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Examiners' report

MATHEMATICS A

H240

For first teaching in 2017

H240/01 Summer 2024 series

Version 1

ocr.org.uk/maths

Contents

Introduction

Our examiners’ reports are produced to offer constructive feedback on candidates’ performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates’ performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 1 series overview

H240/01 is one of the three examination units for the A Level examination for GCE Mathematics A. It is a two-hour paper consisting of 100 marks which tests Pure Mathematics topics. Pure Mathematics topics are also tested on the first half of Papers 2 and 3, and any Pure Mathematics topic could be tested on any of the three papers.

To be successful on this paper, candidates need to be familiar with the entire specification and also have an understanding as to how to apply it to any question. They should be able to draw together their knowledge of different topic areas, so as to devise effective strategies when solving unstructured problems.

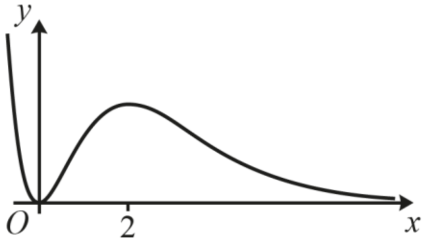
They should appreciate how different parts of the question may link together, with earlier parts of the question possibly being of use in later parts. They should be able to make effective use of their calculator where appropriate, but also make sure that adequate detail is given in questions where 'detailed reasoning' is required. When asked to show a given answer, candidates should make sure that their solutions have sufficient detail and not try to include several steps in a single line of working.

They should be able to clearly convey their intentions, through use of correct notation, such as using brackets effectively, and also through use of correct mathematical language. Their decisions should be fully justified with supporting evidence, and reasoning given when discarding any solutions.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• were able to use a variety of techniques in their calculus work • showed sufficient methodology and reasoning in the 'detailed reasoning', 'prove' and 'determine' questions • were confident in applying co-ordinate geometry and graphing skills to a variety of situations • were able to pull together different areas of the specification to answer unstructured, multi-step, questions.	• were unable to perform algebraic manipulation without slips and errors • did not consider the emphasis or subtleties in the wording of the questions • did not chose appropriate methods of differentiation or integration • were not confident dealing with a variety of problems with algebra rather than values.

Question 1 (a)

1



The diagram shows part of the curve $y = x^2 e^{-x}$.

(a) Use the trapezium rule with 4 intervals of equal width to find an estimate for $\int_0^2 x^2 e^{-x} dx$. Give your answer correct to **3** significant figures. **[4]**

Most candidates made a good attempt at this question and achieved full marks. Those who lost marks often missed out brackets in their formula. Some candidates had used 1 as their first *y*-value rather than 0. Some omitted 0 completely, leading to them incorrectly approximating the integral between 0.5 and 2 with 3 intervals. A small number were not able to access this question, using either *x*-values or incorrect *y*-values placed incorrectly in the formula.

Question 1 (b)

(b) Explain how the trapezium rule could be used to obtain a more accurate estimate for $\int_0^2 x^2 e^{-x} dx$. **[1]**

The vast majority of candidates achieved this mark, stating the use of more trapezia, strips or intervals.

Question 1 (c)

(c) Explain why it is not clear from the diagram whether the value from part **(a)** is an under-estimate or an over-estimate for $\int_0^2 x^2 e^{-x} dx$. **[2]**

Many candidates were able to identify that the tops of the trapezia lie both above and below the curve, leading to both over and underestimates. Many were also able to discuss the convex and concave nature of the curve in the given interval, sometimes confusing the order but this was condoned for the mark. Others correctly referred to there being a point of inflection in the interval. Some candidates incorrectly referred to the 'curve' being increasing and decreasing, rather than the 'gradient'. A common error for those not gaining the marks was to state that it was 'difficult to tell if the curve was convex or concave in the interval'.

Question 2 (a) (i)

2 You are given that y is inversely proportional to x^6 and z is directly proportional to the cube root of y.

(a) **(i)** Find an equation for z in terms of x and k, where k is a constant of proportionality. **[2]**

Most candidates only achieved the method mark because they used the same constant *k* for every constant of proportionality. Some candidates correctly used three different constants of proportionality, and a few worked with proportional statements until they achieved a relationship between *z* and *x*. Of those candidates using different constants of proportionality, some often still lost the accuracy mark by failing to simplify the indices.

