SECTION ONE: Short response (30%) 54 marks

This section has **thirteen (13)** questions. Answer all questions in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 50 minutes.

Question 1 **(4 marks)**

Little Jack Horner drops the plum he pulled out of his Christmas pie. It lands next to a rat which grabs it and races off due west at 11.4 m s^{-1}. It then changes direction (to avoid Jack's shoe which he has thrown at it) and runs due south at 13.7 m s^{-1}. Calculate the rat's change in velocity. Include a clearly labelled vector diagram.

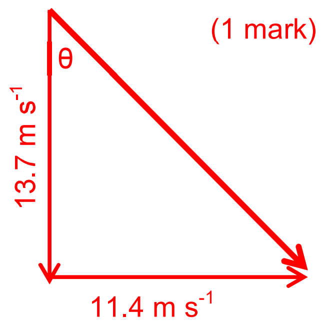
$\Delta v = v - u = v + (-u)$ (1 mark)

$= 13.7$ m s^{-1} south + 11.4 m s^{-1} east

$\Delta v = \sqrt{(13.7^2 + 11.4^2)}$

$= 17.8$ m s^{-1} (1 mark)

$\theta = \tan^{-1}(11.4/13.7)$
$= 39.8°$ (1 mark)



(1 mark)

Change in velocity is 17.8 m s^{-1} S39.8°E

Question 2 **[3 marks]**

Little Boy Blue is blowing his horn. The cow is 10.0 m away in the meadow and hears the sound with an intensity of 4.83×10^{-12} W m^{-2}. With what intensity does the sheep in the corn, 30.0 m away from Little Boy Blue, hear the sound?

$I \propto 1/r^2$

Since distance is increased by a factor of 3, intensity will be decreased by a factor of 3^2 (1 mark)

New intensity = $4.83 \times 10^{-12} / 9$ (1 mark)

= 5.37×10^{-13} W m^{-2} (1 mark)

Question 3 **[4 marks]**

Incy Wincy Spider is climbing up the waterspout (a drainpipe). There is a strong wind blowing over the top of the waterspout and the spider can hear a note being produced.

(a) Explain how the sound is produced in the waterspout. (2 marks)

The wind is producing a forcing frequency (1 mark) which matches the resonant frequency of the pipe (1 mark)

(b) The spider notices that as it is climbing up the waterspout the sound gets louder in some places and quieter in others. Explain this observation. (2 marks)

The standing wave in the pipe results from interference of waves reflected from each end (1 mark) which produced displacement nodes where the sound is quietest, and displacement antinodes where the sound is loudest (1 mark)

Question 4 **[4 marks]**

Humpty Dumpty is sitting on a wall which is 15.5 m high. Suddenly he falls. What is his velocity just before he hits the ground?

$u = 0$ m s^{-1}; $g = 9.80$ m s^{-2} down; $h_i = 15.5$ m; $h_f = 0$ m

Energy conserved so $E_{k\text{-initial}} + E_{p\text{-initial}} = E_{k\text{-final}} + E_{p\text{-final}}$ (1 mark)

$\frac{1}{2}\cancel{m}u^2 + \cancel{m}gh_i = \frac{1}{2}\cancel{m}v^2 + \cancel{m}gh_f$

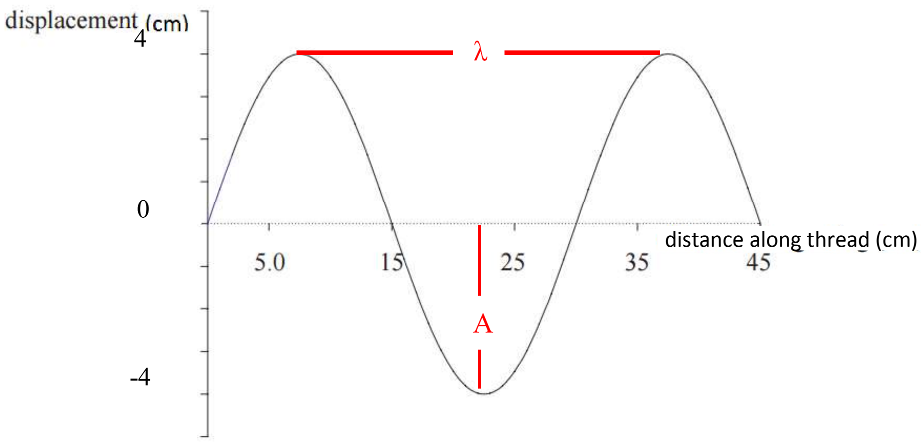
$9.80 \times 15.5 = \frac{1}{2}v^2$ (1 mark)

$v = \sqrt{(2 \times 151.9)}$

$= 17.4$ m s^{-1} down (1 mark for calc, 1 mark for direction)

Question 5 **[4 marks]**

Little Miss Muffet, having overcome her arachnophobia, plucks a long piece of web from which a spider is suspended. The diagram below shows a transverse wave travelling along the silk thread.



a) On the diagram above, show:

- the amplitude of the wave. Label this A. (1 mark)
- The wavelength of the wave. Label this λ. (1 mark)

b) Given that the period of the wave is 12.4 ms, find the velocity of the wave. (2 marks)

$v = \lambda f = \lambda/T$
$= 0.30 / 12.0 \times 10^{-3}$ (1 mark)
$= 24.2$ m s^{-1} (1 mark)

Question 6 **[4 marks]**

A physicist is using a very high-powered microscope to look at a single particle in a medium. Suddenly they notice that it moves in one direction, then moves back in the opposite direction, and then returns to rest.

a) What can they infer from this observation? Expain your answer. (2 marks)

A pulse of energy passed through the medium (1 mark)

This is deduced from the motion of the particle, but with no net displacement (1 mark)

b) What other information would they need in order to be able to make any further conclusion about the nature of the oberved phenomenon? Explain your answer. (2 marks)

They would need to know the direction of propagation of the energy (1 mark)

If it was parallel to the displacement of the particle, it would be a longitudinal wave, if it was perpendicular to the displacement of the particle, it would be a transverse wave. (1 mark)

Question 7 **[4 marks]**

Give two examples of safety features of modern cars which are designed to reduce the impact of forces involved in collisions. Explain, with reference to physics concepts, how they achieve this.

