Name:			Total Mark	
School:				

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2025 Intermediate Physics Challenge

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

You may use any standard exam board formula and data booklet

Section A: Ten multiple choice questions worth 1 mark each (worth 10 marks in total).

Allow about 15 minutes for this section.

Section B: Two short answer questions (worth 10 marks in total).

Questions require a clear explanation of the underlying physics principles.

Allow about 10 minutes for this section.

Section C: Two extended numerical questions requiring calculations (worth 30 marks in total).

Questions may be set on unfamiliar topics. Additional information necessary to answer the question will be given in each question.

Allow about 35 minutes for this section.

Useful Equations

The following useful equation may be unfamiliar to some students:

$\rho = {}^{m}/_{V}$ density = mass ÷ volume

$\Delta p = \rho \times g \times \Delta h$ pressure due to a column of fluid

= density of fluid x gravitational field strength x height of column

$\Delta E = m \times L$ thermal energy for a change of state = mass x specific latent heat

$\Delta E = m \times c \times \Delta\theta$ change in thermal energy

= mass x specific heat capacity x change in temperature

$P = I^2 \times R$ Power dissipated in a resistor = current ^{2} x resistance

$E_e = \frac{1}{2} \times F \times e$ Elastic potential energy = ½ x Force x extension

$E_e = \frac{1}{2} \times k \times e^2$ Elastic potential energy = ½ x spring constant x extension^2

The following constants should be used

$\mathrm{g} = 9.8\,\mathrm{N/kg}$ gravitational field strength on Earth

Section A: Multiple Choice Answers

Write the letter corresponding to your chosen answer in the grid below.

The first column has been done as an example if the answer to **question zero** were C.

Question	0	1	2	3	4	5	6	7	8	9	10
Answer	C										

Section A: Multiple Choice Questions

Question 1

Earth orbits the sun at a distance of 1.0 astronomical units (au). Mars orbits the Sun at a distance of 1.5 au.

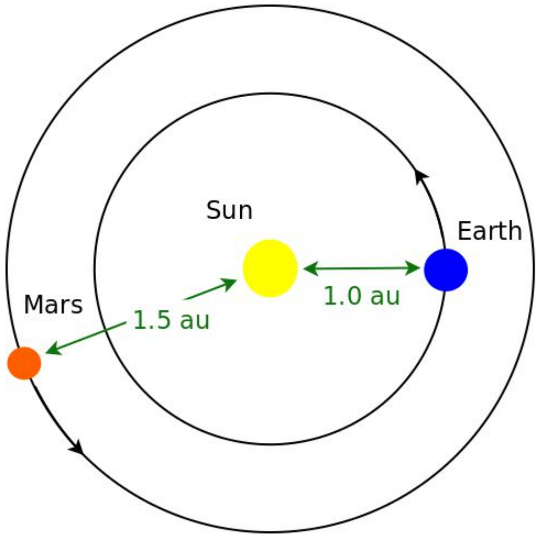
Assume the orbits of both Earth and Mars are circular.

1 au = 1.5×10^{11} m.

Speed of light = 3.0×10^{8} m/s.

As Earth and Mars move along their orbital paths the time to send a signal from Earth to Mars varies.

The minimum time to send a signal from Earth to Mars is approximately:



A. 4 minutes 10 seconds

B. 8 minutes 20 seconds

C. 12 minutes 30 seconds

D. 20 minutes 50 seconds

Question 2

As part of a physics demonstration, a catapult is made from a sample of elastic material.

The elastic material obeys Hooke's law.

The catapult is used to launch a 200 g mass vertically upwards.

A force of 45 N is used to extend the elastic material by 24 cm.

When the catapult is released, the mass gains a maximum height of 2.1 m above its starting position.

