

1969 T2 2003

Question 1 (15 marks)

- a) Two surfers, Barbara and Marilyn, are floating in deep water. Each observes that her vertical motion is sinusoidal and the total displacement from bottom to top during a cycle is 2.4 m. The wave speed is  $10 \text{ ms}^{-1}$ . Marilyn observes that she gets to the top just as Barbara gets to the bottom. They observe that they experience *maximum* accelerations of  $0.015 \text{ g}$ .
- i) Draw a graph of vertical position ( $y$ ) as a function of displacement ( $x$ ) in the direction of travel of the wave. On this graph, locate possible positions for Barbara and Marilyn.
- ii) Showing your working, calculate two possible values for the horizontal separation between Barbara and Marilyn.
- b) The 'solar constant'—a quantity of great interest in solar energy, meteorology, thermal engineering, ecology etc—is the intensity of light from the sun, measured above the Earth's atmosphere, at right angles to a line towards the sun. It has a value of  $1.38 \text{ kWm}^{-2}$ . The Earth is 150 million km from sun. From these data, compute the rate at which the sun is producing energy in the form of light.

Question 2 (15 marks)

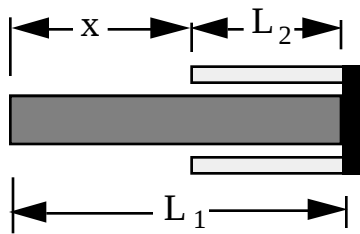
- a) A badly designed cooling system of an industrial plant is mounted on the ground (which you may treat as an infinitely large reflecting surface). It radiates an acoustic power of  $10 \text{ W}$  isotropically into the air.
- i) If unprotected workers are not to be exposed to a continuous sound intensity level exceeding  $90 \text{ dB}$ , (with respect to  $I_0 = 1 \text{ pW.m}^{-2}$ ) how close may they safely stay near the noise source?
- ii) The workers are supplied with hearing protectors giving an insulation of  $26 \text{ dB}$  (ie the sound level inside the ear enclosures is at least  $26 \text{ dB}$  lower than that outside). Wearing their protectors, how close to the noise source may the workers safely stay?
- b) Two exhaust fans turn at 1000 revolutions per minute. One (fan a) has 3 blades in the fan, the other (fan b) has 30 blades. The individual blades on the second fan are smaller than those on the first, with the result that both fan emit exactly the same acoustic power.
- i) What fundamental frequencies do they emit? (Hint: how many times per second do fan blades pass a given point?)
- ii) At the same distance, which one is louder? Explain your answer in one or two clear sentences.
- c) In still air, a motorist travels at an unchanging speed of  $v_m = 110 \text{ km.hr}^{-1}$  along the freeway. A police car, its siren turned on, is travelling in the same direction, is first approaching from behind, and then overtakes the motorist. The motorist, who is a musician, hears the police siren fall in pitch as the police car overtakes. From the fall in pitch, he deduces that the frequency he heard before being overtaken ( $f_1$ ) was 1.20 times higher than that he heard afterwards ( $f_2$ ). The speed of sound is  $340 \text{ ms}^{-1}$ . Determine the speed of the police car,  $\text{km.hr}^{-1}$ . (Hint: you may wish to relate  $f_1$  and  $f_2$  to  $f_s$ , the frequency emitted by the police siren. Diagrams may be helpful.)



**Question 3** (15 marks)

- a) Explain, with the aid of a clearly labelled diagram, how polaroid filters (or polaroid sunglasses) reduce the glare from horizontal surfaces. (Several clear sentences will do. Your diagram should clearly show dominant polarisation directions of the light and the appropriate polarisation direction of the filter.)
- b) 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 laser beam (wavelength 630 nm) is at normal incidence to a grating with 500 lines/mm. The diffraction pattern falls on a wall, 8.0 metres distant. What is the distance on the screen between the position of the primary maximum for light with wavelength 630 nm and the central maximum? Show your working.

**Question 4** (5 marks)



The figure shows a low expansion mounting, designed so that the distance  $x$  has minimal change with temperature. The inner and outer shafts are made of materials with linear thermal expansivity coefficients  $\alpha_1$  and  $\alpha_2$ , respectively. Their lengths  $L_1$  and  $L_2$  are shown on the diagram.

For this device to work, what should be the ratio  $L_1/L_2$ ? (Hint: derive an equation that relates  $L_1/L_2$  to the coefficients  $\alpha_1$  and  $\alpha_2$ .)

**Question 5** (17 marks)

- a) i) What is mechanical hysteresis? (one sentence will do)
- ii) Sketch a stress-strain graph that shows both an elastic response and mechanical hysteresis. Use arrows to indicate how the deformation progresses in time. Indicate on the sketch, or explain in a sentence or two, what part(s) or the sketch represent hysteresis.
- iii) State clearly how a part of your graph relates to an elastic modulus.
- iv) Continue your graph so that it shows an intercept on the strain axis. State clearly the meaning of this intercept.
- b) For a particular type of steel, the Young's modulus  $Y$  is 206 GPa and the bulk modulus  $\kappa$  is 181 GPa
- i) A solid bridge cable made of this material has a diameter of 10 mm. What weight can be supported by the cable with a 1% increase in length?
- ii) What pressure is required to increase the density of steel by 3%?
- iii) Eccentric inventor Josef Lupus has patented *skweezit*<sup>TM</sup>, an amorphous material with the rare and interesting property that its Poisson's ratio  $\nu$  has the value 0.9.

Why is this property so rare and interesting? (Hint: what would happen if you applied an isotropic pressure to a sample of *skweezit*<sup>TM</sup>?) Your answer should include at least one or two equations.

(**Caution:** if you have brought a sample of *skweezit* into the exam room in anticipation of this question, do not handle or ingest it.)

**Question 6** (8 marks)

- a) i) What is an amorphous solid?
- ii) How can one form an amorphous solid? (One technique will suffice)
- iii) When certain types of amorphous solid are heated substantially, but not enough to produce chemical changes, and then allowed to cool, their mechanical and other properties are greatly changed. Explain in a few clear sentences why this is so.
- b) Define surface energy (also called specific surface free energy) **and** surface tension.
- c) State a relation between surface energy and surface tension that applies to a clean interface between two liquids.
- d) Why is surface energy important in the cracking of materials? One or two clear sentences will suffice.