

## A Level Mathematics A

### H240/02 Pure Mathematics and Statistics

### Sample Question Paper

**Date – Morning/Afternoon**

Version 2.1

Time allowed: 2 hours

**You must have:**

- Printed Answer Booklet

**You may use:**

- a scientific or graphical calculator



#### INSTRUCTIONS

- Use black ink. HB pencil may be used for graphs and diagrams only.
- Complete the boxes provided on the Printed Answer Booklet with your name, centre number and candidate number.
- Answer **all** the questions.
- **Write your answer to each question in the space provided in the Printed Answer Booklet.** Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Give non-exact numerical answers correct to 3 significant figures unless a different degree of accuracy is specified in the question.
- The acceleration due to gravity is denoted by  $g \text{ m s}^{-2}$ . Unless otherwise instructed, when a numerical value is needed, use  $g = 9.8$ .

#### INFORMATION

- The total number of marks for this paper is **100**.
- The marks for each question are shown in brackets [ ].
- **You are reminded of the need for clear presentation in your answers.**
- The Printed Answer Booklet consists of **16** pages. The Question Paper consists of **16** pages.

**Formulae**  
**A Level Mathematics A (H240)**

**Arithmetic series**

$$S_n = \frac{1}{2}n(a+l) = \frac{1}{2}n\{2a + (n-1)d\}$$

**Geometric series**

$$S_n = \frac{a(1-r^n)}{1-r}$$

$$S_\infty = \frac{a}{1-r} \quad \text{for } |r| < 1$$

**Binomial series**

$$(a+b)^n = a^n + {}^nC_1 a^{n-1}b + {}^nC_2 a^{n-2}b^2 + \dots + {}^nC_r a^{n-r}b^r + \dots + b^n \quad (n \in \mathbb{N}),$$

$$\text{where } {}^nC_r = {}_nC_r = \binom{n}{r} = \frac{n!}{r!(n-r)!}$$

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \dots + \frac{n(n-1)\dots(n-r+1)}{r!}x^r + \dots \quad (|x| < 1, n \in \mathbb{R})$$

**Differentiation**

$f(x)$	$f'(x)$
$\tan kx$	$k \sec^2 kx$
$\sec x$	$\sec x \tan x$
$\cot x$	$-\operatorname{cosec}^2 x$
$\operatorname{cosec} x$	$-\operatorname{cosec} x \cot x$

$$\text{Quotient rule } y = \frac{u}{v}, \quad \frac{dy}{dx} = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$$

**Differentiation from first principles**

$$f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

**Integration**

$$\int \frac{f'(x)}{f(x)} dx = \ln |f(x)| + c$$

$$\int f'(x)(f(x))^n dx = \frac{1}{n+1}(f(x))^{n+1} + c$$

$$\text{Integration by parts } \int u \frac{dv}{dx} dx = uv - \int v \frac{du}{dx} dx$$

**Small angle approximations**

$$\sin \theta \approx \theta, \cos \theta \approx 1 - \frac{1}{2}\theta^2, \tan \theta \approx \theta \quad \text{where } \theta \text{ is measured in radians}$$

**Trigonometric identities**

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B} \quad (A \pm B \neq (k + \frac{1}{2})\pi)$$

**Numerical methods**

Trapezium rule:  $\int_a^b y dx \approx \frac{1}{2}h\{(y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1})\}$ , where  $h = \frac{b-a}{n}$

The Newton-Raphson iteration for solving  $f(x) = 0$ :  $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

**Probability**

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

$$P(A \cap B) = P(A)P(B | A) = P(B)P(A | B) \quad \text{or} \quad P(A | B) = \frac{P(A \cap B)}{P(B)}$$

**Standard deviation**

$$\sqrt{\frac{\sum(x - \bar{x})^2}{n}} = \sqrt{\frac{\sum x^2}{n} - \bar{x}^2} \quad \text{or} \quad \sqrt{\frac{\sum f(x - \bar{x})^2}{\sum f}} = \sqrt{\frac{\sum fx^2}{\sum f} - \bar{x}^2}$$

**The binomial distribution**

If  $X \sim B(n, p)$  then  $P(X = x) = \binom{n}{x} p^x (1-p)^{n-x}$ , mean of  $X$  is  $np$ , variance of  $X$  is  $np(1-p)$

**Hypothesis test for the mean of a normal distribution**

If  $X \sim N(\mu, \sigma^2)$  then  $\bar{X} \sim N\left(\mu, \frac{\sigma^2}{n}\right)$  and  $\frac{\bar{X} - \mu}{\sigma/\sqrt{n}} \sim N(0, 1)$

**Percentage points of the normal distribution**

If  $Z$  has a normal distribution with mean 0 and variance 1 then, for each value of  $p$ , the table gives the value of  $z$  such that  $P(Z \leq z) = p$ .

