ASSESSOR'S USE ONLY

QUESTION one: WAVE MOTION

The acceleration due to gravity = 9.81 m s^{-2}

A cork floats on the surface of a pond across which a sinusoidal wave-train of wavelength 10 m and amplitude 0.20 m is travelling. The velocity, v, of waves of wavelength, λ, on a liquid surface is given by

$$v^2 = \frac{g\lambda}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$$

where ρ is the density (1.0×10^3 kg m^{-3} for water) and γ is the surface tension, which for water has the value 7.2×10^{-2} N m^{-1}.

(a) Show that the equation is dimensionally consistent.

(b) Calculate the wave speed.

(c) Calculate the maximum speed of the cork as it rises and falls in the water.

Sea waves of wavelength 150 m and velocity of 15.3 m s^{-1} are heading North. A cruise ship is also travelling North at 8.0 m s^{-1}.

(d) Calculate the frequency of the ship's up and down movement.

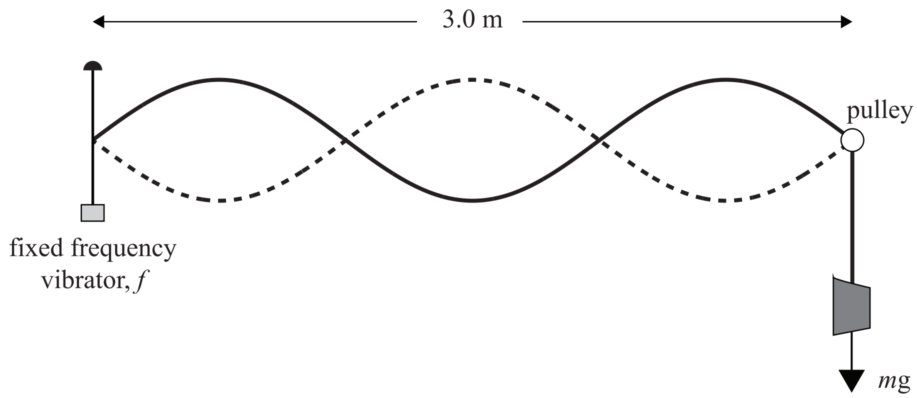
(e) The natural pitch period of the ship (the period of oscillation produced by pulling the front of a ship down in completely flat water) is about 8 s.

By considering the ship when it is travelling normal to the wavefront, explain why the ship must avoid certain speeds.

If the wave has a speed of 10.8 m s^{-1} and wavelength of 75 m, calculate the speeds that should be avoided.

(8)

QUESTION TWO: ALL THINGS WAVES



A string, given a constant small amplitude by the vibrator of fixed frequency f, has the third harmonic standing wave established when under a tension of $T = mg$, as shown above.

(a) Explain how a standing wave forms with this experimental arrangement.

(b) (i) The speed of a wave on a string is given by the relationship

$$v = \sqrt{\frac{T}{\mu}}$$ where μ = mass per unit length and T is the tension.

Show that the tension is given by the following expression: $T = \mu f^2 \lambda^2$

(ii) Show that this expression for the tension is dimensionally correct.

(c) A fan now blows a breeze against the hanging mass, pushing it out at some angle to the horizontal. The standing wave changes under these conditions to the second harmonic.

Determine an expression for the new tension in the string.

(d) Explain, using examples of physical phenomena, how light demonstrates both wave-like and particle-like behaviours.

