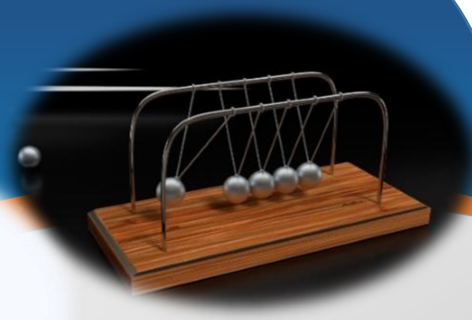
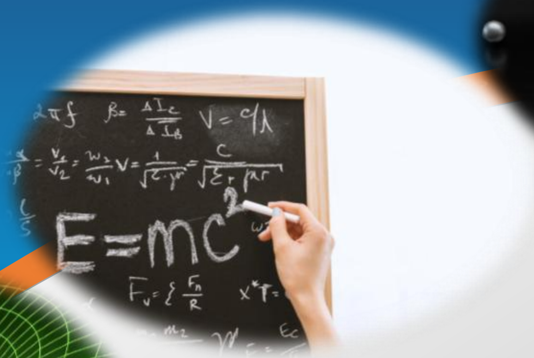
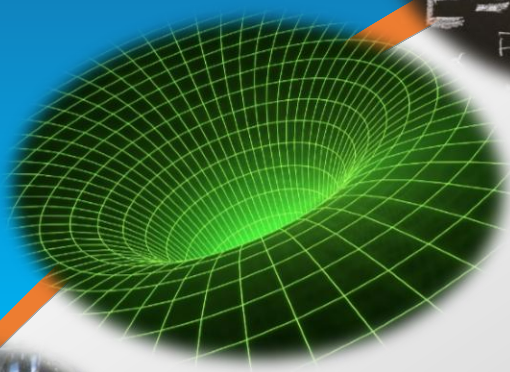
CARIBBEAN EXAMINATIONS COUNCIL

CAPE® PHYSICS UNIT 1







Subject Report with Exemplars

May/June 2024

CARIBBEAN EXAMINATIONS COUNCIL

REPORT ON CANDIDATES' WORK IN THE
CARIBBEAN ADVANCED PROFICIENCY EXAMINATION

MAY/JUNE 2024

PHYSICS
UNIT 1

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INTRODUCTION

This was the sixth examination of the revised syllabus.

There was a candidate entry of approximately 2796 for Physics Unit 1 this year compared to 2757 in 2023 and 2920 in 2022.

This year, for Unit 1, the percentage of candidates earning acceptable grades, Grades I–V, was approximately 96.9 per cent compared with 97.7 per cent in 2023 and 96.5 per cent in 2022.

Candidate performance improved on Module 3 — Thermal and Mechanical Properties of Matter. However, regarding Module 1 — Mechanics, and Module 2 — Oscillations and Waves, there was a decline in performance over the previous year.

PAPER 01 — MULTIPLE CHOICE

Paper 01 consisted of 45 multiple-choice items. It was designed to provide adequate coverage of the content with items taken from all sections of the syllabus. Approximately 70.4 per cent of candidates earned grades I–III on this paper; the mean score was 32 out of 45 marks.

PAPER 02 — STRUCTURED ESSAY

Paper 02 consisted of three questions, one drawn from each of the modules in the syllabus.

Module 1: Mechanics
Module 2: Oscillations and Waves
Module 3: Thermal and Mechanical Properties of Matter

Each question in this section was worth 30 marks. Candidates were required to answer all three questions. The mean score for the entire paper was 34 out of 90. No candidate obtained full marks for Questions 2 or 3, the highest score being 29 out of 30 which was obtained by one candidate for Question 2 and 7 candidates for Question 3.

Question 1

Part (a) assessed candidates' ability to define the terms *displacement* and *acceleration*. A significant number of candidates were unable to define displacement, a concept that they have been exposed to as early as fourth form.

Candidate's Response to Parts (a) (i) to (ii)

(a) Define EACH of the following terms.

(i) Displacement

Displacment is the ~~Length~~ Lengh between an object and its original position in a given direction.

[2 marks]

(ii) Acceleration

Acceleration is the Change in velocity per Second in a given direction

[1 mark]

Examiner's Comments

The candidate was able to define both concepts accurately as per the syllabus requirement.

Part (b) required candidates to plot a graph of velocity, v, versus time, t, to represent the motion of the rocket balloon, and draw the best smooth curve through the points. The graph was generally well plotted but the curves drawn did not have the appropriate symmetry. Candidates should practise drawing smooth curves of best fit.

Candidate's Response to Part (b)

