Hand in your answers by **1pm on Tuesday 16 February**, *at Room E2 in Physics. Put your name and your academic tutor's name on your answers and* **STAPLE** *sheets together. Marks per section are shown in square brackets.*

1. (a) An earthquake emits a longitudinal wave which is felt 5,000km from the epicentre 15 minutes after the event. If the average density of the earth's crust is $\rho = 2.7 \times 10^3$ kg/m^3, calculate the average Young's modulus of the crust. [3]

   (b) A small loudspeaker is driven by an audio oscillator and amplifier, whose frequency can be adjusted from 500 to 2500 Hz only. The loudspeaker is connected to a rigid, cylindrical tube 65 cm long and open at both ends. The loudspeaker is used to drive the air in the tube into resonance.

   (i) If the speed of sound in air is 340 m s^{-1}, at what frequencies will resonance occur in the pipe when the frequency emitted by the speaker is varied from 500 to 2500 Hz? [4]

   (ii) Describe with a sketch the characteristics of the standing wave with the lowest frequency found in 1(b)i above. [3]

2. In this question, assume that the speed of light is given by $c = 3 \times 10^8$ m/s and that the speed of sound in air is 343 m/s.

   (a) Microwaves form standing waves in a microwave oven. Cold spots in a microwave oven are found to be 6.2 cm apart. What is the frequency of the microwaves? [2]

   (b) (i) A shower stall, closed at the top, is 2.40 m tall. For what frequencies less than 300 Hz are there standing sound waves in the shower stall with the door is closed? [3]

   (ii) If the top of the stall is open, for what frequencies less than 300 Hz are there standing sound waves in the shower stall? [3]

   (iii) Draw the graphical representations of the standing waves for the first two frequencies found in Questions 2(b)i and 2(b)ii. [4]

   (c) (i) What are the three longest wavelengths for standing waves on a 260-cm long string that is fixed at both ends? [3]

   (ii) If the frequency of the second-longest wavelength is 60 Hz, what is the frequency of the third-longest wavelength? [2]

3. (a) If you are given two sound intensities, I_1 and I_2, how is the difference in the sound levels β_1 and β_2 related to the intensities? [3]

   (b) By what factor has the intensity increased if the sound level has risen by 15 dB? [2]

4. (a) In what type of environment are the two velocities v_p and v_g equal? What is an example of such an environment? [2]

   (b) Show that, for a medium with dispersion relation $\omega = ak^r$ the group velocity is $v_g = rv_p$ for all frequencies. [3]

   (c) An ionized gas or plasma is a dispersive medium for electromagnetic waves. Given that the dispersion relation is $\omega^2 = \omega_p^2 + c^2k^2$ where ω_p is the constant plasma frequency, show that $c^2 = v_p v_g$. [3]