SECTION A

1. Which pair of units contains one derived unit and one S*I* base unit?

A	ampere	coulomb
B	kilogram	kelvin
C	metre	second
D	newton	pascal

2. What is equivalent to 2000 microvolts?

A $2\,\mu J\,C^{-1}$ **B** $2\,mV$ **C** $2\,pV$ **D** $2000\,mV$

3. The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

where k is a constant that has no units.
What is the value of n?

A $\frac{1}{2}$ **B** 1 **C** $\frac{3}{2}$ **D** 2

4. An experiment is carried out to measure the resistance of a wire.
The current in the wire is (1.0 ± 0.2) A and the potential difference across the wire is (8.0 ± 0.4) V. What is the resistance of the wire and its uncertainty?

A $(8.0 \pm 0.2)\,\Omega$

B $(8.0 \pm 0.6)\,\Omega$

C $(8 \pm 1)\,\Omega$

D $(8 \pm 2)\,\Omega$

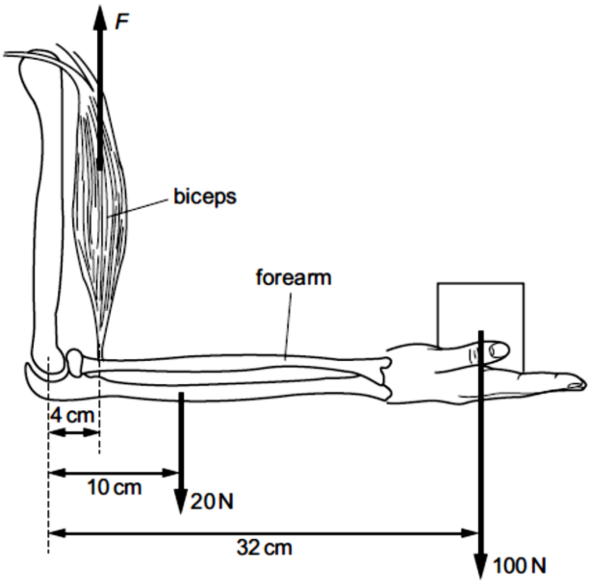
5. The Young modulus of the material of a wire is to be found. The Young modulus E is given by the equation below.

$$E = \frac{4Fl}{\pi d^2 x}$$

The wire is extended by a known force and the following measurements are made. Which measurement has the largest effect on the uncertainty in the value of the calculated Young modulus?

	measurement	symbol	value
A	length of wire before force applied	l	$2.043 \pm 0.002\,m$
B	diameter of wire	d	$0.54 \pm 0.02\,mm$
C	force applied	F	$19.62 \pm 0.01\,N$
D	extension of wire with force applied	x	$5.2 \pm 0.2\,mm$

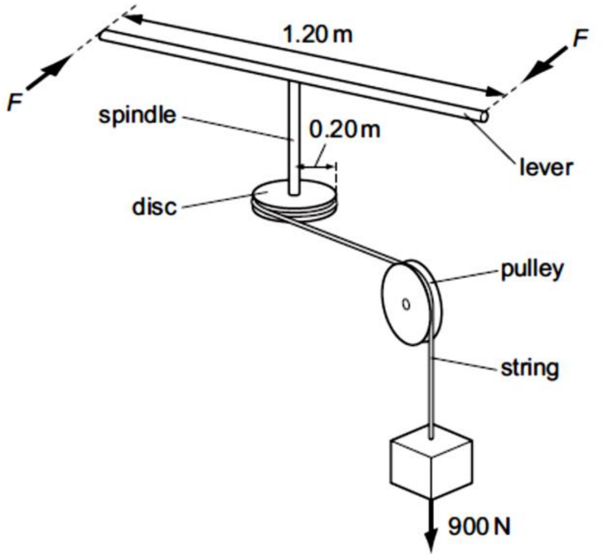
6. A man holds a 100 N load stationary in his hand. The combined weight of the forearm and hand is 20 N. The forearm is held horizontal, as shown.