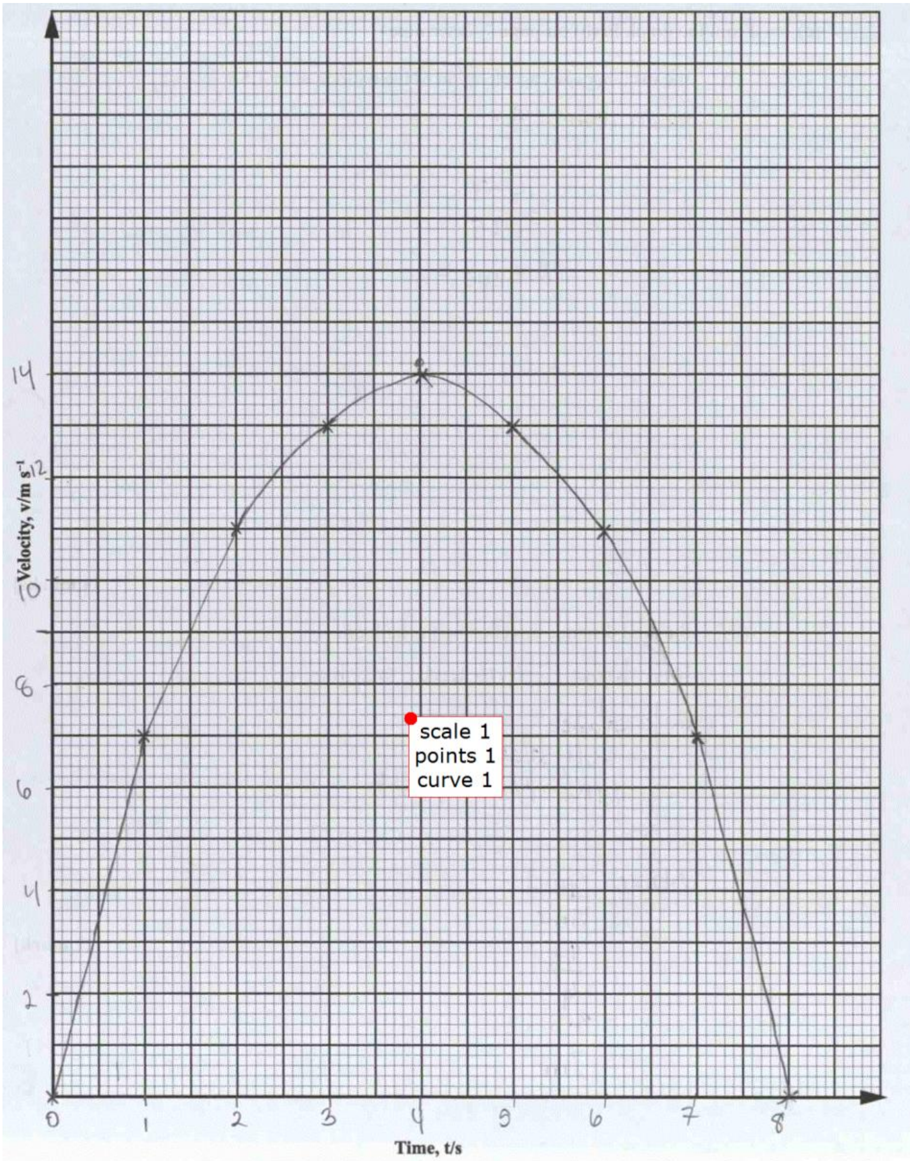


Figure 1. Graph of velocity, v, versus time, t

Examiner's Comments
The candidate demonstrated competence in the plotting of graph; all the necessary components were spot on.

For Part (c), candidates were asked to use the graph from Part (b) to determine (i) the instantaneous acceleration of the balloon after 1.5 s and (ii) the total distance travelled by the balloon.

In Part (c) (i), many candidates did not understand that instantaneous acceleration is linked to the tangent at a point on the graph (in this case at t =1.5 s); they therefore attempted to use an equation of motion at that point. Additionally, some candidates understood that acceleration can be found from the gradient of the graph and simply divided the velocity by the time at 1.5 s; this does not correspond to the gradient of the tangent at that point.

For Part (c) (ii), a significant number of candidates recognized that the area under the graph is used to calculate distance travelled; however, they did not determine this area correctly, for example, by counting squares or by using any other appropriate method.

Candidate's Response to Parts (c) (i) to (ii)

(c) From the graph in (b) **on page 7,** determine

(i) the instantaneous acceleration of the balloon after 1.5 s

$$a = m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{18\,ms^{-1} - 7\,ms^{-1}}{3.8s - 0.9s} = \underline{3.79\,ms^{-2}}$$

a=gradient 1
tangent drawn 1
substitution 1
range 1

(ii) the total distance travelled by the balloon.

Area under graph

$A = 2470\,mm^3 + 137\,cm^3$ **[1 mark]**

$A = 0.47\,cm^3 + 137\,cm^3$

$= 137.47\,cm^3$

$1cm^3 : 0.5m$

$\therefore s = 137.47\,cm^3 \times 0.5\,m\,cm^{-3}$

$\underline{s = 68.7\,m}$

Examiner's Comments

The candidate understood fully what was being tested and executed both objectives seamlessly.

Part (d) (i) asked candidates to calculate the vertical component of the ball's velocity while Part (d) (ii) asked for the calculation of the horizontal component of the ball's velocity. Most candidates correctly calculated the vertical and horizontal components of the ball's velocity though a few candidates mixed up the vertical with the horizontal.

For Part (d) (iii), candidates had to calculate the time it took the football to reach the maximum height. Many candidates calculated this part correctly. However, a significant number of them did not correctly apply the convention, for example, u is positive and a = -g. Also, some candidates calculated the total time of flight but failed to recognize that the time the object takes to reach the maximum height is half the time of flight.

Part (d) (iv) asked candidates to calculate the maximum height reached by the football. This part was done exceptionally well. Most candidates knew and correctly applied the formula for maximum height.

Candidate's Response to Parts (d) (i) to (iv)

(i) the vertical component of the ball's velocity

$\sin\theta = \frac{V_v}{V}$

$V_v = \cancel{si}\, V\sin\theta$

$= 30.0\sin 25°$

$= 12.7\ ms^{-1}$

V_v = vertical velocity

V = initial velocity

$V = 30\ ms^{-1}$

$\theta = 25°$

[3 marks]

(ii) the horizontal component of the ball's velocity

$V_h = V\cos\theta$

$= 30.0\cos 25°$

$= 27.2\ ms^{-1}$

V_h = horizontal velocity

[3 marks]

(iii) the time, *t*, for the football to reach the maximum height, *H*

reaches h_{max} ~~at~~ when ~~t~~ ~~v=o~~ $v\sin\theta = 0$

$a = \frac{v-u}{t}$

$t = \frac{v-u}{a}$

$= \frac{0-12.7}{-9.81}$

$= 1.29\ s$

$u = v\sin\theta = 12.7\ ms^{-1}$

$v = 0\ ms^{-1}$

$a = \cancel{9.8}\ -g$

$= -9.81\ ms^{-2}$

[3 marks]

(iv) the maximum height reached by the football.

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

$h_{max} = (v\sin\theta)t + \frac{1}{2}(-g)(t^2)$

$= (12.7)(1.29) + \frac{1}{2}(-9.81)(1.29)^2$

$= 8.22\ m$

$s = h_{max}$

$u = v\sin\theta$

$a = -g = -9.81\ ms^{-2}$

$t = 1.29\ s$

[3 marks]

Examiner's Comments

The candidate demonstrated mastery in assessing motion in two dimensions (projectile). The candidate was also able to resolve the velocity vector in its respective 'x' and 'y' components and use them appropriately to extract additional information about the object during motion.

Part (e) required candidates to find the equation of the trajectory, *y* as a function of *x*, to show that the motion of the football is parabolic. A fair number of candidates did this part well, with clear steps. The most common mistakes were application of convention, for example, u is positive and a = -g. Some candidates were able to start the derivation but couldn't coherently follow through.

Candidate's Response to Part (e)

(e) Find the equation of the trajectory, *y* as a function of *x*, to show that the motion of the football is parabolic.

