SECTION A

Answer ALL questions.

You MUST write your answers in the spaces provided in this answer booklet.

1. (a) Figure 1 shows a skydiver of mass m falling under the influence of gravity and a drag force F_d that is proportional to v^n ($F_d = bv^n$), where v is the velocity of the skydiver as she falls, b is a constant and n is an integer.

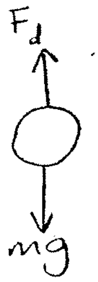


Figure 1

(i) Next to Figure 1 draw a free body diagram to show the forces acting on the sky-diver.

[1 mark]

(ii) Hence show that when her downward acceleration is a, the equation of motion for the skydiver can be written as

$$g - a = \frac{b}{m} v^n.$$

Net force = $W - F_D = mg - bv^n$ ✓

Net force = $F = ma$

$mg - bv^n = ma$

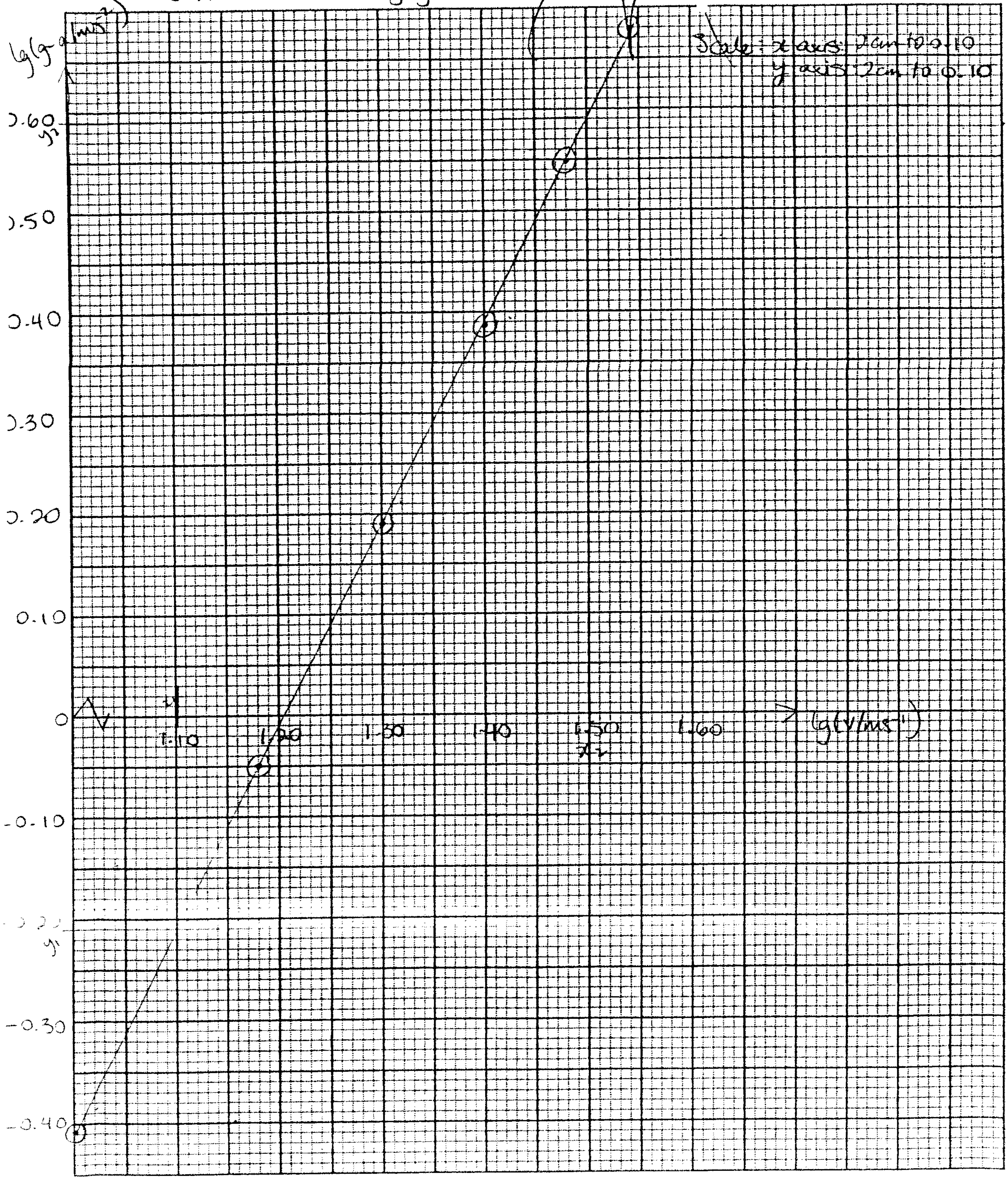
$mg - ma = bv^n$

$m(g-a) = bv^n$

$g - a = \frac{b}{m} v^n$

[2 marks]

GRAPH SHOWING lg(g-a) AGAINST lg v



GO ON TO THE NEXT PAGE

(b) Table 1 shows data recorded for the acceleration and velocity of the skydiver as she underwent free fall.

