if the road has an upwards slope.

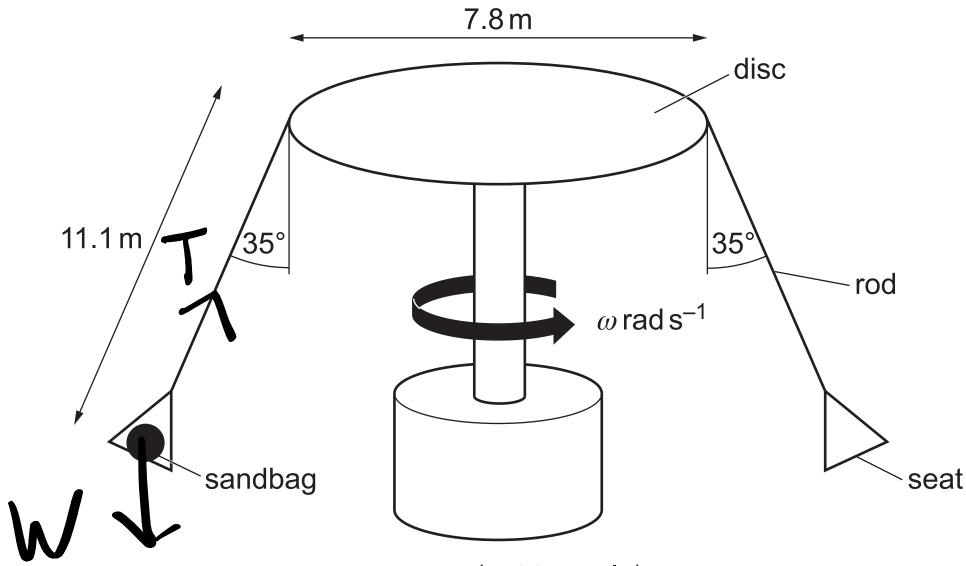
- Some of KE converts to PE thus a decrease in velocity at a higher rate as KE ∝ v²
- Stopping distance is smaller

[2]

17 The diagram below shows a fairground ride. Each rider is secured in a seat suspended by a rod.

The distance from the top of the rod to the base of the seat is 11.1 m.

The rod is attached to the edge of a disc of diameter 7.8 m.



(not to scale)

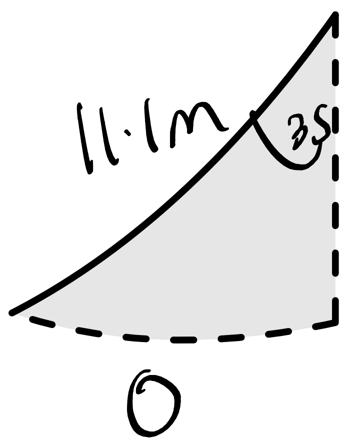
To test the equipment a sandbag is attached to the seat and the ride is started.

The combined mass of the seat and the sandbag is 12 kg.

The rod makes an angle of 35° with the vertical.

(a) **(i)** Draw an arrow labelled T on the diagram to represent the tension in the rod. **[1]**

(ii) Show that the radius of the circular path followed by the sandbag is about 10 m.



$\sin\theta = \frac{O}{H}$

$O = \sin\theta \cdot H$

$= \sin 35 \times 11.1$

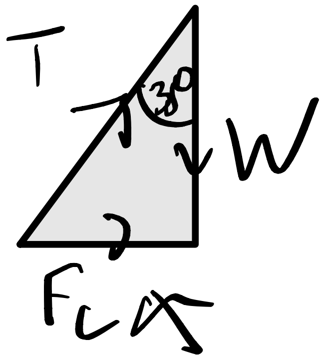
$= 6.37\text{m}$

$\frac{7.8}{2} + 6.37 = 10.27\text{m}$

$\approx 10\text{m}$

[2]

(iii) Calculate the tension T in the rod.