Horizontal component of velocity, $v_H = v\cos\theta$

Since it is assumed that air resistance is neglegable,

$a = 0$

$\therefore x\cancel{s} = ut + \frac{1}{2}at^2$, where, s = displacement, u = initial velocity,

$x\cancel{s} = v\cos\theta \times t + \frac{1}{2}(0)t^2$ a = acceleration and t = time

$x\cancel{s} = v\cos\theta\, t$

Transposing for t $\Rightarrow$ $t = \frac{\cancel{s}x}{v\cos\theta}$ .... equation ①

Vertical component of velocity, $V_v = v\sin\theta$

$\therefore y\cancel{s} = v\sin\theta\, t + \frac{1}{2}(-\cancel{9.81}\,g)t^2$ ... equation ②

Substituting equation ① into equation ②

$\Rightarrow y = v\sin\theta\left(\frac{\cancel{s}x}{v\cos\theta}\right) + \frac{1}{2}(-g)\left(\frac{\cancel{s}x}{v\cos\theta}\right)^2$

~~$y = \tan\theta\, x + \frac{1}{}$~~

$y = \tan\theta\, x - \left(\frac{g}{2v^2\cos^2\theta}\right)x^2$

This equation is of the form $y = bx + ax^2$, which is a parabola.

[7 marks]

Examiner's Comments

This represented an excellent execution of the proof. The candidate used mathematical knowledge and incorporated it into two-dimensional kinematic motion to show that the motion of the object is parabolic.

Overall performance on the Question 1 was fairly good. On average, more than 15 marks were recorded for approximately 50 per cent of the scripts.

Recommendations

- Review of definitions of displacement and acceleration should be done as well as other kinematic concepts.
- Teachers must not only address situations with constant acceleration and equations of motion but include situations where acceleration is changing. They should also guide students regarding how to determine instantaneous acceleration.
- Teachers should include more practice on drawing smooth curves of best fit.
- When formulas such as time of flight are provided, candidates need to demonstrate an understanding of the situations in which those formulas are applicable.
- Teachers should reemphasize convention when teaching projectile motion/motion under gravity since velocity and acceleration can be in opposite directions.
- Teachers are reminded to stress the importance of looking at the units given on axes of graphs and/or column headings instead of assuming a particular unit.

Question 2

This question tested candidates' knowledge of three topics in Module 2. The topics were Physics of the Eye, Refraction and Total Internal Reflection and Frequency Response of the Ear.

Generally, the question was not well done. There were a few instances where candidates did not attempt any part of the question. Additionally, there were a few candidates who, despite having attempted the question, did not attain any marks. Overall, most candidates scored less than 20 marks in this question.

Part (a) contained three subparts. These three parts asked candidates to define common terms as it relates to the eye. Very few candidates were able to give completely accurate definitions. Many candidates got no marks, as they did not know the definitions; a few did not even attempt this part of the question.

Candidate's Response to Parts (a) (i) to (iii)

(a) Define EACH of the following terms.

(i) Depth of focus

Depth of focus is the range of image distances for which a clear image is produced on the retina.

[2 marks]

(ii) Accommodation

Accomodation is the ability of the lens to adjust its focal length, thus its power, to produce clear images on the retina at various (object) distances

[2 marks]

(iii) Astigmatism

Astigmatism occurs ~~#~~ due to uneven surface /bending of the lens i.e. many focal lengths are present (vertically and horizontally) leading to many images being produced on the retina to form 1 overall very blurry /unclear image.

[2 marks]

Examiner's Comments

The candidate correctly defined the terms.

Part (b) required candidates to use annotated optical sketches to explain how short-sightedness occurs and how the defect can be corrected. Some candidates were able to draw the eye with correct labels and annotations. Some candidates did not know how to draw the defect and what lens should be used to correct the defect. Also, some candidates did not remember that the rays should be parallel coming from a distant object; instead, they drew it as coming from a near point.

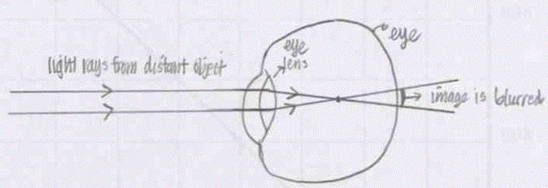
There seems to be a limitation in the teaching and learning experiences to which students are exposed in this area of the syllabus.

Candidate's Response to Part (b)

(b) Short-sightedness is an eye defect that affects many people.

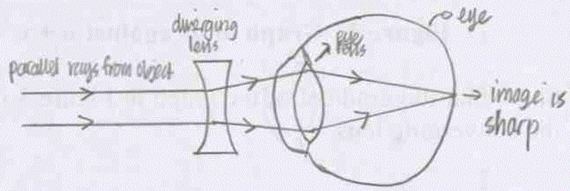
Use annotated optical sketches to explain how short-sightedness occurs AND how the defect can be corrected.

Short-sightedness is when a person can focus on near objects, but cannot focus on distant objects. It occurs when the eyeball is too long, or the person's lens is too powerful i.e. too converging.



In the above diagram, the image is formed before the retina, and thus appears blurry on the retina.

To correct this, a diverging lens can be used so that light rays can focus on retina.



In the above diagram, the ~~image~~ rays is now focused on the retina, producing a sharp image.

Note, however, that diverging lens must be removed for viewing ~~the~~ near objects, as rays would now converge in front of retina.

Examiner's Comments
The candidate drew two clear diagrams — one of the defect and another of the lens used to correct the defect.

For Part (c), candidates were provided with a graph on which *uv* was plotted against *u* + *v* where *u* represented a series of object distances and *v* represented corresponding image distances.

For Part (c) (i), candidates were required to show that the gradient of the graph is equal to the focal length, f, of the converging lens. Only a few candidates were able to manipulate the equation to show that the focal length was equal to the gradient of the graph. Some candidates attempted circular proofs. Quite a few candidates misunderstood the question; they found the numerical value of the gradient and then attempted to show that it was equal to the focal length.

Analysis on performance in this part of the question shows that mathematical techniques need to be reinforced and that candidates need a greater understanding of what a proof should look like.

Candidate's Response to Part (c) (i) — Sample 1

(i) Show that the gradient of the graph in Figure 3 is equal to the focal length, *f*, of the converging lens.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{f} = \frac{u+v}{uv}$$

Cross multiplying :

$$uv = f(u+v), \text{ where}$$

$$y = m\ x$$

$$\therefore y = uv,\ x = u+v,\ m = \text{gradient} = f \ \square$$

[3 marks]

Candidate's Response to Part (c) (i) — Sample 2

(i) Show that the gradient of the graph in Figure 3 is equal to the focal length, *f*, of the converging lens.

$$\frac{1}{f} = \frac{1^{\times v}}{u} + \frac{1^{\times u}}{v}$$

$$\frac{1}{f} = \frac{u+v}{uv}$$

$$\therefore f = \frac{uv}{u+v}$$

$$\text{gradient} = \Delta y / \Delta x$$

$$\text{gradient} = \frac{uv}{u+v}$$

$$\therefore f = \text{gradient} = \frac{uv}{u+v}$$

[3 marks]

Examiner's Comments

These candidates used different methods but were each able to clearly show that f = gradient of the line. The first candidate found the equation of the gradient and equation of frequency and equated them while the second candidate used the lens equation and related it to the equation of a straight line.

