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Friday 23 May 2025 – Morning

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.

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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 of these physical constants requires the greatest number of **different** base SI units?

A Avogadro constant, N_A

B Boltzmann constant, k

C Gravitational constant, G

D Molar gas constant, R

Your answer ☐

[1]

2 A metal block of mass m is at temperature T_0. An electrical heater of constant power P heats the block for time t and it reaches a temperature T_1. The overall efficiency of the process is x.

Which expression gives the correct value of c, specific heat capacity of the block?

A $\frac{Pt}{m(T_1 - T_0)}$

B $\frac{Pt}{mx(T_1 - T_0)}$

C $\frac{Ptx}{m(T_1 - T_0)}$

D $\frac{Px}{mt(T_1 - T_0)}$

Your answer ☐

[1]

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3 Which row of the table describes the conditions which apply to an **inelastic** collision?

	Kinetic energy	Total energy	Momentum
A	Conserved	Not conserved	Conserved
B	Not conserved	Conserved	Conserved
C	Not conserved	Conserved	Not conserved
D	Not conserved	Not conserved	Not conserved

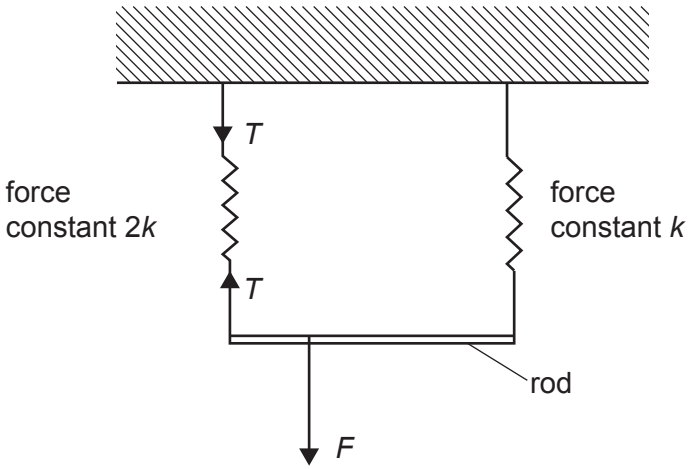
Your answer ☐

[1]

4 A light rod is hung from a horizontal ceiling using 2 springs, one attached to each end. The springs have force constants k and $2k$.

A downwards force F is applied closer to one end of the rod such that the rod is horizontal.

What is the tension T in the spring with the force constant $2k$?



A $\frac{F}{3}$

B $\frac{F}{2}$

C $\frac{2F}{3}$

D F

Your answer ☐

[1]

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5 A material is heated so that it changes state from solid to liquid and after further heating changes to gas.

Which of the following properties of the particles have increased?

1 Mean kinetic energy

2 Order

3 Spacing

A 1 and 3 only

B 1, 2 and 3

C 2 and 3 only

D 3 only

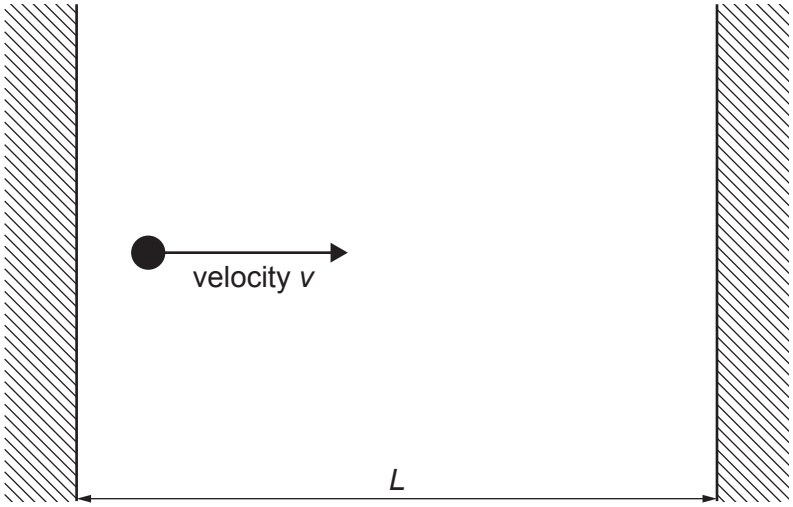
Your answer ☐

[1]

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6 A small particle of mass m is travelling horizontally between two parallel walls with a velocity v. The weight of the particle is equal to the upthrust caused by the air. The distance between the walls is L. The effect of drag on the particle is negligible.

After colliding with a wall the particle rebounds with a velocity of equal magnitude and travels in the opposite direction, hitting the opposite wall. The motion continues.