Question 2 (a) (ii)

(ii) State which of the diagrams below could represent the graph of z against x. **[1]**

Fig. 1.1

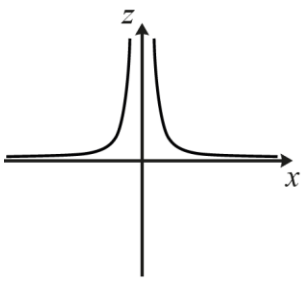


Fig. 1.2

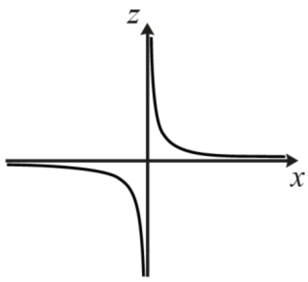


Fig. 1.3

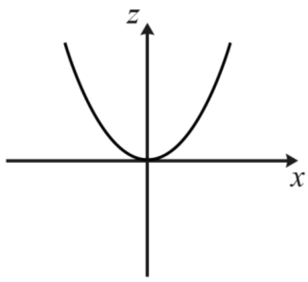
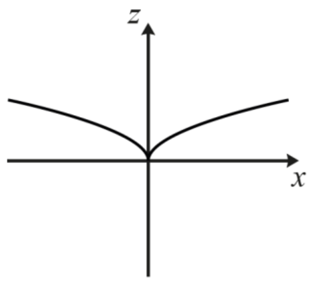


Fig. 1.4



The majority of candidates chose the correct response.

Question 2 (b)

(b) Given that $z = 3$ when $x = 4$, determine the values of x when $z = 12$. **[3]**

Many candidates got at least one of the values of *x* correct, although some forgot the negative solution. Even those who had an incorrect expression in part (a)(i) were usually able to achieve some credit for manipulating their expression to find a *k* value and attempt to solve for *x* when *z = 12*. Note that the question asked candidates to 'determine the values of *x*', so they were required to show working.

Question 3 (a)

3 **(a)** Find a counterexample to disprove the statement that the product of two prime numbers is always odd. **[1]**

Most candidates managed to show a correct product but did not state that the answer was even or not odd. They wrongly assumed it was sufficient to simply show the product.

A small number of candidates believed that 1 is a prime number and some found a sum rather than a product of primes.

Question 3 (b) (i), (ii) and (iii)

(b) In each of the following cases write one of the symbols $\Rightarrow$, $\Leftrightarrow$, $\Leftarrow$ in the box in the Printed Answer Booklet to make each statement correct.

(i) $x^2 = 3x$ ☐ $x = 3$ **[1]**

(ii) $x > 4$ ☐ $x^3 > 64$ **[1]**

(iii) $x° = 45°$ ☐ $\tan x° = 1$ **[1]**

Most candidates used the correct type of arrows, although a single stemmed arrow was condoned. (iii) was the most commonly correct answer and (i) the least commonly correct answer of the three.

A few candidates left blank answer spaces.

Question 3 (c)

(c) Prove that the sum of the squares of **any** two odd numbers is always a multiple of 2 but never a multiple of 4. **[4]**

Many candidates either did not notice or did not realise the significance of 'any' being in bold and gave examples of two consecutive, or otherwise related, odd numbers thus limiting themselves to a maximum of 2 marks. Some used the same expression for both odd numbers, which scored no marks.

From those that did use different variables, many lost the last accuracy mark because they thought it was enough to factorise the 4 out and say they have shown it is not a multiple of 4 without explaining why. Examiners expected to see some comment about there being a remainder of 2 when 4 was factorised out. Alternatively, that the value left after factorisation or division was not an integer.

Question 4 (a)

4 A sequence has terms u_1, u_2, u_3, … defined by $u_1 = 2$ and $u_{n+1} = 1 - \frac{1}{u_n}$ for $n \geqslant 1$.

(a) Find the values of u_2, u_3 and u_4. **[2]**

Most candidates achieved full marks.

Question 4 (b)

(b) Describe the behaviour of the sequence. **[1]**

Many candidates gave a correct description, although some thought that the period was 4 instead of 3. Most candidates used an appropriate term, such as periodic, cyclic or repeating.

