Oxford Cambridge and RSA

A Level Physics A

H556/01 Modelling physics

Practice paper – Set 2

Time allowed: 2 hours 15 minutes

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

You may use:
- a scientific calculator
- a ruler

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **32** pages.

SECTION A

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

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which quantity has the unit hertz (Hz)?

A frequency

B acceleration

C phase difference

D angular frequency

Your answer ☐

[1]

2 The cross-sectional area of a wire is recorded as $0.14 \pm 0.01\,\text{mm}^2$.
The length of the wire is recorded as $100 \pm 1\,\text{mm}$.

What is the percentage uncertainty in the volume of the wire?

A 1.0 %

B 4.6 %

C 7.1 %

D 8.1 %

Your answer ☐

[1]

3 A ball is thrown vertically upwards with a speed of $5.0\,\text{m}\,\text{s}^{-1}$.
Ignore air resistance.

What is the maximum height reached by the ball?

A 0.3 m

B 0.8 m

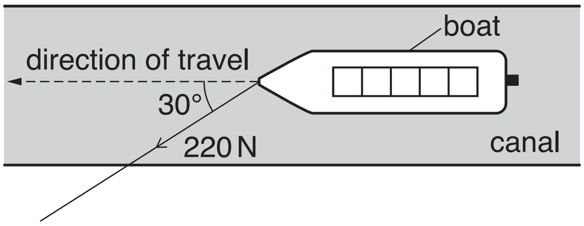
C 1.3 m

D 2.5 m

Your answer ☐

[1]

4 A canal boat is pulled by a single rope.
The tension in the rope is 220 N. The rope makes an angle of 30° to the direction of travel.
The speed of the boat is 1.8 m s^{-1}.



What is the work done per second by the 220 N force in the direction of travel?

A 61 J s^{-1}

B 200 J s^{-1}

C 340 J s^{-1}

D 400 J s^{-1}

Your answer ☐

[1]

5 A student is investigating two wires of different diameters made from the **same** metal. She plots graphs of force against extension and graphs of stress against strain for both wires.

The wires behave elastically.

Which of the following statements is/are correct?

1 Young modulus is equal to the gradient of the stress against strain graph.
2 Force constant is equal to the gradient of the force against extension graph.
3 The graphs of stress against strain have different gradients.

A 1, 2 and 3

B Only 1 and 2

C Only 2

D Only 1

Your answer ☐

[1]

6 A ball of mass m is dropped into water. A constant upthrust U acts on the ball as it travels down through the water. The acceleration of the ball is a when the drag is D.

The acceleration of free fall is g.

What is the correct expression for the acceleration a?

A $a = g - \frac{U + D}{m}$

B $a = g - \frac{U - D}{m}$

C $a = g - \frac{D - U}{m}$

D $a = g + \frac{U + D}{m}$

Your answer ☐

[1]

7 A cylinder of wood is placed in water.
The density of the wood is $6.0 \times 10^2\,\mathrm{kg\,m^{-3}}$. The density of water is $1.0 \times 10^3\,\mathrm{kg\,m^{-3}}$.

What fraction of the volume of the cylinder is **below** the water line?

A 0.2

B 0.4

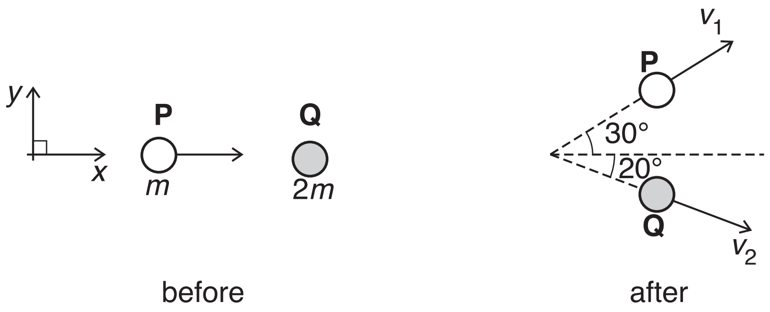
C 0.6

D 1.0

Your answer ☐

[1]

8 A ball **P** of mass m has a velocity in the positive x-direction. It makes a collision with a stationary ball **Q** of mass $2m$. After the collision, the ball **P** has velocity v_1, ball **Q** has velocity v_2 and the balls travel in the directions shown in the diagram below.



After the collision, the total momentum of the balls in the x-direction is p_x and the total momentum in the y-direction is p_y.

