Q1. A student has a diffraction grating that is marked 3.5×10^3 lines per m.

(a) Calculate the percentage uncertainty in the number of lines per metre suggested by this marking.

percentage uncertainty = ... %

(1)

(b) Determine the grating spacing.

grating spacing = ... mm

(2)

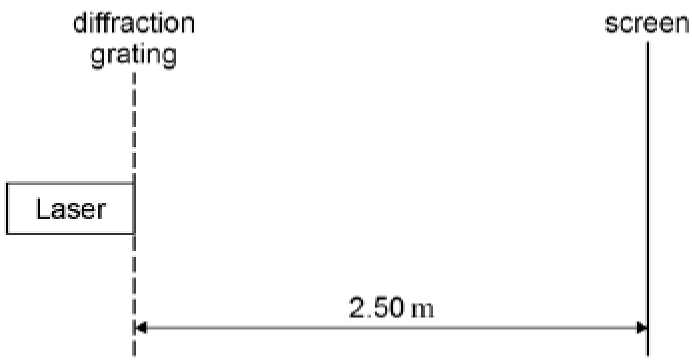
(c) State the absolute uncertainty in the value of the spacing.

absolute uncertainty = ... mm

(1)

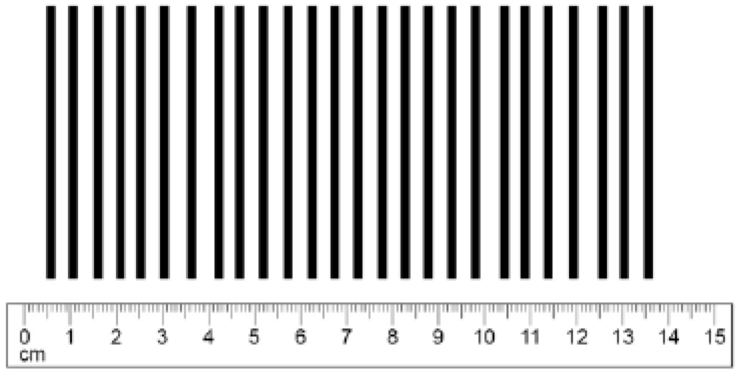
(d) The student sets up the apparatus shown in **Figure 1** in an experiment to confirm the value marked on the diffraction grating.

Figure 1



The laser has a wavelength of 628 nm. **Figure 2** shows part of the interference pattern that appears on the screen. A ruler gives the scale.

Figure 2



Use **Figure 2** to determine the spacing between two adjacent maxima in the interference pattern. Show all your working clearly.

spacing = ... mm

(1)

(e) Calculate the number of lines per metre on the grating.

number of lines = ...

(2)

(f) State and explain whether the value for the number of lines per m obtained in part (e) is in agreement with the value stated on the grating.

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(2)

(g) State **one** safety precaution that you would take if you were to carry out the experiment that was performed by the student.

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(1)
(Total 10 marks)

Q2.Data analysis question

Capillary action can cause a liquid to rise up a hollow tube. **Figure 1** shows water that has risen to a height h in a narrow glass tube because of capillary action.