Which row in the table is correct?

	Change in momentum during each collision	**Time between collisions with the <u>same</u> wall**	**Average force exerted on the wall**
A	mv	$\frac{2L}{v}$	$\frac{mv^2}{2L}$
B	$2mv$	$\frac{2L}{v}$	$\frac{mv^2}{L}$
C	$2mv$	$\frac{L}{v}$	$\frac{2mv^2}{L}$
D	$2mv$	$\frac{2L}{v}$	$\frac{2m}{L}$

Your answer ☐

[1]

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7 The apparent position of a star changes by an angle of 1.0×10^{-4} degrees between observations made 6 months apart from the same place on Earth.

What is the distance of the star from Earth in parsecs?

A 2.8

B 5.6

C 170

D 330

Your answer ☐

[1]

8 A washing machine with a circular drum of diameter 0.60 m is rotating at an angular velocity of 15 radians per second.

What is the magnitude of the force exerted by the drum on a 0.30 kg item of clothing which is at the bottom of the spinning drum?

A 21 N

B 23 N

C 41 N

D 43 N

Your answer ☐

[1]

9 Two spheres each of radius 10 m and mass 1600 kg exert a gravitational force of 1.7×10^{-8} N on each other.

What is the shortest distance between the surfaces of the spheres?

A 80 m

B 100 m

C 120 m

D 9900 m

Your answer ☐

[1]

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10 Which of the following determines whether a super red giant evolves to a black hole?

A Dark matter

B Electron degeneracy

C Mass of the core

D The Chandrasekhar limit

Your answer ☐

[1]

11 Monochromatic light of wavelength 600 nm is passed through a diffraction grating.

Maxima are formed on a screen 3.0 m from the grating. The distance between the two first order maxima, on either side of the zero maximum, is 1.42 m.

What is the spacing, in m, between lines on the diffraction grating?

A 1.3×10^{-6}

B 1.4×10^{-6}

C 2.5×10^{-6}

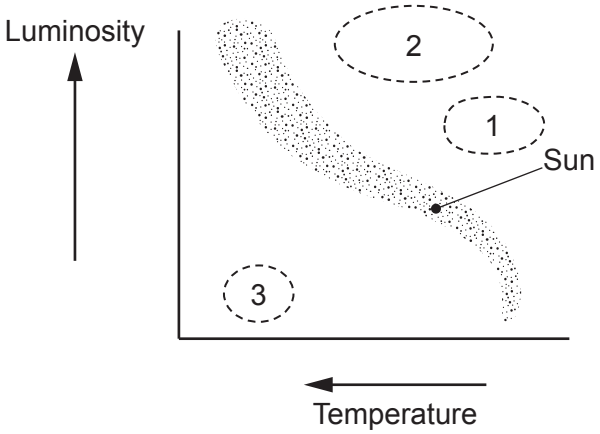
D 2.6×10^{-6}

Your answer ☐

[1]

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12 Which option correctly gives the likely evolution of the Sun?



A $1 \rightarrow 2 \rightarrow 3$

B $1 \rightarrow 3$

C $2 \rightarrow 1 \rightarrow 3$

D $2 \rightarrow 3$

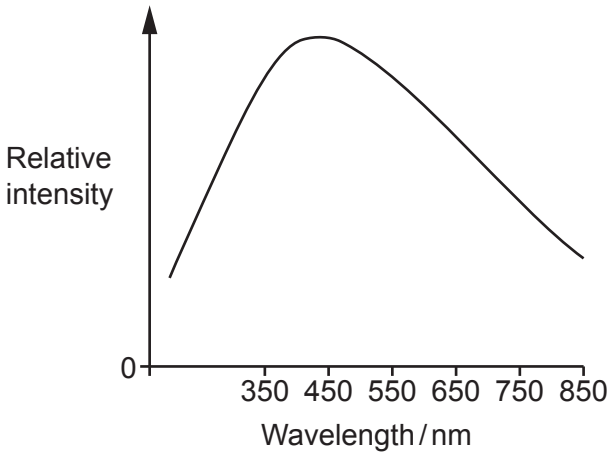
Your answer ☐

[1]

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13 The surface temperature of the Sun is 5800 K and the peak wavelength is 500 nm.

What is the surface temperature, in K, of the star represented by the graph below?



