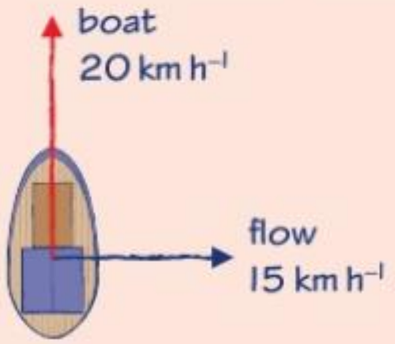
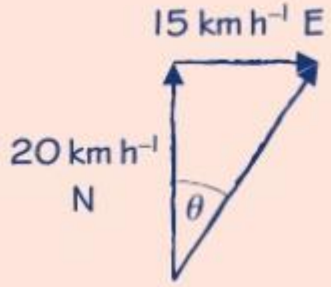
Sem2 Exam Practise 3

Short Answers

Q1

A boat is motoring north with a velocity of 20 km h^{-1} across a river flowing east with velocity 15 km h^{-1}. Find the resultant velocity of the boat. **(2 marks)**





$v = \sqrt{15^2 + 20^2} = 25$ km h^{-1}.

Q2

A cannonball is fired at 150 m s^{-1} at an angle of 30° to the horizontal.

(a) How high does it reach above the ground? (Acceleration due to gravity $g = 9.81\ \mathrm{m\,s^{-2}}$.)

(3 marks)

To calculate how high (vertical displacement, s) the ball travels:

$v^2 = u^2 + 2as$ in which $a = -9.81\ \mathrm{m\,s^{-2}}$

$0^2 = (75)^2 + 2 \times (-9.81)s$

$s = 287\ \mathrm{m}$

(b) How far does it travel and how long is it in flight? **(2 marks)**

The time of flight will be twice the time t to reach the top of the trajectory.

$v = u + at$

$0 = 75 - 9.81t$

$t = 7.65\ \mathrm{s}$

Range (horizontal distance travelled) = horizontal component of velocity × time of flight.

$\therefore$ range $= 150 \cos 30° \times (2 \times 7.65)$

$= 1990\ \mathrm{m}$

Q3

A stone is released from rest at the top of a well. It hits the surface of the water after exactly 3.00 seconds. Calculate the distance between the top of the well and the surface of the water.

($g = 9.81\ \mathrm{m\,s^{-2}}$) **(3 marks)**

$s = ?\ \mathrm{m}$, $u = 0\ \mathrm{m\,s^{-1}}$, $a = 9.81\ \mathrm{m\,s^{-2}}$, $t = 3\ \mathrm{s}$.

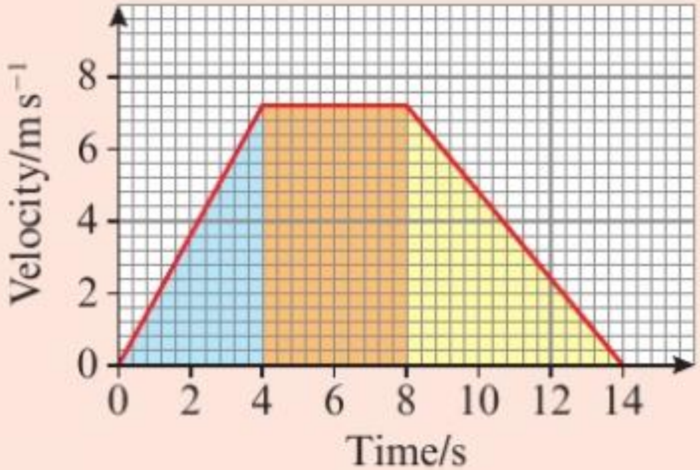
$$s = ut + \frac{1}{2}at^2$$

$$= 0 \times 3 + \frac{1}{2} \times 9.81 \times (3)^2$$

$$= 44.2\ \mathrm{m}\ (3\ \mathrm{s.f.})$$

Q4

(a) Describe the motion of the object in the velocity–time graph shown below. **(6 marks)**



In the first 4 s the object accelerates to 7.2 m s^{-1} with acceleration – from the gradient: 1.8 m s^{-2}.

For the next 4 s the object moves at a constant velocity of 7.2 m s^{-1}.

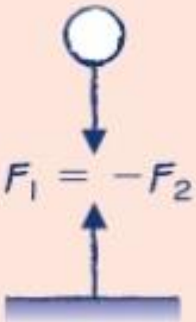
In the last 6 s the object decelerates; $a = -1.2$ m s^{-2}.