What is the vertical force F needed in the biceps?

A 750 N **B** 800 N **C** 850 N **D** 900 N

7. A spindle is attached at one end to the centre of a lever of length 1.20 m and at its other end to the centre of a disc of radius 0.20 m. A string is wrapped round the disc, passes over a pulley and is attached to a 900 N weight.



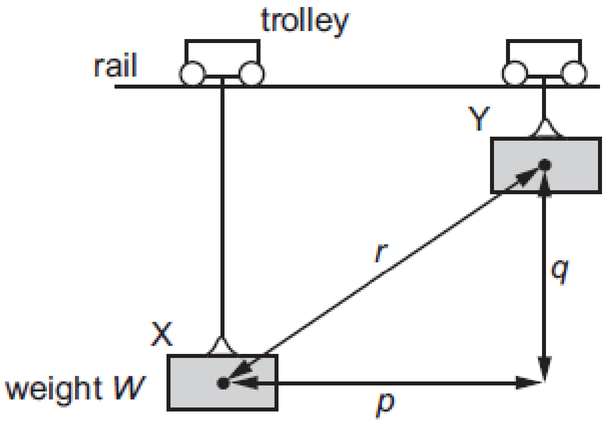
What is the minimum force F, applied to each end of the lever, that could lift the weight?

A 75 N **B** 150 N **C** 300 N **D** 950 N

8. What is the average power output of a laser that can deliver 0.20 J of energy in 10 ns?

A 2 nW **B** 20 mW **C** 200 kW **D** 20 MW

9. A weight W hangs from a trolley that runs along a rail. The trolley moves horizontally through a distance p and simultaneously raises the weight through a height q.



As a result, the weight moves through a distance r from X to Y. It starts and finishes at rest.

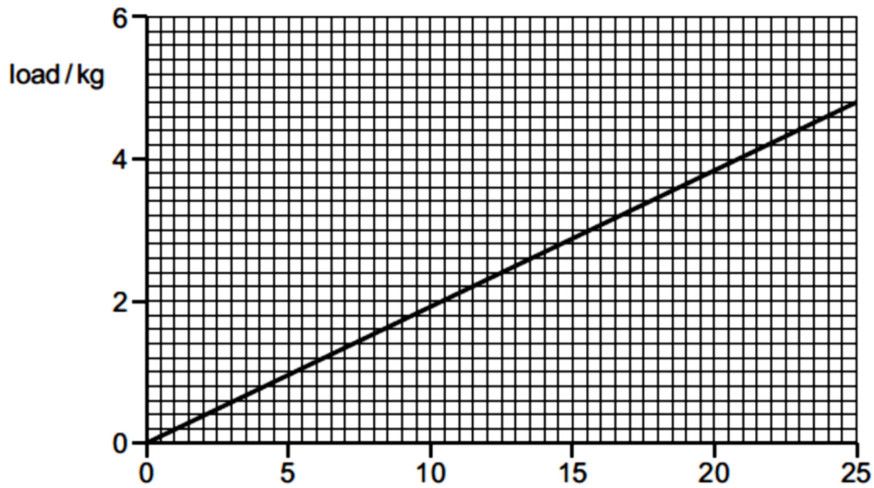
How much work is done on the weight during this process?

A Wp **B** $W(p + q)$ **C** Wq **D** Wr

10. The engine of a car exerts a force of 600 N in moving the car 1.0 km in 150 seconds.
What is the average output power of the engine?

A 4.0 W **B** 4.0 kW **C** 90 kW **D** 90 MW

11. The graph is a load-extension graph for a wire undergoing elastic deformation.



How much work is done on the wire to increase the extension from 10 mm to 20 mm?