For Part (c) (ii), candidates had to use the graph to determine a value for the focal length of the converging lens used in the experiment. Many candidates got this part correct; however, some did not bother to put in their units. The importance of units needs to be reemphasized.

Candidate's Response to Part (c) (ii)

(ii) From the graph in Figure 3, determine a value for the focal length of the converging lens the student used in the experiment.

$$\text{gradient} = \frac{uv}{u+v} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{700 - 0}{35 - 0} = 20\text{cm}$$

$$f = 20\text{cm or } 0.2\text{m}$$

[2 marks]

Examiner's Comments
The candidate correctly chose two points and calculated the gradient using the correct unit.

For Part (c) (iii), candidates were asked to determine the power of the converging lens used in the experiment. While some candidates knew the equation for power of the lens, they did not know that the value calculated in the previous part must be converted to metres. They also did not know that the unit for power of the lens was dioptre (D). Again, the importance of units needs to be emphasized during teaching practice.

Candidate's Response to Part (c) (iii)

(iii) Determine the power of the converging lens used in the experiment.

$$f = 0.2\text{m}$$

$$P = \frac{1}{f} = \frac{1}{0.2} = 5\text{D}$$

Examiner's Comments
The candidate correctly used the equation to find the power of the lens and stated the correct units for both focal length and power.

Part (d) (i) required candidates to state, in words, Snell's law; and Part (d) (ii) asked them to explain how total internal reflection occurs. These parts required definitions and many candidates were unable to score any marks because they did not know the correct definitions. Those who did score marks were unable to get total marks because their definitions were incomplete. Only a few candidates got full marks in this section.

Candidate's Response to Part (d) (i)

(d) (i) State, in words, Snell's law.

Snell's law states that for a wave travelling from one medium to another, the ratio of the sine of angle of incidence to the sine of angle of refraction is constant.

i.e. ${}_1n_2 = \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} = \text{constant}$.

[2 marks]

Examiner's Comments
The candidate correctly defined the term.

Candidate's Response to Part (d) (ii)

(ii) Explain how total internal reflection occurs.

When a wave is travelling from a lower velocity (or higher n) medium to a higher velocity (or lower n) medium, and the angle of incidence is greater than the critical angle, the wave totally internally reflects. (ie. no refraction occurs).

[2 marks]

Examiner's Comments
The candidate correctly defined the term.

For Part (e), candidates were provided with a figure and were asked to (i) calculate the critical angle at the glass/liquid interface and (ii) calculate the angle of emergence of the ray from the cube.

Many candidates calculated Part (e) (i) incorrectly; they applied a formula (1/n = sin c) out of context. While some candidates were able to obtain the value for the refracted angle at the air/glass boundary, they were unable to proceed further to calculate the critical angle at the glass/liquid boundary. Teachers need to expose students to a variety of example involving the use of the equations in this section of the syllabus, with particular emphasis on progression from CSEC-level to CAPE-level questions.

Candidate's Response to Part (e) (i)

(e) A film of liquid separates the lower face of a glass cube resting on a horizontal surface as shown in Figure 4. The refractive index of the glass is 1.50. A ray of light strikes the vertical face of the cube (as shown) at an angle of incidence $i = 48°$. The ray of light undergoes refraction at the vertical air/glass boundary such that it strikes the horizontal glass/liquid interface at the critical angle.

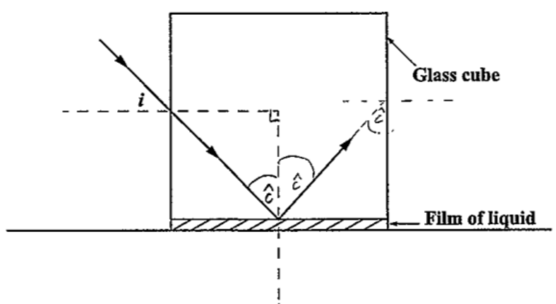


Figure 4. Glass cube resting on film of liquid

(i) Calculate the critical angle at the glass/liquid interface.

$$_a n_g = \frac{n_g}{n_a} = \frac{\sin\theta_a}{\sin\theta_g}$$

$$\Rightarrow \frac{1.5}{1} = \frac{\sin 48°}{\sin\theta_g}$$

$$\theta_g = \sin^{-1}\left(\frac{\sin 48°}{1.5}\right) = 29.7°$$

$$\therefore \hat{c} = 90° - 29.7° = 60.3°$$

[3 marks]

Examiner's Comments

The candidate correctly calculated the angle of refraction and used this to calculate the critical angle at the liquid glass interface.

For Part (e) (ii), many candidates did a lot of calculations when none was necessary. This was because candidates did not know that angle of incidence would be the angle of emergence, if total internal reflection occurred, as suggested by the diagram. However, if the ray was incident on the surface of the liquid at the critical angle, the angle of emergence should have been zero degrees. In addition to syllabus concepts, students should be exposed to simple examination techniques such as understanding that a one-mark question would not require calculations.

Candidate's Response to Part (e) (ii)

(ii) Calculate the angle of emergence of the ray from the cube.

angle of incidence $= 90° - \hat{c} = 90° - 60.3° = 29.7°$

$\therefore\ {}_g n_a = \frac{n_a}{n_g} = \frac{\sin\theta_g}{\sin\theta_a} \Rightarrow \frac{1}{1.5} = \frac{\sin 29.7°}{\sin\theta_a}$

$\therefore\ \theta_a = \sin^{-1}\left((\sin 29.7°) \times 1.5\right) = 48°.$

$= 48.0°.$

Examiner's Comments

The candidate correctly calculated the angle of emergence (48°); however, the response relied solely on the principle that the angle of incidence is equal to the angle of emergence.

Expected Answer

The emergent angle will be equal to the incident angle = 48°

For Part (f), candidates were presented with a scenario where a teenager uses only the right earphone of his headset to listen to music from his mobile device. Candidates were then asked to describe a simple experiment the teenager can perform to determine if the frequency response of his right ear is different from that of his left ear. This part lent itself to many different variations of the experiment, but most candidates understood that there needed to be a varying frequency test for one ear that must be repeated for the other ear and then compared.