(8)

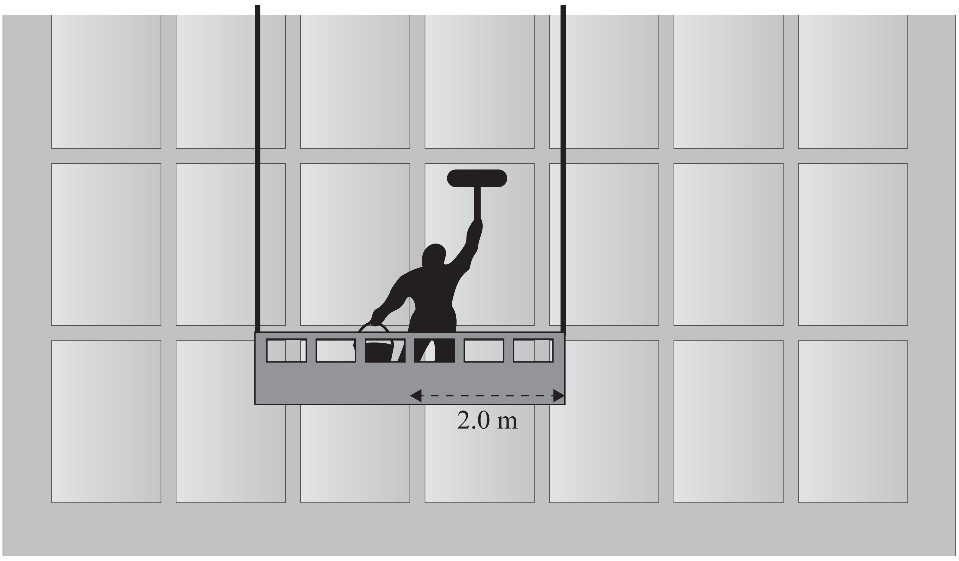
QUESTION THREE: VIBRATING WIRES

Acceleration due to gravity = 9.81 m s^{-2}

Long wires, stretched between two points, can vibrate when a steady wind blows past them. Engineers, in dealing with the problems caused by these vibrations, have found it useful to define the Strouhal number, St, as $\text{St} = f\frac{r}{v_w}$, where f is the frequency of vibration, r is the radius of the wire, and v_w is the wind speed.

(a) Show that the Strouhal number is dimensionless.

A window-washing cradle of width 4.0 m is suspended from two cables of equal length.



A steady wind of 10 m s^{-1} causes the cables to vibrate with a frequency of 200 Hz. In this situation, a Strouhal number of 0.20 is typical. The wave speed in a wire is given as $v = \sqrt{\frac{T}{\mu}}$, where T is the tension and μ is the mass / unit length.

(b) Explain, using physical principles, why the wave speed in a wire depends on the tension and the mass / unit length.

(c) The cradle has a mass of 100 kg and the window washer, who is standing in the middle of the cradle, has a mass of 75 kg (including his mop and bucket).

Given that the density of the cable material is 8.0×10^3 kg m^{-3}, show that the wave speed in the cables is 18 m s^{-1}.

(d) The window washer moves from the centre of the cradle to a position 1.0 m from the centre.

(i) Compare the wavelengths of the vibrations in the two cables.

(ii) In this scenario, the window washer does not hear beats.

Explain the physical conditions required for him to hear beats from vibrations in the wires when he is standing in the window-washing cradle.

(8)

QUESTION FOUR: WAVES ON STRINGS

The speed v of a wave on a string is given by, $v = \sqrt{\dfrac{T}{\mu}}$, where T is the tension in the string, and μ is the mass per unit length, measured in kg m^{-1}.

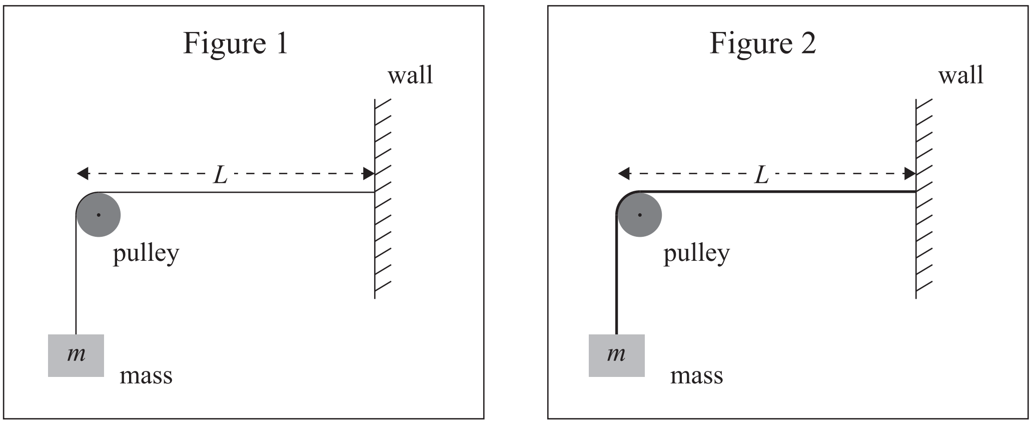
(a) Show that the above equation is dimensionally correct.