Question 4 (c)

(c) Given that $\sum_{n=1}^{k} u_n = 73$, determine the value of k. **[3]**

Some candidates tried to use the formula for the sum of an arithmetic sequence or the sum of a geometric sequence, neither of which were appropriate here. Many candidates realised that the sum of each block of three terms totalled 1.5 and then divided 73 (or a value near 73) by 1.5 to deduce that there were about 48 whole blocks and a bit over or under. Several then multiplied by 3, the number of items in each block, to get *k* = 146, but only some candidates dealt with the excess appropriately to get to *k* = 143.

Question 5

5 The line $x + 13y = 108$ is the normal to the curve $y = ax^2 + b\sqrt{x}$ at the point (4, 8).

Determine the values of the constants a and b. **[8]**

This longer unstructured question was generally well attempted. Quite a few neat, elegant and completely correct solutions were seen.

Some unnecessary work was also seen, with quite a few candidates obtaining the equation of the tangent with some trying to solve that with the given equation.

Only a very small number of candidates did not realise differentiation was involved. When the differentiation was attempted, it was invariably correct with the fractional powers well handled. Those candidates who substituted $x = 4$ into their algebraic expression for the gradient of the tangent, were more likely to score full marks compared to those who went on to form an algebraic expression for the gradient of the normal.

Most candidates were able to find the numerical value for the gradient of the tangent from the equation of the normal, although not everyone was able to use this information to produce a correct equation in *a* and *b* only. A few candidates confused the gradients of the tangent and normal.

Some candidates often omitted substituting *(4,8)* into the equation of the curve, failing to produce a second independent equations in *a* and *b*.

Solving these two equations simultaneously could be completed by using a calculator for the final mark.

Exemplar 1

5

$x + 13y = 108$ $\quad$ $y = ax^2 + b\sqrt{x}$

$13y = -x + 108$ $\quad$ $(4, 8)$

$y = -\frac{1}{13}x + \frac{108}{13}$

$\therefore$ gradient of normal $= -\frac{1}{13}$

gradient of tangent $= 13.$

$y = ax^2 + b\sqrt{x}$

$\frac{dy}{dx} = 2ax + \frac{1}{2}bx^{-\frac{1}{2}}$

$13 = 2a(4) + \frac{1}{2}b(4)^{-\frac{1}{2}}$

$13 = 8a + \frac{1}{4}b$

$52 = 32a + b$

$y = ax^2 + b\sqrt{x}$

$8 = a(4)^2 + b\sqrt{4}$

$8 = 16a + 2b$

$32a + b = 52$

$-\ 32a + 4b = 16$

$-3b = 36$

$b = -12$

$8 = 16a + 2b$

$8 = 16a + 2(-12)$

$8 = 16a - 24$

$16a = 32$

$a = 2$

This is a good solution to Question 5 with efficient and clear working.

Question 6 (a)

6 In this question you must show detailed reasoning.

The cubic polynomial $f(x)$ is defined by $f(x) = 4x^3 - 25x^2 - 58x + 16$.

(a) Show that $x = \frac{1}{4}$ is a root of the equation $f(x) = 0$. **[1]**

Almost all candidates got this correct, with many just showing minimalistic working with the ¼ substituted in followed by = *0*.

Question 6 (b)

(b) Hence express $f(x)$ as the product of a linear factor and a quadratic factor, with all terms in the factors having integer coefficients. **[3]**

There were many correct answers to this question either using inspection to find the correct product or using long division. A few gave their product without integer coefficients so lost the accuracy mark. Very few made errors in their division, usually sign errors in the 2nd or 3rd term.

Some candidates dividing by *(x – ¼)* did so correctly but then when changing this to *(4x – 1)* did not recognise the need to also change the other factor.

Question 6 (c)

(c) Solve the equation $4e^{3y} - 25e^{2y} - 58e^{y} + 16 = 0$, giving each root in the form $y = k\ln 2$ where k is a constant. **[4]**

The question was very well answered with many candidates getting full marks on this question. Most candidates made the connection with the previous parts. The most commonly lost mark was the B mark for explaining why $e^y = -2$ did not result in a solution. It is important in detailed reasoning questions that candidates explain why rejected answers are not used; 'not possible' is not enough and incorrect statements like 'negative logs are not possible' are not given credit. Some candidates realised there was a connection to part (b) but unfortunately, thought it was an equation in e^{3y} instead of e^y.