Candidate's Response to Part (f)

(f) A teenager uses only the right earphone of his headset to listen to music from his mobile device.

Describe a simple experiment he can perform to determine if the frequency response of his right ear is different from that of his left ear.

① Connect the teenager's headset to a signal generator.
② Set at 20Hz and place the right earphone in his right ear.
③ Increase the frequency on the generator to obtain at frequency he first hears any sound, the frequency at which he hears maximum sound and the frequency before which he hears no sound.
④ Repeat steps ② and ③ placing the headset only over his left ear.
⑤ Using the data collected, plot a graph of sensitivity vs. frequency for each ear.
⑥ Use the graphs to determine if sensitivity has changed at certain frequencies, (if graphs do not match, then frequency responses is different)
It is expected that if he plays music loudly, frequency response is lower in right ear than left ear.

[4 marks]

Examiner's Comments
The candidate clearly explained the experiment.

Recommendations

- There needs to be more emphasis on definitions and more practice with calculations.
- Emphasis must also be placed on the understanding of theory rather than rote learning of equations, so that the equations can be used appropriately where relevant.

Question 3

The question was based on the Kinetic Theory of Gases and assessed candidates' ability to

- recall and use the equation of state for an ideal gas: $pV = nRT$ or $pV = NkT$
- plot and interpret a V-T graph based on a table of values
- express the first Law of thermodynamics
- state and use Charles' Law
- deduce work done from a p-V graph
- solve problems involving the first law of thermodynamics
- discuss why the molar heat capacity of a gas at constant volume is different from that of a gas at constant pressure: $C_P = C_v + R$; $C_p > C_v$
- deduce total kinetic energy of a monatomic gas: $E_k = 3/2\ nRT$
- use the term *molar heat capacity*: $E_H = nC_P\ \Delta\theta$; $E_H = nC_v\ \Delta\theta$.

Almost all candidates attempted this question; however, the question was not well done; only 27 per cent of candidates scored above 15 marks; most candidates (some 73 per cent) scored under 15 marks. Furthermore, only five per cent of candidates scored above 25 marks. Candidates performed best in parts (a), b(i), b(iv), (c), d(i) and d(ii) but experienced most challenges in parts b(iii), b(v) and d(iv).

Part (a) required candidates to write the equation of state for an ideal gas, stating the meaning of each symbol. This part was well answered with over 60 per cent of responses being worth the full three marks. Candidates need to be clear and specific when defining quantities; many lost marks for merely stating that 'symbol T was temperature' instead of specifically noting it as *thermodynamic/absolute temperature* or stating that it was *measured in Kelvin*. Similarly, the symbol 'n' was merely stated as 'moles' instead of *the number of moles of gas*.

Candidate's Response to Part (a)

(a) Write the equation of state for an ideal gas, stating the meaning of EACH symbol.

$PV = nRT$

P - pressure of gas in Pa

V - volume of gas in m^3

n - number of moles of gas in mol

R - molar gas constant in $J\ mol^{-1}\ K^{-1}$

T - absolute temperature in K

[3 marks]

Examiner's Comments
These responses reflected the correct equations and symbol meanings.

Part (b) (i) required candidates to complete Column 3 of a given table. Most candidates (98 per cent) scored the mark for correctly calculating the volumes of the gas in the table.

Candidate's Response to Part (b) (i)

(b) A glass tube of cross-sectional area 6 mm^2 is used to explore the relationship between the volume and temperature of a fixed mass of an ideal gas at constant pressure. Table 2 shows the results of the experiment.

TABLE 2: TEMPERATURE AND VOLUME OF FIXED MASS OF IDEAL GAS

Temperature, t/°C	**Length of gas column, L/mm**	**Volume of gas, V/mm^3**
–35	85	~~614000~~ 510
–3	95	~~857000~~ 57[illegible]
27	105	~~1160000~~ 63[illegible]
57	115	~~1520000~~ 6[illegible]
87	125	~~1450000~~ 750

(i) Complete Column 3 of Table 2. **[1 mark]**

Examiner's Comments
The candidate provided correctly calculated values for Volume of gas.

For Part (b) (ii), candidates were asked to plot a graph of volume of gas, V, versus temperature, t using given scale ranges for the temperature axis and the volume axis. Close to a quarter of candidates earned the full four marks for plotting the graph. Some candidates unfortunately still used inconvenient scales, for example, 1:3; 1:6; 1:7 etc., and omitted to label units on the axes. It was heartening to note that most plots were accurate and generally good lines of best fit were drawn.