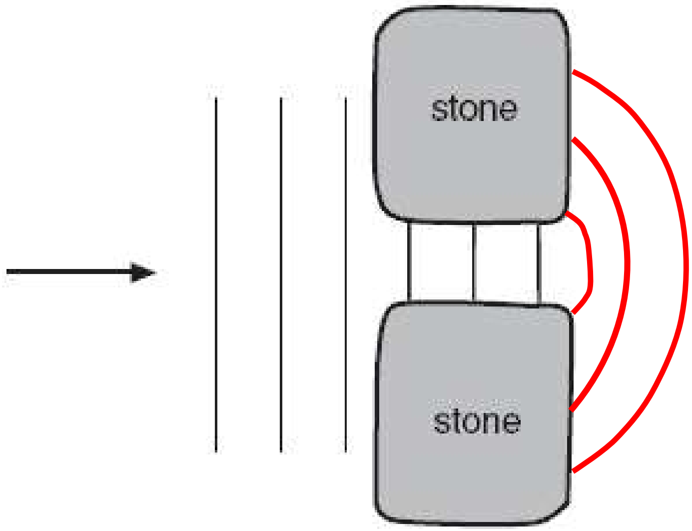
Two examples such as: (1 mark each)

- Seatbelts
- Airbags
- Padded dashboard
- Crumple zones
- Bumpers
- Any other valid example

Explanation of each (if this is too much we can reduce it to an explanation of one of them) (2 marks)

Question 8 **[4 marks]**

Doctor Foster steps in a puddle and produces some water waves which spread out and pass through a gap between two stepping stones (that he hadn't seen earlier).



a) Finish the diagram to show what happens to these waves after they pass through the gap. (1 mark)

Diagram shows diffracted waves

b) Name the phenomenon you have illustrated: (1 mark)

Diffraction

c) State two factors that affect the extent to which this phenomenon is observed. (2 marks)

Distance of the gap between the two stones

Wavelength of the waves

Question 9 **[7 marks]**

Little Tommy is rescuing a cat from the bottom of a well which is 27.4 m deep. He lowers a bucket with a mass of 7.82 kg and the cat, which has a wet mass of 4.57 kg, hops in. Assume the rope is massless and there is no friction in the pulley.

a) How much work is performed by Tommy in bringing the cat to the top of the well? (2 marks)

W = Fs

= (7.82 + 4.57) kg x 9.80 m s^{-2} x 27.4 m (1 mark)

= 3.33 s x 10^3 J (1 mark)

(He can't rescue the cat without raising the bucket as well. If they want to leave out the bucket – they need to state this as an assumption.)

b) If it takes him 3.40 minutes to perform this good deed, how much power does Tommy develop? (3 marks)

t = 3.40 x 60 = 204 s (1 mark)

P = W/t

= 3327 / 204 (1 mark)

= 16.3 W (1 mark)

c) Tommy uses up 8804 J of energy performing this task. What is his efficiency? (2 marks)

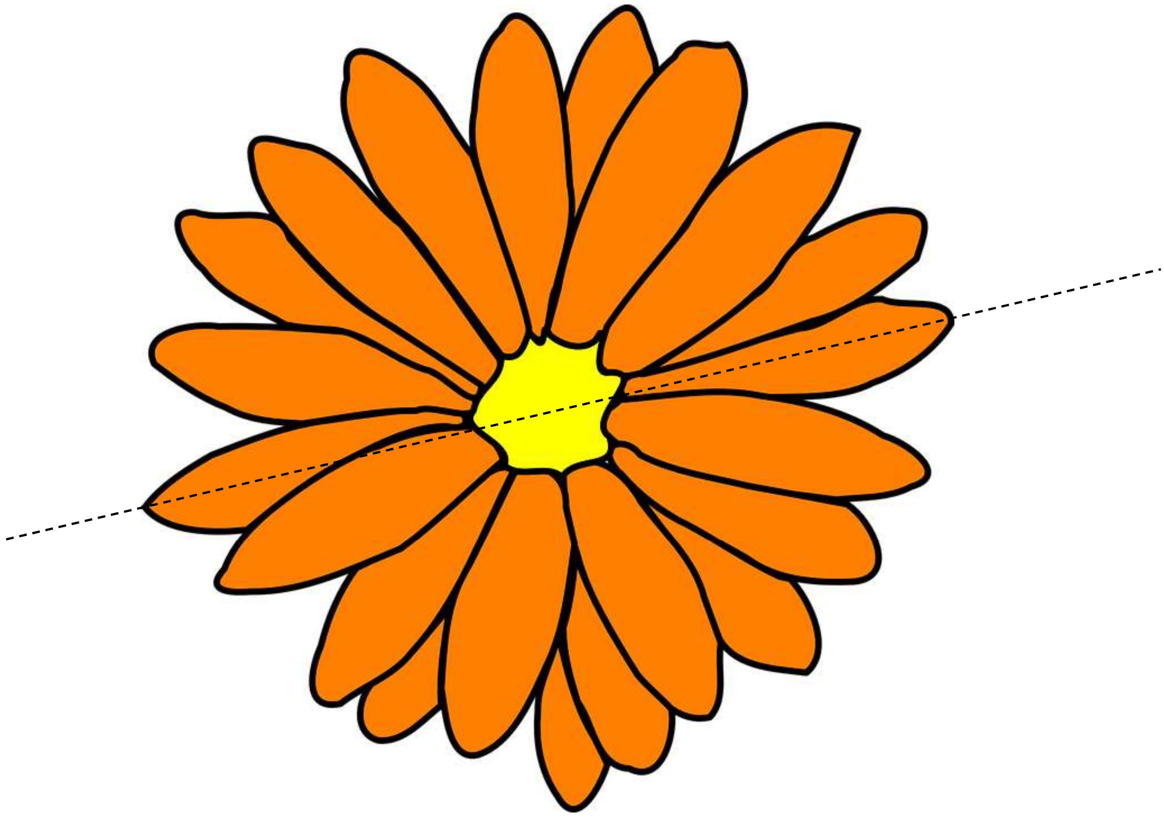
Efficiency = energy output/energy input x 100 %

= 3327 /8804 x 100 % (1 mark)

= 37.8% (1 mark)

Question 10 **[3 marks]**

An inchworm is measuring the diameter of a marigold flower, pictured below. It has been instructed to give metric measurements and so it is using a standard school ruler to do so.



a) Use your ruler to measure the diameter of the flower along the dotted line provided.(1 mark)

Diameter = ________________________ 113 mm (±0.1)

b) What is the absolute error associated with this measurement? (1 mark)

±0.5 mm (accept ±1.0 mm)

c) Calculate the relative/percentage error in the measurement. (1 mark)

% error = abs err/measurement x 100 %

= 0.44% (or 0.88% if using abs err of 1.0 mm)

Question 11 **[4 marks]**

The Grand Old Duke of York marches his 10,000 troops up to the top of the nearest hill. Estimate the gain in their total potential energy.

Estimate for mass of 10,000 adults e.g. 10,000 x 85 = 850,000 kg (1 mark)

Estimate for height of hill e.g. 300 m (1 mark)

$E_P = mgh$

$= 850{,}000 \times 9.80 \times 300$

$= 2.5 \times 10^6$ J (2 s.f.) (1 mark for calc, 1 for 2 sf)

Question 12 **[5 marks]**

A cow jumps from the surface of the Earth to the surface of the Moon and back. Assume that the cow starts and finishes at sea level (at the equator) and returns to Earth when the Earth has completed half a rotation relative to the Moon. The mean Earth-Moon distance is 3.84×10^8 m (from the centre of the Earth to the centre of the Moon). The radius of the Earth is 6.37×10^6 m, and the radius of the moon is 1.74×10^6 m.

a) What is the distance travelled by the cow? (2 marks)

Distance from surface of Earth to the surface of the moon

$= 3.84 \times 10^8 - (6.37 \times 10^6 + 1.74 \times 10^6 \text{ m})$

$= 3.76 \times 10^8$ m (1 mark)

Total distance travelled = $2 \times 3.759 \times 10^8$ m

$= 7.52 \times 10^8$ m (1 mark)

b) What is the cow's final displacement? (3 marks)

$C = 2\pi r$

$= 2 \times \pi \times 6.37 \times 10^6$

$= 4.00 \times 10^7$ m (1 mark)

For half rotation, displacement is 2.00×10^7 m (1 mark)

Since Earth rotates towards the east, the final landing position of the cow will be 2.00×10^7 m west

(1 mark)

Also accept displacement as the diameter of the Earth i.e. straight line through the Earth which will be 1.27×10^6 m

The direction in this case can only be correctly specified as towards the moon.