The efficiency of the catapult is approximately:

A. 15%

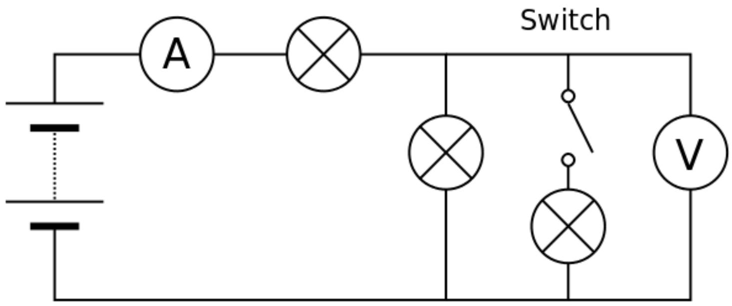
B. 30%

C. 40%

D. 75%

Question 3

A student builds a circuit with a battery, three bulbs and a switch. They include an ammeter and voltmeter as shown.



Initially the switch is open so that only two bulbs are illuminated.

The switch is then closed so that all three bulbs are illuminated.

How do the readings on the voltmeter and ammeter change when the switch is closed?

	Ammeter reading	**Voltmeter reading**
A	increases	increases
B	increases	reduces
C	reduces	increases
D	reduces	reduces

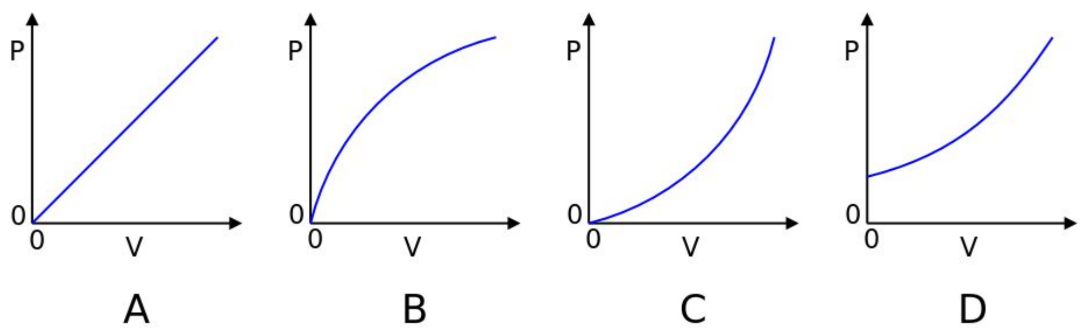
Question 4

A fixed value resistor is connected to a variable power supply.

The potential difference across the resistor starts at zero and is gradually increased.

The resistor dissipates power (and gets hot).

Which graph shows how the power dissipated (P) depends on the potential difference (V) across the resistor?



Question 5

A physics student performs an experiment to determine the thickness of a thin film of oil floating on the surface of water in a tray.

A tiny drop of oil is suspended on a small wire loop. The mass of the oil drop is found to be 0.11 grams.

The oil drop on the water surface spreads out to form a thin circular film with an average radius of 20 cm.

The density of the oil = 850 $\mathrm{kg/m^3}$

The thickness of the oil film is approximately:

A. 0.1 $\mu\mathrm{m}$

B. 0.2 $\mu\mathrm{m}$

C. 1.0 $\mu\mathrm{m}$

D. 2.0 $\mu\mathrm{m}$

Question 6

A depth gauge uses a pulse of ultrasound to determine the depth of water in a lake.

The water in the lake is warmer near the surface and colder at greater depths.

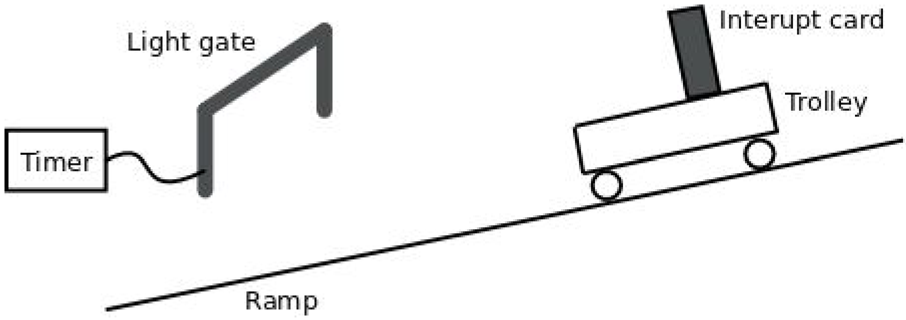
The speed of ultrasound in water increases as the temperature of the water increases.