A 3400

B 5200

C 6400

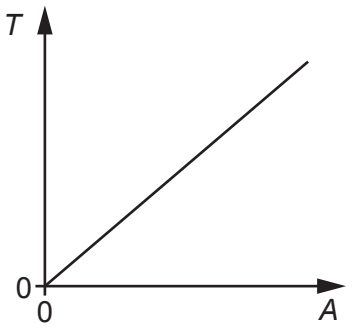
D 9900

Your answer ☐

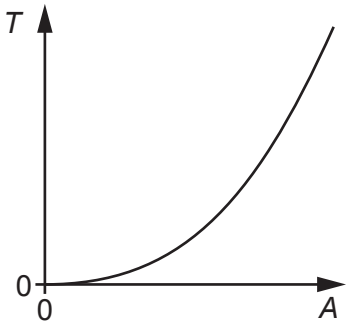
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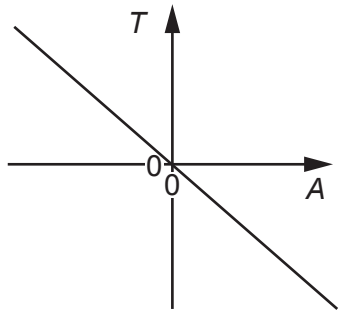
14 A body moves with simple harmonic motion. Which graph shows the correct relationship between its period, T, and its amplitude, A?



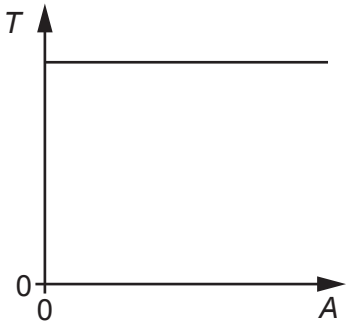
A



B



C



D

Your answer ☐

[1]

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15 Which of these statements about the Universe is implied by the Cosmological principle?

A Dark energy is found in every galaxy

B Kepler's laws can be applied to any solar system

C Matter and anti-matter were formed in the very early Universe

D Microwave background radiation corresponds to a temperature of 2.7 K

Your answer ☐

[1]

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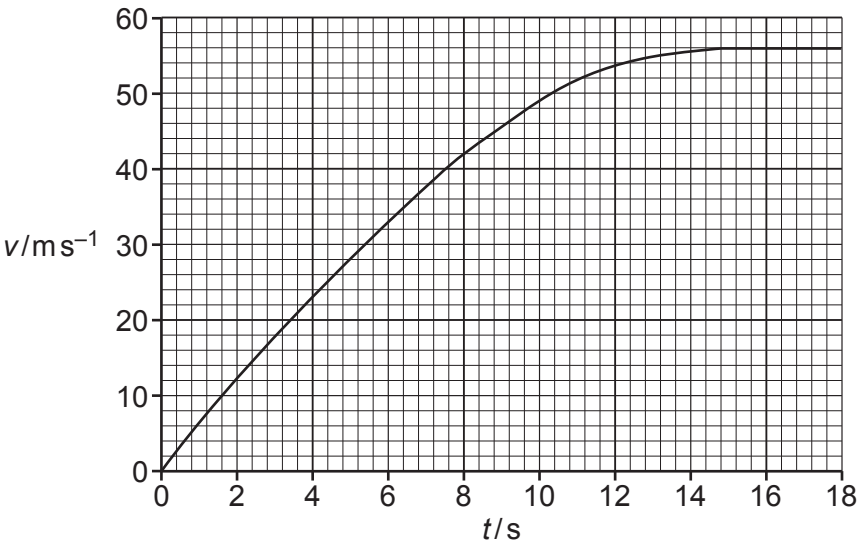
Section B

16 An electric car of mass 1700 kg is tested to measure its maximum speed.

Fig. 16.1 shows a graph of velocity v against time t for the first 18 seconds of the test.

During this time the force produced by the motor is constant.

Fig. 16.1



(a)

(i) Describe using **Fig. 16.1**, the method you would use to estimate the distance travelled in 18 s.

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..... **[2]**

(ii) Use the graph in **Fig. 16.1** to show that the acceleration of the car at time t = 12 s is about 1.5 m s^{-2}.