Question 13 **[4 marks]**

Jack and Jill are going up the hill on a very cold morning. They stop when they get to the top but Jack suddenly starts sliding down the other side, which is a frictionless plane with an elevation of 22.8° above the horizontal. It is 30.7 m from the top of the slope to the bottom.

a) With what acceleration will Jack be moving down the slope? (2 marks)

$a = g\sin(\theta)$ (1 mark)

$= 9.80 \times \sin(22.8°)$

$= 3.80$ m s^{-2} down the slope (1 mark)

b) What will be Jack's speed by the time he reaches the bottom of the slope. If you were unable to calculate a value for acceleration in part (a) you may use an acceleration of 3.95 m s^{-2}.

$v^2 = u^2 + 2as$

$= 0 + 2 \times 3.798 \times 30.7$ (1 mark)

$v = \sqrt{233}$

$= 15.3$ m s^{-1} (1 mark)

NB: $v = 15.6$ m s^{-1} if acceleration of 3.95 m s^{-2} is used

End of Section One

SECTION TWO: Problem-solving (50%) 90 marks

This section has **seven (7)** questions. Answer all questions in the spaces provided.

Suggested working time: 90 minutes.

Question 14 **[8 marks]**

Three blind mice are running around in a panic when two of them collide head on. One of the colliding mice has a mass of 19.2 g and was running towards the kitchen door with a velocity of 13.0 km h^{-1}. The second mouse has a mass of 22.5 g. When they collide, they cling together and have a combined velocity of 1.15 m s^{-1} in the original direction of the second mouse.

a) Calculate the initial velocity of the second mouse (5 marks)

Let the direction of the second mouse be positive (1 mark)

$m_1u_1 + m_2u_2 = m_{1+2}v$ (stated or implied by working) (1 mark)

$u_2 = (m_{1+2}v - m_1u_1) / m_2$

$= ((19.2 + 22.5) \times 10^{-3} \times 1.15) - (19.2 \times 10^{-3} \times -(13.0/3.6)) / (22.5 \times 10^{-3})$ (1 mark)

$= 5.21$ m s^{-1} away from the kitchen door (1 mark answer + 1 mark for direction)

b) Show, by calculation, whether the collision was elastic or inelastic. (3 marks)

$E_{K\text{-initial}} = ½ \times 19.2 \times 10^{-3} \times (13.0/3.6)^2 + ½ \times 22.5 \times 10^{-3} \times 5.21^2$

$= 0.431$ J (1 mark)

$E_{K\text{-final}} = ½ \times 41.7 \times 10^{-3} \times 1.15^2$

$= 2.76 \times 10^{-2}$ J (1 mark)

Since the kinetic energy before and after the collision is not conserved, the collision must be inelastic. (1 mark)

Question 15 **[16 Marks]**

The clarinet, pictured at right, is a wind instrument that behaves like a closed pipe with a natural harmonic frequency of 130 Hz in air at a room temperature of 25ºC.

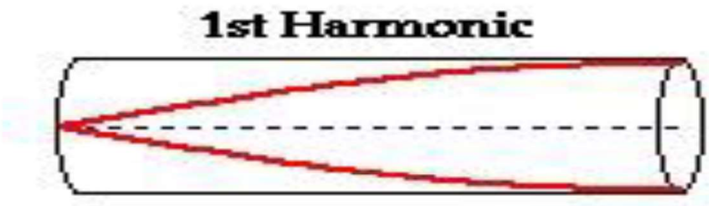
(a) What are the frequencies of the next two higher harmonics? (2 marks)

$f_3 = 3f_1 = 3 \times 130$ Hz $= 390$ Hz (1 mark)

$f_5 = 5f_1 = 5 \times 130$ Hz $= 650$ Hz (1 mark)

(b) Sketch the particle displacement vs distance envelopes for the natural harmonic frequency and for the next highest harmonic for this instrument. (2 marks)

natural frequency



✔

next harmonic frequency

✔

Question 15 (contd)

(c) Calculate the length of the clarinet. (3 marks)

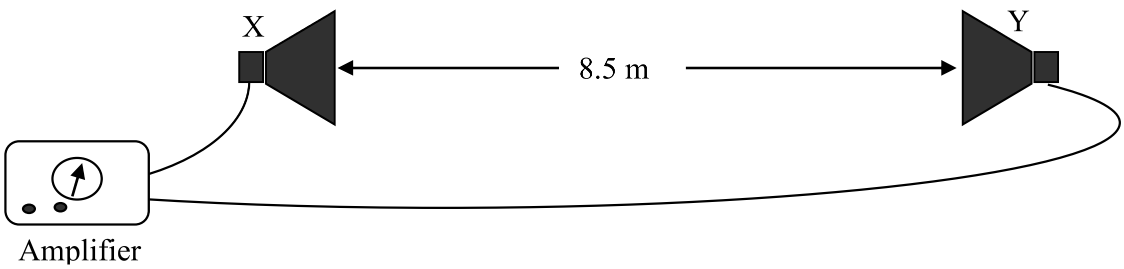
Fundamental frequency has wavelength

$\lambda = v / f = (346 \text{ m s}^{-1}) / (130 \text{ Hz}) = 2.66 \text{ m}$ (1 mark)

For fundamental frequency $\lambda = 4L$ (1 mark)

so length $L = \lambda/4 = (2.66 \text{ m}) / 4 = 0.665 \text{ m}$ (1 mark)

The clarinet is played so as to produce its fundamental frequency, and the sound is captured by a microphone and feed into an amplifier. Two loudspeakers X and Y are connected in phase to the amplifier and set up facing each other a distance of 8.5 m apart, as shown below. A person walking from one of the loudspeakers towards the other hears points where the sound is extremely soft, alternating with points where it is loud.



(d) What are the conditions required in order for a standing (stationary) wave to form? (3 marks)

Same frequency

Same amplitude

Waves travelling in opposite directions

(e) Calculate whether the sound is loud or soft when the person walking between the loudspeakers is 2.92 m from speaker X. (3 marks)

Distance from speaker Y = 8.5 m - 2.92 m = 5.58 m (1 mark)

Path difference = 5.58 m - 2.92 m = 2.66 m = 1 λ (1 mark)

Hence waves interfere in phase ➔ sound is loud (1 mark)

Question 15 (contd)

(e) What is the distance between a soft and a loud point? (1 mark)

Distance between node and antinode = ¼ λ

= ¼ (2.66 m)

= 0.665 m

(f) Determine the number of soft points between the loudspeakers. (2 marks)

Midpoint at 4.25 m from X is an antinode, so nodes occur between X and midpoint at:

4.25 - 0.665 = 3.58 m

4.25 - 3(0.665) = 2.25 m

4.25 - 5(0.665) = 0.92 m (1 mark)

Hence total number of nodes between X and Y = 6 (1 mark)

Question 16 **[13 Marks]**

A road traffic investigator arrives at the scene of an accident on a road where the maximum speed limit is 70.0 km h^{-1}, and observes a damaged car at rest. Skid marks leading to the car are 50.0 m long. The investigator knows that the mass of this make of car is 1.25 tonnes and that the frictional braking force while skidding was 12,500 N. From this evidence she is able to determine the speed of the car immediately before the driver applied the brakes.