As the pulse of ultrasound travels from the surface to the bottom of the lake:

A	The frequency of the ultrasound increases	The wavelength of the ultrasound decreases
B	The frequency of the ultrasound stays the same	The wavelength of the ultrasound decreases
C	The frequency of the ultrasound stays the same	The wavelength of the ultrasound increases
D	The frequency of the ultrasound decreases	The wavelength of the ultrasound increases

Question 7

A physics student determines the acceleration of a trolley on a ramp.



The trolley is released from rest and the time taken to reach the light gate is recorded using a stopwatch. The light gate is connected to a timer that records the time taken for the interrupt card to pass through the light gate.

Knowing the length of the interrupt card, the student calculates the velocity of the trolley.

Knowing the velocity, the student calculates the acceleration of the trolley.

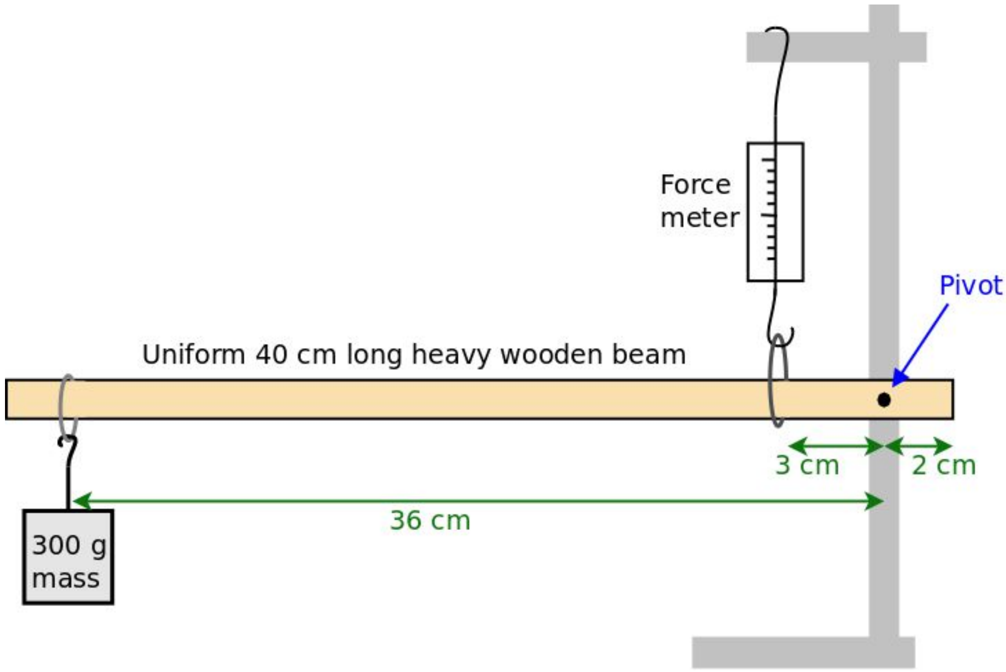
Unfortunately the student measures the length of the interrupt card incorrectly. The student carelessly determines the length of the interrupt card to be 4.0 cm. The correct length of the interrupt card is 3.8 cm.

How does this error in measurement affect the values of velocity and acceleration **calculated** by the student?

	Velocity	**Acceleration**
A	Calculated value is too high	Calculated value is too high
B	Calculated value is too low	Calculated value is too high
C	Calculated value is too high	Calculated value is too low
D	Calculated value is too low	Calculated value is too low

Question 8

A physics demonstration is used to show the forces acting on a model forearm.



The mass of the uniform 40 cm long heavy wooden beam is 200 g.

The pivot is 2 cm from the end of the wooden beam.

A mass of 300 g is suspended 36 cm from the pivot.

A force meter is attached 3 cm from the pivot.

The force recorded on the force meter is:

A. 47 N

B. 35 N

C. 24 N

D. 12 N

Question 9

Ultrasound can be used for medical imaging. Ultrasound frequencies used for medical imaging range from 2 MHz to approximately 15 MHz.