(b) One end of a string of mass per unit length μ is attached to a solid wall, while the other end passes over a pulley, and is attached to a hanging mass, m, as shown in Figure 1.

A second string of the same length and made of the same material, but with twice the diameter, is mounted in a similar fashion with an identical mass, m, as shown in Figure 2.

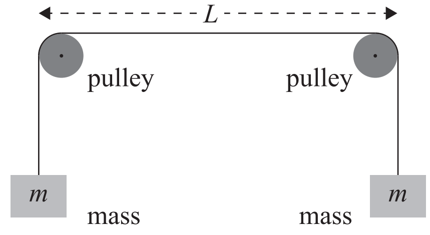
The first string oscillates in its first harmonic when it is driven at a frequency of 200 Hz.

Calculate the frequency that will cause the second string to oscillate in its third harmonic.



(c) Now the first string is hung so that both ends go over pulleys, with the masses suspended at each end, as shown in Figure 3.

Figure 3



Calculate the frequency of the fifth harmonic.

(d) Two strings made from the same material are both fixed at each end, and both are under the same tension. The first string has a length L_1 (= 1.00 m), and is being driven so that it oscillates in a transverse standing wave mode with a frequency of 400 Hz. The second string, with length L_2 (= 1.18 m), is also oscillating in a standing wave mode, but with a slightly lower frequency. An observer notices that the standing wave on the second string has one more node than that on the first string. The observer hears a 4.5 Hz beat, as a result of the combined sound coming from the two standing waves.

Calculate the number of nodes present in the first standing wave.

(8)

QUESTION FIVE: CLARINETS AND FLUTES (8 marks)

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Clarinet

www.life123.com/arts-culture/musical-instruments/clarinets/history-of-the-clarinet.shtml

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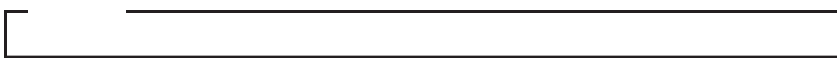
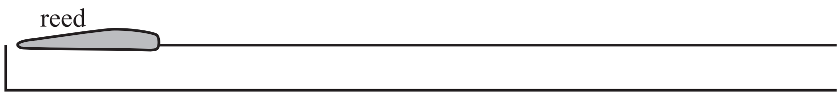
Flute

http://miami.olx.com/flute-lessons-are-dynamic-excellent-results-iid-26298197

The flute is played by blowing air over a large opening.