$W = mg = 12 \times 9.81 = 118\,N$

$\cos\theta = \frac{W}{T}$ $\quad T = \frac{W}{\cos\theta} = \frac{118}{\cos 35} = 144\,N$

$T =$ ....140.... N **[3]**

(iv) Show that the angular velocity of the ride is about 0.8 radians per second.

$\omega = \frac{2\pi}{T}$ $\quad F_c = m\omega^2 r$

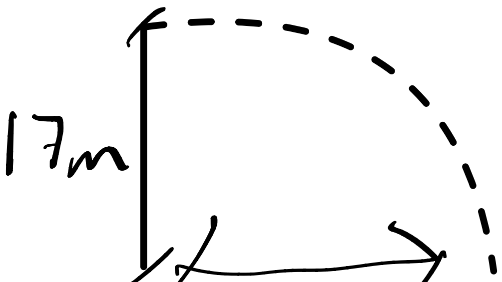
$\tan\theta = \frac{F_c}{W}$ $\quad F_c = \tan 35 \times 118 = 82.6\,N$

$\omega = \sqrt{\frac{F_c}{mr}} = 0.81\,rad\,s^{-1}$

[2]

(b) When the seat is at its highest point the sandbag is 17 m above the ground. The sandbag is released from the seat to model an object being dropped by a rider.

(i) Calculate t, the time taken for the sandbag to reach the ground.



$s = 17,\ u = 0,\ v = ?,\ a = 9.8\ t = ?$

$s = ut + \frac{1}{2}at^2$ $\quad s = \frac{1}{2}gt^2$

$t = \sqrt{\frac{2s}{g}} = 1.86\,s$

$t =$ ....1.9.... s **[2]**

(ii) Using your answer to **(a)(iv)**, determine the horizontal displacement s travelled by the sandbag before hitting the ground.

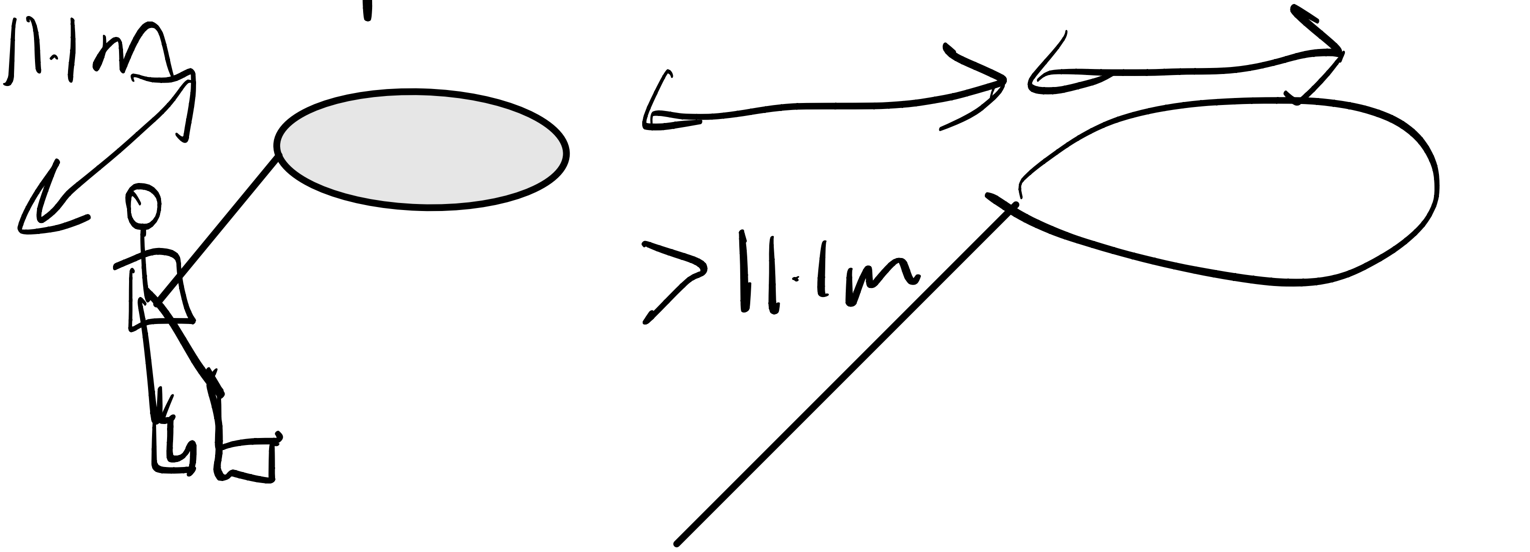
$s = vt$
$= 8.3 \times 1.86$
$= 15.4\,m$

