Subject – Math AI(Higher Level)
Topic - Statistics and Probability
Year - May 2021 – Nov 2024
Paper -1
Answers

Question 1

(a) $\mathrm{P}(X = 8)$ ***(M1)***

Note: Award ***(M1)*** for evidence of recognizing binomial probability.
eg, $\mathrm{P}(X = 8),\ X \sim \mathrm{B}\left(20, \frac{6}{15}\right)$.

$= 0.180\ (0.179705\ldots)$ ***A1***

[2 marks]

(b) let x be the number of male students

recognize that probability of selecting a male is equal to $\frac{x}{80}$ ***(A1)***

$\left(\text{set up equation } {}^{20}\mathrm{C}_8\left(\frac{x}{80}\right)^8\left(\frac{80-x}{80}\right)^{12} = \right) 0.153357$ ***(M1)***

number of male students $= 37$ ***(M1)A1***

Note: Award ***(M1)A0*** for 27.

[4 marks]

Total [6 marks]

Question 2

(a) $\mathrm{H}_0 : m = 3,\ \mathrm{H}_1 : m < 3$ ***A1***

(b) *(let X be the number of fish caught)*
$\mathrm{P}(X \leq 1 \mid m = 3) = 0.199$ ***M1A1***

(c) $\mathrm{P}(X \geq 2 \mid m = 2.5)\ \ (= 1 - \mathrm{P}(X \leq 1 \mid m = 2.5))$ ***M1A1***

$= 0.713$ ***A1***

[3 marks]

Total [6 marks]

Question 3

let T be the time to serve both customers and T_i the time to serve the ith customer

assuming independence of T_1 and T_2 ***R1***

T is normally distributed and $T = T_1 + T_2$ ***(M1)***

$E(T) = 1.5 + 1.5 = 3$ ***A1***

$\text{Var}(T) = 0.4^2 + 0.4^2 = 0.32$ ***M1A1***

$P(T < 4) = 0.961$ ***A1***

Total [6 marks]

Question 4

(a) $s_{n-1} = \sqrt{\frac{10}{9}} \times 0.0196 = 0.02066\ldots$ ***(M1)A1***

[2 marks]

(b) $(1.463, 1.493)$ ***(M1)A1***

Note: If s_n used answer is $(1.464, 1.492)$, award ***M1A0.***

[2 marks]

(c) 95% of the time these results would be produced by a population with mean of less than $1.5\,\text{kg}$, so it is likely the mean weight is less than $1.5\,\text{kg}$ ***R1***

[1 mark]

Total [5 marks]

Question 5

(a) $\frac{4}{18}\left(\frac{2}{9}\right)$ ***A1***

[1 mark]

(b) $-3\times\frac{1}{18}+(-1)\times\frac{4}{18}+0\times\frac{3}{18}+\ldots+5\times\frac{7}{18}$ ***(M1)***

Note: Award ***(M1)*** for their correct substitution into the formula for expected value.

$=1.83\left(\frac{33}{18}, 1.83333\ldots\right)$ ***A1***

[2 marks]

(c) $2\times\frac{1}{18}\times\frac{3}{18}$ ***(M1)(M1)***

Note: Award ***(M1)*** for $\frac{1}{18}\times\frac{3}{18}$, award ***(M1)*** for multiplying their product by 2.

$=\frac{1}{54}\left(\frac{6}{324}, 0.0185185\ldots, 1.85\%\right)$ ***A1***

[3 marks]

Total [6 marks]

Question 6

(a) discrete ***A1***

[1 mark]

(b) $\frac{24+60+3k+40+15+6}{88+k}=2$ ***M1A1***

Note: Award ***M1*** for substitution into the formula for the mean, award ***A1*** for a correct equation.

attempt to solve their equation ***(M1)***

$k=31$ ***A1***

[4 marks]

(c) systematic ***A1***

[1 mark]

Total [6 marks]

Question 7

(a) $158 \times 6 = 948\,(\text{g})$ **(M1)A1**

[2 marks]

(b) variance 6×13^2 **(M1)**

$\text{SD} = 31.8\,(\text{g})$ $(13\sqrt{6},\ 31.8433\ldots)$ **A1**

[2 marks]

(c) $X \sim \text{N}(948,\ 31.8433...^2)$

$\text{P}(X > 1000) = 0.0512$ $(0.0512350\ldots)$ **(M1)A1**

[2 marks]

Total [6 marks]

Question 8

(a) Convenience **A1**

[1 mark]

(b) H_0: 1% of the toys produced are faulty **A1**

H_1: More than 1% are faulty **A1**

[2 marks]

(c) $X \sim \text{B}(200,\ 0.01)$ **(M1)**

$\text{P}(X \geq 4) = 0.142$ **A1**

Note: Any attempt using Normal approximation to find p-value is awarded ***M0A0***.