Which row is correct for p_x and p_y?

	p_x	p_y
A	$2mv_2 \cos 20° + mv_1 \cos 30°$	0
B	$2mv_2 \sin 20° + mv_1 \sin 30°$	0
C	$2mv_2 \cos 20° + mv_1 \cos 30°$	$2mv_2 \sin 30° + mv_1 \sin 20°$
D	$2mv_2 \sin 20° + mv_1 \sin 30°$	$2mv_2 \cos 30° + mv_1 \cos 20°$

Your answer ☐

[1]

9 An oscillator is in simple harmonic motion.

Which statement is **not** correct?

A The acceleration is directly proportional to the displacement.

B The acceleration is zero at maximum displacement.

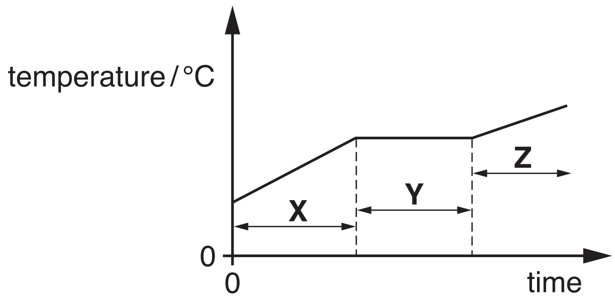
C The maximum velocity is at zero displacement.

D The kinetic energy is zero at maximum displacement.

Your answer ☐

[1]

10 A metal is heated using a heater of constant output power.
The graph below shows the variation of the temperature of the metal with time.



The metal is a solid in region **X**, a mixture of solid and liquid in region **Y** and a liquid in region **Z**.

Which row shows the best description of the energy of the atoms of the metal?

	Internal energy of the atoms	**Potential energy of the atoms**	**Kinetic energy of the atoms**
A	constant throughout	constant throughout	constant throughout
B	increases with time in **X** and **Z**	increases with time in **X** and **Z**	constant in only **Y**
C	increases with time in **X**, **Y** and **Z**	increases with time in **X** and **Z**	increases with time in only **Y**
D	increases with time in **X**, **Y** and **Z**	increases with time in only **Y**	increases with time in **X** and **Z**

Your answer ☐

[1]

11 Planets **X** and **Y** each have a single moon.
Planet **X** has twice the mass of planet **Y**. The orbital radius of the moon around planet **X** is three times the orbital radius of the moon around planet **Y**.
The gravitational potential of the planet **X** is V_X at the position of its moon. The gravitational potential of the planet **Y** is V_Y at the position of its moon.

What is the value of the ratio $\frac{V_X}{V_Y}$?

A 0.22

B 0.67

C 1.50

D 6.00

Your answer ☐

[1]

12 A gas syringe contains 2.0 moles of an ideal gas of volume of 0.040 m^3.
An additional amount of 0.5 moles of the same gas is added to the syringe. The temperature and pressure of the gas remain the same.

What is the final volume of gas in the syringe?

A 0.010 m^3

B 0.032 m^3

C 0.050 m^3

D 0.090 m^3

Your answer ☐

[1]

13 A satellite is in a circular orbit around the Earth. The vertical **height** of the satellite above the surface of the Earth is 3200 km. The radius of the Earth is 6400 km.

What is the ratio

$$\frac{\text{weight of satellite in orbit}}{\text{weight of satellite on the Earth's surface}}?$$

A 0.25

B 0.44

C 0.50

D 0.67

Your answer ☐

[1]

14 The Earth takes 1 day to rotate once about its axis.
What is the angular velocity of a point on the surface of the Earth?

A 2.0×10^{-7} rad s^{-1}

B 7.3×10^{-5} rad s^{-1}

C 4.4×10^{-3} rad s^{-1}

D 2.6×10^{-1} rad s^{-1}

Your answer ☐

[1]

15 An object of mass *m* is attached to a string and then whirled in a horizontal circle. The speed of the object is slowly increased from zero. The string breaks when the object has a maximum speed of $1.00\,m\,s^{-1}$.
The experiment is repeated with an identical string but with an object of mass $1.5\,m$. The radius of the circle is kept constant.

What is the maximum speed of this object when the string breaks?

A $0.67\,m\,s^{-1}$

B $0.82\,m\,s^{-1}$

C $1.22\,m\,s^{-1}$

D $1.50\,m\,s^{-1}$

Your answer ☐

[1]

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Question 16 begins on page 10

SECTION B

Answer **all** the questions.

16 Fig. 16.1 shows an arrangement used by a group of students to determine the acceleration of free fall *g* in the laboratory.