$v = \omega r$
$= 0.81 \times 10.27 = 8.3\,m\,s^{-1}$

$s =$ ....15.... m **[3]**

(iii) Determine, with reasons, the effect on the horizontal displacement travelled if the object released from the ride was a shoe from a rider.

• height is < 17 m, time taken to reach ground is less, as $s \propto t$, horizontal displacements decrease
• As $v \propto r$, and radius ↑, horizontal displacement increases **[3]**



$h < 17m$

$r > 10m$

$v = \omega r$

$v \propto r$

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18* A student is attempting to determine the value of *g*, the acceleration due to gravity, by two different methods.

Method 1. Vertical drop method

Measuring the time of fall of a small dense ball being dropped from rest from different heights.

Method 2. Rolling ball method

Measuring the time it takes for the same ball to roll 1.900 m down a ramp, set at different angles.

Single sets of results are shown below. The times were measured using a standard stopwatch operated by the student.

Compare and discuss the uncertainties of the two values of *g* that could be obtained using these single measurements.

Describe how the student would analyse both sets of data when a full range of results has been taken.

Vertical drop method

Drop height / m	Time taken / s
1.20	0.50

± 0.01m > ± 0.1s

Rolling ball method

Length of ramp / m	Angle / °	Time taken / s
1.900	30	0.90

± 0.001 ± 1 > ± 0.1s

[6]

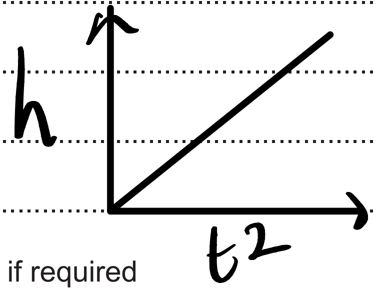
• Reduce uncertainty by collecting more data

• Because time is longer and distance farther in the rolling ball method, will be less uncertain

Vertical

- Record at multiple heights $s = \frac{1}{2}gt^2$

Plot



gradient $= \frac{h}{t^2}$

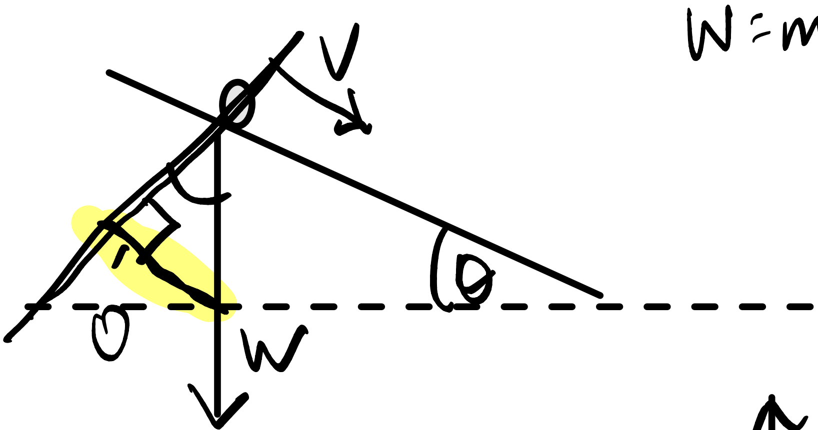
$\frac{h}{t^2} = \frac{s}{t^2} = \frac{1}{2}g$