A 0.028 J **B** 0.184 J **C** 0.28 J **D** 0.37 J

12. Which statement about longitudinal waves is correct?
A Longitudinal waves include radio waves travelling through air.
B Particles in a longitudinal wave vibrate at right-angles to the direction of transfer of wave energy.
C Some types of longitudinal wave can also be transverse.
D Stationary waves can be produced by the superposition of longitudinal waves.

13. The order of magnitude of the frequency of the longest-wavelength ultraviolet waves can be expressed as 10^x Hz.
What is the value of x?

A 13 B 15 C 17 D 19

14. The speed v of waves in deep water is given by the equation

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

where λ is the wavelength of the waves and g is the acceleration of free fall.
A student measures the wavelength λ and the frequency f of a number of these waves.
Which graph should he plot to give a straight line through the origin?

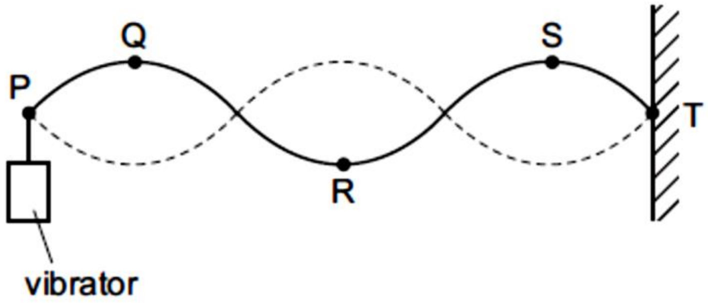
A f^2 against λ

B f against λ^2

C f against $\frac{1}{\lambda}$

D f^2 against $\frac{1}{\lambda}$

15. A stationary wave on a stretched string is set up between two points P and T.



Which statement about the wave is correct?

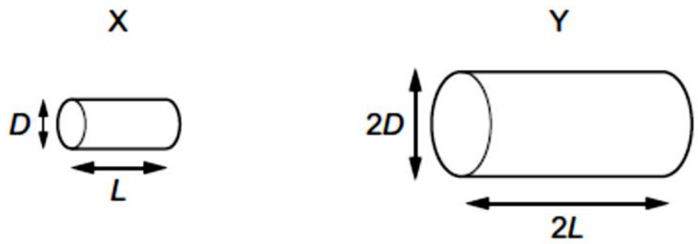
A Point R is at a node.

B Points Q and S vibrate in phase.

C The distance between P and T is three wavelengths.

D The wave shown has the lowest possible frequency.

16. Two electrically-conducting cylinders X and Y are made from the same material.
Their dimensions are as shown.

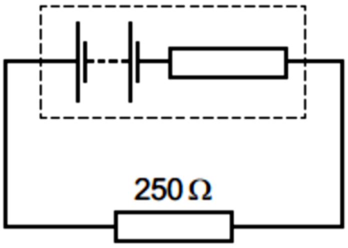


The resistance between the ends of each cylinder is measured.

What is the ratio $\frac{\text{resistance of X}}{\text{resistance of Y}}$?

A $\frac{2}{1}$ B $\frac{1}{1}$ C $\frac{1}{2}$ D $\frac{1}{4}$

17. A battery, with a constant internal resistance, is connected to a resistor of resistance 250 Ω, as shown.

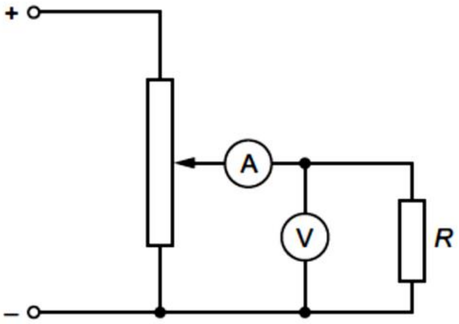


The current in the resistor is 40 mA for a time of 60 s. During this time 6.0 J of energy is lost in the internal resistance.
What are the energy supplied to the external resistor during the 60 s and the e.m.f. of the battery?

	energy / J	e.m.f. / V
A	2.4	2.4
B	2.4	7.5
C	24	10.0
D	24	12.5

18. Which symbol represents a component whose resistance is designed to change with temperature?

19. In the circuit below, a voltmeter of resistance RV and an ammeter of resistance RA are used to measure the resistance R of the fixed resistor.