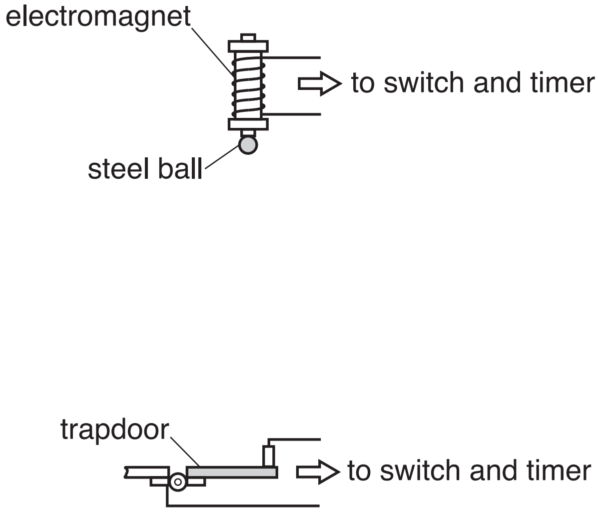

Fig. 16.1

An electromagnet is used to hold a small steel ball in position above a trapdoor. A timer starts as soon as the ball is released, and is stopped when the ball hits and opens the trapdoor. The clamp stands holding the trapdoor mechanism and the electromagnet are not shown in Fig. 16.1.

(a) The distance between the bottom of the steel ball and the top of the trapdoor is 1.200 ± 0.001 m. The steel ball takes 0.50 ± 0.02 s to fall through this distance.

(i) Calculate a value for *g* using these results.

g = ... $m\,s^{-2}$ **[2]**

(ii) Determine the percentage uncertainty in the value for *g*.

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

(b) State **one** source of error when timing the drop of the steel ball and describe how the percentage uncertainty in the measurement of time can be minimised.

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.... **[2]**

(c)* Another group of students decide to determine the acceleration of free fall using a different arrangement shown in Fig. 16.2.

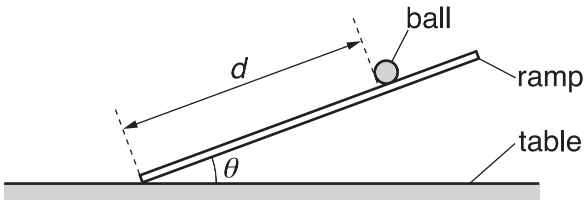

Fig. 16.2

The experiment uses a metal ball and a ramp.
The ball is at a distance d from the bottom of the ramp. The ramp makes an angle θ to the horizontal table. The ball is released from rest at time t = 0. The ball takes time t to travel the distance d.
The relationship between d and t is given by the equation

$$d = \frac{1}{2}(g\sin\theta)t^2.$$

Describe how you can conduct an experiment, and how the data can be analysed to determine the acceleration of free fall g.

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.... **[6]**

17 The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

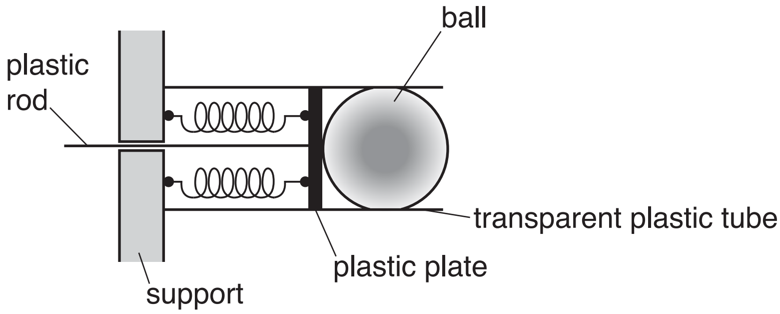

Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

(a) The force constant of each spring is k.
Explain why the force constant of the two springs in parallel in Fig. 17.1 is equal to $2k$.

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.... **[1]**

(b) A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1. The students apply a force *F* and measure the compression *x* of the springs.

The table below shows the results.