TABLE 1

Acceleration a/m s^{-2}	Velocity v/ms^{-1}	$g - a$/m s^{-2}	lg $(g - a)$	lg v
9.41	10	0.390	−0.409	1.00
8.91	15	0.890	−0.051	1.18
8.24	20	1.56	0.193	1.30
7.36	25	2.44	0.387	1.40
6.28	30	3.52	0.547	1.48
5.00	35	4.80	0.681	1.54

(i) Complete Table 1 by filling in the blank columns. **[3 marks]**

(ii) On page 4, plot a graph of lg $(g - a)$ vs lg v. S − 1 P − 2 **[3 marks]**

(iii) Calculate the gradient of the graph and hence determine a value for n (to the nearest integer).

$$\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$(x_1, y_1) = (1.10, -0.21) \quad (x_2, y_2) = (1.50, 0.59)$$

$$\text{gradient} = \frac{0.59 - (-0.21)}{1.50 - 1.10} = \frac{0.8}{0.4} = 2.0$$

$$g - a = \frac{b}{m} V^n$$

$$\lg(g-a) = \lg\frac{b}{m} + n \lg V$$

$$y = c + mx$$

$$n = \text{gradient} = 2$$

[3 marks]

(iv) Calculate the terminal velocity of a skydiver with a mass of 78.5 kg, given that $b = 0.251$ kg m^{-1}.

~~At terminal velocity, $F_D = W = mg$~~

$\cancel{78.5kg\ 78.5kg}\ (9.8\ ms^{-2}) = \frac{0.251 kgm^{-1}}{78.5kg} V^2$

$V^2 = \cancel{24059.8}\ 240597.8$

$V = \sqrt{240597.8}$

$V = 491\ ms^{-1}$

At terminal V,

$F_D = W = bv^2$

$78.5kg(9.8ms^{-2}) = 0.251kgm^{-1}\ v^2$

$v^2 = 3064.9\ m^2s^{-2}$

$V = \sqrt{3064.9 m^2s^{-2}}$

$V = 55.4\ ms^{-1}$

[3 marks]
Total 15 marks

CAPE PHYSICS 2011
Paper 02 - UNIT 1 EXEMPLARS

MODULE 1

Question 1

The candidate demonstrated sound knowledge and understanding of the material presented in this question.

In parts (a) and (b), the candidate correctly drew the free body diagram showing the forces acting on the skydiver and was then able to use the information provided to derive the force equation required for the proof.

In part (b) (i), the candidate showed a good grasp of the use of significant figures and correctly completed each of the three columns of the table provided.

With respect to the graph, the candidate correctly deduced '*n*' as the gradient value and displayed the understanding that an integer does not require decimal places. However, it must be pointed out that the 'broken axis' symbol, as used by the candidate in drawing the graph, is inappropriate in Physics.

In part (b) (iv), although it was not explicitly stated in the response that $a = 0$, the candidate used the fact that at terminal velocity the upward forces = downward forces to obtain the correct value.

2. (a) Figure 2 shows a loudspeaker sounding a constant note placed above a long vertical tube containing water which slowly runs out at the lower end.

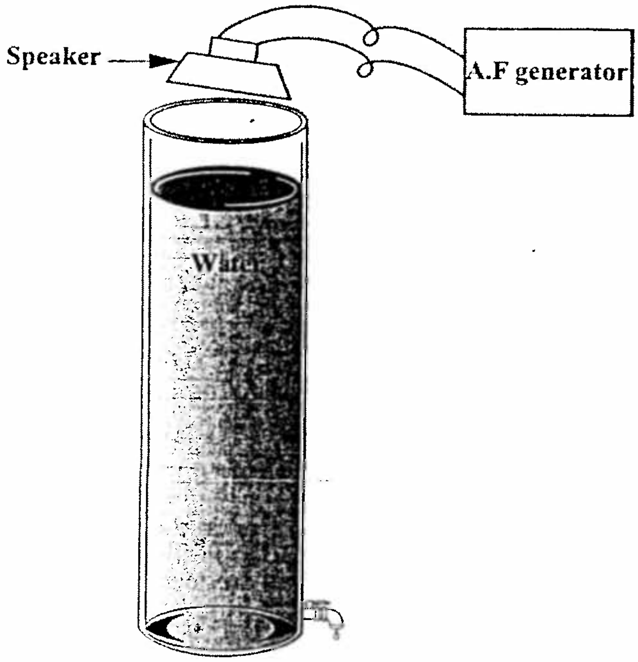


Figure 2

(i) Describe and explain what is heard at a certain level as the water runs out at the lower end.