Exemplar 2

6(c)	$f(x) = (4x-1)(x+2)(x-8)$
	$4e^{3y} - 25e^{2y} - 58e^{y} + 16 = f(e^{y}) = 0$
	$\Rightarrow (4e^{y}-1)(e^{y}+2)(e^{y}-8) = 0$
	$\Rightarrow e^{y} = \frac{1}{4}, -2, 8$
	Disregard $e^{y} = -2$ as $e^{y} > 0$
	$\Rightarrow e^{y} = \frac{1}{4}, 8$
	$\Rightarrow y = \ln(\frac{1}{4}), \ln(8)$
	$y = \ln(2^{-2}), \ln(2^{3})$
	$\therefore y = -2\ln 2, 3\ln 2$

This is a good solution to Question 6 (c), in that it provides clear evidence as to how the solutions are obtained and gives detailed reasoning on why one solution has been rejected.

Assessment for learning

There will be some questions where some of the roots of an equation are not valid solutions to the original problem. It is insufficient to simply state ‘not possible’ or ‘Maths Error’; candidates should be prepared to give compelling reasons whenever a solution is discarded.

Question 7 (a)

7 The point A has coordinates (1, 7), and the point B has coordinates (h, 10).

(a) You are given that the gradient of the line AB is 2.

Find the value of h. **[2]**

Most candidates successfully found the values $h = 2.5$, either by finding the increase in y divided by the increase in x and setting it equal to 2, or by calculating the equation of the line through A with gradient 2 and then putting $x = h$, $y = 10$ into this. Most common errors were either inverting the expression for the gradient or inconsistent order for the x and y-values in the gradient formula.

Question 7 (b)

(b) You are given that B is the midpoint of AC.

Find the coordinates of the point C. **[2]**

Most candidates were able to calculate the coordinates of *C*. If necessary, follow through marks were available for their value for *h*. A common mistake was thinking that *C* was the midpoint of *AB*, instead of *B* being the midpoint of *AC*. A few candidates gave their answer as a column vector rather than using coordinates, as asked for.

Question 7 (c)

(c) You are given that the straight line through the points A, B and C has two distinct points of intersection with the curve $y = x^2 - 4x + k$.

Determine the set of possible values of k. **[6]**

Most candidates found the equation of the line and equated it to the curve to get a quadratic equation in *x* for the points of intersection. The majority then used the discriminant property to get an inequality for *k*, although some lost a minus sign in calculating the discriminant or in dealing with the inequality while others made slips in expanding brackets. A few candidates used 'completing the square' to find the values of *k* for which the quadratic had two roots.

Question 8 (a)

8 **(a)** State the set of values for which $|x| > x$. **[1]**

This question was generally well answered.

Question 8 (b) (i)

(b) You are given that n is an integer such that $|n| \leqslant 9$.

(i) Find the maximum value of $|2n-1|$. **[1]**

There were many different answers given to this question; 17 was the most frequently seen incorrect response.

Question 8 (b) (ii)

(ii) Find the minimum value of $|2n-1|$. **[1]**

Some candidates seemed to forget by this stage that only integer values for *n* were allowed, so used 0.5 to get an answer of 0. Values of –17 and –19 were also commonly seen.

Question 8 (c) (i)

(c) (i) Solve the equation $\left|\frac{1}{2}x-1\right| = |2x-3|$. **[3]**

Candidates who squared both sides and solved the quadratic usually obtained full marks unless they had made a slip in their algebra. Those solving the two linear equations were also successful in general, although a minority got into difficulty changing the signs to find the second solution, with some changing one sign on each side and others changing all signs on both sides, rather than all signs on one side only.

Question 8 (c) (ii)

(ii) Explain why the equation $\left|\frac{1}{2}x-1\right| = 2x-3$ has only one solution, and state the value of this solution. **[1]**

Few candidates successfully answered this question. Those who correctly identified $x = 8/5$ as the only valid solution were often not able to explain in enough detail why.

A common response was to say that the graphs only intersect at one point, without going into detail to justify the statement. Some had sketched graphs in the previous part which would have completed their argument but did not think to use these here.

Some referred to the modulus being positive but did not do the simple calculations to show why $x = 4/3$ did not work. Successful candidates often compared their solutions with the range of values for which $y = 2x - 3$ was positive.