Which condition is necessary for an accurate value to be obtained for R?

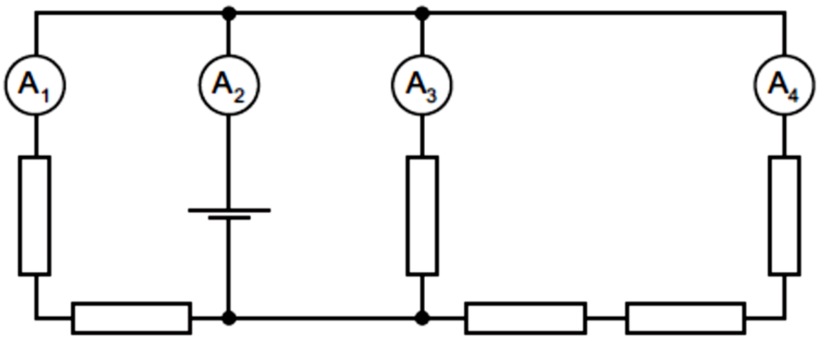
A R is much smaller than R_V.

B R is much smaller than R_A.

C R is much greater than R_V.

D R is much greater than R_A.

20. In the circuit shown, all the resistors are identical and all the ammeters have negligible resistance.



The reading on ammeter A1 is 0.6 A.
What are the readings on the other ammeters?

	reading on ammeter A_2 / A	reading on ammeter A_3 / A	reading on ammeter A_4 / A
A	1.0	0.3	0.1
B	1.4	0.6	0.2
C	1.8	0.9	0.3
D	2.2	1.2	0.4

SECTION B

1. A microphone detects a musical note of frequency *f*. The microphone is connected to a cathode-ray oscilloscope (c.r.o.). The signal from the microphone is observed on the c.r.o. as illustrated in Fig. 1.1.

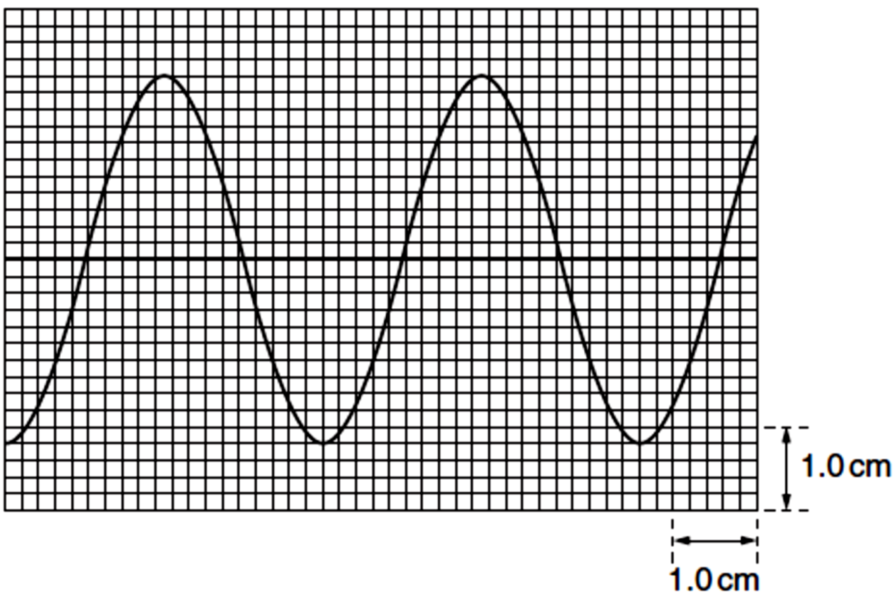


Fig 1.1

The time-base setting of the c.r.o. is 0.50 ms cm^{-1}. The Y-plate setting is 2.5 mV cm^{-1}.