Figure 1

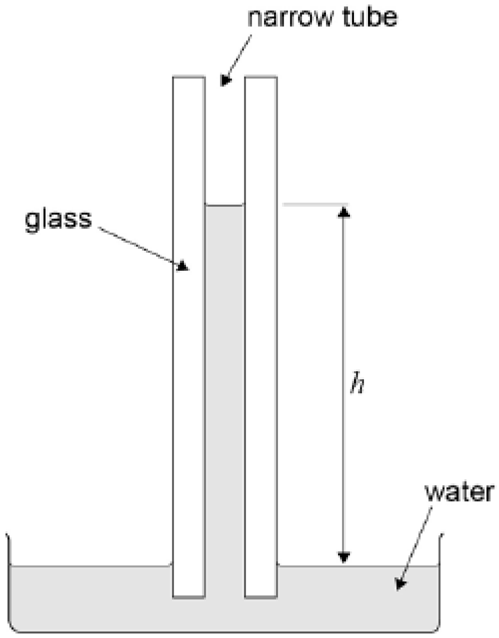
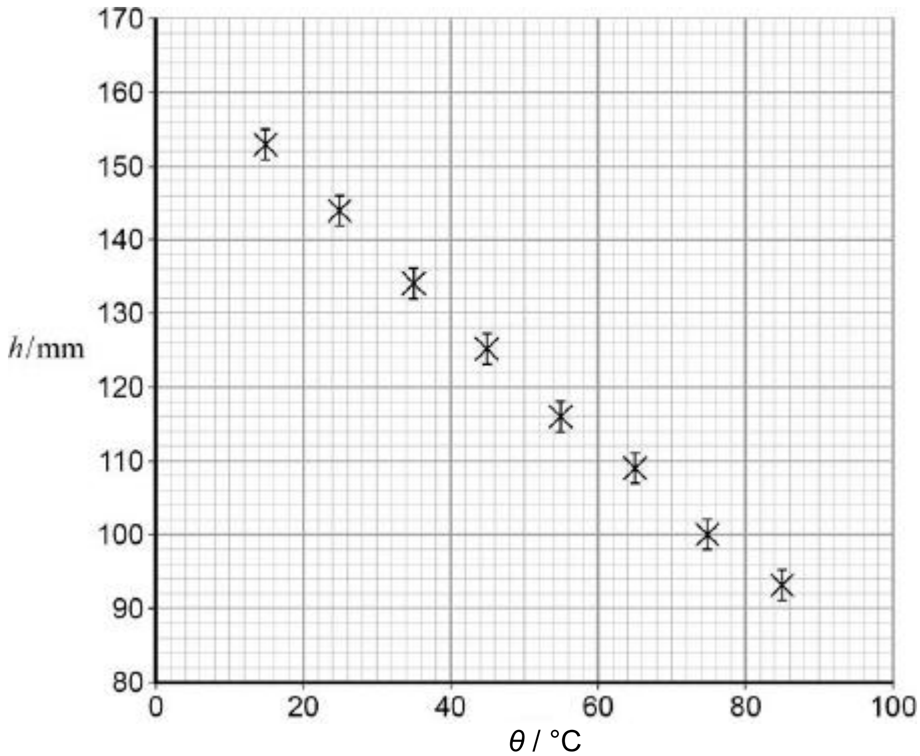


Figure 2 shows the variation of h with temperature θ for this particular tube.

Figure 2



The uncertainty in the measurement of h is shown by the error bars. Uncertainties in the measurements of temperature are negligible.

(a) Draw a best-fit straight line for these data **(Figure 2)**.

(1)

(b) It is suggested that the relationship between h and θ is

$$h = h_0 — (h_0k)\theta$$

where h_0 and k are constants.
Determine h_0.

h_0 = = ... mm

(1)

(c) Show that the value of h_0k is about 0.9 mm K^{-1}.

(3)

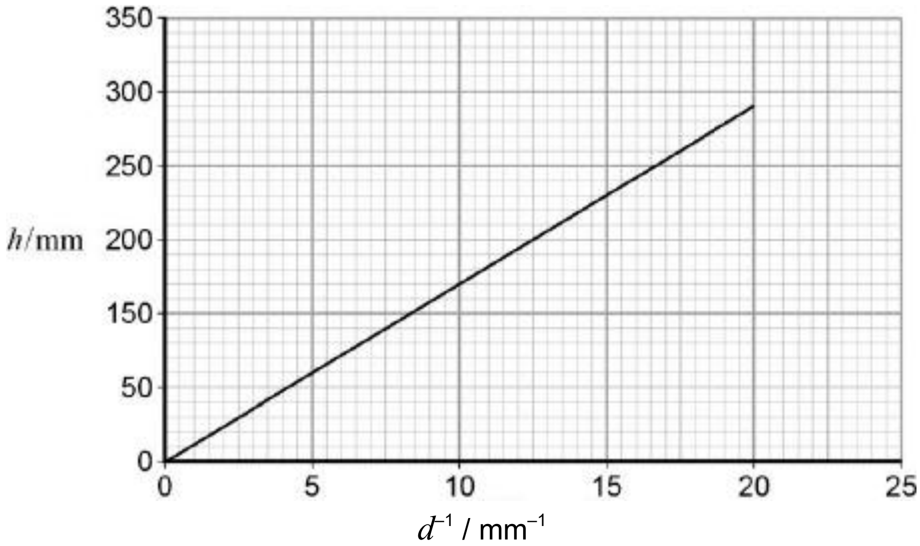
(d) Determine k. State a unit for your answer.

k = ... unit = ...

(2)

(e) A similar experiment is carried out at constant temperature with tubes of varying internal diameter d. **Figure 3** shows the variation of h with $\frac{1}{d}$ at a constant temperature.

Figure 3



It is suggested that capillary action moves water from the roots of a tree to its leaves.

The gradient of **Figure 3** is 14.5 mm^2.

The distance from the roots to the top leaves of the tree is 8.0 m.

Calculate the internal diameter of the tubes required to move water from the roots to the top leaves by capillary action.

