Oxford Cambridge and RSA

Monday 3 June 2019 – Afternoon

A Level Physics B (Advancing Physics)

H557/03 Practical skills in physics

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet (sent with general stationery)

You may 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 may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- 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.

INFORMATION
- The total mark for this paper is **60**.
- 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 **24** pages.

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SECTION A

Answer **all** the questions.

1 Manufacturers of spectacles (glasses) are keen to develop new materials for lenses. The refractive index of such materials is an important property to consider.

This question is about a method to determine the refractive index of a transparent polymer.

A ray box is used to shine a narrow beam of light through a block of the polymer. Fig. 1 shows the path of the light.

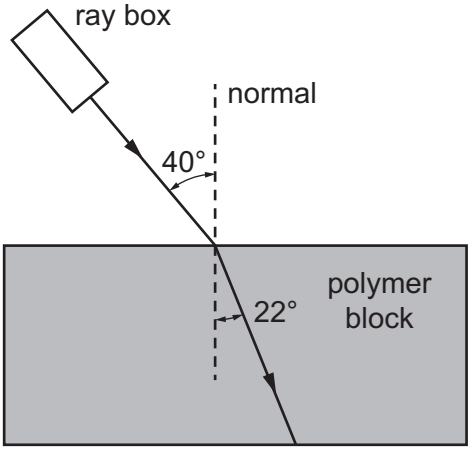

Fig. 1 (not to scale)

The angle of incidence is 40° and the angle of refraction is 22°.

(a) **(i)** Calculate the refractive index *n* of the polymer.

n = ... **[2]**

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(ii) The absolute uncertainty in the measurement of each angle is ±4°.

Complete the table below with maximum and minimum values of the measured angles, and hence determine the absolute uncertainty in the calculated value of refractive index *n*.

Angle	Maximum value / °	Minimum value / °
angle of incidence, *i*		
angle of refraction, *r*		

absolute uncertainty in *n* = ± ..... **[3]**

Question 1 continues on page 4

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(b)* Describe the method which could be used in this experiment to reduce the uncertainty in the calculated value of the refractive index of the polymer.

In your answer, include details of the experimental procedure and the analysis of data.

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2 This question is about determining the acceleration due to gravity g using a simple pendulum.

(a) The pendulum bob has mass m and the length of the pendulum string is L.

Fig. 2.1a shows the pendulum with angle of deflection θ and bob displacement x.

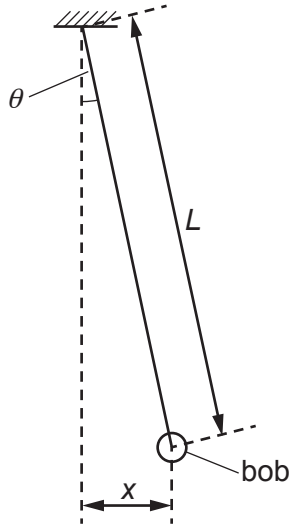

Fig. 2.1a

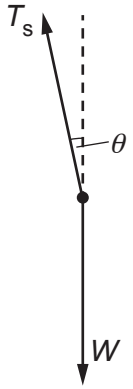

Fig. 2.1b

Fig. 2.1c

Fig. 2.1b shows the free body diagram of the forces on the bob.

Fig. 2.1c shows the restoring (resultant) force F on the bob which is horizontal for **small** deflection angle θ.

The weight of the bob is W and the tension in the string is T_s.

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(i) Explain why, for small angle θ of deflection, F can be given by the expression

$$F \approx -\frac{T_s x}{L}.$$

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(ii) For small angle θ, $T_s \approx mg$. Therefore, the acceleration a of the bob can be given by the expression

$$a \approx -\frac{gx}{L}.$$

Use the equation for simple harmonic motion, $a = -4\pi^2 f^2 x$, to show that $T^2 = \frac{4\pi^2 L}{g}$, where T is the period of oscillation of the pendulum.

[2]

Question 2 continues on page 8

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(b) A student measures the time taken for 10 oscillations of the pendulum bob to determine the period T.

She repeats this for 4 different pendulum lengths.

The results are shown in the table below.

Length of pendulum, L / m	Time taken for 10 oscillations, t / s	Period, T / s	T^2 / s^2
0.300	11.33	1.133	1.284
0.400	12.70	1.270	
0.500	14.44	1.444	
0.600	15.41	1.541	

(i) State and explain the advantage of determining the period T by measuring the time for 10 oscillations.