Additional space if required

Multiply gradient by 2x for estimate of gravity

Rolling ball method

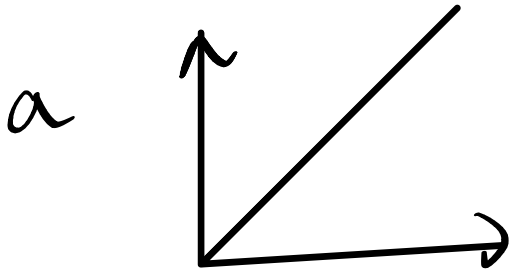
$s = ~~ut~~ + \frac{1}{2}at^2$ $s = \frac{1}{2}at^2$ $a = \frac{2s}{t^2}$



$W = mg$ $F = ma$

$~~m~~g\sin\theta = ~~m~~a$

$a = g\sin\theta$



$\frac{g\sin\theta}{\sin\theta}$ = estimate of g

19 (a) Describe how to find the centre of mass of a 2-dimensional shape, including any equipment required.

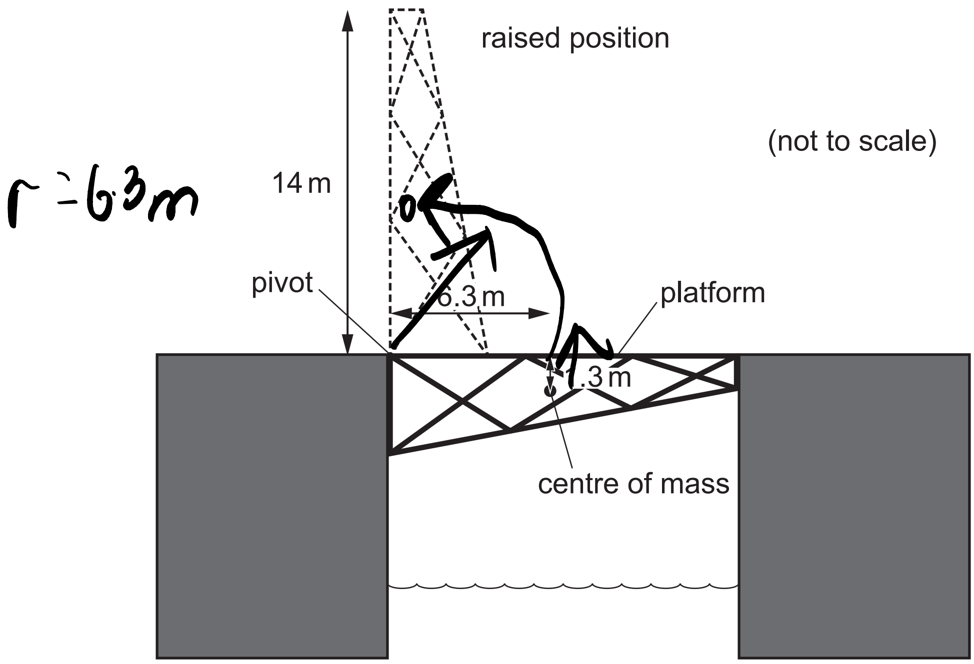
- Suspend shape from pin
- Hang string from shape and draw a straight line (plumb line).
- Rotate shape (pin from another corner) and draw another plumb line
- Intersection = centre of mass

[3]

(b) **Fig. 19** shows a bridge.

The bridge can be raised by an electric motor to allow tall ships to pass underneath.

Fig. 19



The moving section of the bridge is 14 m long and has a weight of 120 kN.

The centre of mass of the structure is 6.3 m from the pivot.

(i) Calculate the average power required to raise the bridge to a vertical position in 90 s.

$W = Fx = 120 \times 10^3 \times (1.3 + 6.3) = 9.12 \times 10^5$ J

$P = \frac{E}{t} = \frac{9.12 \times 10^5}{90} = 1.01 \times 10^4$ W

power 1.0×10^4 W **[2]**

(ii) Suggest why the actual electric motor used to lift the bridge has a maximum power output several times larger than the value calculated in **(b)(i)**.

System isn't 100% efficient so more power required

[1]

20 (a) A sealed container contains *n* moles of an ideal gas. The gas has pressure *p*, absolute temperature *T* and occupies volume *V*.