$p$	0.75	0.90	0.95	0.975	0.99	0.995	0.9975	0.999	0.9995
$z$	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

**Kinematics**

Motion in a straight line

$$v = u + at$$

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

$$s = \frac{1}{2}(u + v)t$$

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

$$s = vt - \frac{1}{2}at^2$$

Motion in two dimensions

$$\mathbf{v} = \mathbf{u} + \mathbf{a}t$$

$$\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$$

$$\mathbf{s} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$$

$$\mathbf{s} = \mathbf{v}t - \frac{1}{2}\mathbf{a}t^2$$

**Section A: Pure Mathematics**Answer **all** the questions**1** Simplify fully.

(a)  $\sqrt{a^3} \times \sqrt{16a}$  [2]

(b)  $(4b^6)^{\frac{5}{2}}$  [2]

**2** A curve has equation  $y = x^5 - 5x^4$ .

(a) Find  $\frac{dy}{dx}$  and  $\frac{d^2y}{dx^2}$ . [3]

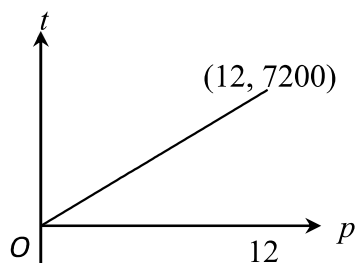
(b) Verify that the curve has a stationary point when  $x = 4$ . [2]

(c) Determine the nature of this stationary point. [2]

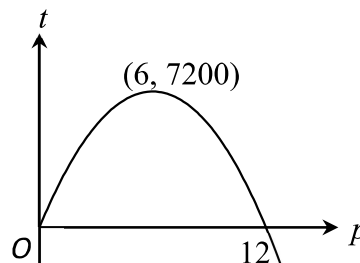
- 3 A publisher has to choose the price at which to sell a certain new book. The total profit, £ $t$ , that the publisher will make depends on the price, £ $p$ . He decides to use a model that includes the following assumptions.

- If the price is low, many copies will be sold, but the profit on each copy sold will be small, and the total profit will be small.
- If the price is high, the profit on each copy sold will be high, but few copies will be sold, and the total profit will be small.

The graphs below show two possible models.



Model A



Model B

- (a) Explain how model A is inconsistent with one of the assumptions given above. [1]
- (b) Given that the equation of the curve in model B is quadratic, show that this equation is of the form  $t = k(12p - p^2)$ , and find the value of the constant  $k$ . [2]
- (c) The publisher needs to make a total profit of at least £6400. Use the equation found in part (b) to find the range of values within which model B suggests that the price of the book must lie. [4]
- (d) Comment briefly on how realistic model B may be in the following cases.
- $p = 0$
  - $p = 12.1$
- [2]

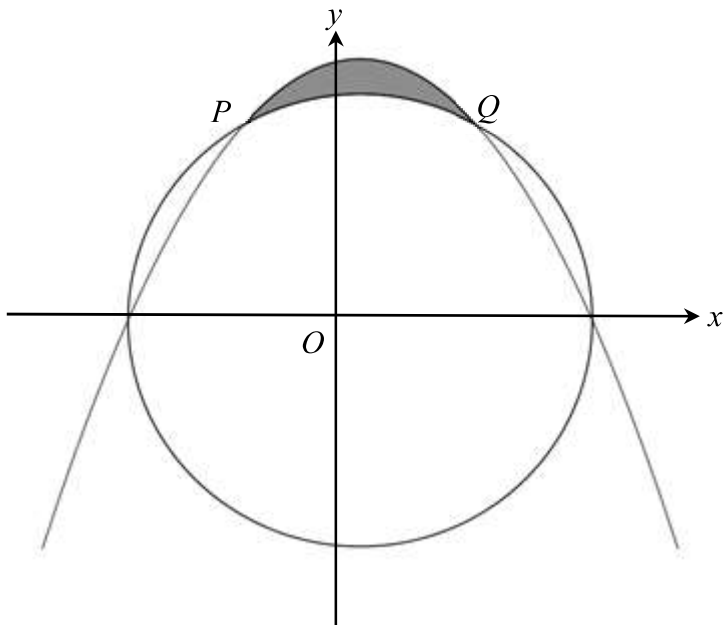
4 (a) Express  $\frac{1}{(x-1)(x+2)}$  in partial fractions [2]

(b) In this question you must show detailed reasoning.