At a certain level, the distance from the surface of the water to a height above the tube would be equal to $\frac{1}{4}\lambda$ of the stationary wave produced as a result of the superposition of the soundwave and its reflected wave. At this level, the sound would be heard loudest

[2 marks]

(ii) What name is given to this phenomenon?

resonance

[1 mark]

(b) The frequency of a vibrating string is given by $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$, where T is the tension in the string, μ is the mass per unit length of the string and l is the length of the string.

While the tension of a vibrating string was kept constant at 100 N, its length was varied in order to tune the string to a series of tuning forks. The results obtained are shown in Table 2.

TABLE 2

Frequency of Fork, f (Hz)	256	288	320	384	450	512
Length of String, l (m)	0.781	0.695	0.625	0.521	0.444	0.391
$1/l$ (m^{-1})	1.28	1.44	1.60	1.92	2.25	2.56

(i) Complete the table by filling in the values for $1/l$. **[1 mark]**

(ii) On page 9, plot a graph of frequency f vs $1/l$. **[3 marks]**

(iii) Use the graph to determine the frequency of an unmarked fork which was in tune with 41.7 cm of the string.

~~gradient = y x vertical axis scale / x horizontal axis scale~~

~~= 15.0 x 25 Hz / 15.0 x 0.125 m⁻¹~~

~~= 200 Hz m = 200 m s⁻¹~~

$41.7\text{ cm} = 0.417\text{ m}$

$\frac{1}{0.417} = 2.40\text{ m}^{-1}$

when $1/l = 2.40\text{ m}^{-1}$

$f = 480\text{ Hz}$

[2 marks]

(iv) Calculate the gradient of the graph.

$$\text{gradient} = \frac{y \times \text{vertical axis scale}}{x \times \text{horizontal axis scale}}$$

$$= \frac{10.0 \times 25\text{ Hz}}{10.0 \times 0.125\text{ m}^{-1}}$$

$$= 200\text{ Hz m} = 200\text{ m s}^{-1}$$

[3 marks]

(v) Determine the value of the mass per unit length, μ, of the wire.