The mass of one mole of the gas is *M*.

Use an ideal gas equation to show that the density ρ of the gas is given by the expression $\rho = \frac{pM}{RT}$.

$pV = nRT$

$V = \frac{nRT}{p}$

$\frac{m}{\rho} = \frac{nRT}{p}$

$\rho = \frac{m}{V}$

$V = \frac{m}{\rho}$

$\rho = \frac{pM}{nRT}$ ↑ $n=1$

$\rho = \frac{pM}{RT}$

[3]

(b) An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is 12 000 m^3.
The temperature of the helium and the surrounding air is 20 °C.
Atmospheric pressure is 1.0×10^5 Pa.
The molar mass of air is 0.029 $kg\,mol^{-1}$.
The volume of the cabin is negligible compared to the volume of the gasbag.

(i) Show that the density of air under the conditions described is about 1.2 $kg\,m^{-3}$.

$\rho = \frac{pM}{RT} = \frac{1.0 \times 10^5 \times 0.029}{8.31 \times (273 + 20)} = 1.19 \approx 1.2$

[1]

(ii) Calculate the weight of air displaced by the airship.

$V = 12000\ m^3$, $\rho = 1.2 \rightarrow m = \rho V$
$= 1.2 \times 12000$
$= 14400\ kg$

$W = mg$
$= 14400 \times 9.81 =$
$= 1.4 \times 10^5$

weight of air .... 1.4×10^5 .... N **[2]**

(iii) Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

Archimedes principle : Weight of the airship is equal to the weight of the air displaced by ship. Resultant force = 0 so weight of ship = weight of displaced air **[2]**

(iv) The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
Suggest why a larger pressure is not used.

pressure increases density of air. We need to increase volume to create more upthrust

[2]

(c) The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1}, so the airship starts to move.

All other conditions given in **(b)** remain the same.

$\Delta p = F \times \Delta t \quad t = 1$

Calculate the thrust that the engine produces.

$\Delta p = m(v-u) \quad F = m(v-u)$

$F = 7.8(45-0)$

$= 351 N$

thrust ....350.... N **[2]**

(d) The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine.

Explain these observations.

Higher speed due to less drag in a less dense atmosphere.
The air is less dense so smaller rate of change of momentum so less force

[2]

21 (a) **Fig. 21.1** shows a stationary glider of mass *m* on an air track.

The glider has identical springs with force constant *k* attached to each end which are secured to fixed posts.

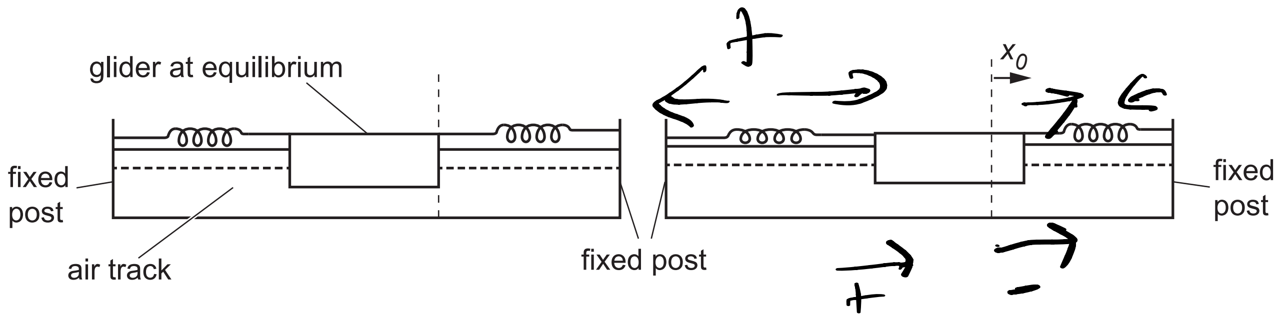
The air track blower is turned on and the glider is displaced a small distance x_0, as seen in **Fig. 21.2**. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period *T* calculated.