***F*/N**	***x*/cm**
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a *F* against *x* graph.

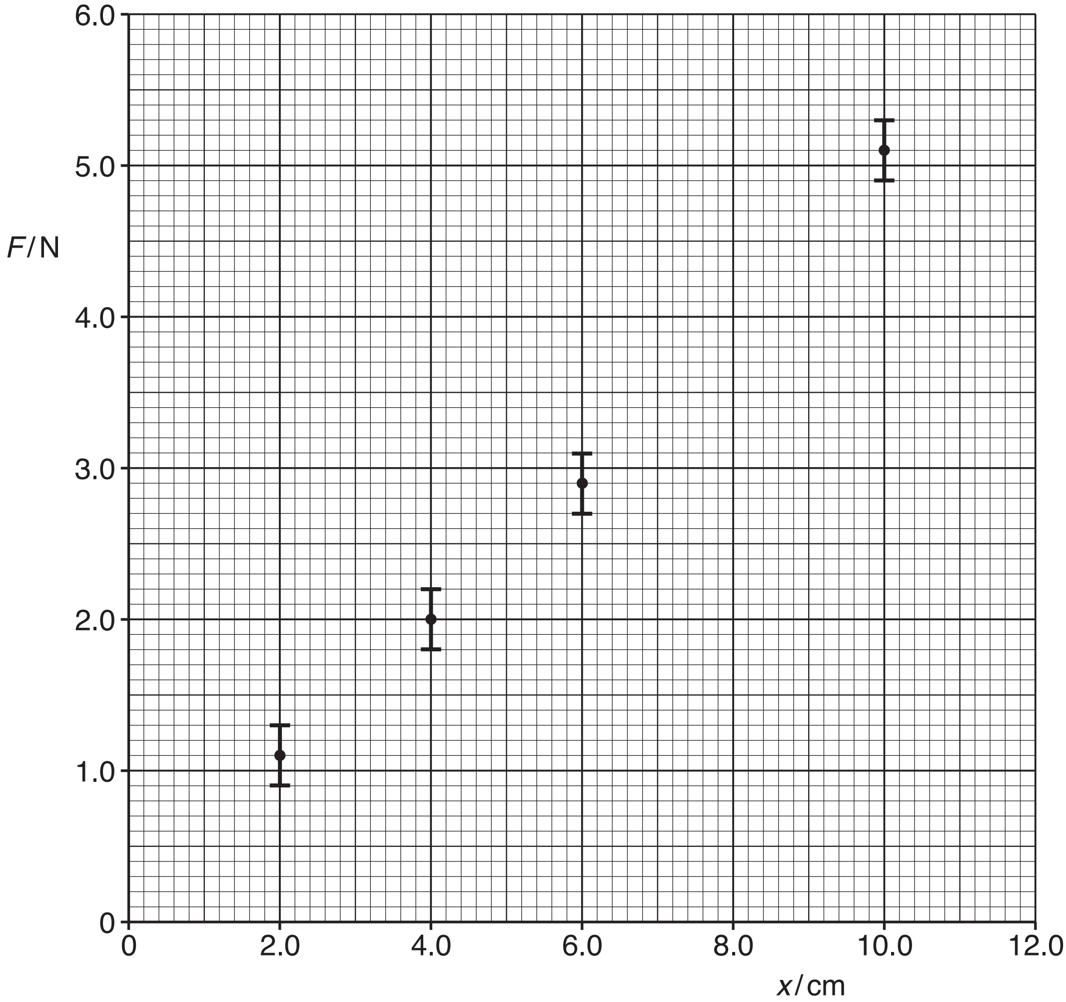

Fig. 17.2

(i) Plot the missing data point and the error bar on Fig. 17.2. **[1]**

(ii) Describe how the data shown in the table may have been obtained in the laboratory.

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.... **[2]**

(iii) Draw the best fit and the worst fit straight lines on Fig. 17.2.
Use the graph to determine the force constant *k* for a **single** spring and the absolute uncertainty in this value.

k = ... ± .... $N m^{-1}$ **[4]**

(iv) State the feature of the graph that shows Hooke's law is obeyed by the springs.

....

.... **[1]**

(v) The mass of the ball is 0.39 kg.

Use your answer from **(iii)** to calculate the launch speed *v* of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

v = ... $m s^{-1}$ **[3]**

(c) A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

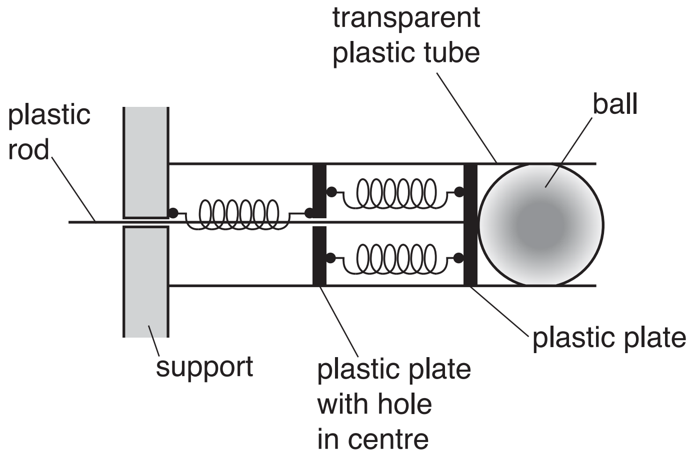

Fig. 17.3

The force constant of each spring is k.
The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of x.