Hence find  $\int_2^3 \frac{1}{(x-1)(x+2)} dx$ .

Give your answer in its simplest form. [5]

5 The diagram shows the circle with centre  $O$  and radius 2, and the parabola  $y = \frac{1}{\sqrt{3}}(4-x^2)$ .



The circle meets the parabola at points  $P$  and  $Q$ , as shown in the diagram.

(a) Verify that the coordinates of  $Q$  are  $(1, \sqrt{3})$ . [3]

(b) Find the **exact** area of the shaded region enclosed by the arc  $PQ$  of the circle and the parabola. [8]

- 6 Helga invests £4000 in a savings account.  
After  $t$  days, her investment is worth £ $y$ .  
The rate of increase of  $y$  is  $ky$ , where  $k$  is a constant.

- (a) Write down a differential equation in terms of  $t$ ,  $y$  and  $k$ . [1]
- (b) Solve your differential equation to find the value of Helga's investment after  $t$  days.  
Give your answer in terms of  $k$  and  $t$ . [4]

It is given that  $k = \frac{1}{365} \ln\left(1 + \frac{r}{100}\right)$  where  $r$  % is the rate of interest per annum.

During the first year the rate of interest is 6% per annum.

- (c) Find the value of Helga's investment after 90 days. [2]

After one year (365 days), the rate of interest drops to 5% per annum.

- (d) Find the total time that it will take for Helga's investment to double in value. [5]

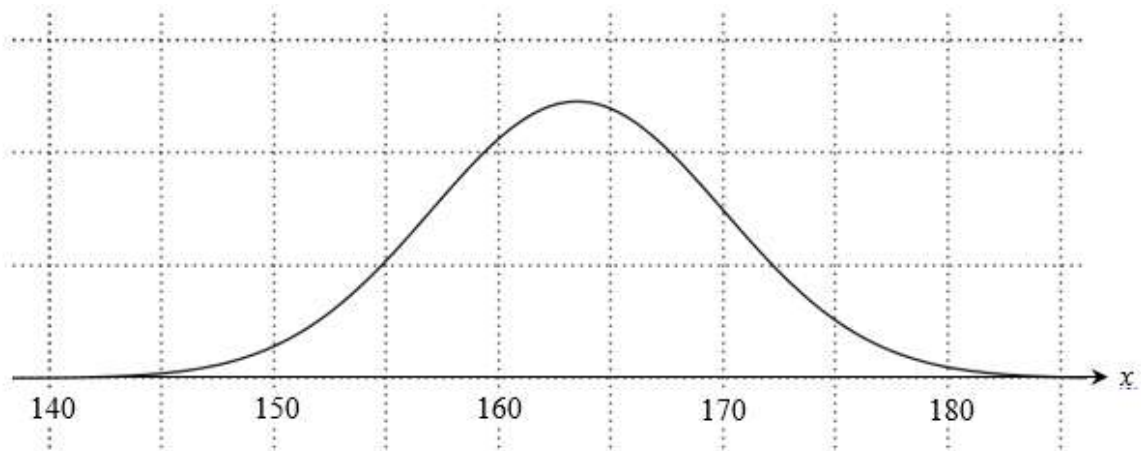
**Section B: Statistics**  
Answer **all** the questions

- 7 (a) The heights of English men aged 25 to 34 are normally distributed with mean 178 cm and standard deviation 8 cm.  
Three English men aged 25 to 34 are chosen at random.

Find the probability that all three men have a height less than 194 cm.

[3]

- (b) The diagram shows the distribution of heights of Scottish women aged 25 to 34.



The distribution is approximately normal. Use the diagram in the Printed Answer Booklet to estimate the standard deviation of these heights, explaining your method.

[3]



- 8 A market gardener records the masses of a random sample of 100 of this year's crop of plums. The table shows his results.

Mass, $m$ grams	$m < 25$	$25 \leq m < 35$	$35 \leq m < 45$	$45 \leq m < 55$	$55 \leq m < 65$	$65 \leq m < 75$	$m \geq 75$
Number of plums	0	3	29	36	30	2	0

- (a) Explain why the normal distribution might be a reasonable model for this distribution. [1]

The market gardener models the distribution of masses by  $N(47.5, 10^2)$ .