Fig. 21.1 **Fig. 21.2**



The relationship between the period *T*, the mass of the glider *m* and the force constant *k* is described by the equation

$$T^2 = \frac{2\pi^2 m}{k}.$$

(i) Show that the equation above is homogeneous by reducing the equation to SI base units.

T^2 = seconds^2 mass = kg k = ? F = kx

k = $\frac{F}{x}$ = kgms^{-2} m^{-1}

$\frac{kg}{kg\,s^{-2}} = \frac{1}{s^{-2}} = s^2$

[2]

(ii) Explain why the magnitude of the resultant force *F* on the glider is given by *F* = 2*kx* where *x* is the displacement at any time.

F = kx → both strings have same but opposite extensions. ΔF = Δkx
kx − k(−x) = 2kx
F = 2kx **[2]**

(iii) State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

Period is exclusive of displacement so not affected. **[2]**

(b) Masses are added to the glider, and the measurement of $20T$ repeated.

The results table is below.

m / kg	$20T$ / s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(i) Describe **two** different errors in the table.

1 Time period (T/T^2) should have units

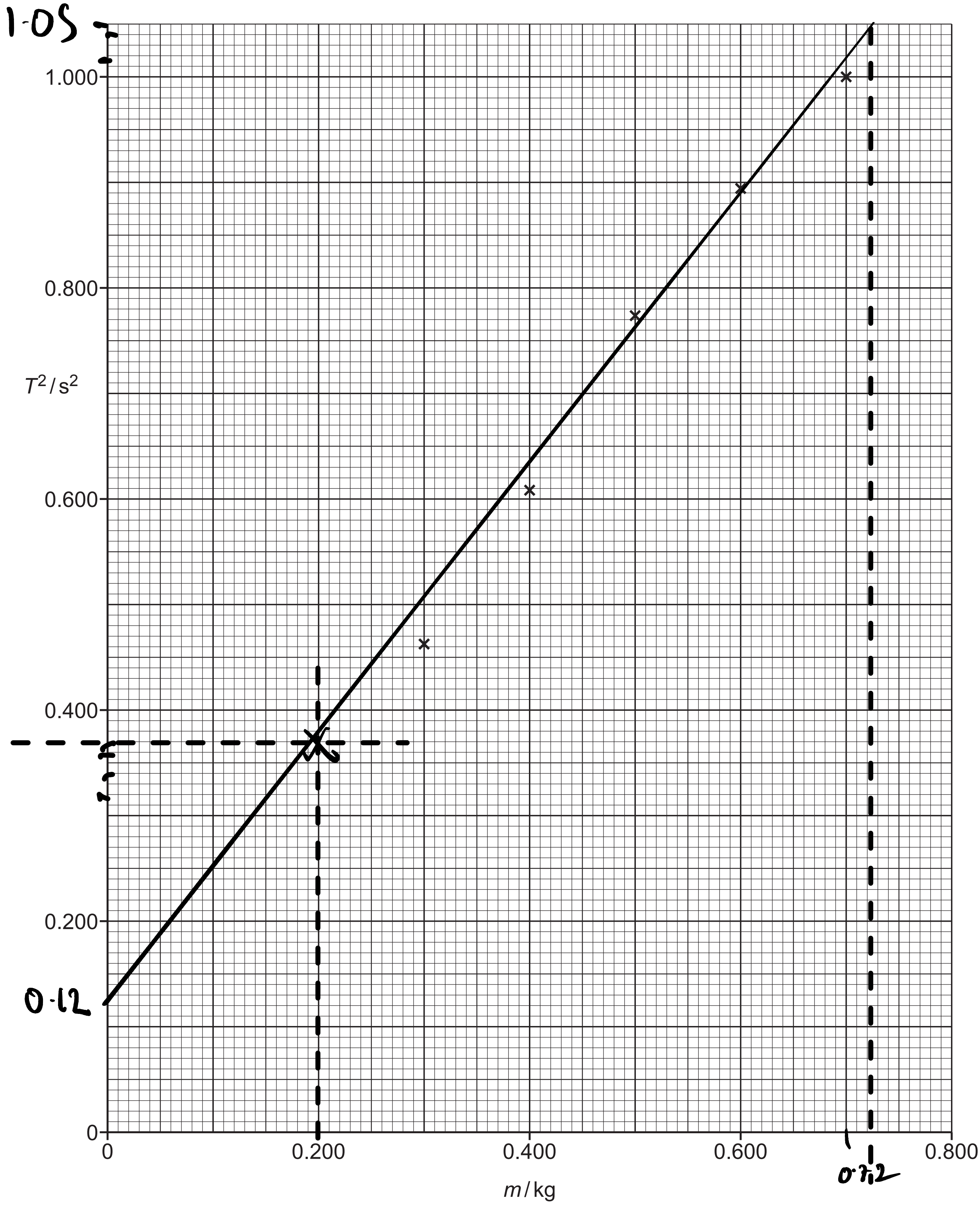
2 All data should have the same significant figures