Show that initial acceleration a of this ball is given by the equation

$$a = 1.7\,kx.$$

[2]

18 **(a)** State the *principle of moments*.

....

.... **[1]**

(b) A cylinder head gasket is a thin sheet of material used in a car engine.
A car manufacturer wants to locate the centre of gravity of the gasket shown in Fig. 18.1.

Fig. 18.1

Describe how the centre of gravity of the gasket can be determined using equipment from a laboratory.

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.... **[4]**

(c) Fig. 18.2 shows an arrangement for lifting a car engine in a repair workshop.

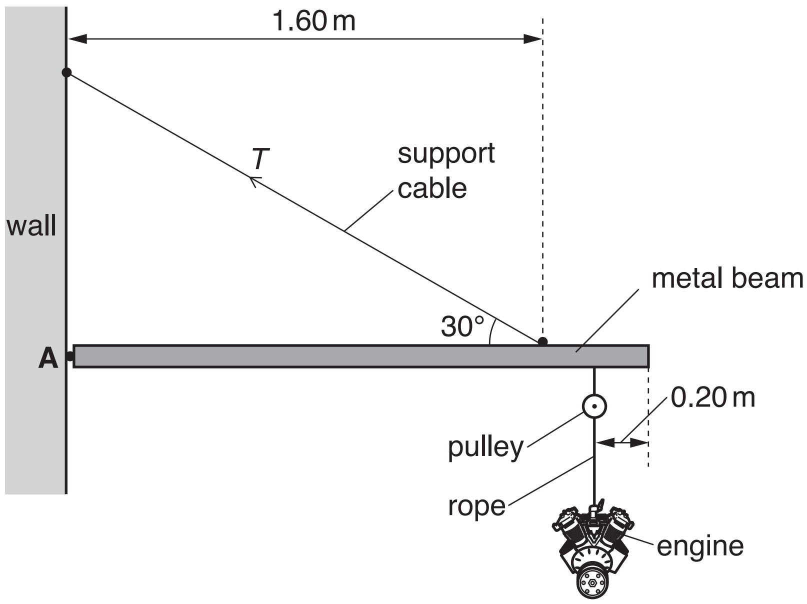

Fig. 18.2 (not to scale)

A **uniform** metal beam of length 2.00 m is hinged to a vertical wall at point **A**. The beam is held at rest in a horizontal position by a support cable of diameter of 3.0 cm. One end of this cable is fixed to the wall and the other end is fixed to the beam at a perpendicular distance of 1.60 m from the wall. The support cable makes an angle of 30° to the horizontal.
The car engine is lifted and lowered using a rope and a pulley. The pulley is fixed to the lower end of the beam at a distance of 0.20 m from the far end of the beam.
The metal beam has a mass of 120 kg and the car engine has a mass of 95 kg.

(i) Calculate the tension *T* in the support cable.

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

(ii) Calculate the tensile stress *σ* in the support cable in kPa.

σ = ... kPa **[2]**

(iii) The engine is lowered using the pulley and the rope. The engine accelerates downwards. Explain briefly the effect this would have on the tension *T* in the support cable.

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.... **[1]**

19 A ball of mass 160 g is at rest. The ball is hit with a stick.
Fig. 19.1 shows the variation of the force *F* exerted by the stick on the ball with time *t*.

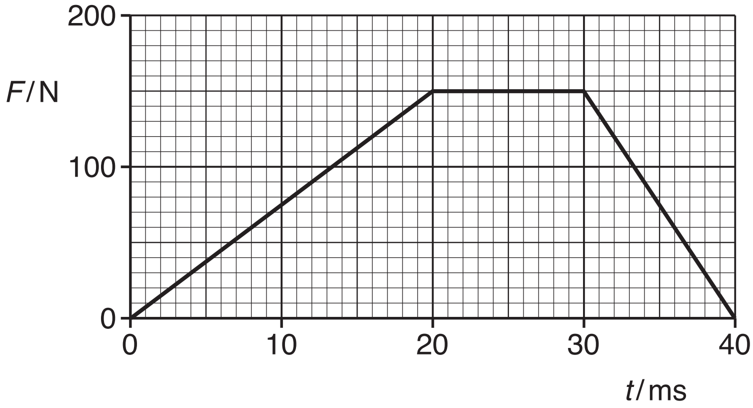

Fig. 19.1

(a) Use Fig. 19.1 to determine the **final** velocity *v* of the ball as it leaves the stick.

v = ... $m\,s^{-1}$ **[3]**

(b) Sketch a graph on Fig. 19.2 to show the variation of the velocity of the ball between t = 30 ms and t = 40 ms. You do not need to show any values on the vertical axis.