Higher ultrasound frequencies provide images with better detail because:

A. Higher frequency ultrasound has a shorter wavelength

B. Higher frequency ultrasound has a longer wavelength

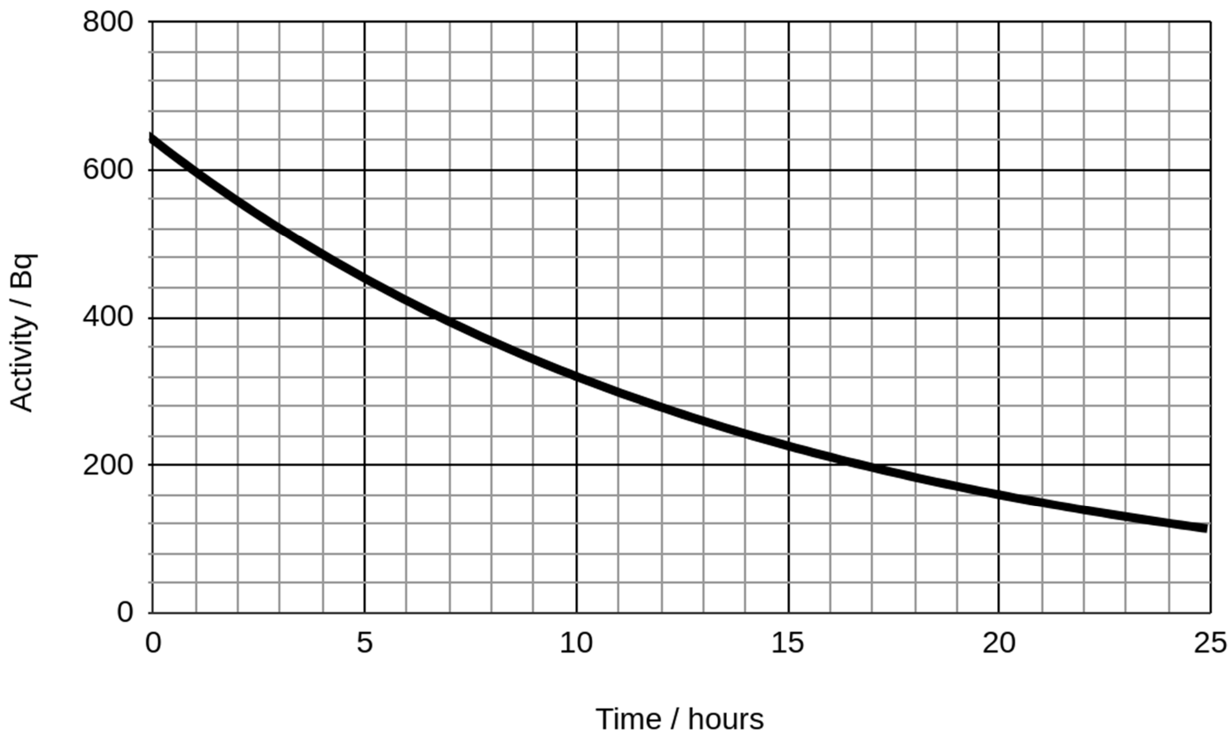
C. Higher frequency ultrasound has a higher energy

D. Higher frequency ultrasound is absorbed (attenuated) more easily

Question 10

A sample of a radioactive isotope with an initial activity of 640 Bq and a half-life of several hours is prepared for use in a medical procedure.

The graph shows how the activity of the sample changes with time



The time taken for the activity of the sample to reduce to 10 Bq is approximately:

A. 40 hours

B. 60 hours

C. 80 hours

D. 100 hours

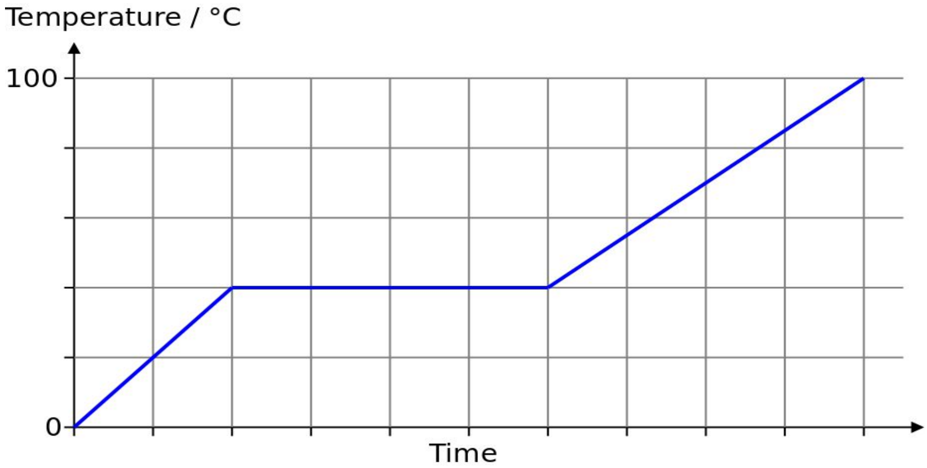
Section B: Short Answer Questions

Question 11

A well insulated sample of material of mass m is heated using an electric heater of power P. The heater transfers energy to the sample of material at a **constant rate**.

The sample is solid at 0 °C and liquid at 100 °C.

The graph shows the temperature of the sample as a function of time as it is heated.



Using information from the graph, **explain how the graph shows** that:

- the specific heat capacity of the material when it is a liquid **is greater** than the specific heat capacity of the material when it is a solid
- the specific latent heat of fusion of the material derived from the graph in units of $\mathrm{J/kg}$ is **numerically greater** than the specific heat capacity of the material as a liquid derived from the graph in units of $\mathrm{J/(kg\ ^\circ C)}$

[5 marks]

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Question 12

When current flows through a filament lamp (bulb) the filament heats up.

Explain why:

- When the bulb is turned on and current flows, the temperature of the filament increases from its initial value to some higher temperature
- The filament reaches a **constant** final temperature

[5 marks]

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Section C: Extended Numerical Questions

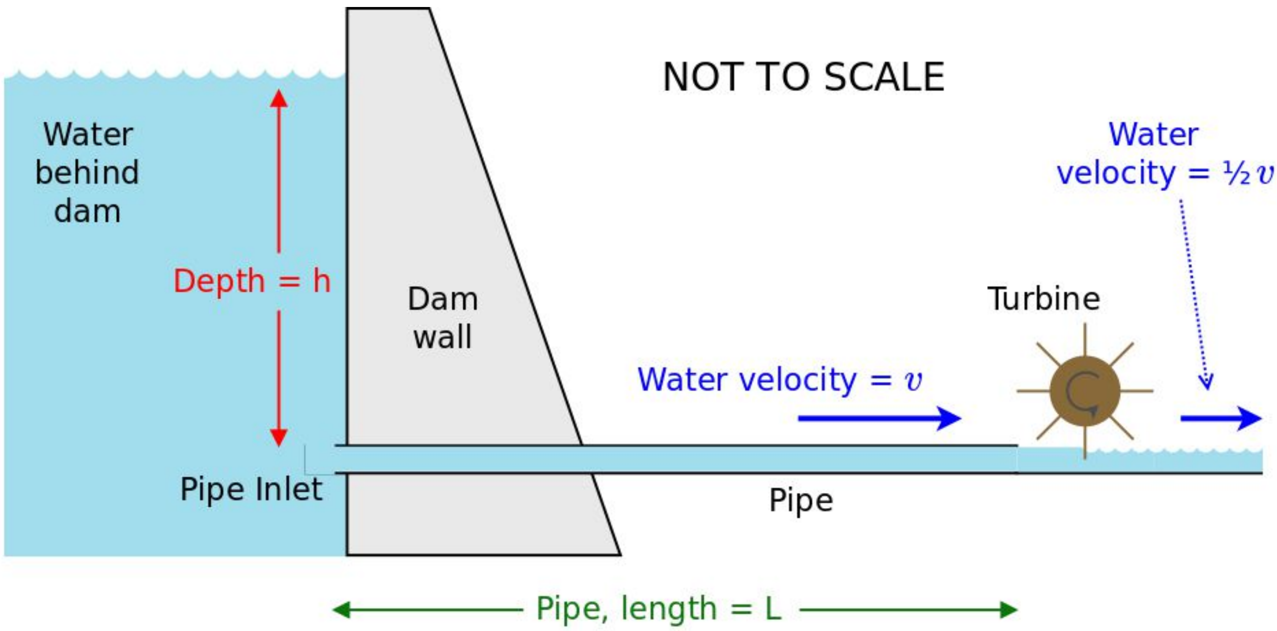
Question 13: Power from a model water turbine

A student makes a model of a hydroelectric power station using water held back behind a model dam, a long drinking straw as a pipe and a small model turbine.