Question 9 (a) (i)

9 The depth of the water, d metres, in a tidal river during a given day is modelled by the equation

$$d = 1.9 + 1.1\cos(30t - 60)^\circ$$

where t is the number of hours after midnight.

(A tidal river is one whose level is influenced by tides.)

(a) **(i)** Find the minimum depth of water given by this model. **[1]**

Although 1.9m and 2.45m were commonly seen errors, most candidates could successfully find the minimum depth value of 0.8. A large proportion gave no units, and so did not gain the mark for the question.

Question 9 (a) (ii)

(ii) Find the value of t when the minimum depth first occurs. **[2]**

While most candidates correctly identified where the minimum occurred, and as a result obtained the correct answer of 8 hours, some candidates incorrectly set $\cos(30t - 60) = 0$, resulting in the incorrect answer of 5 hours. Some also made errors when solving $30t - 60 = 180$, with $30t = 120$ and then $t = 4$ seen.

Question 9 (b)

(b) A boat can only enter the river when the depth of water is at least 1 metre.

Determine the two periods of time during the day between which this boat will **not** be able to enter the river. Give your answers correct to the **nearest minute**. **[5]**

Most candidates scored the first 2 marks in this question, substituting $d = 1$ into the equation and rearranging to find the first value of t correctly. Many went on to find the second value of t. Very few candidates understood that this was a full day and that they should find all four values of t within the 24-hour period, with many giving only one period of time.

Those who converted these values into times of the day and gave a single correct time period earned 3 out of the 5 marks. Some candidates completed the question, sometimes by using symmetry rather than all the values of t. Often candidates lost marks because they did not write their answers as 'periods of time' with many leaving their answers in minutes or hours/minutes after midnight.

Key Point – Time

The question asked for 'periods of time during the day'. We were therefore looking for answers given as times of the day. For example. 'The boat would be unable to sail between 6.50am and 9.10am'.

Question 9 (c)

In reality the depth of the river decreases as this boat travels along the river. An improved model uses the equation

$$d = \mathrm{e}^{-cp}(1.9 + 1.1\cos(30t - 60)°)$$

where c is a positive constant and p is the distance, in kilometres, travelled along the river after entering it.

(c) Explain how this new equation could give an improved model. **[1]**

While many candidates correctly identified that e^{-cp} would reduce the depth equation as the boat travelled along the river, very few correctly linked this to a reduction in the difference between maximum and minimum depths.

Question 10

10 In this question you must show detailed reasoning.

The first three terms of a convergent geometric progression are $2x+3$, $x+9$ and $2x-6$ respectively.

Determine the sum to infinity of this geometric progression. **[8]**

This question was well answered with many candidates scoring 7 or 8 marks. Almost all candidates obtained a correct expression for *r*, and most went on to form a correct equation in *x*. Most also solved their equation in *x*, either a quadratic or a cubic, to find the correct values of *x*.

Despite this being a 'detailed reasoning' question, some candidates went straight from the quadratic equation to stating the roots. On this occasion this was condoned, but candidates would be well advised to make sure that sufficient detail is always provided in these types of questions.

The majority then went on to find at least one value for *r*. However, many discarded the solution *r = –2* without clear reasoning and in a few cases attempted to incorrectly calculate a second sum to infinity for this incorrect *r* value.

Those candidates that didn't score well, often tried to use their algebraic expression for *r* in the formula for the sum to infinity but were then unable to progress from this.

Question 11 (a)

11 A curve has equation $y = 5\ln(1-\cos 2x)$, where x is in radians.

(a) State the values of x for which $5\ln(1-\cos 2x)$ is not defined. **[2]**

This proved to be a challenging question as although the vast majority recognised when the logarithmic function is undefined and related *cos 2x* to 1 in some way, very few were able to identify the full set of values. Candidates seem comfortable solving a trigonometric equation in a given range, so most simply proceeded to give an incomplete answer with negative values of *x* rarely considered.

Question 11 (b)

(b) P is the stationary point on the curve that has the smallest positive x-coordinate.

Determine the exact coordinates of P. **[4]**

The differentiation of the logarithmic function was reasonably well done with the correct derivative often seen. Many did not produce a non-zero value for *x* when seeking the required stationary point. The most common incorrect answers given were $x = 0$ and $x = \pi$. The correct *y*-value often came from an incorrect *x* value and so was not given credit.