(b) How far does the object travel? **(4 marks)**

Total displacement = area under graph = 14.4 + 28.8 + 21.6 = 64.8 m

Q5

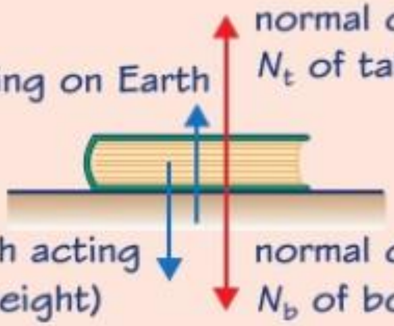
Ignoring air resistance and upthrust, describe the action-reaction pair for a ball in free-fall. **(2 marks)**



The ball experiences the gravitational pull of the Earth and the Earth experiences an upward pull due to the ball. The forces act on different bodies and are both gravitational forces.

Q6

A book is resting on a level table. Describe the action-reaction pair **(4 marks)**



There are two action–reaction pairs: weight and contact force.

Weight: Gravity pulls down on the book. The reaction to this is the upward pull of the book on the Earth.

Contact force: The table pushes upwards on the book. The reaction to this is the downward contact force of the book on the table. In this case the book is in equilibrium and at rest.

Q7

A block of ice of mass 1.0 kg slides across a frozen pond at 6.0 m s^{-1} and collides with a stationary block of ice of mass 2.0 kg. After the collision the 2.0 kg block moves off with a velocity of 4.0 m s^{-1} in the same direction. Assuming that friction is negligible, calculate the velocity of the 1.0 kg block after the collision. **(3 marks)**

Total momentum before collision
= total momentum after collision

$$(1.0 \times 6.0) + (2.0 \times 0) = (1.0 \times v) + (2.0 \times 4.0)$$

$$v = (6 - 8) = -2.0\,\mathrm{m\,s^{-1}}$$

The minus sign shows that the 1 kg block rebounds, moving in the opposite direction to its initial motion.

Q8

A bullet with a mass of 20 g is fired from a rifle with a barrel 80 cm long with a velocity of 500 m s^{-1}.

(a) What is the kinetic energy of the bullet? **(2 marks)**

$E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2} \times 0.020 \times (500)^2 = 2500\,\text{J}$

(b) What is the average force on the bullet whilst it is accelerating along the barrel? **(2 marks)**

2500 J = ΔW, the work done on the bullet by the average force in the barrel

average force $F = \frac{\Delta W}{s} = \frac{2500}{0.8} = 3100\,\text{N}$

Q9

A student of mass 50 kg climbs 25 steps up a tall ladder. The rungs on the ladder are 30 cm apart. What is the increase in the student's gravitational potential energy when at the top of the ladder? **(2 marks)**

Total height climbed = $0.30 \times 25 = 7.5$ m

$\Delta E_{grav} = mgh$

$\Delta E_{grav} = 50 \times 9.81^{-1} \times 7.5 = 3700$ J

Q10

An object of mass 2.0 kg is raised to a height of 30 m above the ground and then dropped.

(a) Describe the energy changes that take place from the moment the object is released until after it has come to rest on the ground. **(4 marks)**

The object has gained gravitational potential energy (GPE) $E_{grav} = mg\Delta h$ $(= 2.0 \times 9.81 \times 30\,\text{J})$ from being raised.

As it falls, its GPE decreases (h decreases) and it gains kinetic energy (KE) as it accelerates.

At any given moment throughout the fall, by the principle of conservation of energy, loss of GPE = gain in KE.

On impact all the GPE the object gained when it was raised has been transferred into KE. It is assumed there is no air resistance.

During the impact the energy is converted into sound, heat and deformation of the ground.

(b) Use the principle of conservation of energy to calculate the speed with which it hits the ground. **(3 marks)**

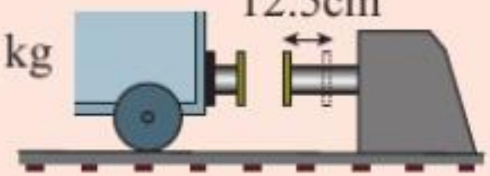
GPE lost = KE gained

$mg\Delta h = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2g\Delta h}$

$\therefore v = \sqrt{(2 \times 9.81 \times 30)} = 24.3\,\text{m s}^{-1}$

Q11

The diagram shows a railway truck hitting a buffer. The buffer spring is compressed by 12.5 cm when the truck is brought to rest.