A diagram of the model hydroelectric power station is shown below.

The water behind the dam causes a pressure difference between the ends of the pipe (the drinking straw) and, as a result, water flows through the pipe. The water from the pipe is used to turn the turbine.

The density of the water is $\rho = 1000\ \mathrm{kg/m^3}$.



a) Show that the pressure **due to the water** at a depth of h = 10 cm below the surface of the water is approximately 1000 Pa.

[1 mark]

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The volume of water that flows through a pipe (the straw) can be estimated using the equation *

$$\frac{\Delta V}{\Delta t} = \frac{\pi r^4 \Delta p}{8\eta L}$$

Where

ΔV = volume of water flowing through the pipe (m^3)

Δt = time taken for water to flow (s)

$\Delta V/\Delta t$ = flow rate (m^3/s)

r = radius of pipe (m)

Δp = difference in pressure across the length of the pipe

η = viscosity of water. This is a constant with a value of $\mathbf{9 \times 10^{-4}}$ Pa s

L = length of the pipe (m)

The model hydroelectric power station uses a drinking straw as a pipe that is 30 cm long and has a diameter of 5.0 mm.

The inlet to the pipe is 10 cm below the surface of the water behind the dam.

The outlet of the pipe is at atmospheric pressure.

b) Show that the volume of water flowing through the pipe per second, i.e. the flow rate $(\Delta V/\Delta t)$, is approximately $6 \times 10^{-5}\ \mathrm{m}^3/s$

[2 marks]

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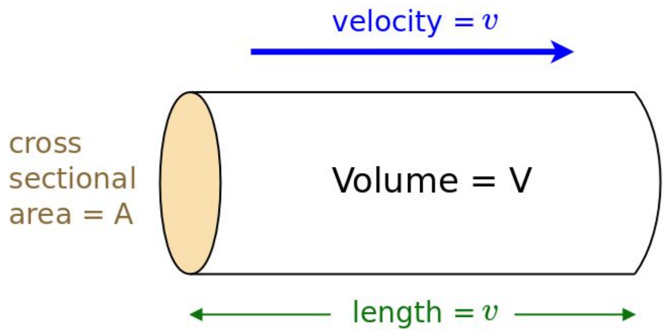
The volume of water emerging from the pipe in **one second** can be thought of as a cylinder of water with a length v, where v is the velocity (length travelled per second) of the water.



c) Calculate the velocity of the water emerging from the pipe.

[3 marks]

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d) Calculate the mass of water leaving the pipe each second.

[2 marks]

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The water leaving the pipe has kinetic energy.

The moving water is incident on the turbine blades and turns the turbine. Some of the water's kinetic energy store is transferred to electrical work in an external circuit and the kinetic energy of the water leaving the turbine is reduced.

The water leaving the turbine has half the velocity of the water that hits the turbine blades as it emerges from the pipe (see diagram).

e) Determine the maximum possible power output of the turbine.

[4 marks]

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The students suggests two changes to the model power station to increase the power output from the turbine:

- Use two identical 30 cm long drinking straws side by side, each with a diameter of 5 mm

OR

- Use one larger diameter, 30 cm long drinking straw, with **twice the cross-sectional area** of the original drinking straw

f) **Explain** which of these two changes would lead to the greatest increase in power output from the turbine.