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

$(\div \frac{1}{l})$ $f \div 1/l = \frac{1}{2}\sqrt{\frac{T}{\mu}}$

but $f \div 1/l$ = gradient

$\therefore \frac{1}{2}\sqrt{\frac{T}{\mu}}$ = gradient

$\frac{1}{2}\sqrt{\frac{T}{\mu}} = 200\text{ m s}^{-1}$

$\sqrt{\frac{T}{\mu}} = 400$

$\frac{T}{\mu} = 400^2$

$\mu = T/400^2$

$= \frac{100}{400^2}$

$\mu = 6.25 \times 10^{-4}\text{ kg m}^{-1}$

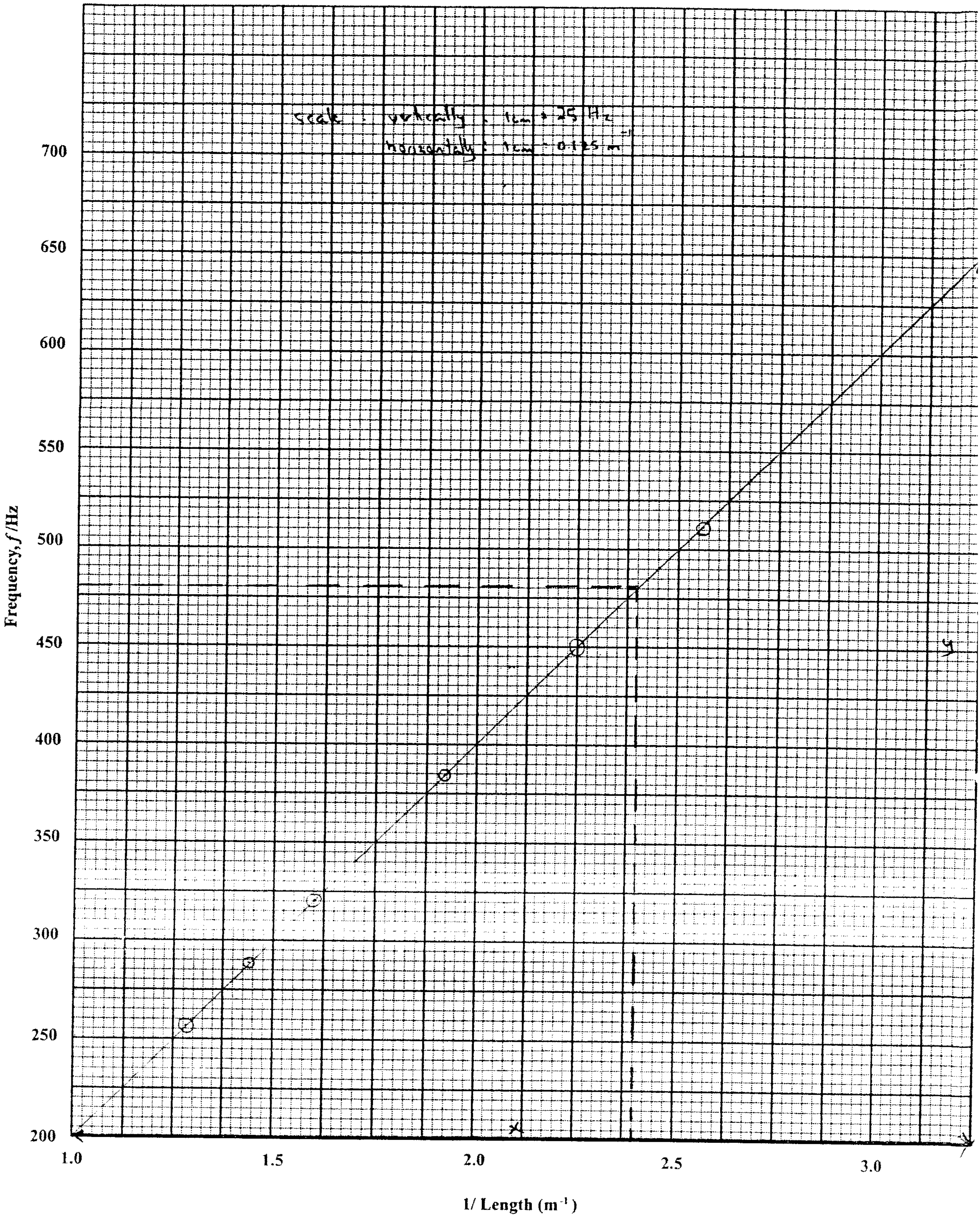
$\mu = 6.25 \times 10^{-4}\text{ kg m}^{-1}$

[3 marks]

Total 15 marks

GO ON TO THE NEXT PAGE

Graph of frequency f vs 1/L



CAPE PHYSICS 2011

Paper 02 - UNIT 1 EXEMPLARS

MODULE 2

Question 2

This script represented an outstanding response to the question.

In part (a), the candidate was able to correctly describe and explain the loud sound heard at a certain level in terms of the wavelength of the sound compared to the length of the air column above the water surface in the tube ($l = \lambda/4$).

In part (b), $1/l$ was found correctly to three significant figures and the graph of f vs $1/l$ was accurately plotted. The frequency of the unmarked fork was correctly determined by first finding $1/l$ when $l = 41.7\ cm$ and using the value to deduce the corresponding frequency of $f = 480\ Hz$ from the best fit line.

In part (b) (iv), the candidate calculated the gradient by using the large triangle on the graph and dividing the vertical change in frequency by the corresponding horizontal change in $1/l$ using the formula

$$\frac{y \text{ x vertical axis scale}}{x \text{ x horizontal axis scale}},$$

in which x and y represented the number of units along the horizontal and vertical lengths respectively of the gradient triangle. Many of the other candidates who correctly calculated the gradient used the more popular $m = \frac{y_2 - y_1}{x_2 - x_1}$ formula.

Finally, the candidate also correctly determined the value of mass per unit length, μ, using the gradient found in part (i) and then equated the gradient to $\frac{1}{2}\sqrt{\frac{T}{\mu}}$ to solve for μ.

6. Figure 4 shows some gas contained in a cylinder with a piston in thermal equilibrium at a temperature of 315 K. The cylinder is **thermally isolated from its surroundings**. Initially the volume of gas is 2.90×10^{-4} m^3 and its pressure is 1.03×10^5 Pa.