(a) Use Fig. 1.1 to determine

(i) the amplitude of the signal,

(ii) the frequency *f*,

(iii) the actual uncertainty in *f* caused by reading the scale on the c.r.o.

(b) State *f* with its actual uncertainty.

f = ... ± .... Hz

2. **(a)** State the principle of conservation of momentum.

(b) A ball X and a ball Y are travelling along the same straight line in the same direction, as shown in Fig. 2.1.

Fig 2.1

Ball X has mass 400 g and horizontal velocity 0.65 m s^{-1}. Ball Y has mass 600 g and horizontal velocity 0.45 m s^{-1}.

Ball X catches up and collides with ball Y. After the collision, X has horizontal velocity 0.41 m s–1 and Y has horizontal velocity *v*, as shown in Fig. 2.2.

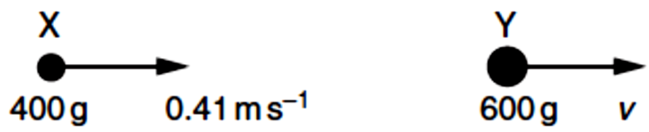


Fig 2.2

Calculate

(i) the total initial momentum of the two balls,

(ii) the velocity *v*,

(iii) the total initial kinetic energy of the two balls.

(c) Explain how you would check whether the collision is elastic.

(d) Use Newton's third law to explain why, during the collision, the change in momentum of X is equal and opposite to the change in momentum of Y.

3. **(a)** A wire has length 100 cm and diameter 0.38 mm. The metal of the wire has resistivity 4.5×10^{-7} Ω m. Show that the resistance of the wire is 4.0 Ω.

(b) The ends B and D of the wire in **(a)** are connected to a cell X, as shown in Fig. 3.1.

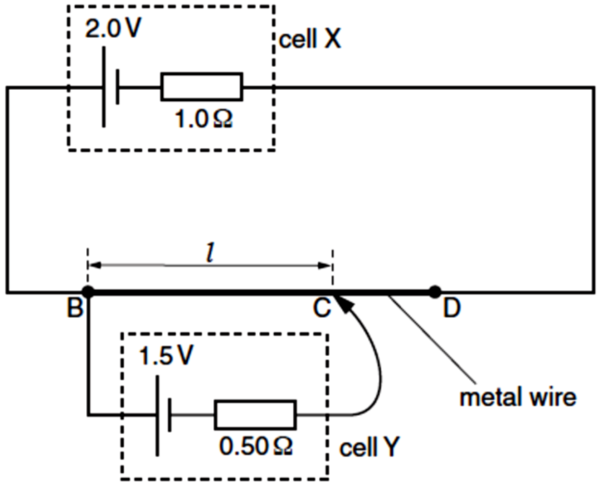


Fig 3.1

The cell X has electromotive force (e.m.f.) 2.0 V and internal resistance 1.0 Ω.
A cell Y of e.m.f. 1.5 V and internal resistance 0.50 Ω is connected to the wire at points B and C, as shown in Fig. 3.1.
The point C is distance *l* from point B. The current in cell Y is zero.
Calculate

(i) the current in cell X,
(ii) the potential difference (p.d.) across the wire BD,
(iii) the distance *l*.

(c) The connection at C is moved so that *l* is increased. Explain why the e.m.f. of cell Y is less than its terminal p.d.

4. **(a) (i)** Explain what is meant by a *progressive transverse* wave.
(ii) Define frequency.
(b) The variation with distance *x* of displacement *y* for a transverse wave is shown in Fig. 4.1.