(a) Assuming a constant braking force, calculate the speed of the car just before the driver applied the brakes. Show your working. (4 marks)

$s = 50.0$ m; $v = 0.0$ m s^{-1}; $m = 1.25 \times 10^3$ kg; $F_{friction} = -12500$ N

$F = ma$

$\therefore a = F/m$ **(1 mark)**

$= -12500/1.25 \times 10^3$

$= -10.0$ m s^{-1} **(1 mark)**

$v^2 = u^2 + 2as$

$0 = u^2 + 2 \times -10.0 \times 50.0$ **(1 mark)**

$\therefore u = \sqrt{1000}$

$= 31.6$ m s^{-1} **(1 mark)**

OR

$W = Fs = E_K$

$\therefore Fs = ½mv^2$ **(1 mark)**

$v = \sqrt{(2Fs/m)}$ **(1 mark)**

$= \sqrt{(2 \times 12500 \times 50.0/1.25 \times 10^3)}$ **(1 mark)**

$= 31.6$ m s^{-1} **(1 mark)**

(b) Was the car speeding? Justify your answer. (2 marks)

The speed of the car just prior to the brakes being applied was 31.6 m s^{-1} which is ~114 km h^{-1}. **(1 mark)**

Since the speed limit on this road was 70.0 km h^{-1}, the car was speeding at the time.**(1 mark)**

Question 16 (contd)

(c) How long did it take the car to stop? (2 marks)

$v = u + at$ **(1 mark)**

$\therefore t = (v-u)/a$

$= (0 - 31.62)/-10.0$

$= 3.16$ s **(1 mark)**

(d) How much heat was given out in melting the rubber of the tyres? (3 marks)

$E_K = \frac{1}{2}mv^2$ **(1 mark)**

$= 0.5 \times 1.25 \times 10^3 \times 31.62^2$ **(1 mark)**

$= 6.25 \times 10^5$ J **(1 mark)**

OR

$W = Fs$ **(1 mark)**

$= 12500 \times 50.0$ **(1 mark)**

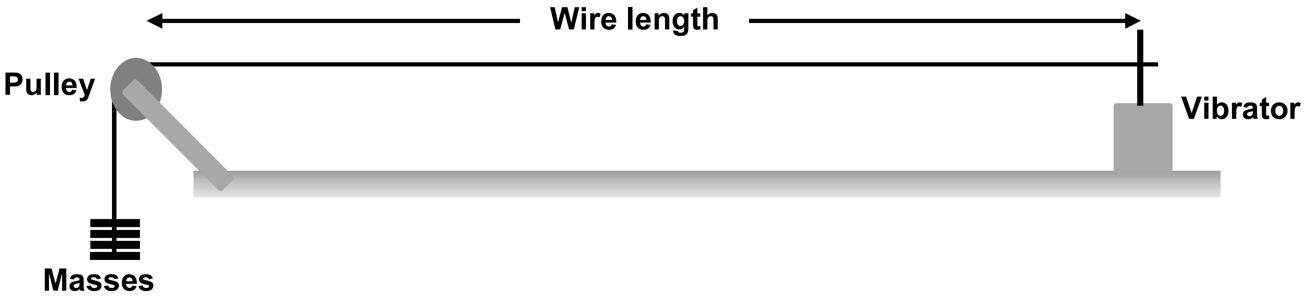
$= 6.25 \times 10^5$ J **(1 mark)**

(e) One observer says that the original momentum of the car was lost during the braking, but a second observer maintains that momentum is always conserved. Where did the momentum of the car go to? (2 marks)

The momentum of the car was transferred to the road/Earth. **(1 mark)**
The Earth would have exerted an equal and opposite force to that of the friction of the car. This would result in a change in the magnitude and direction of the Earth's velocity (although the mass of the Earth is so much greater than that of the car that it would be imperceptible). **(1 mark)**

Question 17 **[14 Marks]**

A student set up an experiment in order to investigate the relationship between tension and the velocity of transverse waves in a string. She set up the apparatus as shown in the diagram below and set it vibrating at a constant frequency.



From the apparatus, she determined the velocity and tension. The data is shown in the table below:

Tension, T (N)	1.00	2.00	3.00	4.00	5.00	6.00
Velocity, v (m s^{-1})	8.32	11.8	14.2	16.6	18.4	20.6
Velocity^2, v^2 (m^2 s^{-2})	69.2	139	201	276	339	424

a) What was the dependent variable in this experiment? (1 mark)

Velocity

For a stretched string of a given mass per unit length (μ), and for a given tension (T), the velocity (v) of a wave in the string is given by the formula below:

$$v = \sqrt{(\frac{T}{\mu})}$$

b) How would you **convert** the results to produce a linear graph which will allow you to determine a value for μ? Add the values you require to do this to the Table above. (2 marks)