Candidate's Response to Part (b) (ii) — Sample 1

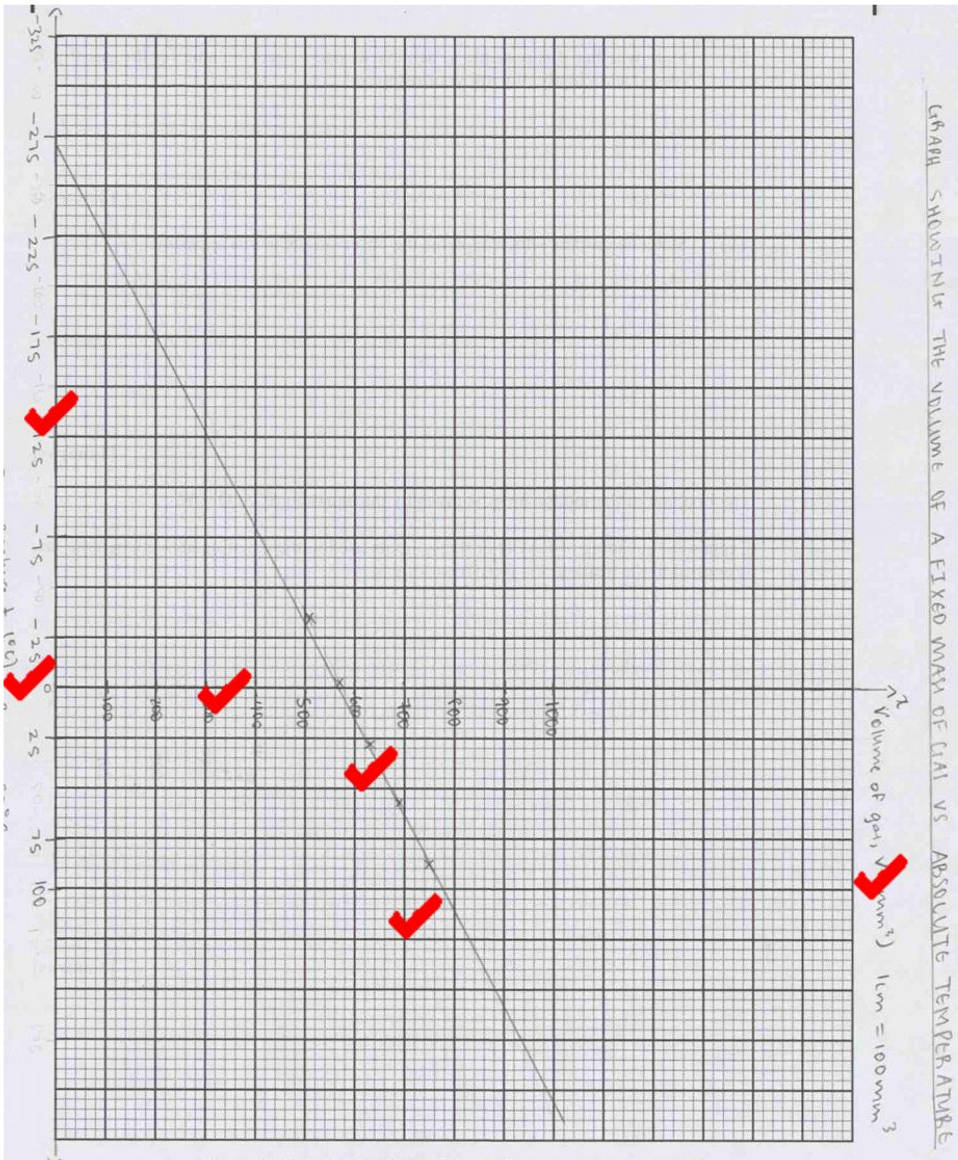


Figure 5. Graph of volume of gas, *V*, versus temperature, *t*.

Examiner's Comments
This was a well-constructed graph with convenient scales, well-labelled axes with symbol/unit and best line.

Candidate's Response to Part (b) (ii) — Sample 2

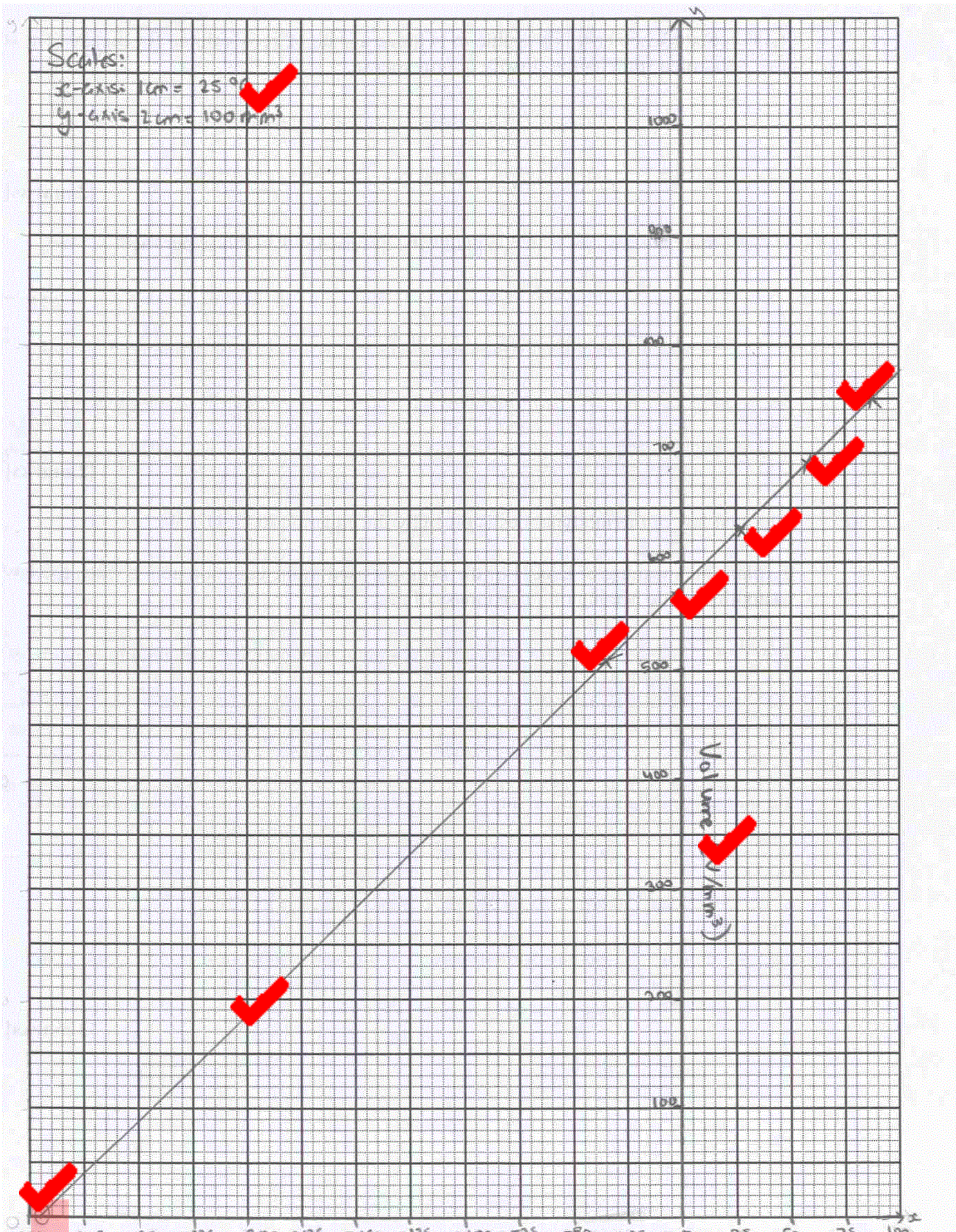


Figure 5. Graph of volume of gas, V, versus temperature, t.

Examiner's Comments

The candidate's response showed accurate plotting, use of a convenient scale, well-labelled axes and a well-drawn best fit line.

For Part (b) (iii), candidates had to use the graph plotted in (b) (ii) to determine the temperature at which the volume is 0 mm^3. Approximately 40 per cent of candidates successfully read off the temperature at zero volume from the graph, thereby earning the two marks. However, several candidates omitted drawing the extrapolated line, failed to include the negative sign for temperature, or inaccurately read the value. Teachers should ensure that they give students ample opportunity to practise plotting, analysing and determining values from graphical work.