[2 marks]

(d) $14\% > 10\%$ ***R1***

so there is insufficient evidence to reject H_0. ***A1***

Note: Do not award ***R0A1***. Accept "fail to reject H_0" or "accept H_0".

[2 marks]

Total [7 marks]

Question 9

(a)

t	1	2	3	4	5	6
$\mathrm{P}(T=t)$	$\frac{1}{36}$ (0.027777…)	$\frac{3}{36}$ (0.083333…)	$\frac{5}{36}$ (0.138888…)	$\frac{7}{36}$ (0.194444…)	$\frac{9}{36}$ (0.25)	$\frac{11}{36}$ (0.305555…)

A2

Note: Award ***A1*** if three to five probabilities are correct.

[2 marks]

(b) (i) $\frac{32}{36}$ $\left(\frac{8}{9}, 0.888888..., 88.9\%\right)$ ***(A1)***

(ii) use of conditional probability ***(M1)***
e.g. denominator of 32 **OR** denominator of $0.888888…$, etc.
$\frac{11}{32}$ $(0.34375, 34.4\%)$ ***A1***

[3 marks]

(c) $\frac{1\times1+3\times2+5\times3+...+11\times6}{36}$ ***(M1)***

$=\frac{161}{36}$ $\left(4\frac{17}{36}, 4.47, 4.47222...\right)$ ***A1***

[2 marks]

Total [7 marks]

Question 10

$X \sim \mathrm{Po}(8.8)$ ***(M1)***

Note: Award ***(M1)*** for calculating the mean, 8.8, of the distribution

$\mathrm{P}(X>9)=\mathrm{P}(X\geq10)$ **OR** $\mathrm{P}(X>9)=1-\mathrm{P}(X\leq9)$ ***(M1)***

$\mathrm{P}(X>9)=0.386$ $(0.386260...)$ ***(M1)A1***

Note: Award ***(M1)(M0)(M1)A0*** for finding $\mathrm{P}(X\geq9)=0.518$ $(0.517719...)$
OR $\mathrm{P}(X\leq9)=0.614$ $(0.613740...)$.

Total [4 marks]

Question 11

(a) $H_0 : m = 110$, $H_1 : m > 110$ ***A1***

Note: Accept other appropriate variables for the mean.
Accept 22 in place of 110.

[1 mark]

(b) $P(X \geq 128) = 0.05024$ ***(M1)(A1)***

$P(X \geq 129) = 0.04153$ ***(M1)***

(probability of making a type I error is) 0.0415 ***A1***

Note: If other probabilities are seen, the final ***A1*** cannot be awarded unless 0.0415 is clearly identified as the final answer.

[4 marks]

(c) $X \sim \text{Po}(110)$

$P(X \geq 126) = 0.072 > 0.05$ **OR** recognizing $126 < 129$ or ≤ 128 ***R1***

so there is insufficient evidence to reject H_0 ***A1***

(*ie* there is insufficient evidence to suggest that the number of coffees being sold has increased)

Note: Accept 'Accept H_0'.
Do not award ***R0A1***.

[2 marks]

Total [7 marks]

Question 12

(a) $\bar{x} = \frac{\sum x}{n} = \frac{2506}{30} = 83.5 \ \ (83.5333\ldots)$ **A1**

[1 mark]

(b) $\left(s_{n-1}^2 = \frac{\sum x^2 - \frac{\left(\sum x\right)^2}{n}}{n-1} = \right) \frac{209738 - \frac{2506^2}{30}}{29}$ **(M1)**

$= 13.9 \ \ (13.9126\ldots)$ **A1**

[2 marks]

(c) $(82.1,\ 84.9) \ \ (82.1405\ldots,\ 84.9261\ldots)$ **A2**

[2 marks]

(d) 85 is outside the confidence interval and therefore Talha would suggest that the manufacturer's claim is incorrect **R1**

[1 mark]

Total [6 marks]

Question 13

(a) $\left(\frac{74+97+91+86+112}{5}\right) = 92$ **A1**

[1 mark]

(b) (i) H_0 : The data satisfies the model **A1**

H_1 : The data does not satisfy the model **A1**

Note: Do not accept "H_0 : The same number of copies will be sold each day" but accept a similar statement if the word 'expect' or 'expected' is included. Similarly for H_1.