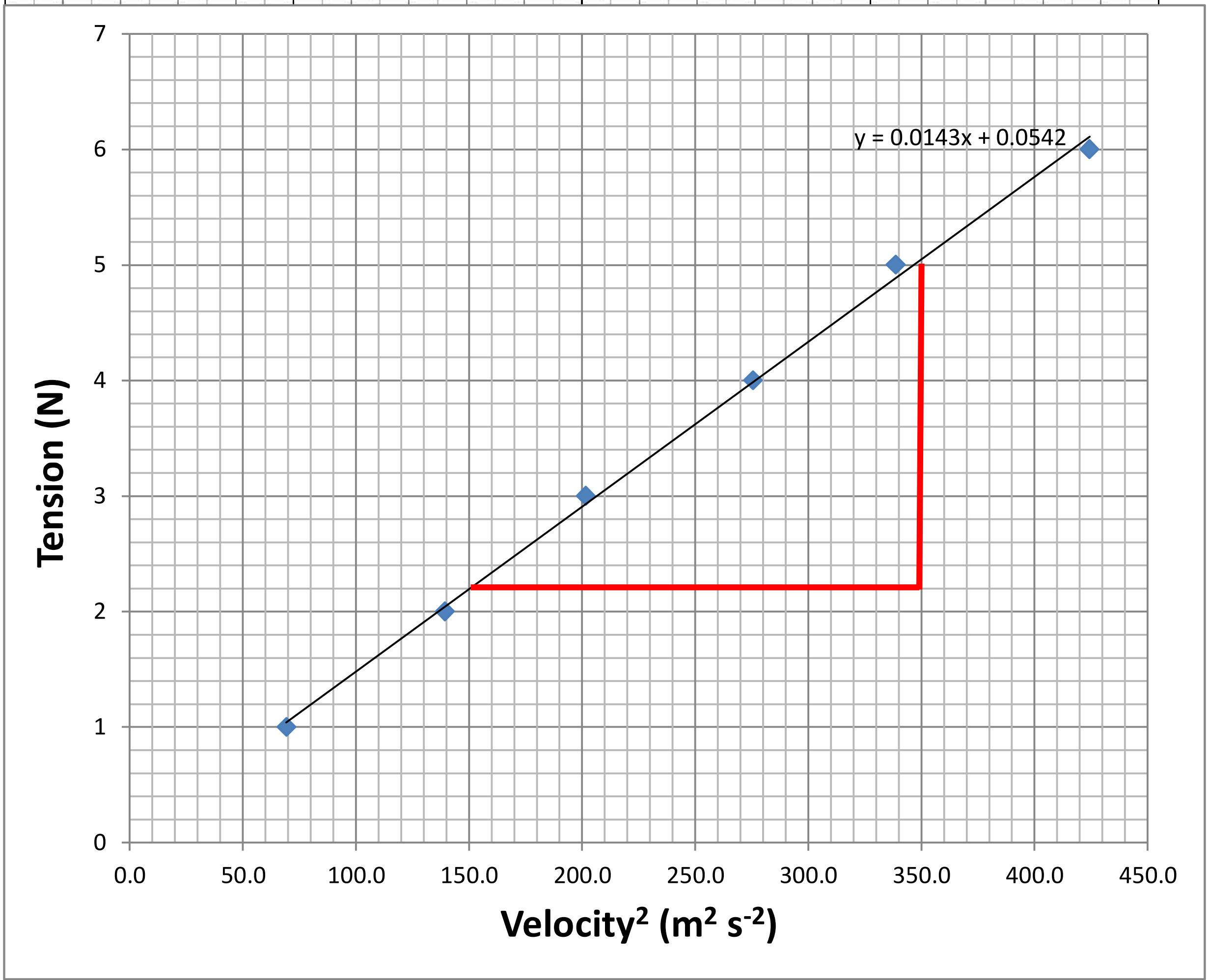
$v^2 = T / \mu$ OR $T = \mu v^2$

$\mu = T / v^2$ (1 mark);

add v^2 to table (1 mark)

Question 17 (contd)

c) Plot the data required to give μ is the slope of the graph on the grid below. (5 marks)



1 mark each for

- Axes labels with units
- Uniform scales
- Points plotted correctly
- LOBF
- Title

Question 17 (contd)

d) Use the gradient of the graph to estimate a value for the mass per unit length (μ) of the string used in the experiment. Include the correct units for this value. (3 marks)

Gradient = Δrise/Δrun

= (5-2.2) / 350-150) (1 mark – points used must be shown on graph)

= 0.014 N m^{-2} s^2 (1 mark – answer ±0.01; 2 sig figs)

(1 mark – correct units)

The mass per unit length (μ) can be determined formulaically when a length of string (L) is vibrating at its fundamental frequency (f_1), under a certain tension (T), using the following formula:

$$\mu = \frac{T}{4\,L^2\,f_1^2}$$

e) If the experimental string was tightened until its tension was 53.0 N, calculate the fundamental frequency produced by this string when its effective length is 330 mm, and using the value for mass per unit length (μ) from your answer to 17 d) above. If you were unable to determine an answer to 17 d) you may use a value for **μ** of 0.015 (3 marks)

$f_1 = \sqrt{(T / (4L^2\mu))}$

$= \sqrt{(53 \text{ N} / (4 \times 0.33^2 \text{ m}^2 \times 0.014 \text{ N m}^{-2} \text{ s}^2))}$

$= \sqrt{8691 \text{ s}^{-2}}$

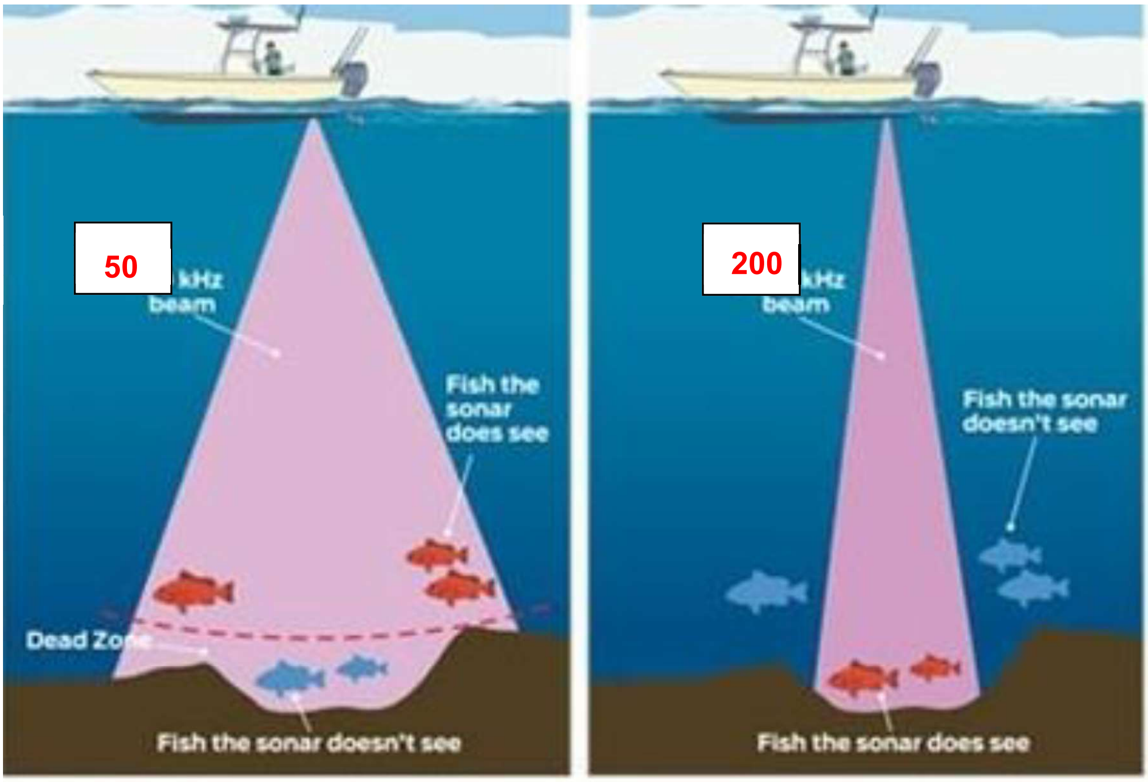
= 93.2 Hz

Or 90.1 Hz (if μ = 0.015 is used)

Question 18 **[15 Marks]**

A commercial fishing boat leaves Fremantle harbour. The boat is equipped with sonar technology in order to locate schools of fish before deploying its nets. In order to locate fish, the boat can use either a 200 kHz beam or a 50 kHz beam. The speed of sound in saltwater is 1500 m s^{-1}.

a) Label the beams in the boxes in the diagram below. (1 mark)