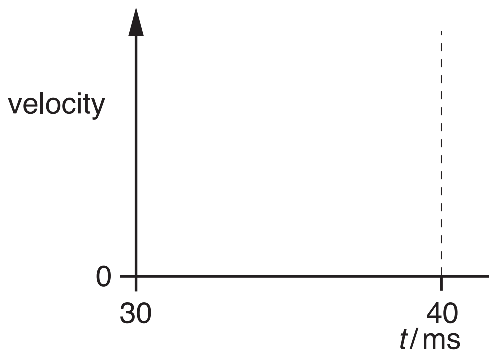

Fig. 19.2

[2]

(c) After time t = 40 ms, the ball travels along the horizontal ground.
The ball experiences a constant friction of 0.80 N.

Calculate the time T for it to come to a stop.

T = ... s **[2]**

20 **(a)** Define *specific heat capacity* of a substance.

....

.... **[1]**

(b) A group of students conduct an experiment using water to heat glycerol in a boiling tube. The apparatus they use is shown in Fig. 20.1.

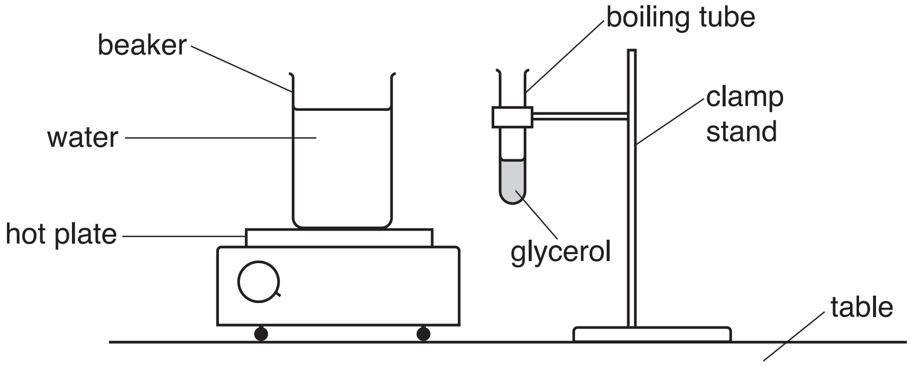

Fig. 20.1

The table below shows the mass *m* and the specific heat capacity *c* for water and glycerol used in the experiment.

	m / g	*c* / $J\,kg^{-1}\,K^{-1}$
Water	150	4200
Glycerol	20	2400

(i) The water is initially heated from 20 °C to 75 °C on a hot plate.
Calculate the energy supplied to the water.

energy = ... J **[1]**

(ii) The beaker of hot water at 75 °C is removed from the hot plate.
The boiling tube, which contains the glycerol at 20 °C, is now placed into the hot water.
Both liquids reach a common temperature θ.

Calculate the temperature θ.

θ = ... °C **[3]**

(iii) Explain why the actual temperature θ is different from your value calculated in **(ii)**.

....

.... **[1]**

(c) In a specialist laboratory, energy is supplied at a constant power to solid glycerol initially at a temperature of −100 °C. The glycerol is then heated from this temperature until it boils.
The specific heat capacity of solid glycerol is less than the specific heat capacity of liquid glycerol. Glycerol melts at a temperature of about 20 °C and starts to boil at a temperature of about 290 °C.

Sketch a graph on Fig. 20.2 to show the variation of the temperature of glycerol with time. Assume that there is no heat transfer to the surroundings.