(ii) 4 **A1**

(iii) $\chi^2_{calc} = 8.54 \ \ (8.54347\ldots)$ **OR** $p\text{-value} = 0.0736 \ \ (0.0735802\ldots)$ **A2**

$8.54 < 9.49$ **OR** $0.0736 > 0.05$ **R1**

therefore there is insufficient evidence to reject H_0 **A1**

(i.e. the data satisfies the model)

[7 marks]

Total [8 marks]

Question 14

(a) (let μ_c = population mean for chinchilla rabbits, μ_s = population mean for sable rabbits)

$H_0 : \mu_c = \mu_s$ **A1**

$H_1 : \mu_c > \mu_s$ **A1**

Note: Accept an equivalent statement in words, must include mean and reference to "**population** mean" / "mean for **all** chinchilla rabbits" for the first ***A1*** to be awarded. The terms "*on average*" and "*generally*" are also acceptable to indicate populations.
Do not accept an imprecise *"the means are equal"*.

[2 marks]

(b) p-value $= 0.0408$ $(0.0408065...)$ **A2**

Note: Award ***A1*** for an answer of $0.041565\ldots$, from "unpooled" settings on GDC.

[2 marks]

(c) $0.0408 < 0.05$. **R1**

(there is sufficient evidence to) reject (or not accept) H_0 **A1**

(there is sufficient evidence to suggest that chinchilla rabbits are (generally) heavier than sable rabbits)

Note: Do not award ***R0A1***. Accept 'accept H_1'.

[2 marks]

Total [6 marks]

Question 15

(a) let X be the random variable "the weight of a sack of potatoes"

$P(X < 50)$ ***(M1)***

$= 0.588$ kg $(0.587929...)$ ***A1***

[2 marks]

(b) $P(X < l) = 0.25$ ***(M1)***

49.2 kg $(49.1929\ldots)$ ***A1***

[2 marks]

(c) attempt to sum 10 independent random variables ***(M1)***

$Y = \sum_{i=1}^{10} X_i \sim N(498, 10 \times 0.9^2)$ ***(A1)***

$P(Y > 500) = 0.241$ ***A1***

[3 marks]

Total: [7 marks]

Question 16

(a) 75 **A1**

[1 mark]

(b) recognition that all entries add up to 120 ***(M1)***

$a = 120 - 6 - 13 - 26 - b$ **OR** $a = 75 - b$ ***A1***

[2 marks]

(c) (i) $\dfrac{6\times1+13\times2+26\times3+(75-b)\times4+b\times5}{120} = 3.65$ ***(M1)(A1)***

Note: Award ***(M1)*** for attempt to substitute into mean formula, LHS expression is sufficient for the ***M*** mark. Award ***(A1)*** for correct substitutions in one variable **OR** in two variables, followed by evidence of solving simultaneously with $a + b = 75$.

$(b =)$ 28 ***A1***

(ii) 120 − their part (c)(i) seen (e.g. 92 indicated on graph) ***(M1)***

84 ***A1***

[5 marks]

Total: [8 marks]

Question 17

(a) $X \sim \text{Po}(324)$ ***A1***

Note: Both distribution and mean must be seen for ***A1*** to be awarded.

[1 mark]

(b) $\text{P}(X \leq 300)$ ***(M1)***

$= 0.0946831... \approx 0.0947$ ***A1***

[2 marks]

(c) (mean number of cars =) $4.5\times60 = 270$ ***(A1)***

$\text{P}(X > 300 \mid \lambda = 270)$ ***(M1)***

Note: Award ***M1*** for using $\lambda = 270$ to evaluate a probability.