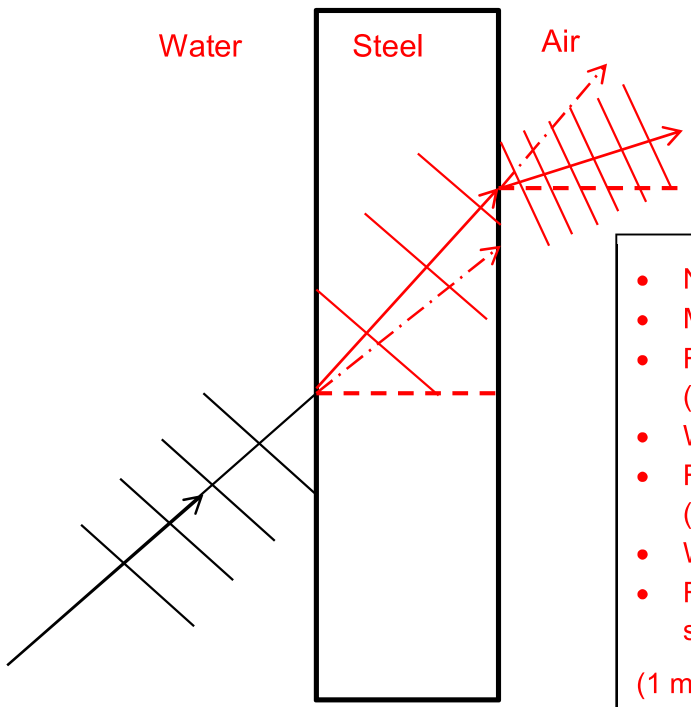
b) With reference to wave properties, how does sonar allow the boat to detect fish, and what is one advantage of each different frequency used? (3 marks)

Waves diffract as they propagate and reflect when they encounter an obstacle (effectively a change in medium) (1 mark)
The lower frequency waves have a longer wavelength and will diffract to a greater extent, allowing a greater coverage. (1 mark)
The higher frequency waves have a shorter wavelength and will diffract less, but will have greater directionality, and better penetrating ability as they will attenuate less (1 mark)
NB: they don't have to say all of this, but they need to make one good point per mark

Question 18 (contd)

c) Complete the diagram below to illustrate how sound waves behave when they pass from water, through the steel hull of the ship and then into the air on the other side of the hull.

(7 marks)



- Normals drawn, and as dotted lines
- Media labelled
- Ray refracts away from normal in steel (faster medium)
- Wavefronts further apart in steel
- Ray refracts towards normal in air (slower medium)
- Wavefronts closer in air
- Rays & wavefronts also shown to be slower in air than water

(1 mark per point)

d) How long will it take for a 50 kHz sound pulse to be detected by the boat if it is reflected by a car tyre 413 m below the boat? (3 marks)

t = s/v

= 413/1500 (1 mark)

= 0.275 s (1 mark)

Since the pulse has to reach the tyre and be reflected back to the boat, the time taken to detect the pulse will be 2t = 0.551 s (1 mark)

e) What will be the frequency of the 50 kHz pulse as it passes from the water into the 2.50 cm thick steel hull of the boat? (1 mark)

50 kHz

Question 19 **[15 Marks]**

An inattentive driver is texting while driving and crashes their car (of mass 1.85×10^3 kg) into a concrete pylon of an overpass on the Kwinana Freeway at 100 km h^{-1}.

a) What is the car's change in momentum? (2 marks)

$u = 100$ km $h^{-1} = 27.78$ m s^{-1}
$\Delta p = m(v-u)$
$= 1.85 \times 10^3 \times (0 - 27.78)$
$= 5.14 \times 10^4$ kg m s^{-1} backwards (1 mark for answer; 1 mark for correct units & direction)
(-1 for just using sign)

b) What impulse will the car undergo? (1 mark)

5.14×10^5 N s (must have correct units)

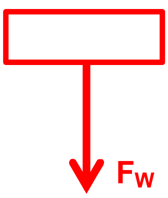
c) During the collision a physics textbook on the back window shelf 'flies forward' and strikes the windscreen. Explain the motion of the book in terms of Newton's Laws. (2 marks)

As per the first Law of Motion (Law of Inertia) the book will continue moving with the same speed and direction unless acted on by an unbalanced force (1 mark)

In this case it will continue moving at 100 km h^{-1} in a forwards direction and strike the windscreen. (1 mark)

NB: They are welcome to introduce weight force & air resistance if they feel they have to, but no marks for them.

d) Draw a free body diagram of the book while it is 'in flight' i.e. between leaving the back window shelf shelf and hitting the windscreen. (2 marks)



Only significant force acting is weight force – shown with labelled arrow. Less one mark for any additional or spurious forces.

Question 19 (contd)

Meanwhile, on another part of the Freeway, a sports car is travelling at 120 km h^{-1} when it passes an unmarked police car which is cruising at 80.0 km h^{-1}. The police car accelerates uniformly at 1.25 m s^{-2} and chases the sports car.

e) Calculate the time taken for the police car to catch the sports car. (4 marks)

Both cars will have travelled the same distance by the time the police catch up
$s_{police} = ut + ½at^2 = 22.2t + ½ \times 1.25 \times t^2 = 0.625t^2$ (1 mark)
$s_{hoons} = ut + ½at^2 = 12.0/3.6 \times t + 0 = 33.33t$ (1 mark)
$(22.2 + 0.625)t^2 = 33.33t$ (1 mark)
$t = (33.33-22.22)/0.625$
$= 17.8$ s (1 mark)

f) Calculate the distance travelled by the police in that time. (2 marks)

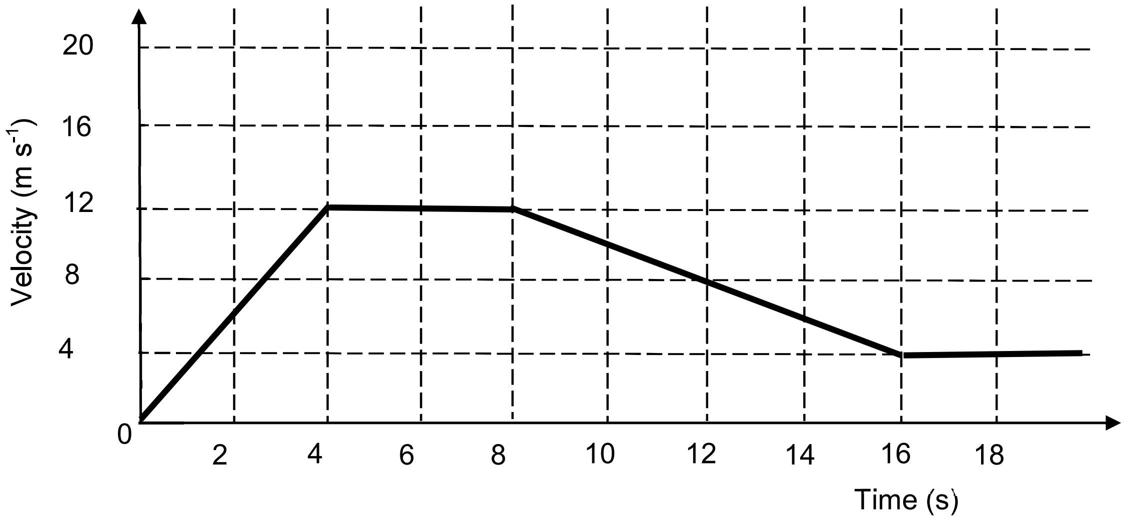
$s = ut + ½at^2$
$= 22.2 \times 17.8 + ½ \times 1.25 \times 17.8^2$ (1 mark)
$= 593$ m (1 mark)

g) Calculate the speed of the police car when it catches up to the sports car. (2 marks)