(a) What is the kinetic energy of the moving truck? **(3 marks)**

$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 2.5 \times 10^3 \times (0.50)^2$

$= 312.5 = 310\,\mathrm{J}$ to 2 s.f.

(b) What is the average force F exerted by the buffer, assuming all the truck's kinetic energy is converted to stored energy in the buffer spring? **(3 marks)**

Work compressing the spring = $F \times$ distance

$F \times 0.125 = 312.5$

$F = 2500\,\mathrm{N}$

Q12

1 A man pushes a box at a steady rate of $2.5\,\mathrm{m\,s^{-1}}$ for 12 seconds by applying a force of 80 N. Calculate the work he does and his power output. **(3 marks)**

The distance through which the push of 80 N is applied is $2.5\,\mathrm{m\,s^{-1}} \times 12\,\mathrm{s} = 30\,\mathrm{m}$

$\therefore\ \Delta W = 80 \times 30 = 2400\,\mathrm{J}$

$$P = \frac{W}{t} = \frac{2400}{12} = 200\,\mathrm{W}$$

2 A forklift truck lifts a 250 kg pallet and load through 180 cm in 1.2 s. Calculate the work done and the power of the forklift. **(3 marks)**

$W = F\Delta s = mg\Delta s$

$= 250 \times 9.81 \times 1.8 = 4414.5$

or 4400 J to 2 s.f.

$$P = \frac{W}{t} = \frac{4414.5}{1.2} = 3700\,\mathrm{W} \text{ or } 3.7\,\mathrm{kW}$$

3 An electric motor raises a 600 kg lift at $3.0\,\mathrm{m\,s^{-1}}$. Assuming no energy is wasted, calculate the power of the electric motor. **(3 marks)**

In one second the motor does work $= mg\Delta h$ $= 600 \times 9.81 \times 3 = 17658\,\mathrm{J}$.

Motor power $= 17.7\,\mathrm{kW}$.

Q13

Lamp A is a tungsten filament lamp. These are only 5% efficient. Lamp B is a compact fluorescent lamp. These are claimed to use 75% less energy than filament bulbs. Lamp A is rated at 60 W.

Lamps A and B are both in use for 2.0 hours.

(a) Find the total electrical energy input to lamp A in joules. Calculate the useful light output of lamp A in joules and say how the remaining amount is 'wasted'. **(4 marks)**

$E = P \times t$

Energy input = 60 × (2 × 3600)
= 432 000 J

Useful output as light = 432 000 × 0.05
= 21 600 J

The remaining 410 400 J are converted into heat energy.

(b) Assuming that both lamps have the same useful light output and the maker's claim for B is accurate, calculate how much electrical energy lamp B uses in 2.0 h, and the efficiency of lamp B. **(4 marks)**

If lamp B uses only 25% of the energy used by A:

Energy input = 432 000 × 0.25
= 108 000 J

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{Efficiency} = \frac{21\,600}{108\,000} = 0.20 \text{ (or 20\%)}$$

Q14

A lamp has a current of 50 mA through it. Calculate the electric charge that passes through it in 1 minute. **(1 mark)**

Convert to S.I. units: 0.050 A and 60 s

$\Delta Q = I \times \Delta t$

$\Delta Q = 0.050 \times 60 = 3.0\,\text{C}$

An electric heater operates from a 230 V supply and draws a current of 12.5 A.

(a) Calculate the power of this heater. **(1 mark)**

$P = VI = 230 \times 12.5 = 2875$

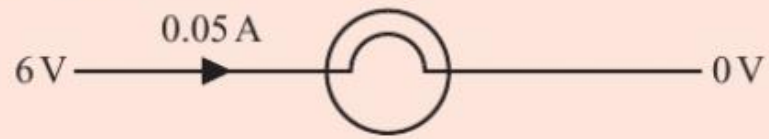
$= 2880\,\text{W}$ (3 s.f.)

(b) Calculate how much energy is transferred into heat in 1 hour and 40 minutes by the heater. **(2 marks)**

Energy transferred $W = Pt$

$= 2875 \times (100 \times 60) = 17.3\,\text{MJ}$ (3 s.f.)