$\text{P}(X \geq 301)$ **OR** $1 - \text{P}(X \leq 300)$ ***(M1)***

$= 0.0334207... \approx 0.0334$ ***A1***

[4 marks]

[Total 7 marks]

Question 18

(a) $\log_{10} 100 = a - 3$ **(M1)**

$a = 5$ **A1**

[2 marks]

(b) **EITHER**

$N = 10^{5-M}$ **(M1)**

$= \frac{10^5}{10^M} \left(= \frac{100000}{10^M} \right)$

OR

$100 = \frac{b}{10^3}$ **(M1)**

THEN

$b = 100000 \ \ (= 10^5)$ **A1**

[2 marks]

(c) $N = \frac{10^5}{10^{7.2}} = 0.00631 \ \ (0.0063095...)$ **A1**

Note: Do not accept an answer of $10^{-2.2}$.

[1 mark]

(d) **METHOD 1**

$Y > 100 \Rightarrow$ no earthquakes in the first 100 years **(M1)**

EITHER

let X be the number of earthquakes of at least magnitude 7.2 in a year

$X \sim \text{Po}(0.0063095\ldots)$

$(\text{P}(X = 0))^{100}$ **(M1)**

OR

let X be the number of earthquakes in 100 years

$X \sim \text{Po}(0.0063095\ldots \times 100)$ **(M1)**

$\text{P}(X = 0)$

THEN

0.532 (0.532082…) **A1**

METHOD 2

$Y > 100 \Rightarrow$ no earthquakes in the first 100 years **(M1)**

let X be the number of earthquakes in 100 years

since n is large and p is small

$X \sim \text{B}(100, 0.0063095\ldots)$ **(M1)**

$\text{P}(X = 0)$

0.531 (0.531019…) **A1**

[3 marks]

[Total 8 marks]

Question 19

(a) let X be the weight of sugar in the bag

$\mathrm{P}(X < 950) = 0.308537... \approx 0.309$ ***(M1)A1***

[2 marks]

(b) **METHOD 1**

let $\bar{X}$ be the mean weight of 5 bags of sugar

$\mathrm{E}(\bar{X}) = 1000$ ***(A1)***

use of $\mathrm{Var}(\bar{X}) = \frac{\sigma^2}{n}$ ***(M1)***

$\mathrm{Var}(\bar{X}) = \frac{100^2}{5} \ (= 2000)$ ***(A1)***

$\bar{X} \sim \mathrm{N}(1000,\ 2000)$

$\mathrm{P}(\bar{X} > 950) = 0.868223... \approx 0.868 \ (86.8\%)$ ***A1***

METHOD 2

let T be the total weight of 5 bags of sugar

$\mathrm{E}(T) = 5000$ ***(A1)***

use of $\mathrm{Var}(X_1 + X_2) = \mathrm{Var}(X_1) + \mathrm{Var}(X_2)$ for independent random variables ***(M1)***

$\mathrm{Var}(T) = 5 \times 100^2 \ (= 50\,000)$ ***(A1)***

$T \sim \mathrm{N}(5000,\ 50\,000)$

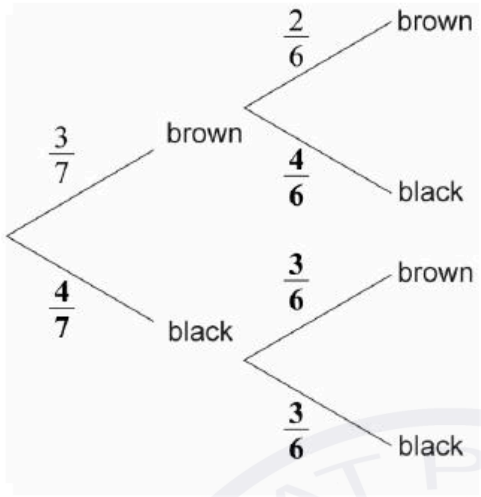
$\mathrm{P}(T > 4750) = 0.868223... \approx 0.868 \ (86.8\%)$ ***A1***

[4 marks]

[Total 6 marks]

Question 20

(a)



A1A1

[2 marks]

(b) multiplying along branches and then adding outcomes **(M1)**

$\frac{3}{7}\times\frac{2}{6}+\frac{4}{7}\times\frac{3}{6}$

$=\frac{18}{42}\left(=\frac{3}{7}\approx 0.429\ (42.9\%)\right)$ **A1**

[2 marks]

(c) use of conditional probability formula **M1**

$\frac{\left(\frac{3}{7}\times\frac{2}{6}\right)}{\left(\frac{3}{7}\right)}$ **A1**

$=\frac{6}{18}\left(=\frac{1}{3}\right)\ \left(\frac{252}{756}, 0.333, 33.3\%\right)$ **A1**