$v = u + at$
$= 22.2 + 1.25 \times 17.8$ (1 mark)
$= 44.5$ m s^{-1} (1 mark)
(= 160 km h^{-1})

Question 20 **[9 Marks]**

The graph below shows the velocity of a car, moving in a straight line, as a function of time.



a) What was the car's velocity at a time of five seconds after it began to move? (1 mark)

12 m s^{-1} forward (direction must be given, will let them away if 3 sf rather than 2 sf)

b) What was the car's acceleration at a time of three seconds after it began to move? Show your working. (3 marks)

Acceleration = Δvelocity/Δtime
= (12-0)/(4-0) (actual points used may vary) (1 mark)
= 3.0 m s^{-2} forward (1 mark for correct answer with 2 sf)
(1 mark for direction of vector quantity)

Question 20 (contd)

c) What is the car's displacement at a time of eight seconds after it began to move? Show your working. (3 marks)

AUC = (½ x 12 x 4) + (4 x 12) (1 mark)
= 72 m forward (1 mark for answer, 1 mark for direction)

NB: If they have already lost 2 marks for direction in the previous parts of the question – don't penalise them a third time i.e. max of 2 marks off for neglecting direction of vectors

d) According to the graph, the car was decelerating for eight seconds during the motion shown. Why is this likely to be inaccurate? (1 mark)

The car could not instantly go from accelerating up to the 4 second mark, and then instantly change to zero acceleration without a brief period of deceleration.

e) Was the car travelling backwards at a time of ten seconds after it began to move? (1 mark)

Circle the correct answer: Yes No

End of Section Two

SECTION THREE: Problem-solving (20%) 36 marks

This section has **two (2)** questions. Answer both questions in the spaces provided.

Suggested working time: 40 minutes.

Question 21 **LOCATION OF A SOUND** **(18 marks)**

(Paragraph 1)
The precise method by which a human being is able to discover the location of a particular sound in relation to themselves has exercised the minds of scientists for many years. Lord Rayleigh, in his Theory of Sound, published in 1896, comments briefly on the theory prevalent at the time. This was that the effect of the bulk of the head between the two ears produced a sound shadow, and thereby caused an amplitude difference in the sound reaching the two ears from a given source. Rayleigh pointed out that this theory could only operate at frequencies above about 1000 Hz, that is at frequencies above that at which the physical distance between the ears is equal to one wavelength. He suggested that a possible explanation for the perception of sound direction at low frequencies might be the difference in time of arrival of the sound wave from a source at the two ears.

(Paragraph 2)
Early workers conducting investigations into sound localisation were very limited in their activities by their lack of electrical equipment, and were forced to use clicks and other noises as sound sources. Furthermore, the rooms that they used for their experiments were far from good acoustically, and so the positions of the sound sources were confused by reverberation effects. However, the early experimenters established that it is possible to locate noises more easily than pure tones, and that it is possible to distinguish sounds appearing from the right or the left.

(Paragraph 3)
Stevens and Newman, in 1934, devised an open-air experiment in order to overcome the difficulties of sound reflections. They mounted a swivel chair on top of the roof of one of the buildings at Harvard University. The source of the sound was mounted at the end of a four metre arm that could be moved noiselessly in a complete circle on a horizontal plane level with the listener’s ears. The sound generator was a loudspeaker that could produce pure tones and various noises, such as clicks. It was found that the listener hardly ever confused the positions of sounds that were to the right or left, but, depending upon the type of sound used, fairly frequent confusion of whether the sound was in front or behind took place. It was found that pure tones at low frequencies could be localised with reasonable accuracy, as could tones at very high frequencies, but there was a band of middle frequencies between 2000 and 4000 Hz where localisation appeared to be more difficult.

(Paragraph 4)
Stevens and Newman concluded that the observed results from their experiments were “consistent with the hypothesis that the localisation of low tones is made on the basis of a phase difference at the two ears, and that the localisation of high tones is made on the basis of intensity differences”. These experimental results seemed to confirm the earlier theories attributed to Rayleigh and others.

Question 21 (contd)

a) Briefly explain what is meant by each of the following expressions

(i) …"an amplitude difference in the sound reaching the two ears"… (paragraph 1) (1 mark)

difference in loudness (volume/intensity) of sound reaching each ear

(ii) …"pure tones"… (paragraphs 2 & 3) (1 mark)

single frequencies (no harmonics mixed in)

(iii) …"a phase difference at the two ears"… (paragraph 4) (2 marks)

phase refers to the part of the cycle that a wave is at (1 mark)
so sound waves reach each ear at a different part of the wave cycle (1 mark)

b) What were the "difficulties of sound reflections" (paragraph 3) found by early experimenters in rooms which were "far from good acoustically" (paragraph 2)? (2 marks)

Sound waves would reflect off walls and other surfaces in the rooms (1 mark)
causing the sound to appear to come from multiple positions in the room (1 mark)

c) Why do you think people would be more easily confused about whether a sound came from in front of them or behind them, while sounds coming from the left or right are rarely confused? (paragraph 3) (2 marks)

Sounds from in front or behind arrive at both ears at the same time and with equal amplitude, so it is difficult to assign a direction. (1 mark)
Sounds from the sides arrive at the different ears at different times and with different amplitudes, so they are much more easily distinguished (1 mark)

Question 21 (contd)

d) Why does the frequency have to be above about 1000 Hz for the amplitude difference effect to be significant? (paragraph 1) (3 marks)

For frequencies above 1000 Hz the wavelength of the sound will be smaller than the size of the head (1 mark), so the sound will not diffract significantly around the head (1 mark), and the ear further away from the source of sound experiences a reduced amplitude of sound (1 mark)

e) The information provided in paragraph 1 would enable you to make a very rough estimate of the speed of sound provided you make one further estimate of a simple measurement. Make an estimate of this simple measurement, and hence estimate the speed of sound. (4 marks)

Assume distance between ears = 25 cm (15 – 30 cm okay) (1 mark)

Hence wavelength of sound at 1000 Hz = 25 cm (1 mark)

$v = \lambda f = 0.25 \text{ m} \times 1000 \text{ Hz} = 2.5 \times 10^2 \text{ m s}^{-1}$ (1 mark for answer; 1 mark for 2 sf)

f) If the ear does detect sound direction for low frequencies by differences in times of arrival at the two ears, make a rough estimate of the time difference our hearing mechanism must be detecting. (paragraph 1) (3 marks)

Assume distance between ears = 25 cm (15 – 30 cm okay)

$v = s / t$

$t = s / v$ (1 mark)

$= (0.25 \text{ m}) / (346 \text{ m s}^{-1})$ (1 mark)

$= 7 \times 10^{-4} \text{ s}$ (1 mark)

Question 22 NEW BALLS PLEASE, AND MAKE THEM BIGGER [18 marks]

The following is an article by Bob Holmes published in the *New Scientist*, February 1996.