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(ii) Complete the table by calculating the three missing values of T^2 / s^2. **[1]**

(iii) On Fig. 2.2, plot a graph of T^2 (on the y-axis) against L (on the x-axis) and draw a straight line of best fit through the data points. **[4]**

(iv) Use the graph to determine a value for the acceleration due to gravity g.

Show your working.

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

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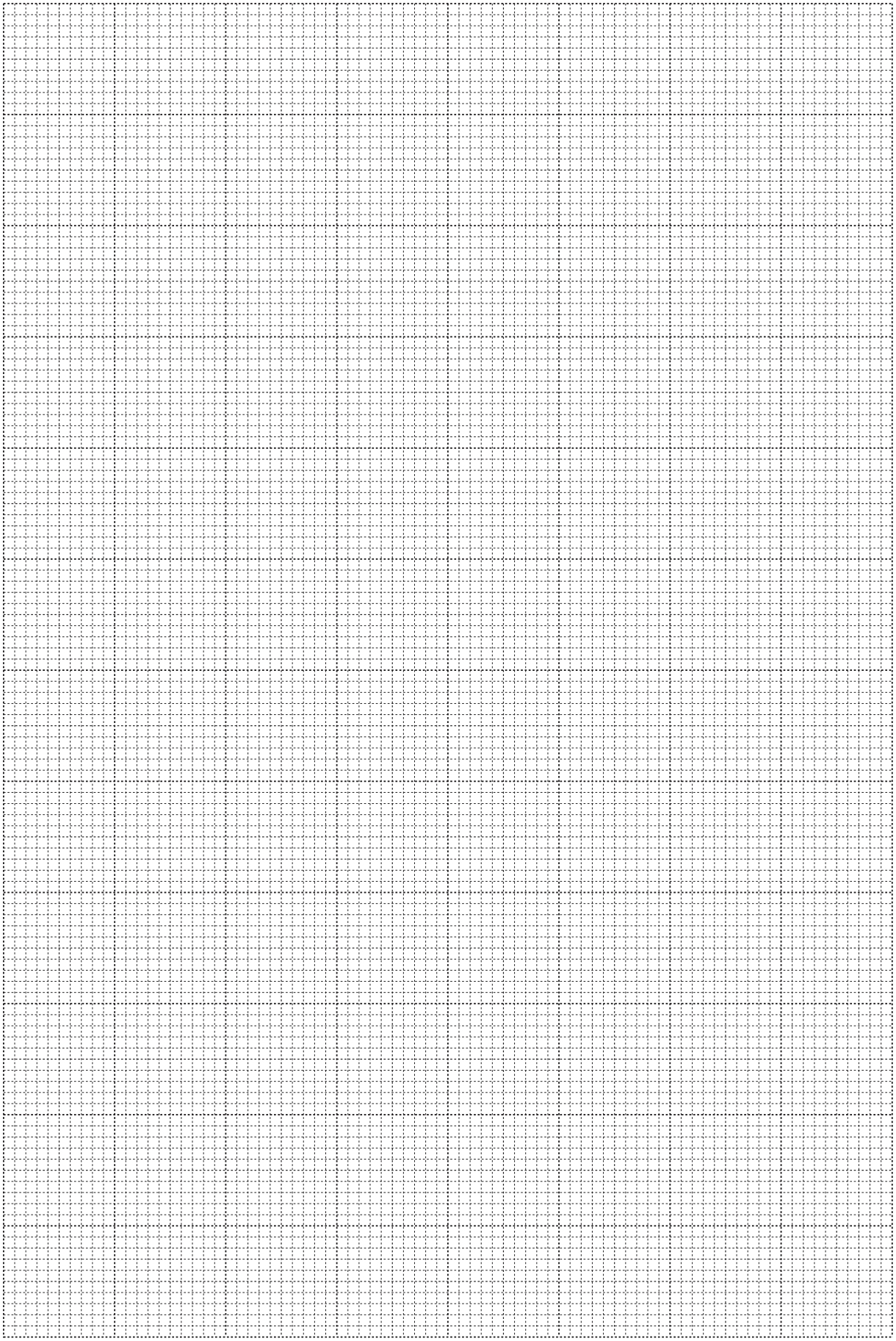

Fig. 2.2

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(c) The student is considering the uncertainty in her value for *g*.

She thinks that data collected for the shorter pendulums have greater percentage uncertainty than those for the longer ones.