(2)

(f) Comment on the accuracy of your answer for the internal tube diameter in part (v).

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(1)
(Total 10 marks)

Q3. The term **ultrasound** refers to vibrations in a material that occur at frequencies too high to be detected by a human ear. When ultrasound waves move through a solid, both longitudinal and transverse vibrations may be involved. For the longitudinal vibrations in a solid, the speed c of the ultrasound wave is given by

$$c = \sqrt{\frac{E}{\rho}}$$

where E is the Young modulus of the material and ρ is the density. Values for c and ρ are given in the table below.

Substance	**c / m s^{-1}**	**ρ / kg m^{-3}**
glass	5100	2500
sea water	1400	1000

Ultrasound waves, like electromagnetic radiation, can travel through the surface between two materials. When all the energy is transmitted from one material to the other, the materials are said to be **acoustically matched**. This happens when ρc is the same for both materials.

(a) Calculate the magnitude of the Young modulus for glass.

Young modulus = ...

(1)

(b) State your answer to (a) in terms of SI fundamental units.

(1)

(c) The passage states that 'when ultrasound waves move through a solid both longitudinal and transverse vibrations may be involved'.

State the difference between longitudinal and transverse waves.

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(2)

(d) Show that when two materials are acoustically matched, the ratio of their Young moduli is equal to the ratio of their speeds of the ultrasound waves.

(2)

(e) The wave speed in a material X is twice that in material Y. X and Y are acoustically matched.

Determine the ratio of the densities of X and Y.

X = ... Y = ...

(1)

(f) Ultrasound waves obey the same laws of reflection and refraction as electromagnetic waves.

Using data from **Table 1**, discuss the conditions for which total internal reflection can occur when ultrasound waves travel between glass and sea water.

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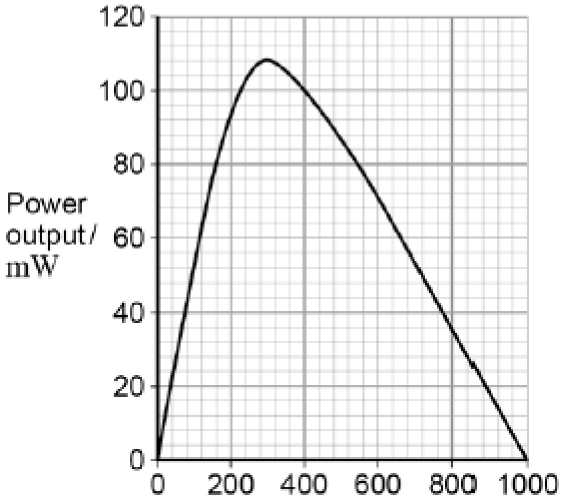
(3)
(Total 10 marks)

Q4.Figure 1 shows data for the variation of the power output of a photovoltaic cell with load resistance. The data were obtained by placing the cell in sunlight. The intensity of the energy from the Sun incident on the surface of the cell was constant.

Figure 1



(a) Use data from **Figure 1** to calculate the current in the load at the peak power.

(3)

(b) The intensity of the Sun's radiation incident on the cell is 730 W m^{-2}. The active area of the cell has dimensions of 60 mm × 60 mm.

Calculate, at the peak power, the ratio $\frac{\textit{electrical energy delivered by the cell}}{\textit{energy arriving at the cell from the Sun}}$

(3)

(c) The average wavelength of the light incident on the cell is 500 nm. Estimate the number of photons incident on the active area of the cell every second.

(2)

(d) The measurements of the data in **Figure 1** were carried out when the rays from the sun were incident at 90° to the surface of the panel. A householder wants to generate electrical energy using a number of solar panels to produce a particular power output.

Identify **two** pieces of information scientists could provide to inform the production of a suitable system.

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(2)
(Total 10 marks)

Q5. In which of the following do both quantities have the same unit?

A	Electrical resistivity and electrical resistance.	⬭
B	Work function Planck constant	⬭
C	Pressure and the Young modulus.	⬭
D	Acceleration and rate of change of momentum.	⬭

(Total 1 mark)

Q6. Which of the following is **not** a unit of power?

A	$N\ m\ s^{-1}$	⬭
B	$kg\ m^2\ s^{-3}$	⬭
C	$J\ s^{-1}$	⬭
D	$kg\ m^{-1}\ s^{-1}$	⬭

(Total 1 mark)

Q7. Which of the following gives a correct unit for $\left(\frac{g^2}{G}\right)$?

A N

B N kg^{-1}

C N m

D N m^{-2}

(Total 1 mark)