Question 11 (c) (i)

(c) (i) Show that $\frac{d^2y}{dx^2} + 20e^{-\frac{1}{5}y} = 0$. **[5]**

The attempts at the second derivative were very good when a correct first derivative had been obtained in part (b). The majority used the quotient rule rather than the product rule, the latter of which proved trickier for candidates to manipulate correctly to secure full marks.

With a given answer, there is an expectation that method is clearly shown, and many candidates were able to simplify their second derivative by using a trigonometric identity but often struggled to obtain a fully correct solution.

Those who struggled with part (b) often did not make progress with this part.

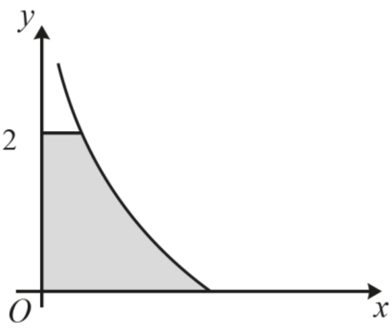
Question 11 (c) (ii)

(ii) State what can be deduced about all of the stationary points on this curve, giving a reason for your answer. **[1]**

This was not well answered and was often left blank. Quite a few candidates who deduced that the stationary points must all be maxima did not give sufficient reasoning.

Question 12 (a)

12 In this question you must show detailed reasoning.



The diagram shows the curve with parametric equations $x = \frac{2}{(2t+1)^4}$, $y = 2t^2 + 3t$ for $t \geqslant 0$.

The shaded region is enclosed by the curve, the x-axis, the y-axis and the line $y = 2$.

(a) Show that the area of the shaded region is given by $\int_a^b \frac{8t+6}{(2t+1)^4}\,\mathrm{d}t$, where a and b are constants to be determined. **[5]**

This question was challenging for most candidates to gain all the marks. Most candidates were able to achieve the method mark for equating the *y* equation to 2 to find the upper limit. These candidates often also equated *y* to 0 and solved both equations for *t* to find the correct limits, although the incorrect values from these equations were often chosen.

Many candidates did not know how to find the area between a parametric curve and the *y*-axis and often set about forming the $\int y \frac{dx}{dt}\, dt$, with little success in obtaining the given answer.

Some candidates were able to work out how to arrive at the given expression inside the integral, but their reasoning was insufficient for the requirements of the question.

OCR support

Some candidates did not seem familiar with the command words, such as 'show detailed reasoning' in this question and 'hence', 'prove' and 'determine' elsewhere on the paper. These are clearly detailed in the specification on pages 10–15, and OCR have also produced a command word poster for display in the classroom that can be found on the OCR website.

Misconception

Many candidates believed that they could only find the area between a parametric curve and the *x*-axis. They seemed unaware that they could find an area between the curve and the *y*-axis by using $\int x\frac{dy}{dt}\,dt$

Question 12 (b)

(b) Determine the exact area of the shaded region. **[6]**

This question proved challenging for many candidates. There may be some indication that time management was a problem as there were a significant proportion of blank responses. However, there were many strong responses covering a variety of methods, most commonly substitution and integration by parts, and these were the most successful. Those not determining the correct limits from part (a) were unable to access the last two marks of this part. Some candidates attempted to use their knowledge on partial fractions but had mixed success in doing so. There were also many candidates that used a combination of methods, the most common being separate fractions and then integration by parts.

Exemplar 3

12(b)

$\int_0^{\frac12} \frac{8t+6}{(2t+1)^4}\,dt$ let $u=2t+1$

$\frac{du}{dt}=2$ $du\times\frac12=dt$

@ $t=\frac12$ $u=2$

@ $t=0$ $u=1$

$8t+6=4u+2$

$\therefore \int_1^2 \frac{4u+2}{u^4}\times\frac12\,du = \int_1^2 \frac{2u+1}{u^4}\,du$

$=\int_1^2 2u^{-3}+u^{-4}\,du$

$=\left[-u^{-2} - \frac13 u^{-3}\right]_1^2$

$=\left(\left(-\frac14-\frac13\left(\frac18\right)\right)-\left(-1-\frac13\right)\right)$

$=\left(-\frac{7}{24}\right)-\left(-\frac43\right)$

$=\frac{25}{24}$

This is a good and efficient solution to Question 12 (b).

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