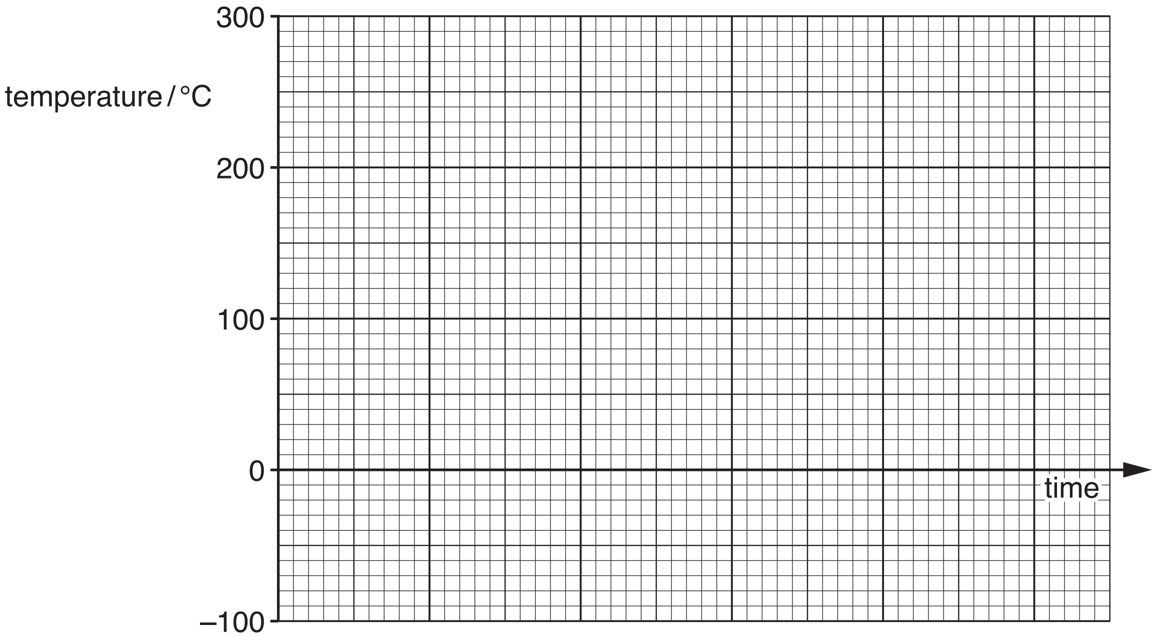

Fig. 20.2

[3]

21 (a) A mass is hung from the bottom end of a flexible spring.
Describe and explain how the mass can be made to show resonance.

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.... **[2]**

(b) A mechanical oscillator is forced to oscillate in a viscous fluid.

The graph in Fig. 21.1 shows the variation of amplitude *A* of the oscillator with driving (forced) frequency *f*.

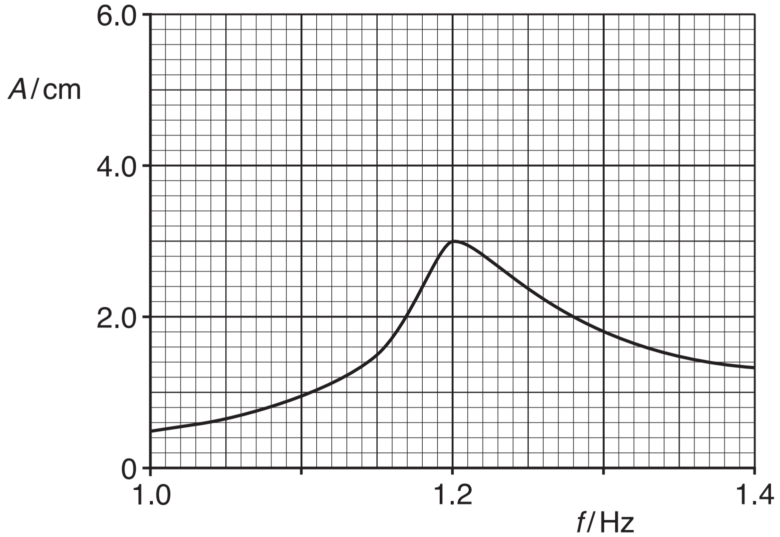

Fig. 21.1

(i) Use Fig. 21.1 to determine the **maximum** acceleration of the oscillator at resonance.

maximum acceleration = ... $m\,s^{-2}$ **[3]**

(ii) The oscillator is now removed from the viscous fluid. It is now forced to oscillate in air.
On Fig. 21.1 sketch the new shape of the amplitude against frequency graph. **[2]**

(c) Fig. 21.2 shows the displacement *x* against time *t* graph of an oscillator damped in air.