[3 marks]

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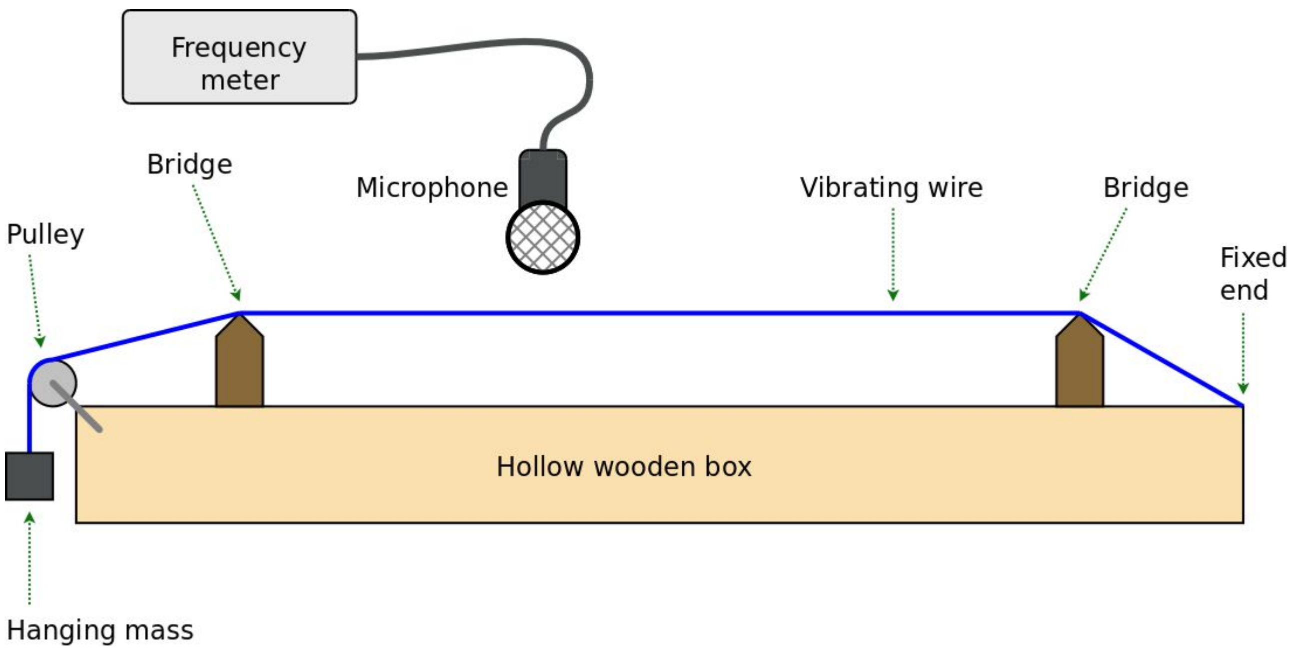
* Note: The equation used assumed a smooth laminar flow through a long narrow pipe. The equation is unlikely to be completely valid for the situation given in the question. However, the general principle is correct and illustrates the ideas behind a hydroelectric power station.

Question 14: Using a sonometer

A sonometer is used to investigate the vibration of a wire under tension and can be used to model a musical instrument such as a guitar or piano.