[2]

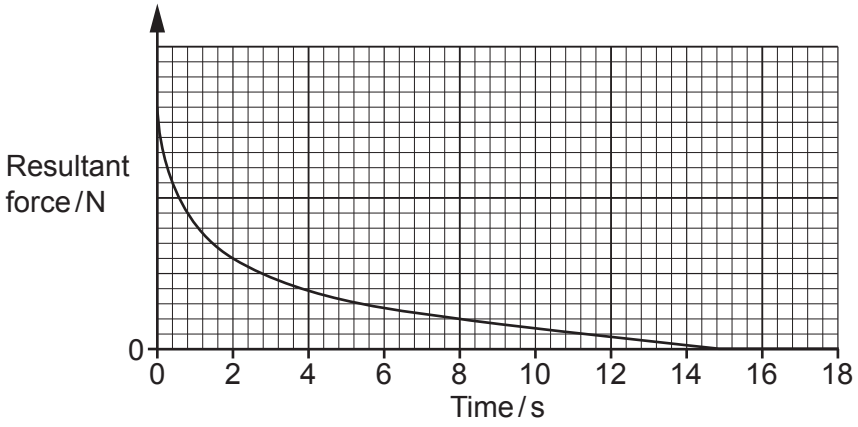
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(iii) Use **Fig. 16.1** to calculate the change of momentum of the car in 18 s.

= ..... kg m s^{-1} **[2]**

(b) **Fig. 16.2** shows a graph of **resultant** force against time during the test.

Fig. 16.2



(i) Explain, in terms of the forces acting on the car, the shape of the graph in **Fig. 16.2**.

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..... **[2]**

(ii) Explain why the value you have calculated in **(a)(iii)** is the area under the graph in **Fig. 16.2**.

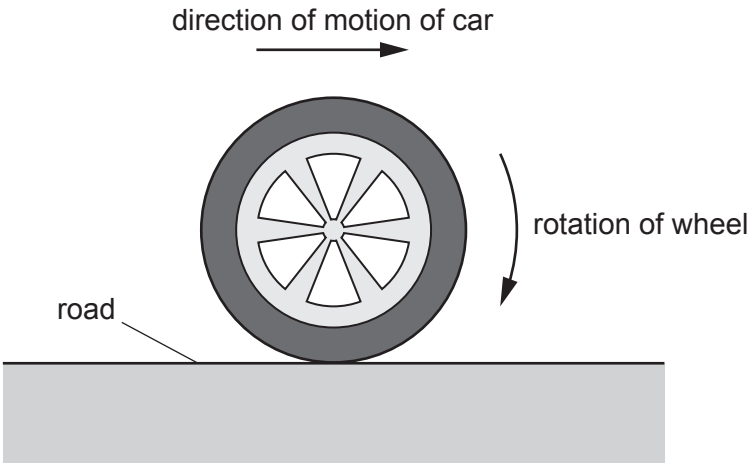
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..... **[1]**

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(c) The diagram below shows one of the wheels of the car that is driven by the electric motor.



(i) Use Newton's third law to explain how frictional forces cause the car to accelerate.

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..... **[2]**

(ii) Calculate the resultant force acting on the car at t = 12 s, using your answer to **(a)(ii)**.

resultant force = ... N **[1]**

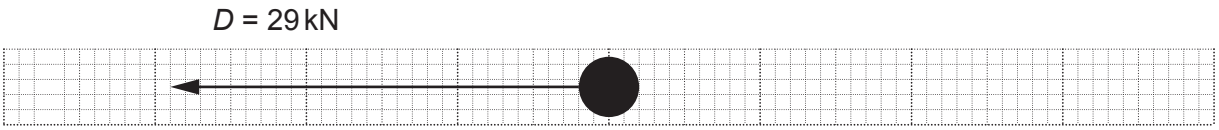
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(iii) The black dot in the diagram below represents the car at time t = 12 s. The total resistive forces acting on the car, D, are shown.

Calculate the constant **total** frictional force F from the powered wheels of the car which provides the thrust on the car.

Use your answer to draw an arrow on the diagram below to show the direction and magnitude of F.

F = ... kN



[2]

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17 An aircraft is flying horizontally at an altitude of 10 000 m and a constant speed of 220 m s^{-1}.

While maintaining this speed, the controls are adjusted so that the aircraft is in **projectile** motion until the altitude is 7500 m.

Throughout the projectile motion the passengers experience apparent weightlessness.

(a)

(i) A condition for projectile motion is constant vertical acceleration. State the other condition.

.....

..... **[1]**

(ii) Show that t, the time taken to reach the new altitude of 7500 m, is about 23 s.

[2]

(iii) Determine the magnitude and direction of the velocity of the aircraft at time t.

velocity = ... m s^{-1}

angle to the vertical ..... ° **[4]**

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(iv) Explain why the engines of the aircraft must provide thrust during the projectile motion.

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..... **[2]**

(b)

(i) The average radius of the Earth is 6400 km.

Show that the ratio below is greater than 0.99.

$$\frac{\text{gravitational field strength at 10 000 m altitude}}{\text{gravitational field strength at the surface of the Earth}}$$

[2]

(ii) Explain why the passengers are described as 'weightless' during the projectile motion of the aircraft.