The lamp in the example on the left was connected to a 6 V supply:



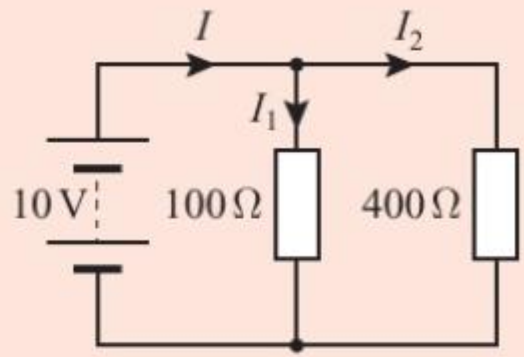
How much energy is transferred into heat and light in the lamp if the lamp is on for 1 minute? **(2 marks)**

$W = V \times Q$

$W = 6.0 \times 3.0 = 18\,\text{J}$

Q15

1 Calculate the current through the two resistors. Hence state the current, I, supplied by the battery. **(3 marks)**



The p.d. across both resistors is 10 V.

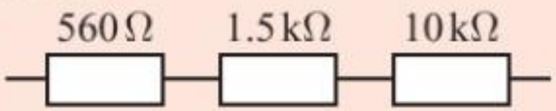
$I_1 = \frac{10}{100} = 0.1\,\text{A}$; $I_2 = \frac{10}{400} = 0.025\,\text{A}$.

$I = I_1 + I_2 = 0.125\,\text{A}$

Q16

Find the total resistance of the following resistor networks.

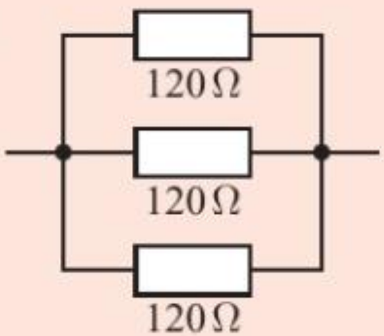
(a) **(1 mark)**



$R = 560\,\Omega + 1500\,\Omega + 10\,000\,\Omega$

$= 12\,060\,\Omega$

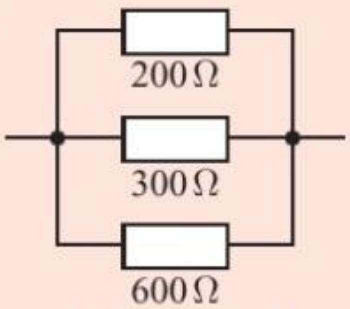
(b) **(2 marks)**



$$\frac{1}{R} = \frac{1}{120\Omega} + \frac{1}{120\Omega} + \frac{1}{120\Omega} = \frac{3}{120\Omega}$$

Therefore $R = 40\,\Omega$

(c) **(2 marks)**



$$\frac{1}{R} = \frac{1}{200\Omega} + \frac{1}{300\Omega} + \frac{1}{600\Omega} = \frac{6}{600\Omega}$$

Therefore $R = 100\,\Omega$

Q17

Find the resistance of a 1.5 m length of wire of diameter 0.50 mm and resistivity $5.0 \times 10^{-7}\,\Omega\,\text{m}$. **(3 marks)**

$$\text{area } A = \pi r^2 = \pi \times \left(\frac{0.50}{2} \times 10^{-3}\right)^2 \text{m}^2$$

$$R = \frac{\rho l}{A}$$

$$= 5.0 \times 10^{-7} \times \frac{1.5}{\left(\pi \times \frac{0.50}{2} \times 10^{-3}\right)^2}$$

$$= 3.8\,\Omega \text{ to 2 s.f.}$$

Q18

The resistance of a 1.30 m length of wire is 0.8 Ω.
The average diameter is 0.40 mm.
Calculate the resistivity of the material the wire is made from. **(3 marks)**

$$A = \pi r^2 = \pi \times \left(\frac{0.40}{2} \times 10^{-3}\right)^2 \text{ m}^2$$