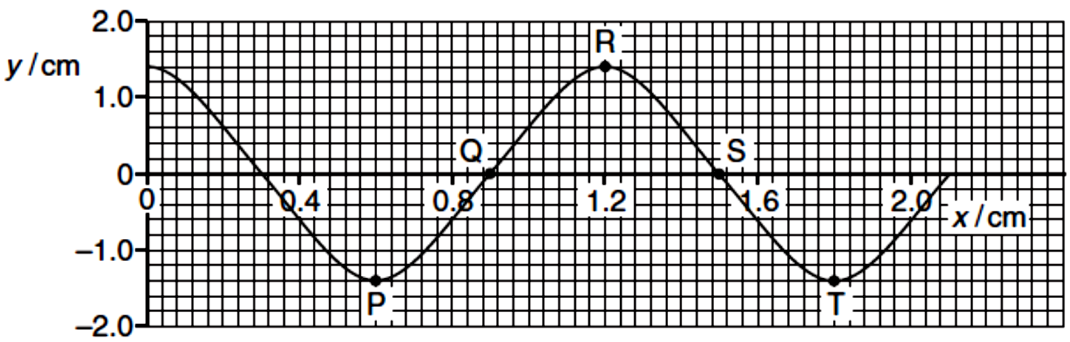


Fig 4.1

On Fig. 4.1, five points are labelled.
Use Fig. 4.1 to state any two points having a phase difference of

(i) zero,
(ii) 270°.

(c) The frequency of the wave in **(b)** is 15 Hz.

Calculate the speed of the wave in **(b)**.

(e) Two waves of the same frequency have amplitudes 1.4 cm and 2.1 cm.
Calculate the ratio

$$\frac{\text{intensity of wave of amplitude 1.4 cm}}{\text{intensity of wave of amplitude 2.1 cm}}.$$

5. A fixed mass of gas has an initial volume of 5.00×10^{-4} m^3 at a pressure of 2.40×10^5 Pa and a temperature of 288 K. It is heated at constant pressure so that, in its final state, the volume is 14.5×10^{-4} m^3 at a temperature of 835 K, as illustrated in Fig. 5.1.

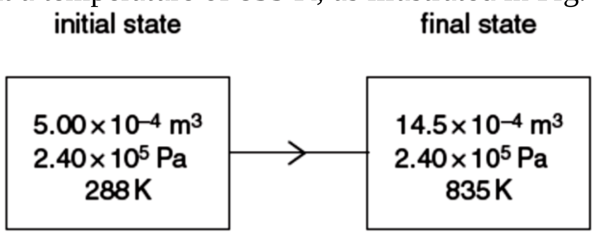


Fig 5.1

(a) Show that these two states provide evidence that the gas behaves as an ideal gas.
(b) The total thermal energy supplied to the gas for this change is 569 J.
Determine

(i) the external work done,

(ii) the change in internal energy of the gas. State whether the change is an increase or a decrease in internal energy.

6. **(a)** Define *electric potential* at a point.

(b) An isolated metal sphere is charged to a potential V. The charge on the sphere is q. The charge on the sphere may be considered to act as a point charge at the centre of the sphere.

The variation with potential V of the charge q on the sphere is shown in Fig. 6.1.