[3 marks]
[Total 7 marks]

Question 21

(a) H_0: The die is fair **OR** $P(\text{any number}) = \frac{1}{6}$ **OR** probabilities are equal

H_1: The die is not fair **OR** $P(\text{any number}) \neq \frac{1}{6}$ **OR** probabilities are not equal ***A1***

[1 mark]

(b) 5 ***A1***

[1 mark]

(c) 10 ***A1***

[1 mark]

(d) (p-value =) 0.287 (0.28724163….) ***A2***

[2 marks]

(e) $0.287 > 0.05$ ***R1***

EITHER
Insufficient evidence to reject the null hypothesis ***A1***

OR
Insufficient evidence to reject that the die is fair ***A1***

Question 22

(a) $P(\text{Type I error}) = P(\text{stating female when male})$
$= P(W_{Male} > 11.5)$ ***(M1)***
$= 0.00135 \quad (0.00134996\ldots)$ ***A1***

[2 marks]

(b) $P(\text{Type II error}) = P(\text{stating male when female})$
$= P(W_{Female} < 11.5)$ ***(M1)***
$= 0.309 \quad (0.308537\ldots)$ ***A1***

[2 marks]

(c) attempt to use the total probability ***(M1)***
$P(\text{error}) = 0.9 \times 0.00134996\ldots + 0.1 \times 0.308537\ldots$
$= 0.0321 \quad (0.0320687\ldots)$ ***A1***

[2 marks]
Total [6 marks]

Question 23

(a) $\bar{x} = 4.63$ (4.62686…) ***A1***

[1 mark]

(b) $s_{n-1} = 1.098702$ ***(A1)***

$s_{n-1}^2 = 1.21$ (1.207146…) ***A1***

Note: Award ***A0A0*** for an answer of 1.19 from biased estimate.

[2 marks]

(c) (i) $H_1 : \mu > 4.4$ ***A1***

(ii) **METHOD 1**

using a z-test ***(M1)***

$p = 0.0454992\ldots$ ***A1***

$p < 0.05$ ***R1***

reject null hypothesis ***A1***

(therefore there is significant evidence that the IB HL math students know more digits of π than the population in general)

Note: Do not award ***R0A1***. Allow ***R1A1*** for consistent conclusion following on from their p-value.

METHOD 2

using a t-test ***(M1)***

$p = 0.0478584\ldots$ ***A1***

$p < 0.05$ ***R1***

reject null hypothesis ***A1***

(therefore there is significant evidence that the IB HL math students know more digits of π than the population in general)

Note: Do not award ***R0A1***. Allow ***R1A1*** for consistent conclusion following on from their p-value.

[5 marks]

Total [8 marks]

Question 24

(a) *Accept any one of the following (or equivalent):*
one minimum and one maximum point
three x-intercepts or three roots (or zeroes)
one point of inflexion **R1**

Note: Do not accept "S shape" as a justification.

[1 mark]

(b) (i) $(d =) -5$ **A1**

(ii) $8 = a + b + c$
$4 = 8a + 4b + 2c$
$0 = 27a + 9b + 3c$ **A2**

Note: Award ***A2*** if all three equations are correct.
Award ***A1*** if at least one is correct. Award ***A1*** for three correct equations that include the letter "d".

(iii) $a = 2,\ b = -12,\ c = 18$ **A1**

[4 marks]

(c) equating found expression to zero **(M1)**
$0 = 2t^3 - 12t^2 + 18t - 5$
$t = 0.358216\ldots,\ 1.83174\ldots,\ 3.81003\ldots$ **(A1)**

(so total time in debt is $3.81003\ldots - 1.83174\ldots + 0.358216 \approx$)
2.34 (2.33650…) years **A1**

[3 marks]
Total [8 marks]

Question 25

(a) $(\mathrm{E}(X) =) 10 \times 0.8$ **(M1)**
8 (people) **A1**

[2 marks]

(b) recognition of binomial probability **(M1)**
0.0881 (0.0880803…) **A1**

[2 marks]

(c) 0.8 and 6 seen **OR** 0.2 and 3 seen **(A1)**
attempt to use binomial probability **(M1)**
0.121 (0.120873…) **A1**

[3 marks]
Total [7 marks]

Question 26

(a) $\left(\frac{17+25}{130}=\right)\frac{42}{130}$ $\left(\frac{21}{65}, 0.323076\ldots\right)$ ***A1***

[1 mark]

(b) $\left(\frac{17}{17+25}=\right)\frac{17}{42}$ $(0.404761\ldots)$ ***A1A1***

Note: Award ***A1*** for correct numerator and ***A1*** for correct denominator.
Award ***A1A0*** for working of $\frac{17/130}{\text{their answer to (a)}}$ if followed by an incorrect answer.