- (b) Find the number of plums in the sample that this model would predict to have masses in the range:

(i)  $35 \leq m < 45$  [2]

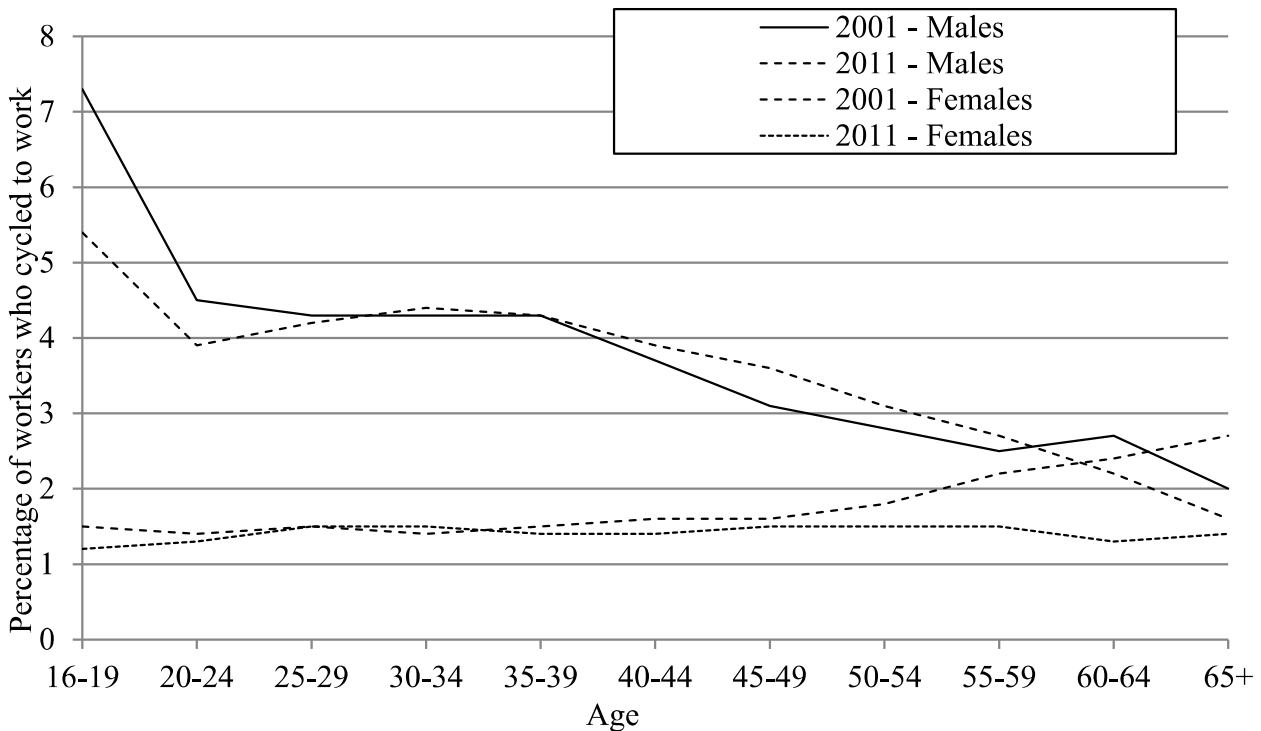
(ii)  $m < 25$ . [2]

- (c) Use your answers to parts (b)(i) and (b)(ii) to comment on the suitability of this model. [1]

The market gardener plans to use this model to predict the distribution of the masses of next year's crop of plums.

- (d) Comment on this plan. [1]

- 9 The diagram below shows some “Cycle to work” data taken from the 2001 and 2011 UK censuses. The diagram shows the percentages, by age group, of male and female workers in England and Wales, excluding London, who cycled to work in 2001 and 2011.



The following questions refer to the workers represented by the graphs in the diagram.

- (a) A researcher is going to take a sample of men and a sample of women and ask them whether or not they cycle to work.

Why would it be more important to stratify the sample of men?

[1]

A research project followed a randomly chosen large sample of the group of male workers who were aged 30-34 in 2001.

- (b) Does the diagram suggest that the proportion of this group who cycled to work has increased or decreased from 2001 to 2011?

Justify your answer.

[2]

- (c) Write down one assumption that you have to make about these workers in order to draw this conclusion.