[2]

(ii) Plot the **first** data point from the table on the graph below.

The other points have all been plotted. The table of results is repeated on the opposite page.

Include on your graph a line of best fit. **[2]**



m / kg	$20T$ / s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(iii) Use the graph to determine the value of k.

$T^2 = \frac{2\pi^2 m}{k}$ → gradient $= \frac{2\pi^2}{k}$ gradient $= \frac{T^2}{m}$

$\frac{T^2}{m} = \frac{2\pi^2}{k}$ $k = \frac{2\pi^2}{\text{gradient}}$ $k = 15.3$

gradient $= \frac{\Delta y}{\Delta x} = \frac{1.05 - 0.12}{0.72} = 1.29$

k = 15 N m^{-1} **[3]**

(c) When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

- PE from stretching spring > PE lost from the slack spring
- $EPE = \frac{1}{2}kx^2$ → $EPE \propto x^2$, EPE increases if displacement increases
- More PE means more transferred to kinetic energy during oscillation
- At equilibrium ($x = 0$), maximum velocity reached $KE = \frac{1}{2}mv^2$ $KE \propto v^2$

[4]

22* A star has a mass similar to that of the Sun.

Describe how the position of this star on a Hertzsprung-Russell (H-R) diagram changes as it evolves.

Fig. 22.1 is a blank H-R diagram.

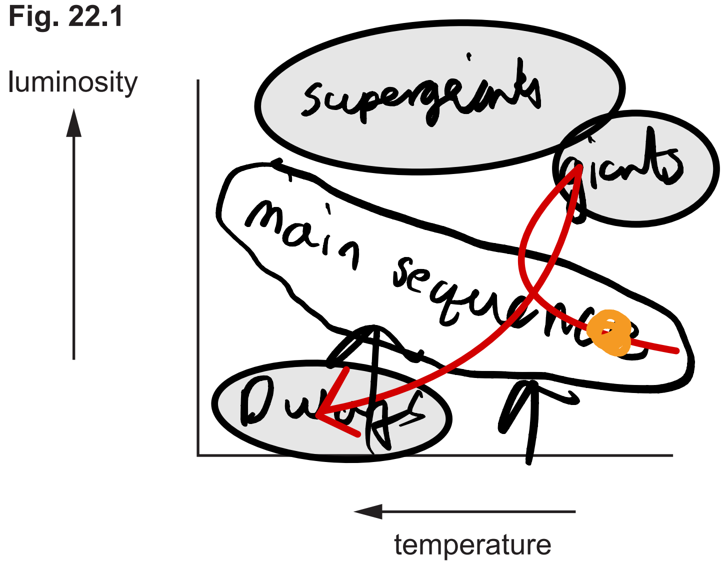
You may add information to **Fig. 22.1** as part of your response.

Fig. 22.2 shows the relative intensities of different wavelengths of light in the spectrum of a star.

Explain how information from **Fig. 22.2** could be used to suggest the stage of evolution of the star. Describe the limitations of the analysis.