[2 marks]

(c) $\frac{41}{130}\times\frac{40}{129}$ ***A1M1***

Note: Award ***A1*** for two correct fractions seen, ***M1*** for multiplying their fractions.

$=\frac{1640}{16770}\approx 0.0978$ $\left(0.0977936\ldots, \frac{164}{1677}\right)$ ***A1***

[3 marks]
Total [6 marks]

Question 27

(a) $D = S - R$

METHOD 1

$= \text{Re}(1.15e^{(0.0165t-2.97)i}) - \text{Re}(1.08e^{(0.0165t+0.413)i})$ $(+18.9 - 4.94)$ ***(M1)(A1)***

$= \text{Re}\left(e^{0.0165ti}(1.15e^{-2.97i} - 1.08e^{0.413i})\right)$ $(+13.96)$ ***(M1)***

$= \text{Re}\left(e^{0.0165ti}(2.21379...e^{-2.85310...i})\right)$ $(+13.96)$ ***(A1)***

$= 2.21\cos(0.0165t - 2.85) + 13.96$ $\left(2.21379...\cos(0.0165t - 2.85310...) + 13.96\right)$ ***A1A1***

$(a = 2.21,\ b = -2.85,\ c = 13.96)$

Note: Award ***A1*** for $2.21\cos(0.0165t - 2.85)$ and ***A1*** for "$+13.96$". The ***A1*** for 13.96 is independent of the previous marks.

METHOD 2

$c = 13.9 - 4.94\ldots = 13.96$ ***A1***

using a graph of D ***M1***

maximum $(172.915\ldots, 16.1738\ldots)$ ***(A1)***

minimum $(-17.4842\ldots, 11.7462\ldots)$ ***(A1)***

EITHER

amplitude $16.1738\ldots - 11.7462\ldots = 4.4276\ldots$

$a = 2.21$ $(2.2138\ldots)$ ***A1***

OR

$a = 16.1738\ldots - 13.96 = 2.21$ $(2.2138\ldots)$ ***A1***

THEN

EITHER

when $t = 0$, $D = 11.8377\ldots$

$11.8377\ldots = 2.2138\cos(b) + 13.96$

$b = -2.85$ $(2.85309\ldots)$ ***A1***

OR

$b = -0.0165 \times 172.915\ldots = -2.85$ $(2.85309\ldots)$ ***A1***

[6 marks]

(b) 16.2 $(16.1737\ldots)$ hours on day 173 ***A1A1***

Note: Accept an answer of "day 172" for the second ***A1***.

[2 marks]

Total [8 marks]

Question 28

(a) (let p be the probability of a student choosing healthy options)

$H_0: p = 0.3$ **A1**

$H_1: p > 0.3$ **A1**

Note: Award ***A0A1*** for correct hypotheses with μ in place of p. Accept equivalent hypotheses in words.

[2 marks]

(b) a type I error is rejecting H_0 when H_0 is true ***(M1)***

(let N = number of students choosing a healthy option)

$N \sim B(80, 0.3)$

$P(31 \leq N \leq 80)$ **OR** $P(N \geq 31)$ **OR** $1 - P(N \leq 30)$ ***(M1)***

Note: Do not accept the use of the Normal approximation.

0.0587 $(0.0587481\ldots)$ ***A1***

[3 marks]

(c) a type II error is accepting H_0 when H_0 is not true ***(M1)***

$N \sim B(80, 0.4)$

$P(0 \leq N \leq 30)$ **OR** $P(N \leq 30)$ ***(M1)***

0.369 $(0.368726\ldots)$ ***A1***

[3 marks]

Total [8 marks]

Question 29

(a) $0.5 \times 0.1 + 0.4 \times 0.4 + 0.1 \times 0.5$ ***(M1)(M1)(M1)***

Note: Award ***M1*** for 0.5×0.1 or 0.1×0.5, ***M1*** for 0.4×0.4, ***M1*** for adding three correct products.