(*Paragraph 1*)
Larger tennis balls would restore the excitement that modern, high-tech rackets have robbed from Wimbledon and other professional tournaments, an American physicist told the AAAS.

(*Paragraph 2*)
Improvements in racket design over recent years have allowed modern players to hit the balls faster and more accurately than ever before, said Howard Brody of the University of Pennsylvania, Philadelphia. Modern rackets are stiffer than their wooden predecessors, so the ball receives more of the energy of a shot than before. The new rackets are also lighter, so players can swing them faster and with more whip from the wrist. Brody's experiments show that the power of a stroke depends more on racket speed than weight, so the new rackets allow players to hit the ball harder.

(*Paragraph 3*)
The "sweet spot", the point at which the ball and racket meet to give maximum power to a stroke, is also higher up the head of today's rackets, Brody said. As a result, players can reach higher for the ball when they serve, opening up more of the opponent's court. This is a huge advantage, he said, because players can smack the ball that much harder instead of aiming carefully.

(*Paragraph 4*)
All this helps learners reach a passable level of skill more quickly, and adds excitement to the game for intermediate and advanced amateurs. But the serves of top male players have become so fast that the volleying game has all but disappeared, said Brody. On fast grass courts such as those at Wimbledon service speeds can reach 130 miles per hour (mph) or 209 kilometres per hour. The next generation of rackets will make the problem even worse. "People will stop going to Wimbledon," he said. "All they'll see is people serving."

(*Paragraph 5*)
As a result, tennis authorities are showing a growing interest in taming the speed of serves to bring the player's other skills back into play, Brody said. Surprisingly, his calculations show that the most obvious change -–making the ball bounce less – will have little effect on the speed of serves. Making the ball larger so that it has higher wind resistance has a much greater effect, he has found. For example, increasing the ball's diameter by 20 per cent would slow a 125 mph serve to 113 mph. "People can return 113 mph serves," he said. "They do it all the time." An article describing his analysis will appear in the March issue of Physics Today.

(*Paragraph 6*)
Brody's suggestion would require the governing bodies of tennis to change the rules regulating the ball size for tournaments. He will be proposing such a change to the United States Tennis Association in early March. He envisages a time when every tournament will choose a ball size appropriate to its court surface and the players' level of skill.

Question 22 (contd)

a) Estimate the increase in surface area of a regular tennis ball if its diameter is increased by 20% as Brody (the researcher) in the article suggests. You will need to list any assumptions you make. (The surface area of a sphere is $4\pi r^2$). (4 marks)

Estimate of tennis ball's diameter is 6.0 cm (1 mark)

Surface area of regular = $4\pi r^2$

$= 4 \times \pi \times 3.0^2$

$= 113 \text{ cm}^2$ (1 mark)

Surface area of "new" ball = $4 \pi r^2$

Radius is 20% greater = 3.6 cm

So surface area of "new ball" = $4 \times \pi \times 3.6^2$

$= 163 \text{ cm}^2$ (1 mark)

So increase in surface area is $163 - 113 \text{ cm}^2$

$= 49.8 \text{ cm}^2$ increase

$= 50 \text{ cm}^2$ (2 sf for estimate) (1 mark)

b) Why would the ball travel slower if its diameter was increased? (2 marks)

It would travel slower because of the increased surface area being presented to the air. (1 mark)

This is a frictional force which therefore opposes the direction of motion and thus results in the ball have a slower speed. (1 mark)

c) Calculate the time it would take for a tennis ball served at 209 km h^{-1} by a top male player to reach an opponent at the opposite end of a Wimbledon tennis court. The length of the tennis court is 24.0 m. (2 marks)

$v = 209 \text{ km h}^{-1} = 58.06 \text{ m s}^{-1}$

$t = s/v$

$= 24.0/58.06$ (1 mark)

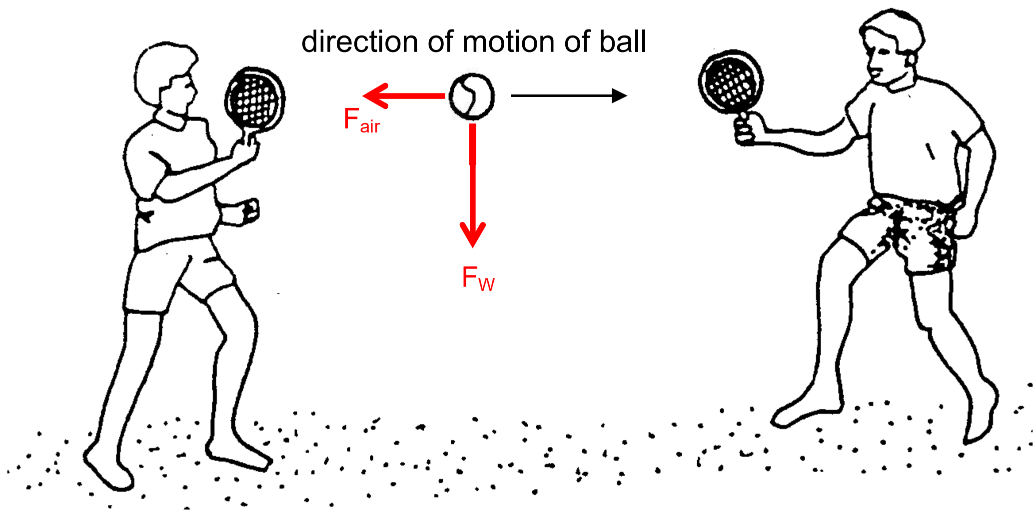
$= 0.413$ s (1 mark

Question 22 (contd)

d) What are the main factors in modern racket design which allow players to give maximum power to a stroke? (2 marks)

The fact that rackets are lighter, stiffer and are able to be swung faster with more whip from the wrist is the main factor which allows players to give maximum power to a stroke.

e) Below is a diagram of the new, larger tennis ball showing it moving horizontally between two players. On a sketch of the situation, draw labelled arrows on the ball to show the forces acting on the ball. (2 marks)



1 mark per labelled force, less one mark for incorrect or spurious forces

Question 22 (contd)

f) Why do players using the regular size ball have to aim more carefully? (2 marks)

The regular ball travels very much faster than the "new" ball. (1 mark)

Hence there is less room for error. Careful placement of the regular ball is necessary to prevent it landing out of court. The regular balls, travelling at a higher horizontal velocity, have less time to drop vertically into the opponent's court. (1 mark)

g) The article uses the term "sweet spot". What is meant by the term "sweet spot" and why is a large "sweet spot" on a racket an advantage for a less talented player? (3 marks)

The sweet spot is an area on the racket which when the ball hits it will produce a maximum rebound momentum. (1 mark)

Hitting outside the sweet spot will result in loss of momentum and hence rebound velocity. (1 mark)

A less talented player can maintain good rebound velocity from a large sweet spot because there is greater room for error in striking the ball. The player has a greater area with which to strike the ball and still retain maximum rebound velocity. (1 mark)

h) If a player has a tantrum and throws their racket on the ground, how will a modern racket behave compared to its wooden predecessor? (1 mark)

Likely to bounce higher, less likely to break. Any reasonable answer.

End of Examination