Candidate's Response to Part (b) (iii) — Sample 1

(iii) From the graph in (b) (ii), determine the temperature at which the volume is 0 mm^3.

~~−290°C~~ −270°C

[2 marks]

Candidate's Response to Part (b) (iii) — Sample 2

(iii) From the graph in (b) (ii), determine the temperature at which the volume is 0 mm^3.

at V= 0mm^3, T = −295 °C according to the graph

[2 marks]

Examiner's Comments
The candidate showed the intercept on the graph, read off the temperature correctly and included the negative sign.

Part (b) (iv) asked candidates to state whether it is possible to achieve a state of zero volume for the gas if it is cooled sufficiently. Candidates were also required to justify their response. Although approximately 65 per cent of candidates demonstrated the knowledge that it was not possible for the gas to achieve zero volume, only one third was able to provide a reasonable justification for their statement.

Candidate's Response to Part (b) (iv) — Sample 1

(iv) State whether it is possible to achieve a state of zero volume for the gas if it is cooled sufficiently. Justify your response.

No, it is not possible for a gas to reach a state of zero volume as, at while very low temperatures gas molecules move closer together, they still have a volume. **[2 marks]**

Examiner's Comments
The candidate clearly indicated that gas molecules do have a volume.

Candidate's Response to Part (b) (iv) — Sample 2

(iv) State whether it is possible to achieve a state of zero volume for the gas if it is cooled sufficiently. Justify your response.

No, because the gas will condense (and its volume will be comparable to the volume of container and $PV = nRT$ no longer valid as gas no longer behaves ideally and has been condensed into a liquid.) **[2 marks]**

Examiner's Comments
Gas not ideal, change of state may have occurred.

For Part (b) (v), candidates had to state the gas law which explains the observations in the experiment. The question proved challenging — half of the candidates correctly identified Charles Law as the gas law that explained the observations; only 25 per cent of them were able to comprehensively state it. Candidates need to pay particular attention to each term in definitions and laws and ensure that they are explicitly specified.

Candidate's Response to Part (b) (v) — Sample 1

(v) State the gas law which explains the observations in this experiment.

Charles law :- The volume of a fixed mass of gas is directly proportional to its absolute temperature, provided pressure is kept constant

[2 marks]

Candidate's Response to Part (b) (v) — Sample 2

(v) State the gas law which explains the observations in this experiment.

Charle's law states that for a fixed mass of gas the volume is directly proportional to the absolute temperature at constent pressure.

$\frac{V_1}{V_2} = \frac{T_1}{T_2}$

[2 marks]

Examiner's Comments

This candidate provided the correct law and statement.

Part (c) required candidates to explain the meaning of each of the symbols used in the equation $\Delta U = Q + W$ (the first law of thermodynamics) when the law is applied to the heating of a fixed mass of gas. Only a quarter of candidates achieved the full three marks for explaining the meaning of the symbols; another quarter were not awarded any marks. Though more than 70 per cent understood that the symbols generally alluded to internal energy, work and heat, many candidates had difficulty distinguishing whether the heat was supplied or lost; or whether the work done was on or by the gas. Candidates failed to state that ΔU was the change or increase in internal energy.

Candidate's Response to Part (c) — Sample 1

(c) The first law of thermodynamics is given by the equation $\Delta U = Q + W$.

Explain the meaning of EACH of the symbols used in the equation above when the law is applied to the heating of a fixed mass of gas.

$\Delta U = Q + W$

ΔU = change in internal energy of the gas / J.

(Internal energy refer to the sum of the random distribution of kinetic and potential energies of a gas)

Q = heat supplied to the gas / J.

W = work done on the gas / J.

Candidate's Response to Part (c) — Sample 2

(c) The first law of thermodynamics is given by the equation $\Delta U = Q + W$.

Explain the meaning of EACH of the symbols used in the equation above when the law is applied to the heating of a fixed mass of gas.

ΔU = Change in internal energy

Q = heat energy Supplied to gas

W = Work done on gass (+ve for a compression)

$U = E_p + E_k$, but $E_p = 0$ because substance is a gas with very spread out particles so no intermolecular bonds $\therefore U = E_k \Rightarrow \Delta U = \Delta E_k$ of the gas because when temperature (average measure of kinetic energy) increases when heat is added, E_k also rises, thus a change in internal energy is seen,

($Q = E_H$ $+W = -p\Delta V$ for a compression & $-W = +p\Delta V$ for expansion at constant pressure)

[3 marks]

Examiner's Comments
These samples shoe correct explanations for each symbol.

The questions in Part (d) were based on a figure which showed the cycle of a monatomic gas.

For Part (d) (i), candidates were asked to calculate the work done during the cycle. Sixty per cent of candidates were able to score total marks; other candidates made calculation errors or did not appreciate that work done was represented by the area under the graph.

Candidate's Response to Part (d) (i) — Sample 1

(d) One mole of an ideal monoatomic gas, $C_V = \frac{3}{2}R$, is taken through the cycle represented by States 1 to 4 as shown in Figure 6. At State 1, $T_1 = 273$ K and at State 3, $T_3 = 1092$ K. On the graph, the vertical scale is set by $p = 1.01 \times 10^5$ N m^{-2} and the horizontal scale by $V = 0.0225$ m^3.

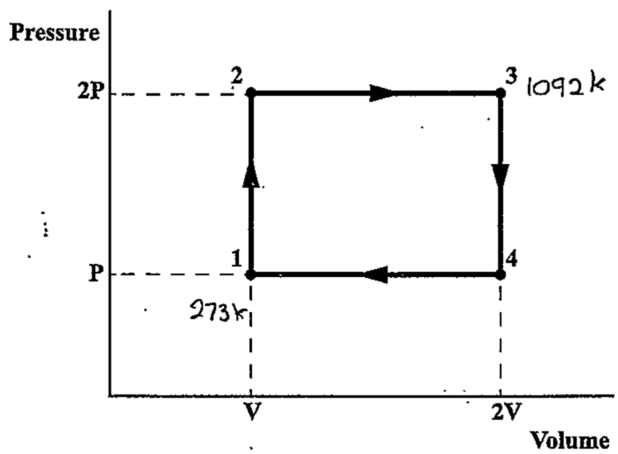


Figure 6. Cycle of a monatomic gas

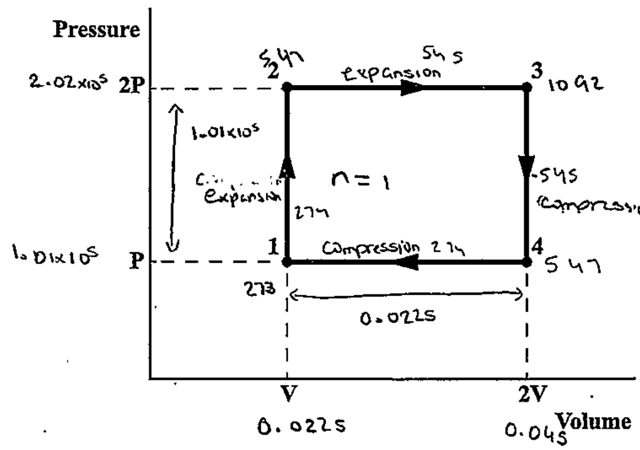
(i) Calculate the work done during the cycle.