[1]

- 10** In the past, the time spent in minutes, by customers in a certain library had mean 32.5 and standard deviation 8.2.

Following a change of layout in the library, the mean time spent in the library by a random sample of 50 customers is found to be 34.5 minutes.

Assuming that the standard deviation remains at 8.2, test at the 5% significance level whether the mean time spent by customers in the library has changed. [7]

- 11** Each of the 30 students in a class plays at least one of squash, hockey and tennis.

- 18 students play squash
- 19 students play hockey
- 17 students play tennis
- 8 students play squash and hockey
- 9 students play hockey and tennis
- 11 students play squash and tennis

- (a)** Find the number of students who play all three sports. [3]

A student is picked at random from the class.

- (b)** Given that this student plays squash, find the probability that this student does not play hockey. [1]

Two different students are picked at random from the class, one after the other, without replacement.

- (c)** Given that the first student plays squash, find the probability that the second student plays hockey. [4]

- 12 The table shows information for England and Wales, taken from the UK 2011 census.

Total population	Number of children aged 5-17
56 075 912	8 473 617

A random sample of 10 000 people in another country was chosen in 2011, and the number,  $m$ , of children aged 5-17 was noted.

It was found that there was evidence at the 2.5% level that the proportion of children aged 5-17 in the same year was higher than in the UK.

Unfortunately, when the results were recorded the value of  $m$  was omitted.

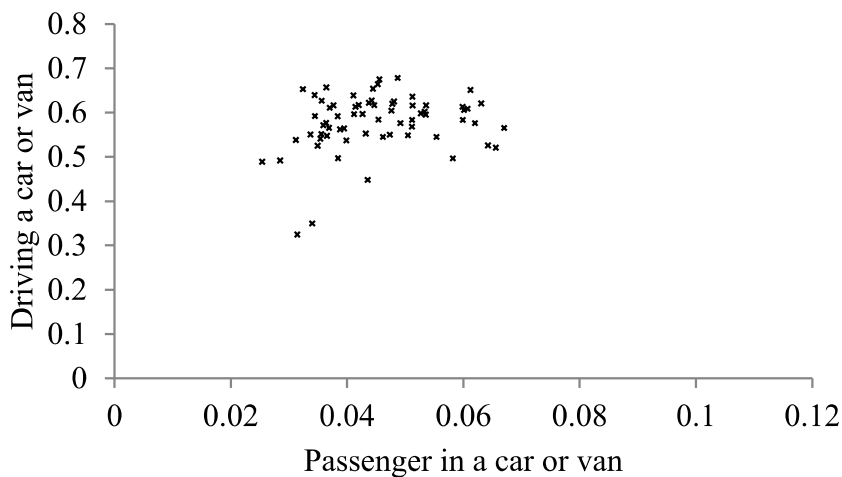
Use an appropriate normal distribution to find an estimate of the smallest possible value of  $m$ . [5]

**TURN OVER FOR THE NEXT QUESTION**

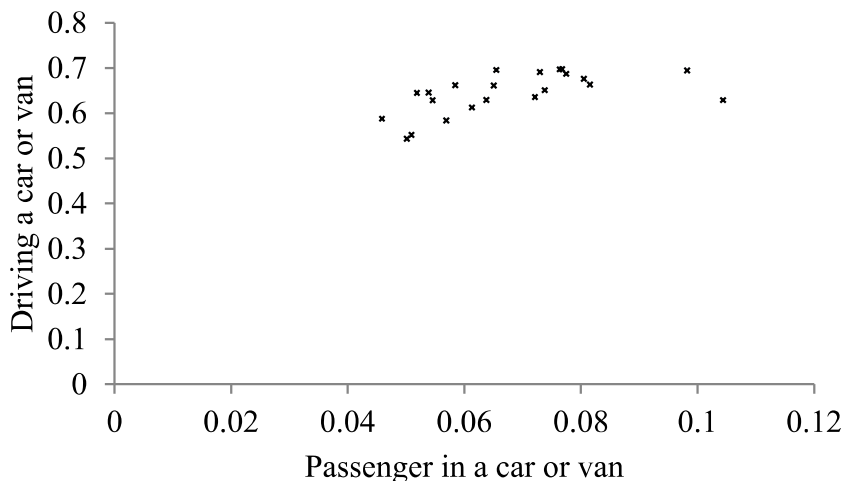
- 13 The table and the four scatter diagrams below show data taken from the 2011 UK census for four regions. On the scatter diagrams the names have been replaced by letters. The table shows, for each region, the mean and standard deviation of the proportion of workers in each Local Authority who travel to work by *driving* a car or van and the proportion of workers in each Local Authority who travel to work as a *passenger* in a car or van. Each scatter diagram shows, for each of the Local Authorities in a particular region, the proportion of workers who travel to work by *driving* a car or van and the proportion of workers who travel to work as a *passenger* in a car or van.