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..... **[2]**

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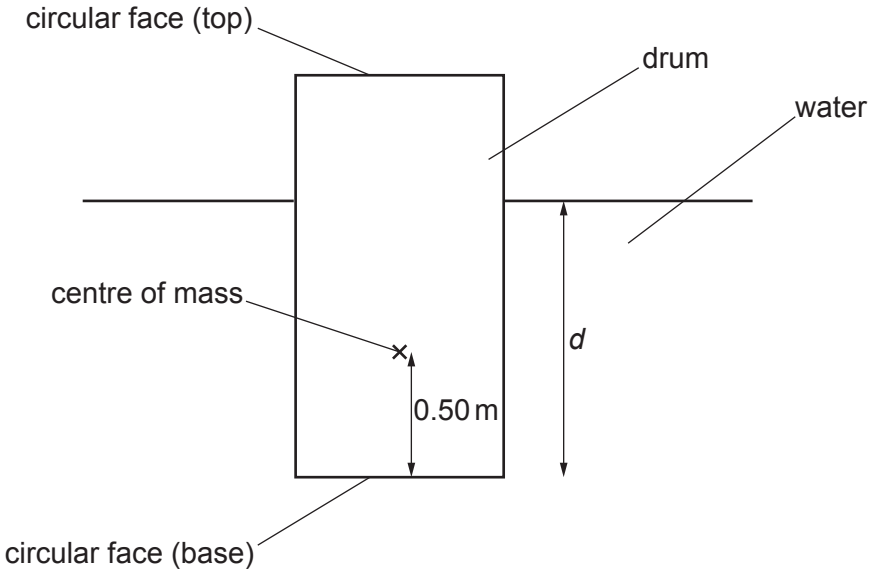
18 Part of a machine to generate electrical energy using waves is a cylindrical drum whose cross-section is shown below. The height of the drum is 2.0 m and its cross-sectional area is 0.79 m^2.

The mass of the drum is 1200 kg.

The centre of mass of the drum is 0.50 m from one of the circular faces, on a line joining the centres of the circular faces.

The density of water is 1000 kg m^{-3}.

The drum floats in flat water with its long axis vertical. The base of the drum is a distance *d* below the surface, where *d* is measured in m.



(a)

(i) Explain why the weight of water displaced must be equal to the weight of the drum.

.....

.....

..... **[1]**

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(ii) Calculate d.

d = ... m **[3]**

(iii) Upthrust forces act at the centre of mass of the fluid displaced.

Explain why the drum cannot float in **equilibrium** on its side with the long axis horizontal.

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..... **[2]**

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(b)

(i) When the vertical drum is displaced a distance x deeper into the water from the equilibrium position, the magnitude of the resultant force on the drum, F, is given by

$F = -kx$

where k is a constant and d is measured in m.

By considering the magnitude of the additional upthrust on the drum, show that k is about $8000\,\text{Nm}^{-1}$.

[2]

(ii) When the drum is released, it oscillates vertically. Explain why the oscillations are simple harmonic motion.

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..... **[2]**

(iii) Calculate the natural frequency f of the oscillations.

$f =$ ..... Hz **[2]**

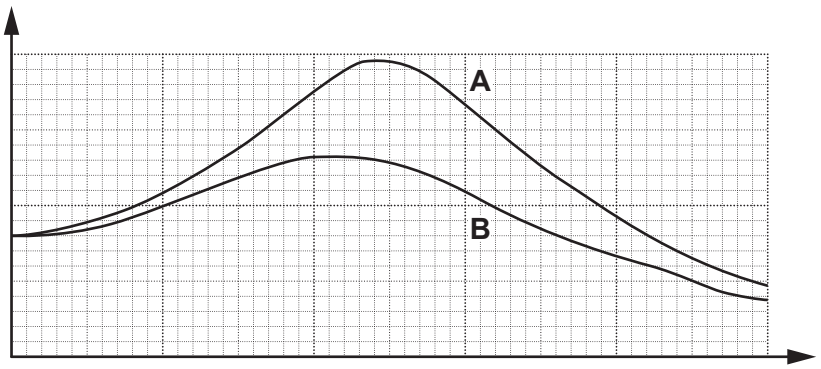
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(c)* Two designs, **A** and **B**, of the machine are tested in a large ripple tank.

The ripple tank can produce waves whose amplitude and frequency can be varied over wide ranges.

The natural frequencies of the two machines are identical. The graphs show the results of the tests but are incomplete.

