What you need to know:

Longitudinal Waves: Displacement in direction of motion of pulse/wave.

2D and 3D Waves:

Wave Fronts: Represent crests (amplitude maxima) of the wave.

Rings for symmetric 2D waves. Spherical shells for symmetric 3D waves.

Sound Waves: longitudinal mechanical waves, can travel through solids, liquids or gases.

Speed of sound in fluid:

$$v = \sqrt{\frac{B}{\rho}}$$

Interference in 1D: Special Cases:

Maximum Constructive Interference: Waves are in phase. Crest meets crest.

Maximum Destructive Interference: Waves are 180° out of phase. Crest meets trough.

Interference in 2 and 3D:

For sources in phase:

Maximum Constructive Interference:

$$Path\,difference\ \ \Delta r = r_1 - r_2 = m\lambda \quad m = 0,1,2,3,...$$

Crest meets crest.

Maximum Destructive Interference:

$$Path\,difference\ \ \Delta r = r_1 - r_2 = \left(m + \frac{1}{2}\right)\lambda \quad m = 0,1,2,3,...$$

Crest meets trough.

Standing Sound Waves:

In a (sinusoidal) travelling sound wave the pressure variation and displacement have a phase difference of 90° i.e. pressure maxima occur for zero displacement and displacement maxima occur when pressure is at equilibrium value.

Pipe with one end closed:

Require displacement node at the closed end and opposite condition at open end i.e. displacement antinode.

Pipe with two ends closed:

Require displacement nodes at the closed ends.

Pipe with both ends open:

What you need to know:

Require displacement antinodes at the open ends

Power, Intensity and Sound Level:

Power = rate at which energy transferred by wave.

Intensity = Power per unit area in wave.

$$Intensity\ I = \frac{power}{area} \quad (Units: W.m^{-2})$$

$$\text{Sound intensity level: } \beta = (10\ dB)\log_{10}\left(\frac{I}{I_0}\right) \quad (Units: dB)$$

Beats:

Two sinusoidal travelling waves same amplitude, phase constants but different frequency (and different wavelengths):

$$D = D_1 + D_2 = -A\left[\sin(\omega_1 t) + \sin(\omega_2 t)\right]$$

$$\boxed{\Rightarrow f_{beat} = 2f_{\text{mod}} = f_1 - f_2}$$

Doppler Effect:

Doppler effect = change in frequency which occurs when a sound source and an observer, e.g. you, are moving relative to one another.

e.g. change in frequency that you hear when an emergency vehicle drives past while sounding its siren.

$$\text{Frequency detected } f_D = \left(\frac{v \pm v_D}{v \mp v_S}\right) f_S$$

Which sign do I need? Towards corresponds to greater frequency.

For the exam:

- You may be asked to add travelling waves together using trigonometric identities and discuss whether or not the resultant wave represents a travelling wave or a standing wave.
- You may be asked to find node/antinode positions for a standing wave.
- You may be asked to draw diagrams of standing waves and resonance conditions for transverse waves on strings and sound waves in pipes. You may be asked to find wavelengths and frequencies for the first few harmonics.
- You may be asked to identify whether two 1D waves interfere constructively or destructively.

What you need to know:

- You may be asked to find the intensity of a wave at some distance from a sound source.
- You may be asked to calculate a sound intensity level given an intensity or vice versa.
- You may be asked to find frequencies or velocities for moving sources and/ or detectors using the Doppler formula.
- <u>You may be asked whether sound waves from two different sources produce constructive or destructive interference at some location based on the path difference between the sources and the location.</u>
- You may be asked to find the beat frequency for two waves with different frequencies.

<u>Training:</u>

Homework Problems and Problem Class Sheets

<u>And then try an exam question:</u>

2102 Exam, Q 10 (b) **[2 + 2 = 4 marks]**

(b) The whirling tube is a musical instrument consisting of a length of corrugated plastic tubing that is open at both ends. To play the whirling tube it is held near one end and then the other end is whirled above the head. Flow of air across the corrugations of the tube causes the air column within the tube to resonate.

(i) For a whirling tube of length 110 cm find the frequency of the longest wavelength standing wave. (Assume air temperature is 20 °C)

(ii) Briefly describe what factors you expect will affect the frequencies of sound heard by someone listening to this instrument.

2102 Exam, Q 11 **[3 + 3 = 6 marks]**

Polly the parrot wants to escape from her enclosure at the zoo. The enclosure has a glass door and by tapping on the door with her beak Polly has been able to determine that the natural resonant frequency of the door is 900 Hz. The highest frequency squawk Polly can muster is 850 Hz but at one time she belonged to a Physics professor (Don't ask how she ended up in the zoo!) so Polly knows about the Doppler effect.

(a) Find a value for how fast Polly will have to fly toward the glass so that her Doppler-shifted squawk matches the resonant frequency of the door. Assume that the speed of sound is 343 m/s.

(b) If the sound intensity level needed to break the glass is 110 dB and Polly wants to be able to break the glass from a distance of 1.0 m, find a value for the power in Watt of her squawk that will be required to achieve this. You may assume that Polly is a point source of sound.

<u>Some Formulae from Exam:</u>

$$\sin\alpha + \sin\beta = 2\sin\frac{1}{2}(\alpha+\beta)\cos\frac{1}{2}(\alpha-\beta)$$

What you need to know:

$f = \frac{1}{T}, \quad \omega = 2\pi f$	$x(t) = A\cos(\omega t)$	$\omega = \sqrt{\frac{k}{m}}$
$\omega = \sqrt{\frac{g}{l}}$	$\omega = \sqrt{\frac{Mgl}{I}}$	$\beta = 10\log_{10}\left(\frac{I}{I_0}\right), \quad I_0 = 10^{-12} W/m^2$
$D(x,t) = A\sin(kx \pm \omega t + \phi_0)$	$f_D = \left(\frac{v \pm v_D}{v \mp v_S}\right) f_S$	$v = \sqrt{\frac{T_s}{\mu}}, \quad v = \sqrt{\frac{B}{\rho}}$

Answers: Q10 (b) (i) 156 Hz, (ii) I can think of a number of things. Q11 (a) 19 m/s, (b) 1.3 W.