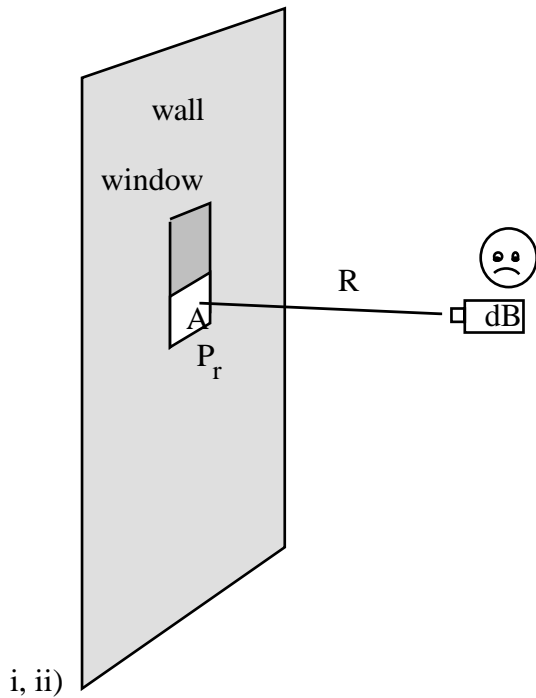


**1169T2/2002****Question 1 ( marks)**

- a) i) A wave with amplitude  $A$ , wave number  $k$  and angular frequency  $\omega$  is travelling to the left, in the negative  $x$  direction. The displacement  $y$  due to this wave is zero at position  $x = 0$  and time  $t = 0$ . Write an equation that gives the displacement  $y_1$  due to this wave at any time  $t$  and position  $x$ .
- ii) Derive an expression for the particle velocity  $v(t)$  at a position  $x = L$ , due to the action of this wave alone.
- iii) The wave in part (i) is reflected at  $x = 0$  by a rigid boundary condition, ie total displacement  $y$  at  $x = 0$  is zero for all time. Write an equation for the displacement  $y_2$  due to the reflected wave.
- iv) Determine the points on the positive  $x$  axis for which  $y = y_1 + y_2$  is always zero, in terms of the variable given in part (i). Explain your answer briefly.
- b) A chimney pipe has a cylindrical cross-section, and is 10 m tall. It is closed at the bottom and open at the top.
- i) Determine the three lowest frequencies at which the air in the chimney may resonate. The speed of sound in the hot air in the chimney is  $440 \text{ ms}^{-1}$ .
- ii) Draw sketches to represent the resonances of part (i). State whether your sketch represents sound pressure or particle displacement.

**Question 2** ( marks)



During an end-of-exam party, the sound level inside a student's flat, just inside the window, is  $L_i = 106$  dB, with respect to reference intensity  $I_0 = 10^{-12} \text{ W m}^{-2}$ . Because of her passion for rock music, this student has fitted the flat with insulation and double-glazed insulating windows, which may be regarded as perfect sound insulators for the purposes of this question. Hence, the only sound that escapes does so via the open part of the window.

- i) During the party, the window is open leaving an area  $A$  through which sound escapes into the environment outside. The sound level just inside the window is still  $L_i = 106$  dB, with respect to reference intensity  $I_0 = 10^{-12} \text{ W m}^{-2}$ . Derive an expression for the sound power  $P_r$  that is radiated out through this open window, in terms of the open area  $A$ .
- ii) Assume that this escaping sound is radiated uniformly in all directions outside the building, and that the external wall is large and absorbs no sound. You may also assume that the window is effectively a point source. Derive an expression for the sound intensity  $I_n$  that is experienced by a neighbour at a distance  $R$  from the open window.
- iii) The neighbour at  $R = 10$  m from the window has a sound level meter. He has decided to call the police if the sound level  $L_n$  at his position reaches 70 dB. Showing your working, determine the area  $A$  of open window at which this will happen. (Neglect other sources of sound, and any reflections from surfaces other than the wall.)

**Question 3** (   marks)

- a) i) A diffraction grating has a spacing between adjacent slits of  $d$ . For normally incident light of wavelength  $\lambda$ , intensity is of the diffracted light is a maximum at several angles  $\theta$  from the normal to the grating. Using a sketch, derive a relation between the spacing  $d$  and the angles  $\theta$  at which diffraction maxima occur.
- ii) A particular diffraction grating has a spacing between adjacent slits of  $d = 2.00 \mu\text{m}$ . Normally incident white light is diffracted by the grating and falls on a screen placed at a distance  $L = 500 \text{ mm}$  from the grating, parallel to it. What is the distance on the screen between the position of the primary maximum for light with wavelength  $630 \text{ nm}$  and the central maximum? Show your working.
- b) Unpolarised light is normally incident upon two ideal polarisers, placed one on top of the other. One of the sheets is rotated so that no light is transmitted. This orientation is kept constant throughout the problem. A third sheet of ideal polarising material is now placed between the other two, and rotated so that the light transmitted through all three sheets is a maximum. Determine the direction of its polarisation direction with respect to that of one of the other sheets, and use this to derive an expression for ratio of the intensity of the incident unpolarised light to the light transmitted through all three sheets. You may use without proof the relation  $\sin 2\theta = 2 \sin \theta \cos \theta$ .

**Question 4** (   marks)

- a) Using the equation of state for an ideal gas, derive a simple expression for the thermal coefficient of volume expansion for an ideal gas at constant pressure.
- b) For a fancy-dress party, you are dressed as an astronaut. The suit covers you completely, has an area of  $2.0 \text{ m}^2$ , and a uniform thickness of  $2.0 \text{ mm}$ . During the dancing, you find that your both your skin temperature and the inside temperature of the suit has risen to  $35^\circ\text{C}$  and remains steady at that temperature, while the constant outside temperature of the suit is  $30^\circ\text{C}$ . You estimate that you producing heat at  $800 \text{ W}$ . Neglect the effects of thermal radiation. Showing your working, estimate the thermal conductivity of the material from which the suit is made.

**Question 5** (   marks)

- a) What is an amorphous solid?
- b) Some liquids can form either a crystal or an amorphous solid when they cool. Explain briefly how such a liquid can be cooled to form an amorphous solid, and why this procedure results in such a solid.
- c) The attractive and repulsive forces between atoms and molecules are in general rather complicated functions of the inter-atomic or inter-molecular spacing. Nevertheless, Hooke's law of elasticity works well for many such materials.
- i) What limitation on the strain is necessary for Hooke's law to be true?
- ii) Subject to this limitation, and **with the aid of a clearly labelled sketch**, explain briefly how Hooke's law arises.
- d) Draw a stress-strain curve that exhibits (i) linear elastic response, (ii) yield and (iii) hysteresis. Indicate which region or feature corresponds to each of these phenomena.
- e) During the cycle you have described in (d), is mechanical energy conserved? Explain your answer briefly.

**Question 6** (   marks)

- a) With the aid of simple sketch, explain why molecules at the surface of a liquid have a higher energy than those in the interior of the liquid.
- b) Derive the Young-Laplace equation that relates the pressure excess  $\Delta P$  inside a droplet to its radius  $r$  and the surface tension  $\gamma$ .