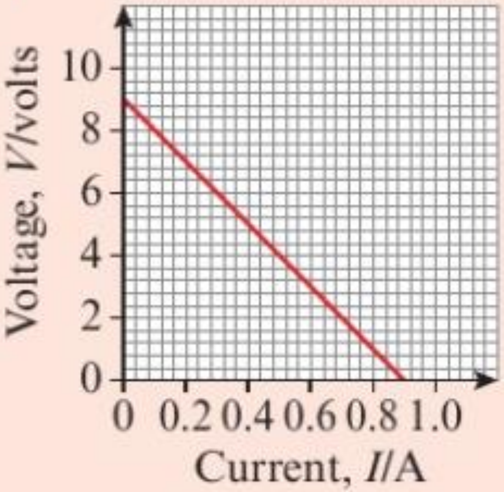
$$R = \frac{\rho l}{A} \text{ so } \rho = \frac{RA}{l}$$

$$= \frac{0.8 \times \pi \times \left(\frac{0.40}{2} \times 10^{-3}\right)^2}{1.30}$$

$$= 7.7 \times 10^{-8}\,\Omega\,\text{m}$$

Q19

The graph shows how the terminal p.d. of a battery of six cells varies with the current drawn from the battery.



(a) Determine the e.m.f. of one of the cells in the battery. **(2 marks)**

The intercept on the p.d. axis gives the e.m.f of the battery, 9 V. Therefore the e.m.f of one cell is 1.5 V, assuming the cells are identical and connected in series.

(b) Determine the internal resistance of one of the cells in the battery. **(2 marks)**

The gradient of the line is −10 so the internal resistance *r* of the battery is 10 Ω, and of one cell is 1.7 Ω.

Q20

The circuit of fig. 1 consists of a direct current supply of e.m.f. 24 V, negligible internal resistance and three resistors.

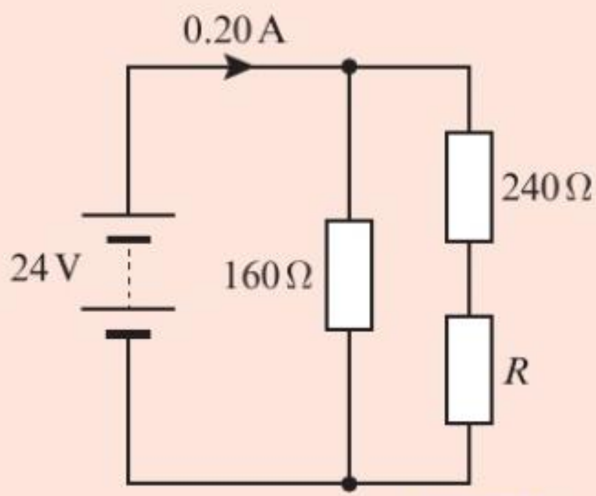


fig. 1

Two of the resistors have resistances 160 Ω and 240 Ω as shown.

The current drawn from the supply is 0.20 A.

(a) Calculate the resistance of R. **(3 marks)**

The current through the 160 Ω resistor is

$I = \frac{24}{160} = 0.15\text{ A}$.

The current through the other two resistors is therefore 0.20 − 0.15 = 0.05 A.

The total resistance of the two resistors on the right is $R_{TOT} = \frac{24}{0.05} = 480\,\Omega$.

Therefore $R = 480 - 240 = 240\,\Omega$

(b) Resistor R is now short-circuited by connecting a wire of negligible resistance in parallel with it.

State and explain what happens to the currents in each arm of the circuit when R is short-circuited. **(3 marks)**

There is no change in the current through the 160 Ω resistor. This is because it still has a potential difference of 24 V across it.

The current is $\frac{24}{160} = 0.15\text{ A}$.

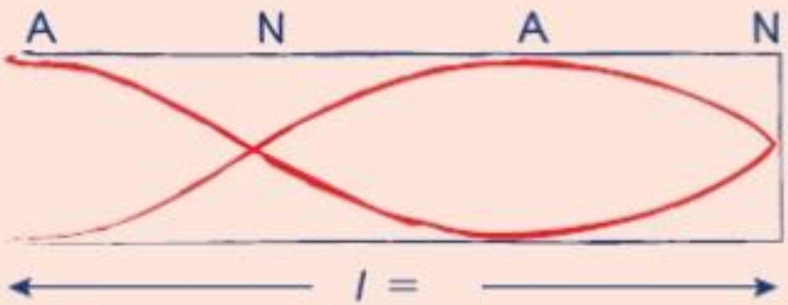
The current through the 240 Ω resistor increases. This is because the resistance of this arm has reduced but the potential difference across it has remained the same (24 V).

The current rises to $I = \frac{24}{240} = 0.10\text{ A}$.