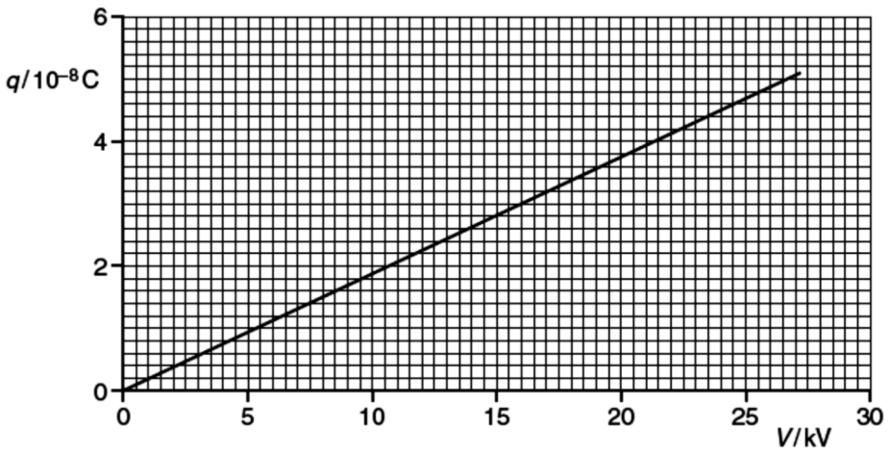


Fig 6.1

Use Fig. 6.1 to determine

(i) the radius of the sphere,

(ii) the energy required to increase the potential of the sphere from zero to 24 kV.

(c) The sphere in **(b)** discharges by causing sparks when the electric field strength at the surface of the sphere is greater than 2.0×10^6 V m^{-1}.

Use your answer in (b)(i) to calculate the maximum potential to which the sphere can be charged.

7. **(a)** State what is meant by *quantisation* of charge.

(b) Charged parallel plates, as shown in Fig. 7.1, produce a uniform electric field between the plates.

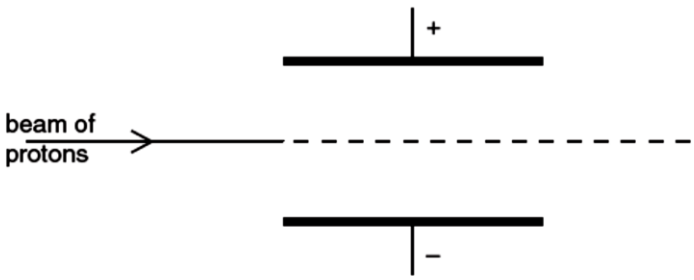


Fig. 7.1

The electric field outside the region between the plates is zero.

A uniform magnetic field is applied in the region between the plates so that a beam of protons passes undeviated between the plates.

(i) State and explain the direction of the magnetic field between the plates.

(ii) The magnetic flux density between the plates is now increased.

On Fig. 7.1, sketch the path of the protons between the plates.

8. (a) By reference to ultrasound waves, state what is meant by the specific acoustic impedance of a medium.

(b) A parallel beam of ultrasound of intensity *I* is incident normally on a muscle of thickness 3.4 cm, as shown in Fig. 8.1.

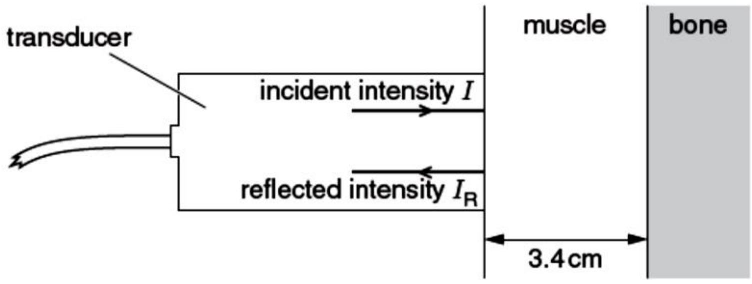


Fig 8.1

The ultrasound wave is reflected at a muscle-bone boundary. The intensity of the ultrasound received back at the transducer is I_R.

Some data for bone and muscle are given in Fig. 8.2.

	specific acoustic impedance / $kg\,m^{-2}\,s^{-1}$	linear absorption coefficient / m^{-1}
bone	6.4×10^6	130
muscle	1.7×10^6	23

Fig 8.1

(i) The intensity reflection coefficient α for two media having specific acoustic impedances Z_1 and Z_2 is given by

$$\alpha = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}.$$

Calculate the fraction of the ultrasound intensity that is reflected at the muscle-bone boundary.

(ii) Calculate the fraction of the ultrasound intensity that is transmitted through a thickness of 3.4 cm of muscle.

(iii) Use your answers in **(i)** and **(ii)** to determine the ratio I_R/I

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