- Describe how the amplitude of the machine could be measured at each frequency tested. You do not need to describe how to vary the amplitude or frequency of the waves.
- Complete the graphs with suitable labels and annotations.
- Discuss which of the designs is the most effective at generating electrical energy. **[6]**



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19 A lorry used to transport liquid oxygen has a tank with a maximum volume of $10\,m^3$.

The tank is filled until it contains $9.8\,m^3$ of liquid oxygen.

The pressure of the gas above the liquid is 100 kPa and the temperature of the gas and the liquid is –183 °C, the boiling point of oxygen.

The temperature of the oxygen remains constant.

The walls of the tank allow thermal energy to pass through at a constant rate of 1.3 kW.

The latent heat of vaporisation of oxygen is $214\,kJ\,kg^{-1}$.

The density of **liquid** oxygen is $1140\,kg\,m^{-3}$.

(a) State why thermal energy passes into the tank.

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..... **[1]**

(b) Explain, in terms of particle energies, why the temperature of the oxygen remains constant despite the transfer of thermal energy into the tank.

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..... **[2]**

(c) Show that in one hour the volume of liquid oxygen that evaporates is about $0.02\,m^3$.

[3]

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(d) After one hour the number of moles of gas above the remaining liquid oxygen is 710.

Calculate the pressure of the gas.