Q21

(a) Sketch the next simplest standing wave that can be set up in a pipe closed at one end. What is the wavelength of the sound in terms of the length, l, of the pipe? **(3 marks)**

There must be an antinode at the open end and a node at the closed end, so: $\lambda = \frac{4l}{3}$ (that is, $\frac{1}{3}$ of the fundamental wavelength).



(b) State what happens to the frequency of the sound wave produced. **(1 mark)**

The speed of sound ($v = f\lambda$) is unchanged, so the frequency increases by a factor of 3.

Q22

(a) Ripples travel across the surface of a pond at 15 cm s^{-1}. If the frequency of the ripples is 6.0 Hz find their wavelength. **(2 marks)**

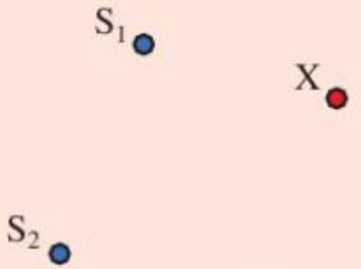
$v = f\lambda$ so $\lambda = \frac{v}{f} = \frac{0.15}{6} = 0.025$ m

(b) State what happens to the wavelength if the frequency is doubled. **(1 mark)**

From the formula it can be seen that doubling the frequency will halve the wavelength to 0.0125 m.

Q23

Two similar sets of circular ripples are made at S_1 and S_2 with a frequency of 5.0 Hz and travel at 16 cm s^{-1} across the surface of a ripple tank. X is a point on the water surface 8 cm away from the source S_1.



(a) What is the path length S_1X in terms of the wavelength, λ, of the ripples? **(3 marks)**

$$\lambda = \frac{v}{f} = \frac{0.16}{5.0} = 0.032\,\text{m}$$

$$S_1X = \frac{0.080}{0.032} = 2.5\,\lambda$$

(b) Suggest a value of S_2X such that the two sets of waves arrive at X in phase (i) in terms of λ, (ii) in cm. **(2 marks)**

For the two sets of ripples to arrive at X in phase the path difference ($S_2X - S_1X$) must be a whole number of λ (or zero, but this is clearly not the case), so (i) $S_2X = 3.5\,\lambda$, or (ii) $3.5 \times 0.032\,\text{m} = 0.112\,\text{m}$.

Q24

On a standard guitar, the lowest-pitch string has a frequency of $f_1 = 82.4\,\text{Hz}$ and the highest has a frequency of $f_2 = 329.6\,\text{Hz}$. The strings have the same tension and the same length. Find the ratio of their masses m_1 and m_2. **(2 marks)**

The length, l, of the strings is $\frac{\lambda}{2}$ (distance between adjacent nodes).

Combining $f = \frac{v}{\lambda}$ and $\lambda = 2l$ with the velocity equation gives $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

so $\frac{f_2}{f_1} = \frac{\sqrt{\mu_1}}{\sqrt{\mu_2}} = \frac{\sqrt{m_1}}{\sqrt{m_2}}$ as T and l are the same for both strings.

$\frac{f_2}{f_1} = 4$, $\frac{m_1}{m_2} = 16$.

Q25

An ultrasound scanner produces sound waves with a wavelength of 0.50 mm. The waves travel through soft body tissue at 1540 m s^{-1}. An echo is detected from the fetus at a distance of 8.0 cm. (a) Find the frequency of the ultrasound transmitted. **(2 marks)**

$$f = \frac{v}{\lambda} = \frac{1540}{(5.0 \times 10^{-4})} = 3.08 \times 10^{6}\,\text{Hz}\ (3.1\,\text{MHz})$$

(b) Find the time interval between pulse and echo. **(3 marks)**

$$\text{Time} = \frac{2d}{v} = \frac{0.16}{1540} = 1.04 \times 10^{-4}\,\text{s}\ (100\,\mu\text{s})$$

Q26

A sonar pulse–echo detection system uses sound with a frequency of 2.5 kHz. Sound travels at $1500\ \mathrm{m\,s^{-1}}$ in sea water.

(a) Find the wavelength of sound waves in sea water. **(2 marks)**

$$\lambda = \frac{v}{f} = \frac{1500}{2500} = 0.60\ \mathrm{m}$$

(b) An echo is detected 2.4 s after the pulse is transmitted. Find the distance to the detected object. **(3 marks)**

Distance travelled = $v \times t = 1500 \times 2.4 =$ 3600 m. This is the distance to the object and back, so the distance to the object is 1800 m.