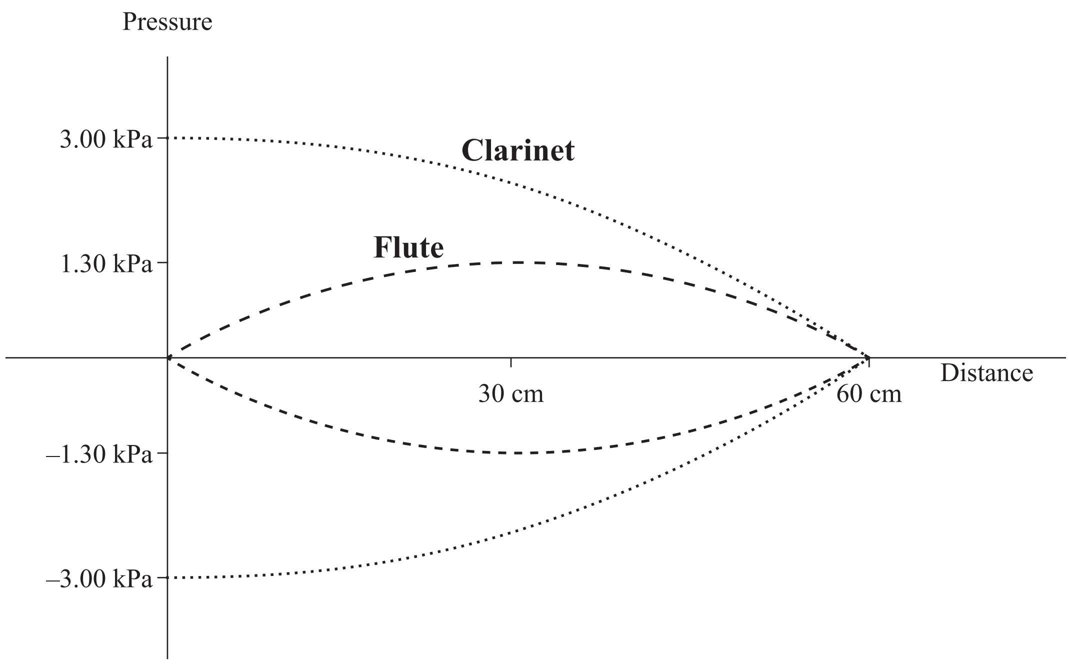


The clarinet is played by blowing air through a small opening covered by a vibrating reed.



The "acoustic pressure" in these wind instruments is the difference between the air pressure inside the instrument and the atmospheric pressure outside.

When the acoustic pressure is measured inside a flute and inside a clarinet, the maximum and minimum pressures are found to vary along the length of the instruments, as shown in the following graph. (Both the flute and the clarinet are 60 cm long, with the opening at 0 cm.)



(a) Explain why, at each point inside the instruments, the pressure is recorded as having both a positive and a negative value.

(b) At the left hand end (where the reed is positioned) of the clarinet pipe, the acoustic pressure is a maximum.

Explain why there is a displacement node at this end of the clarinet.

(c) It is possible to blow some wind instruments harder so that the sound is **double** the frequency of the fundamental.

Explain why this is possible with a flute and is not possible with a clarinet.

(d) When the wind instrument is being played, the air inside can warm up and the notes played become sharper (have a slightly higher frequency).

Explain why this happens.

(e) Explain how standing sound waves can occur in open pipes.

(8)

QUESTION SIX: STANDING WAVES (8 marks)

Solar radius = 6.96×10^{8} m

A pulsating variable star is a star whose intensity varies in a regular, periodic fashion. White dwarf stars are examples of such a star.

In one model, the period of a pulsating variable star may be estimated by considering the star to be executing radial pulsations in the fundamental standing wave mode. That is, the star's radius varies periodically with time, with a displacement antinode at the star's surface.

(a) Would the centre of the star be a displacement node or antinode? Explain.

(b) The pulsating variable star can be modelled as a pipe with one open end.

Explain how a standing wave can be formed in a pipe with one end open.

(c) By analogy with a pipe with one open end, show that the period of the fundamental pulsation, T, of the variable star is given by, $T = \frac{4R}{v_{av}}$, where R is the equilibrium radius of the star, and v_{av} is the average speed of sound in the star.

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(d) A typical white dwarf star is composed of material with a bulk modulus of 1.33×10^{22} Pa, density of 1×10^{10} kg m^{-3} and a radius equal to 9.0×10^{-3} × solar radius. The bulk modulus is a measure of the compressibility of the material – a high bulk modulus indicates a high degree of incompressibility.

It can be shown that in a fluid or gas, the average speed of sound is given by the following relationship, $v_{av} = \sqrt{\frac{\beta}{\rho}}$ where β = bulk modulus and ρ = density.

By using this relationship and that given in (c), calculate the pulsation period for a typical white dwarf star.

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(8)