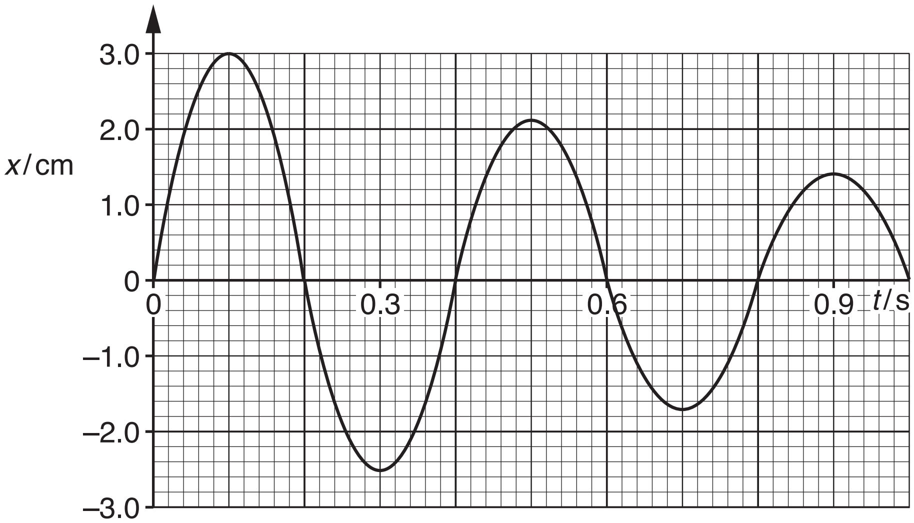

Fig. 21.2

(i) According to a student, the amplitude of the oscillator decays by the same fraction every half oscillation.
Analyse Fig. 21.2 to assess whether or not the student is correct.

....

.... **[2]**

(ii) State and explain at which time the oscillator dissipates **maximum** energy.

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.... **[2]**

22 (a)* The Big Bang theory explains the origin and the evolution of the early Universe.
The table below shows the distance *d* and recession velocity *v* of some galaxies close to our own galaxy.

Galaxy	*d* / Mpc	*v* / $km\,s^{-1}$
NGC-5357	0.45	200
NGC-3627	0.90	650
NGC-4151	1.7	960
NGC-4472	2.0	850

Discuss the evidence for the Big Bang theory of the Universe. Use data in the table and your knowledge of electromagnetic radiation in your answer.

$1\,pc = 3.1 \times 10^{16}\,m$

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.... **[6]**

(b) The chemical composition of the stars in our galaxy can be determined by analysing in the laboratory the absorption spectral lines for these stars.
The closest star to us is the Sun. The wavelength of the hydrogen-beta spectral line from the Sun is 486 nm.

(i) Use the information from the table in **(a)** to calculate the **observed** wavelength λ of the hydrogen-beta spectral line from a star in the galaxy NGC-4151.

λ = ... nm **[3]**

(ii) A diffraction grating with 800 lines per mm is used to observe and analyse the light from the Sun in the laboratory.
A narrow beam of light from the Sun is incident normally at the diffraction grating.

Calculate the angle θ between the central beam of light through the grating and the hydrogen-beta spectral line in the **second** order spectrum.

θ = ... ° **[2]**

(c) Other than matter, state what else may be present in the Universe that may affect its density.

.... **[1]**

23 A group of students have gathered data on four stars from the Internet. The information is shown in the table below.

Star	***T*/K**	**λ_{max}/μm**
Antares	3.1×10^3	9.4×10^{-1}
Zeta	3.0×10^4	9.7×10^{-2}
Vega	9.3×10^3	3.1×10^{-1}
OTS-44	2.3×10^3	1.3×10^0

The surface temperature of the star in kelvin is T and λ_{max} is the wavelength of the emitted electromagnetic radiation at which the intensity is maximum.

(a) Analyse and evaluate this data to show whether or not Wien's displacement law is obeyed.

[2]

(b) A sensor of cross-sectional area $4.0 \times 10^{-4}\,m^2$ mounted on a satellite orbiting the Earth is used to gather the electromagnetic radiation from the star Antares.
Antares is 550 light years from the Earth. The radiant power entering the sensor from Antares is 2.6×10^{-11} W.

(i) Calculate the luminosity L of Antares.

L = ... W **[3]**

(ii) Use your answer in **(i)** and the data in the table to calculate the radius r of Antares.

r = ... m **[2]**

(iii) The mean density of Antares is $4.4 \times 10^{-5}\,kg\,m^{-3}$.
Calculate the gravitational field strength g at the surface of Antares.

g = ... $N\,kg^{-1}$ **[2]**

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).

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Oxford Cambridge and RSA