Explain her reasoning.

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Question 3 begins on page 12

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3 This question is about the electrical conductivity of a metal.

(a)* Describe a suitable experimental procedure which could be used to determine the electrical conductivity σ of the metal.

The following apparatus is available.

Length of metal wire
Meter rule
Micrometer screw gauge
Ammeter
High resistance voltmeter
Battery
Variable resistor
Connecting wires and crocodile clips

You should include details of the measurements to be taken and how they are used to accurately determine the electrical conductivity σ of the metal. You should also consider the uncertainties present in the investigation.

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(b) The conductivity σ of the metal wire in **(a)** at room temperature is $2.1 \times 10^6\,\Omega^{-1}\,m^{-1}$. The cross-section area, A, of the wire is $0.166\,mm^2$.

The potential difference across 0.330 m of the wire is 2.0 V.

(i) Calculate the current I in the wire.

I = ... A **[3]**

(ii) Use the relationship $I = nAvq$ and the data below to estimate the mean drift velocity, v, of electrons in the wire.

number density of free electrons in the metal $n \approx 10^{28}\,m^{-3}$
charge on one electron $q = 1.6 \times 10^{-19}\,C$

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

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(iii) The temperature of the metal wire is now increased.

State and explain qualitatively the change, if any, to the mean drift velocity v of the electrons in the wire.

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SECTION B

Answer **all** the questions.

4 This question is about the behaviour of gases.

(a) The pressure p and volume V of an ideal gas are related by the equation $pV = \frac{1}{3}Nm\overline{c^2}$.

(i) Explain what is meant by an *ideal gas*.

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(ii) The average kinetic energy of the particles (atoms) in an ideal gas at absolute (kelvin) temperature T is given by the equation

average kinetic energy = $\frac{3}{2}kT$

where k is the Boltzmann constant.

Use this equation and the equation $pV = \frac{1}{3}Nm\overline{c^2}$ to show that the pressure p of a fixed mass of an ideal gas at constant volume is directly proportional to its absolute (kelvin) temperature T.

Explain your reasoning.

[3]

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(b) Argon is a gas at room temperature. You may assume that it behaves as an ideal gas at this temperature.

The molar mass of argon is 0.0399 kg mol^{-1}.

Calculate the root mean square speed of argon atoms when the gas is at a temperature of 293 K.

root mean square speed = ... m s^{-1} **[3]**

(c) A student performs an experiment to investigate if the pressure of a constant volume of air is directly proportional to its absolute (kelvin) temperature.

Fig. 4.1 shows the apparatus used.

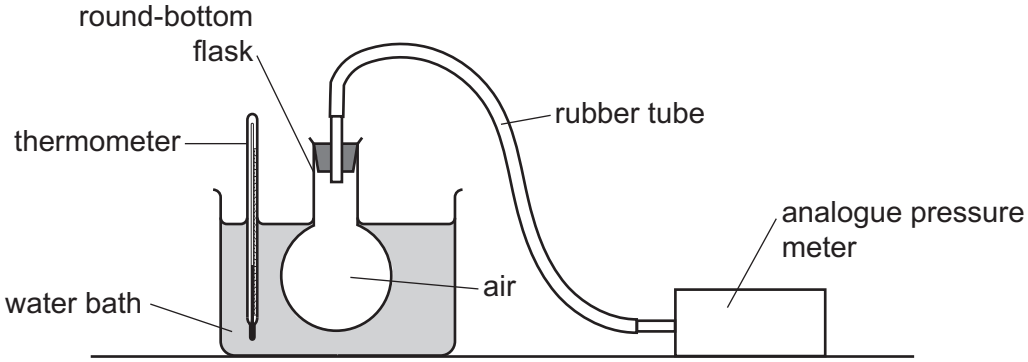

Fig. 4.1

(i) Fifteen apparently identical thermometers are available.

Describe how the student can determine the uncertainty in the reading of the temperature by using all the available thermometers.

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(ii) Fig. 4.2 shows the graph of the data collected, including the uncertainty in the pressure readings.