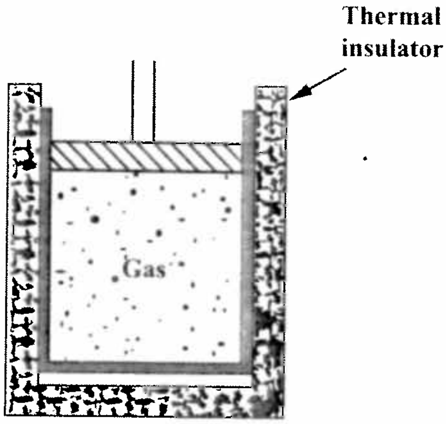


Figure 4

(a) Use the equation of state for an ideal gas to find the amount, in moles, of gas in the cylinder. **[3 marks]**

(b) The gas is then compressed to 3.5×10^{-5} m^3 and its temperature rises to 790 K. Explain this rise in temperature

(i) on a macroscopic scale, using the first law of thermodynamics **[3 marks]**

(ii) on a microscopic scale, using the kinetic theory of gases. **[3 marks]**

(c) Calculate the pressure of the gas after this compression. **[2 marks]**

(d) The work done on the gas during the compression is 90 J. Use the first law of thermodynamics to find the **increase** in the internal energy of the gas during the compression. **[1 mark]**

(e) Calculate the molar heat capacity of the gas in the container. **[3 marks]**

Total 15 marks

GO ON TO THE NEXT PAGE

You MUST write the answer to Question 6 here.

6. (a) $pV = nRT$

$$n = \frac{pV}{RT} = \frac{1.03\times10^{5} \times 2.90\times10^{-4}}{8.31 \times 315}$$

$$= 1.14\times10^{-2} \text{ moles}$$

(b) i) First Law of thermodynamics: $\Delta U = \Delta Q + \Delta W$

ΔU - change in internal energy ΔQ - heat supplied ΔW - work done on gas

Since the gas is being compressed, work done on the gas is positive i.e. ΔW is positive. Hence ΔU is increasing and since the temperature of ~~an gidea~~ a gas and its internal energy are directly related, the temperature rises.

ii) when a gas is compressed, the molecules of the gas collide with a greater frequency. Also, as the piston moves in, molecules hitting the piston rebound with a greater velocity hence they ~~posses~~ possess more kinetic energy since $KE = \frac{1}{2}mv^2$.

The temperature of a gas is the average kinetic energy of the molecules so if the kinetic energy increases, the temperature increases.

(c) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$P_1 = 1.03 \times 10^5\,Pa$ $\quad P_2 = ?$
$V_1 = 2.90 \times 10^{-4}\,m^3$ $\quad V_2 = 3.5 \times 10^{-5}\,m^3$
$T_1 = 315\,K$ $\quad T_2 = 790\,K$

$$P_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{V_2} = \frac{(1.03 \times 10^5 \times 2.90 \times 10^{-4})}{315} \times \frac{790}{3.5 \times 10^{-5}}$$

$$= 2.14 \times 10^6\,Pa$$

(d) $\Delta U = \Delta Q + \Delta W$

Since no heat is added to the system $\Delta Q = 0$

$\Rightarrow \Delta U = \Delta W = 90\,J$

(e) $E = nC\Delta\theta$

$\Delta\theta = 790 - 315 = 475\,k$

$n = 1.14 \times 10^{-2}$ moles

$E = 90\,J$

$$C = \frac{E}{n\Delta\theta} = \frac{90}{(1.14 \times 10^{-2}) \times 475} = 16.6\,J\,mol^{-1}\,K^{-1}$$

END OF TEST

CAPE PHYSICS 2011
Paper 02 - UNIT 1 EXEMPLARS

MODULE 3

Question 6

The candidate demonstrated sound understanding of the thermal properties of matter. In part (a), the candidate selected the correct equation, made the correct substitutions and provided the answer correct to three significant figures.

In explaining the rise in temperature in part b (i), the candidate first defined the first law of thermodynamics and each of the associated terms. The candidate correctly indicated that work is being done on the gas and that this leads to an increase in the internal energy and an increase in temperature. However the candidate failed to indicate that because the cylinder is thermally insulated $Q = 0$ and so all the work done goes into increasing the internal energy.

In part (b) (ii), the candidate accurately explained that as the piston moves in, it hits the molecules which rebound with greater speed thus increasing their kinetic energy and resulting in the increase in temperature.

The candidate correctly used the equation $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ in the calculation for part (c). However, in this case, the equation $P\ V = n\ R\ T$ could also have been used.

In parts (d) and (e), the candidate again used the proper substitutions and correctly manipulated the equations to find the increase in the internal energy of the gas and the molar heat capacity of the gas.

It should also be noted that the candidate consistently calculated all answers in parts (a), (c) and (e) to three significant figures.