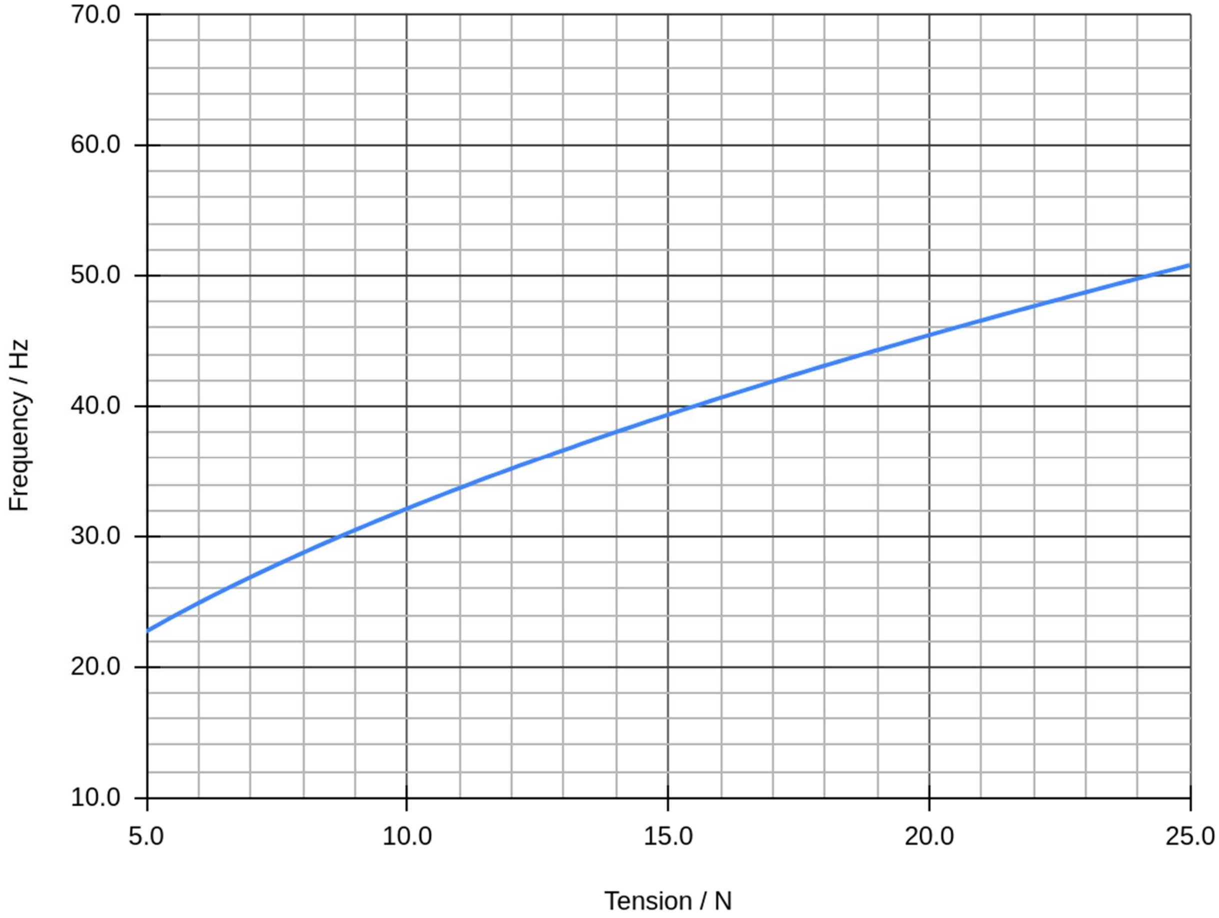
The sonometer shown in the diagram has a wire under tension between two supports called bridges.

The wire **between the two bridges** is plucked and vibrates, making an audible sound. The hollow wooden box makes the sound louder. The tension in the wire is varied by adjusting the hanging mass.



The frequency of the sound produced by the vibrating wire can be measured using a microphone connected to a frequency meter.

A graph of the frequency of the sound produced as a function of the tension in the wire is shown below.



a) Use data from the graph to show that $Frequency^2$ is directly proportional to $Tension$

i.e. show that $f^2 \propto T$

[3 marks]

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The equation for the frequency of vibration of the wire is

$$f^2 = \frac{T}{4L^2\mu}$$

Where

f = frequency of vibration of the wire (Hz)

T = tension in the wire (N)

L = length of the wire (m)

μ = mass per unit length (kg/m) i.e. the mass of a 1 m length of wire

b) The length of the wire between the two bridges is 110 cm.

Using information from the graph, determine a value for the mass per unit length, μ.

[3 marks]

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c) The distance between the two bridges can be changed by moving the bridges.

For the same piece of wire, the distance between the bridges is reduced to 90 cm.

Add a line to the graph to show the relationship between frequency and tension for the shorter section of wire. **Label the line "part (c)"**.

[3 marks]

d) The diameter of the wire used to make the sonometer can be changed.

The wire is replaced with a different wire made of the same material but having **twice** the diameter of the original wire.

For a distance between the bridges of 110 cm, **add a line to the graph** to show the relationship between frequency and tension for the thicker wire. **Label the line "part (d)"**.

[3 marks]

The sonometer can be used to model a stringed musical instrument such as a guitar or piano. Stringed instruments have different strings under tension. When the string is plucked or struck, the string vibrates at a particular frequency producing a musical note.

e) A grand piano uses strings that are different thicknesses and different lengths to produce different notes.

Explain why a grand piano needs to use strings that are different thicknesses and different lengths.

[3 marks]

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END OF QUESTIONS