Question 1 (20 marks)

A subwoofer loudspeaker consists of a rigid cone of mass m supported by a spring-like suspension system with a spring constant k. In order to design a speaker box, we need to measure both m and k. This is done by first measuring the resonant frequency, f_0, of the speaker.

Next, a small piece of Blu Tack (or plasticine) of known mass m_1 is attached rigidly to the cone. The new resonant frequency, f_1, is then measured.

(a) Do you expect f_1 to be greater or less than f_0? Explain your reasoning.

(b) Write an expression for the mass of the speaker cone, m, in terms of the measured quantities f_0, f_1 and m_1.

(c) Write an expression for the spring constant, k, in terms of these same measured quantities.

(d) The subwoofer is subsequently installed in its well-designed speaker box, and is found to reproduce sounds down to 20 Hz. What is the minimum length that an organ pipe would need to be to produce this frequency? Assume the organ pipe is open at one end and closed at the other.

(e) Would your answer to (d) change if the organ pipe were open at both ends? Explain your answer.

Question 2 (20 marks)

A trumpet player stands in a field and plays a note at 440 Hz. A steady wind of 20 ms^{-1} is blowing.

(a) What frequency is heard by a listener who is standing 5 metres downwind of the trumpeter?

(b) The listener straps on roller-skates and finds themselves carried downwind at a steady 15 ms^{-1}. What frequency do they hear now?

(c) If the listener was initially experiencing a sound level of 86 dB from the trumpet, and the wind creates an ambient sound level of 40 dB, how long after the listener starts moving will it be before the trumpet is no longer audible? Explain your reasoning and any assumptions made.

[Note: take the speed of sound to be 343 ms^{-1}]

Question 3 (20 marks)

A string is stretched between two rigid supports 9 cm apart. It vibrates according to the expression

$$y = 0.5\sin\left(\frac{\pi x}{3}\right)\cos 40\pi t$$

where x and y are in centimetres and t is in seconds.

(a) What is the maximum amplitude of the wave at a point in the middle of the string (i.e. halfway between the supports)?

(b) What is the distance between adjacent nodes?

(c) What values of x correspond to positions of maximum transverse acceleration of the string?

(d) Write an expression for the two component travelling waves whose superposition gives rise to this wave.

(e) If the string has a mass of 24 g what is the tension in the string?

Question 4 (20 marks)

Lenses of high quality cameras are anti-reflection coated. This is achieved by coating a thin film of refractive index $\sqrt{n_1}$ on the surface of the lens, where n_1 is the refractive index of the lens itself.

(a) If the refractive index of the lens is $n_1 = 1.50$, what thickness should the coating be in order to be most effective at a wavelength of 550 nm?

(b) Why does this lens appear to have a purple colour when viewed in reflected light?

(c) Suppose the lens is now immersed in a liquid with a refractive index of 1.7. Does the anti-reflection coating still have the optimum thickness? If not, what thickness should it be?

Question 5. (10 marks)

The Parkes radio telescope is 64 m in diameter. During the Apollo moon-landing missions, it tracked the spacecraft on a down-link frequency of 2.20 GHz.

(a) What is the angular resolution of the telescope at this frequency?

(b) What linear distance does this correspond to at the distance of the moon (380,000 km)?

Question 6 (10 marks)

(a) You are looking upwards at the sky. At what time of day (approximately) will the blue sky directly overhead have the greatest degree of polarization?

(b) You are standing next to a lake in Singapore, close to the equator. You are looking at the reflection of the Sun in a lake. At what time of day (to the nearest half hour) will the reflected light be most highly polarized?

[Take the refractive index of water to be $n = 1.33$]