Work done = Area under graph
$= \cancel{p}\, \Delta p \times \Delta v$
$= 1.01 \times 10^5 \times 0.0225$
$= 2272.5$ J

Candidate's Response to Part (d) (i) — Sample 2

(d) One mole of an ideal monoatomic gas, $C_v = \frac{3}{2}R$, is taken through the cycle represented by States 1 to 4 as shown in Figure 6. At State 1, $T_1 = 273$ K and at State 3, $T_3 = 1092$ K. On the graph, the vertical scale is set by $p = 1.01 \times 10^5$ N m^{-2} and the horizontal scale by $V = 0.0225$ m^3.

$U = E_K = E_K = \frac{3}{2}nRT$



$T_4 =$

Figure 6. Cycle of a monatomic gas

(i) Calculate the work done during the cycle.

Work done = area in box

$(0.0225 \times 1.01 \times 10^5)$

$= 2272.5$ J

Work done = 2270 J (3 sf)

$n = \frac{PV}{RT} = \frac{1.01 \times 10^5 \times 0.0225}{8.31 \times 273}$

$= 1.00$

Examiner's Comments

Both samples contain well-executed solutions.

For Part (d) (ii), candidates had to calculate the temperature, T2, at State 2. The question was generally well answered with 69 per cent of sampled scripts being worth two of the three marks for this question. Although most candidates were able to recall and use the gas law equations, some were unable to correctly transpose to make T the subject.

Candidate's Response to Part (d) (ii) — Sample 1

(ii) Calculate the temperature, T_2, at State 2.

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$= \frac{(2 \times 1.01 \times 10^5)(0.0225)}{(1) \times (8.31)}$$

$$= 546.93\,K$$

[3 marks]

Candidate's Response to Part (d) (ii) — Sample 2

(ii) Calculate the temperature, T_2, at State 2.

$$P_2V_2 = nRT_2$$

$$\Rightarrow T_2 = \frac{P_2V_2}{nR}$$

$$= \frac{2.02 \times 10^5 \times 0.0225}{1 \times 8.31}$$

$$T_2 = 547\,K \ (3\ sf)$$

[3 marks]

Examiner's Comments

The candidates provided well-executed solutions.

Part (d) (iii) required candidates to calculate the energy added as heat during the process from State 1 to State 2. The question presented somewhat of a challenge to almost a third of the candidates; although 45 per cent scored the full four marks, many candidates still need to practice doing questions involving calculations with gas laws and thermodynamics.

Candidate's Response to Part (d) (iii) — Sample 1

(iii) Calculate the energy added as heat during the process from State 1 to State 2.

$\Delta W = 0$

$\therefore \Delta U = \Delta Q$

$T_1 = 273k$

$T_2 = 546.93k$

$\Delta Q = n C_v \Delta T$

$= 1 \times \frac{3}{2}(8.31) \times (546.93 - 273)$

$= 3414.53\ J$

Candidate's Response to Part (d) (iii) — Sample 2

(iii) Calculate the energy added as heat during the process from State 1 to State 2.

$C_v = \frac{Q}{n \Delta T} = \frac{3}{2} R$

① ② ③

Using ① & ③

Where $\Delta T = T_2 - T_1$

$= 547 - 273$

$= 274K$

$\frac{Q}{n \Delta T} = \frac{3R}{2}$

$Q = \frac{3 R n \Delta T}{2}$

$Q = \frac{3 \times 8.31 \times 1 \times 274}{2}$

$Q = 3415.41\ J$

$Q = +3420\ J$ (3 sf)

Examiner's Comments

In both samples, the candidates provided well-executed solutions.

For Part (d) (iv), candidates had to derive an expression for Cp for the gas in terms of R. This question proved challenging for most candidates. Teachers need to ensure that students practise deriving expressions as required by the syllabus. Only about 40 per cent of candidates were able to correctly execute the derivation.

Candidate's Response to Part (d) (iv) — Sample 1

(iv) Derive an expression for C_p for the gas in terms of R.

$$C_p = C_v + R$$
$$C_p = \frac{3}{2}R + R$$
$$\underline{C_p = \frac{5}{2}R}$$

$$Q_p = nC_p\Delta T \mp p\Delta V \quad \cancel{p\Delta v} =$$
$$C_p = \frac{Q_p}{n\Delta T} + p\Delta V$$

Candidate's Response to Part (d) (iv) — Sample 2

(iv) Derive an expression for C_p for the gas in terms of R.

$$C_p = C_v + R \qquad C_v = \frac{3}{2}R$$
$$= \frac{3}{2}R + R$$
$$\therefore C_p = \frac{5}{2}R$$

Examiner's Comments

The candidates' solutions were well executed.

Part (d) (v) asked candidates to state two reasons why the cycle in the given figure is not 100% efficient. Candidates performed well in this section; almost 70 per cent gained a mark for stating generally that heat energy was lost to the environment. However, many candidates simply gave another form of heat loss as a second reason instead of providing other distinct reasons such as *appreciating that the gas or conditions was not ideal*, or *that the state of the gas could change* etc.

Candidate's Response to Part (d) (v) — Sample 1

(v) State TWO reasons why the cycle in Figure 6 is NOT 100% efficient.

• Heat energy may be lost to the surroundings

• Figure 6 represents an ideal gas and not a real gas therefore for a real gas the collisions may not be perfectly elastic.

[2 marks]

Candidate's Response to Part (d) (v) — Sample 2

(v) State TWO reasons why the cycle in Figure 6 is NOT 100% efficient.

Heat ~~en~~ energy supplied may have been lost to the environment and an ideal gas does not exist so heat energy may go into increasing the potential energy.

[2 marks]

Examiner's Comments
Both candidates stated two distinct reasons.