	Driving a car or van		Passenger in a car or van	
	Mean	Standard deviation	Mean	Standard deviation
London	0.257	0.133	0.017	0.008
South East	0.578	0.064	0.045	0.010
South West	0.580	0.084	0.049	0.007
Wales	0.644	0.045	0.068	0.015

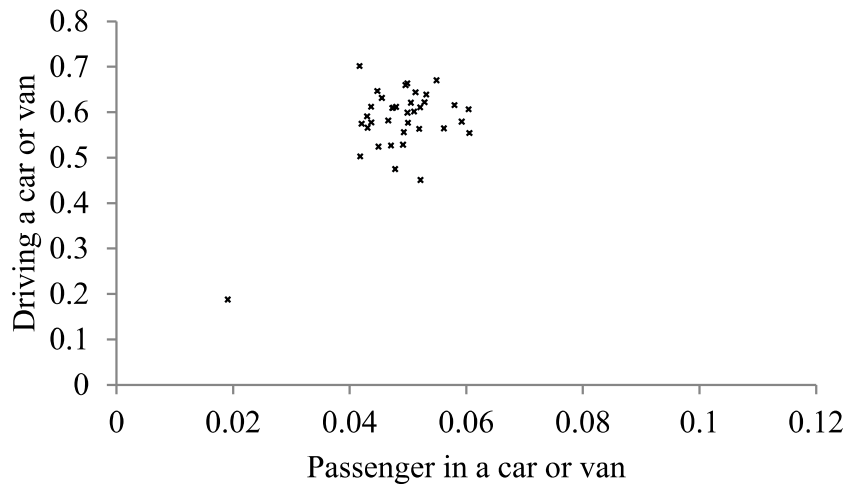
Region A



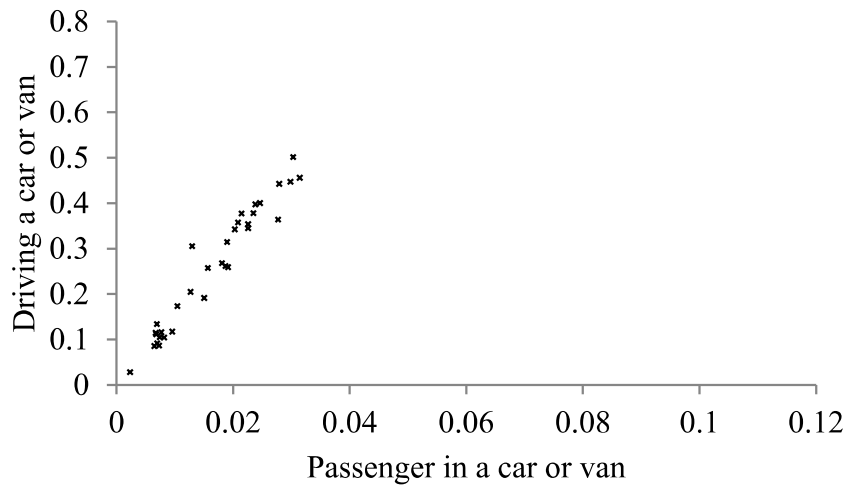
Region B



Region C



Region D



(a) Using the values given in the table, match each region to its corresponding scatter diagram, explaining your reasoning. [3]

(b) Steven claims that the outlier in the scatter diagram for Region C consists of a group of small islands.

Explain whether or not the data given above support his claim. [1]

(c) One of the Local Authorities in Region B consists of a single large island.

Explain whether or not you would expect this Local Authority to appear as an outlier in the scatter diagram for Region B. [1]

**14** A random variable  $X$  has probability distribution given by  $P(X = x) = \frac{1}{860}(1 + x)$  for  $x = 1, 2, 3, \dots, 40$ .

**(a)** Find  $P(X > 39)$ . **[2]**

**(b)** Given that  $x$  is even, determine  $P(X < 10)$ . **[6]**

**END OF QUESTION PAPER**

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