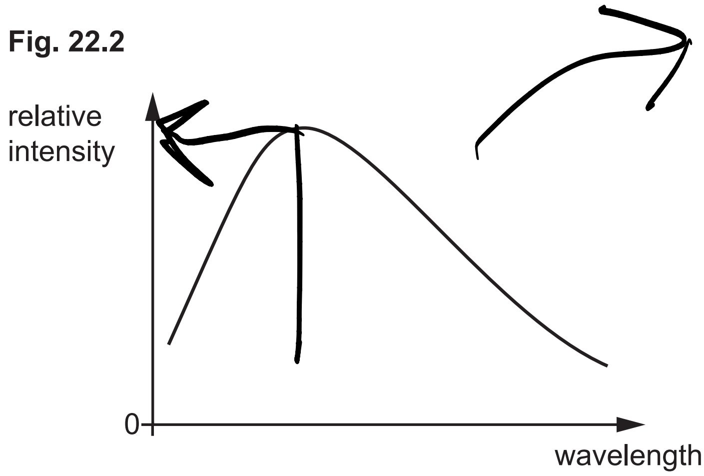
[6]

Fig. 22.1



$\lambda_{max} \propto \frac{1}{T}$

Fig. 22.2



• Low mass star → evolves just to a giant. Then it evolves a white dwarf

If a star has a shorter wavelength, its hotter ($\lambda_{max} \propto \frac{1}{T}$) $b = 2.9 \times 10^{-3}$ mK

- $\lambda_{max} \times T = b\ (2.9 \times 10^{-3})$
re-arrange for T to find horizontal coordinate of HR-diagram

- We have no way to find luminosity so can't distinguish between similar temperature stars.

Additional space if required

23 The Hipparcos space telescope used stellar parallax with a precision of 9.7×10^{-4} arcseconds to determine the distance to stars.

One of the stars studied was Polaris A. Data about this star is in the table below.

Parallax angle	7.5×10^{-3} arcseconds
Radius	2.1×10^{10} m
Mass	1.1×10^{31} kg
Surface temperature	6000 K
Temperature of the atmosphere of the star	4.0×10^{6} K

(a) **(i)** Estimate the maximum stellar distance in parsecs that could be measured using Hipparcos.

maximum stellar distance = ... pc **[1]**

(ii) Calculate the percentage uncertainty in the calculated value of the distance to Polaris A.

percentage uncertainty = ... % **[2]**

(b) A continuous stream of particles called a solar wind flows from the surface of the star into the surrounding space.

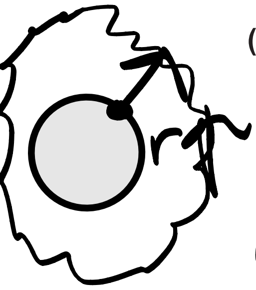
These particles include helium nuclei of mass 6.6×10^{-27} kg.

Assume that the atmosphere is modelled as an ideal gas.

(i) Show that the typical kinetic energy of a helium nucleus in the atmosphere is about 10^{-16} J.

[2]

$\downarrow E = -\frac{GMm}{r\uparrow}$



(ii) The gravitational potential energy of a helium nucleus in the outer layer of the star is -2.3×10^{-16} J. $\Rightarrow 0$

Calculate the gravitational potential energy U at the maximum distance from the star that a helium nucleus could reach.

GPE + KE = $-2.3\times10^{-16} + 8.28\times10^{-17} = -1.472\times10^{-16}$

U = -1.5×10^{-16} J **[1]**

(iii) Calculate the distance from the centre of the star reached by this helium nucleus.

$E = -\frac{GMm}{r}$ $\quad r = \frac{-GMm}{E}$

$= \frac{-6.67\times10^{-11}\times1.1\times10^{31}\times6.6\times10^{-27}}{-1.5\times10^{-16}} = 3.23\times10^{10}$

distance = 3.2×10^{10} m **[3]**

(iv) Explain why the star has a solar wind that reaches a much greater distance from the star than found in **(iii)**.

KE calculated using mean velocity. In reality, some particles will be travelling much faster so will reach greater distance! **[1]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).