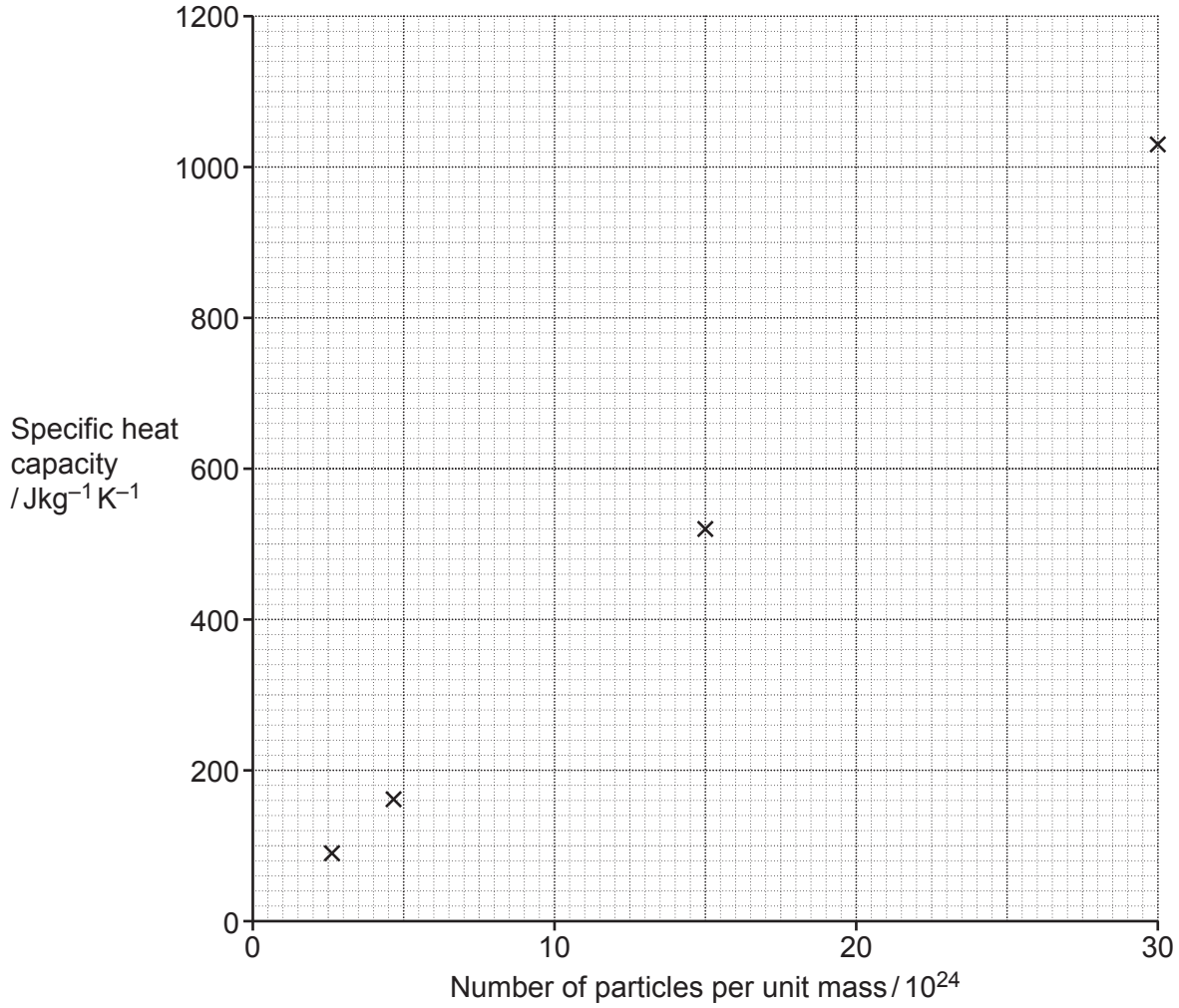
pressure = ... kPa **[3]**

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20 The specific heat capacities and molar masses of some common gases are given in the table.

Gas	Specific heat capacity / $Jkg^{-1}K^{-1}$	Molar mass / $kg\,mol^{-1}$	Number of particles per unit mass / 10^{24}
Neon	1030	0.020	30
Argon	520	0.040	15
Krypton	250	0.084	
Xenon	160	0.130	4.6
Radon	90	0.220	2.7

(a) Complete the missing value in the table. **[1]**



(b) Plot the missing data point on the graph above and draw a line of best fit. **[2]**

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(c) Describe the relationship suggested by the graph and suggest an explanation.

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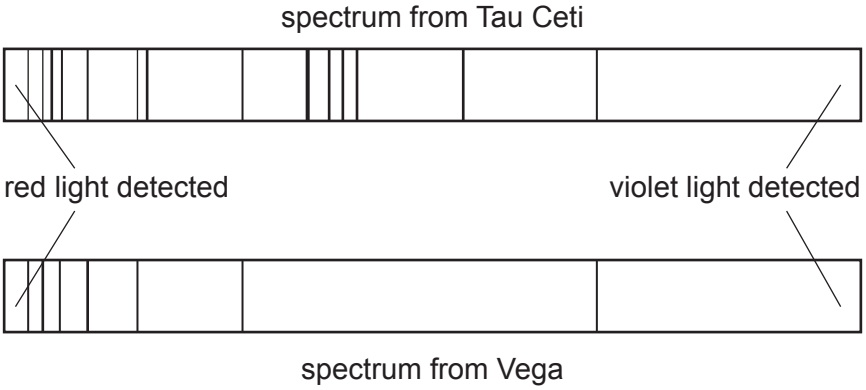
..... **[4]**

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21* Analysis of stellar light can identify the elements that are present in the outer layers of a star.

Absorption spectra of visible light collected from two main sequence stars, Vega and Tau Ceti, are shown below. The spectra were collected by a telescope orbiting the Earth. The dark lines on the diagram show wavelengths where the intensity was zero or close to zero.

- Explain the cause of the dark lines.
- Describe and explain at least one difference between the spectra.
- Analyse the spectra to determine which star is older.



[6]

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22 An asteroid of mass 10 kg is in a circular orbit around the Sun at a distance of 3.5 AU from the centre of the Sun.

1 AU = 1.5×10^{11} m

(a)

(i) Use Kepler's third law to calculate the period of the orbit of the asteroid in years.

An object orbiting the Sun at a distance of 1 AU has a period of 1 year.

period = ... years **[2]**

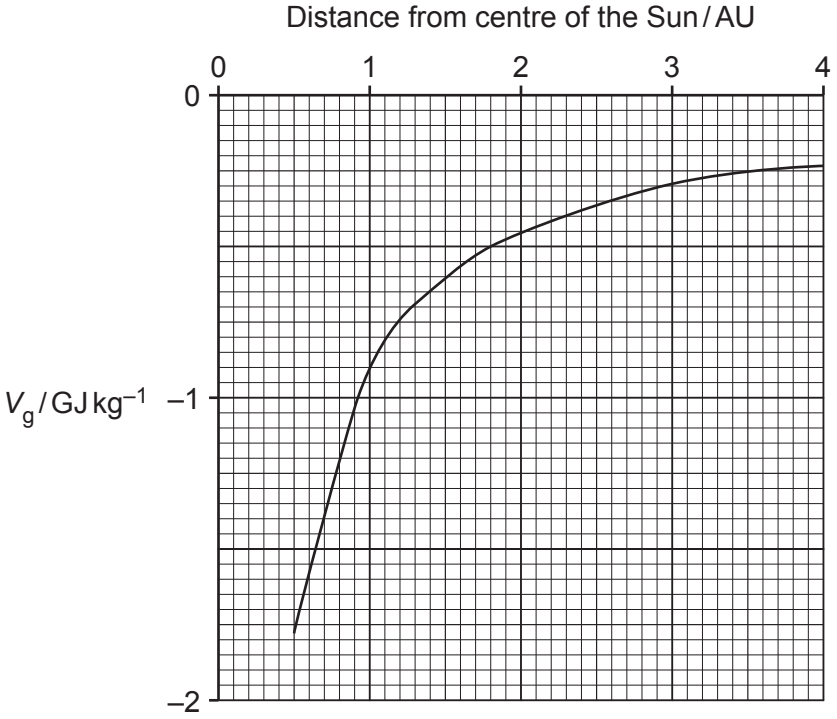
(ii) Calculate the kinetic energy of the asteroid.