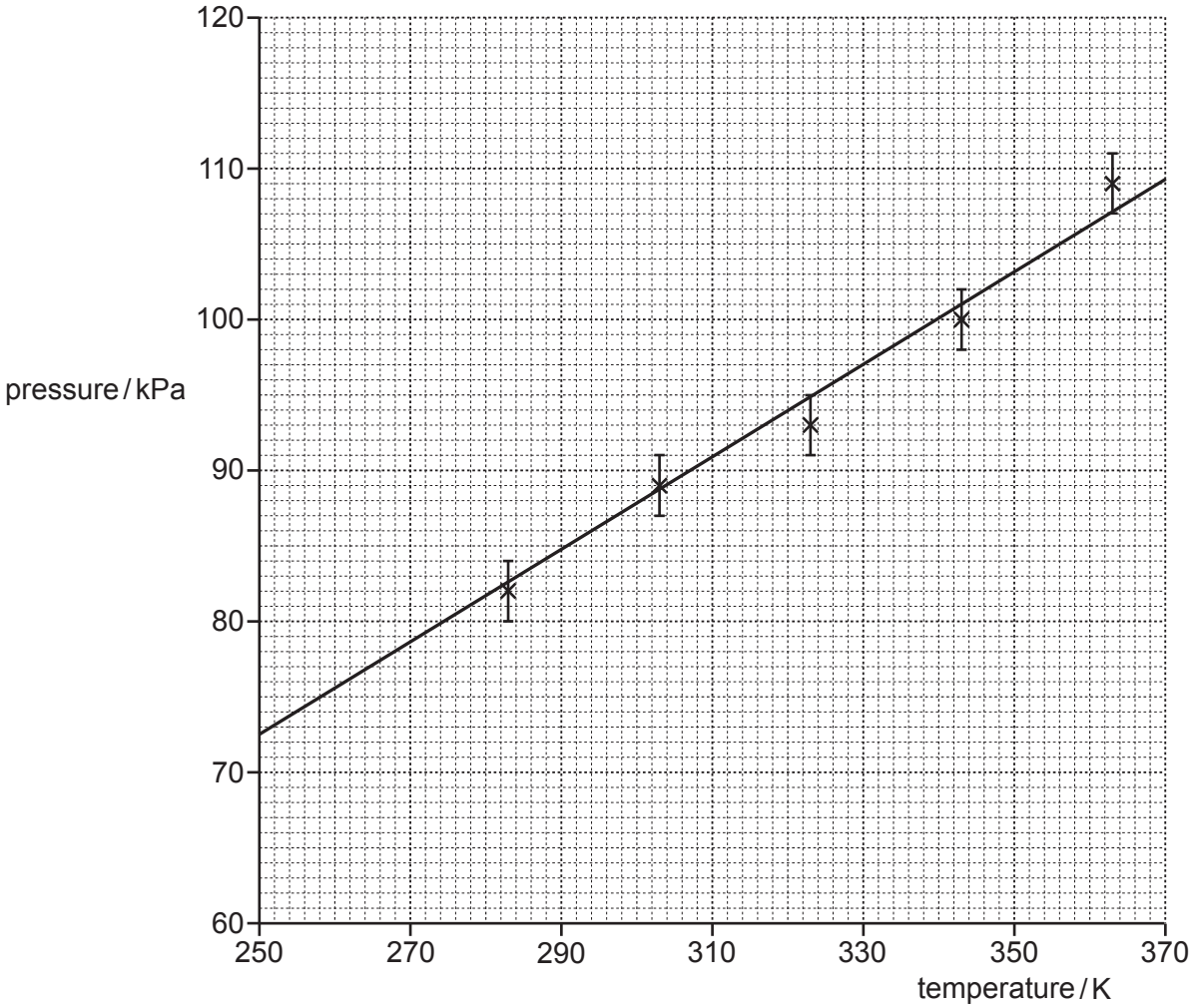

Fig. 4.2

1 The best-fit straight line is shown.

On Fig. 4.2, add a worst-fit straight line that gives the **maximum** gradient. **[1]**

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2 The gradient of the best-fit straight line suggests that the pressure of the gas will fall to zero at a temperature of about 10 K.

Determine the gradient of your worst-fit straight line.
Use your gradient value to calculate the temperature at which the pressure falls to zero, assuming the change in pressure per unit kelvin is constant.
Show all your working.

temperature at which pressure falls to zero = ...K **[5]**

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(d) The student notices that the top of the round-bottom flask is above the level of the liquid in the water bath and suggests that this will produce a systematic error in the data which could account for the incorrect value for the temperature at which the gas pressure falls to zero.

The temperature of the laboratory at the time of the experiment was 25 °C.

Explain what is meant by a *systematic error*. Explain how the low level of liquid in the water bath could lead to a systematic error and assess if the error is likely to be significant.

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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