kinetic energy = ... J **[3]**

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(b) After a collision the asteroid falls towards the Sun.

The graph below shows the variation of gravitational potential, V_g, due to the Sun with the distance from the centre of the Sun.



(i) Use the graph to calculate the change in gravitational potential energy of the satellite from the moment of collision until it crosses the Earth's orbit.

change in gravitational potential energy = ... GJ **[2]**

(ii) Eventually, the asteroid falls into a new orbit around the Sun. This orbit is elliptical.

State the other feature of this orbit predicted by Kepler's first law.

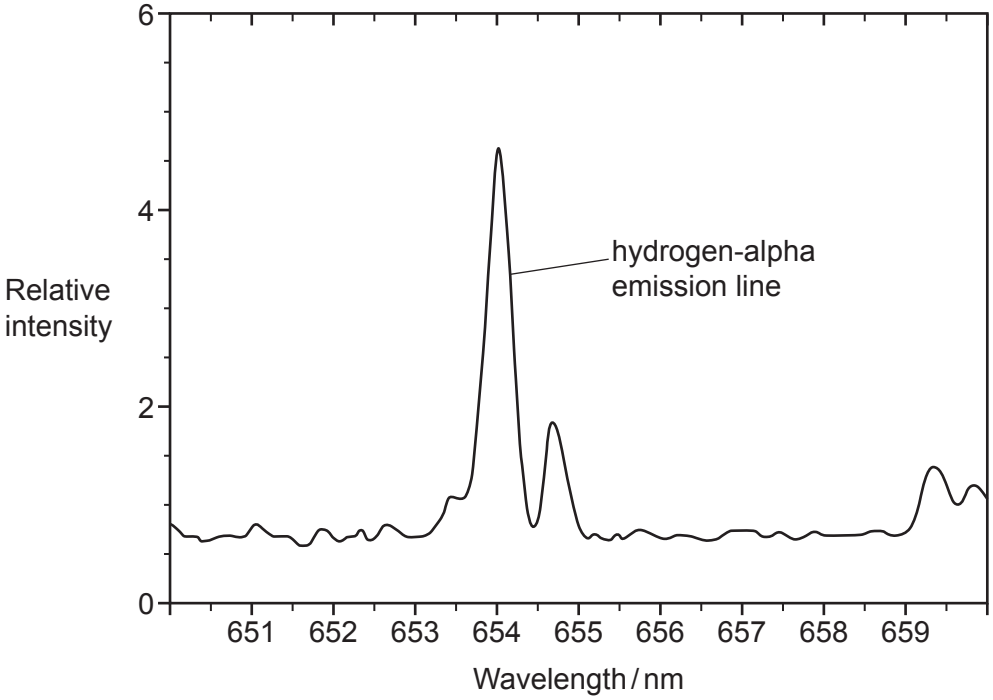
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..... **[1]**

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23 The diagram below shows the part of the spectrum of light from the galaxy M87 with a strong hydrogen-alpha emission line.

The spectrum of a sample of hydrogen gas analysed in a laboratory on Earth showed this emission line to be at 656.3 nm.



(a) Calculate the magnitude of the recession velocity of M87.

velocity = ... $km\,s^{-1}$ **[3]**

(b) Estimate the distance in light years to M87 using Hubble's law.

Hubbles constant $H_o = 2.5 \times 10^{-19}\,s^{-1}$

distance = ... ly **[2]**

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(c) Estimate the percentage uncertainty in the distance calculated in part **(b)** using the width of the emission line in the diagram.

percentage uncertainty = +/– ..... % **[2]**

(d) Other methods have shown M87 is actually 50 million light years from Earth.

Suggest why M87 might contradict Hubble's law.

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..... **[2]**

(e) Suggest **one** reason why the Big Bang theory is still the accepted model of the origin of the Universe.

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..... **[1]**

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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