0.26 ***A1***

[4 marks]

(b) $0 = -8 \times 0.5 + 4 \times 0.4 + 0.1k$ ***(M1)(M1)***

Note: Award ***M1*** for correct substitution into the formula for expected value, award ***M1*** for the expected value formula equated to zero.

$(k =)$ 24 (points) ***A1***

[3 marks]

Total [7 marks]

Question 30

(a) The favourite breakfast/berry (of adults) is independent of (their) income (level). ***A1***

[1 mark]

(b) $\chi^2 = 2.27 \ \ (2.26821...)$ ***A2***

[2 marks]

(c) **EITHER**

$2.27 < 7.78$ **OR** $2.27 <$ critical value ***R1***

OR

$0.687 > 0.1$ (using p-value)

THEN

(Do not reject H_0)

Insufficient evidence (at the 10% significance level) that the favourite berry depends on income level. ***A1***

[2 marks]

Total [5 marks]

Question 31

(a) attempt to find what the model predicts in terms of k ***(M1)***

$k, \frac{k}{4}, \frac{k}{25}$

correct expression for sum of square residuals ***(A1)***

$(k-42)^2+\left(\frac{k}{4}-11\right)^2+\left(\frac{k}{25}-1.5\right)^2$

valid attempt to find c by expanding or recognizing the constant terms ***(M1)***

$c = 42^2+11^2+1.5^2$

$=1887.25$ ***A1***

[4 marks]

(b) valid method to find the k value at the minimum ***(M1)***

$k=\frac{89.62}{2\times 1.0641}$ $(=42.1107...)$, graph, completing the square

(so least squares regression is) $I=\frac{42.1}{d^2}$ ***A1***

[2 marks]

[Total: 6 marks]

Question 32

recognizing that a log-log graph results in a power function model ***(M1)***

$y=a\times x^b$

attempt to find a power regression model using the given two points ***(M1)***

$a=5$ and $b=1.4$ ***(A1)(A1)***

(so the equation is) $y=5\times x^{1.4}$ ***A2***

[Total: 6 marks]

Question 33

Let $D = O - L - L$ ***(A1)***

$(\text{mean} =)\ 205 - 105 - 105\ \ (= -5)$ ***(A1)***

manipulating variances (not standard deviations) ***(M1)***

$(\text{variance} =)\ 25 + 9 + 9\ \ (= 43)$ **OR** $(\text{SD} =)\ 6.55743...$ ***(A1)***

$D \sim \text{N}(205 - 105 - 105,\ 25 + 9 + 9)$

attempt to find the probability that $D > 0$ ***(M1)***

$\text{P}(D > 0)$

$= 0.223\ \ (0.222882...)$ ***A1***

Note: If $D = O - 2L$ is seen or implied, award at most ***(A0)A1(M0)(A0)M1A0***.

[Total: 6 marks]

Question 34

(a) attempt to find the difference between 75.7 and 67.3 ***(M1)***

$\frac{75.7 - 67.3}{2}$

$4.2\ (\text{km h}^{-1})$ ***A1***

[2 marks]

(b) **METHOD 1 (Comparing areas above and below the mean)**

$\text{P}(67.3 < \text{speed} < 74)$ **OR** Normal CDF$(67.3, 74, 67.3, 4.2)$ **OR** sketch of normal distribution with 67.3 and 74 labelled and shaded between ***(M1)***

area of region between mean and q is at least $0.445\ \ (0.444670\ldots)$ ***A1***

Hence no more than $0.375\ \ (0.375329\ldots)$ between mean and p ***R1***

The region between p and q is not symmetrical ***AG***

METHOD 2 (Comparing areas in the tails)

attempt to calculate probability that speed $< p$ and speed $> q$ with $q = 74$ ***(M1)***

$\text{P}(\text{speed} < 74) = 0.944670\ldots$

$\text{P}(\text{speed} < p) = (0.944670\ldots - 0.82 =)\ 0.124670\ldots$

$\text{P}(\text{speed} > q) = (1 - 0.944670\ldots =)\ 0.0553295\ldots$ ***A1***

if $q \geq 74$, then $\text{P}(\text{speed} > q) \leq 0.0553295$ and $\text{P}(\text{speed} < p) \geq 0.124670$ so

$\text{P}(\text{speed} > q)$ will never equal $\text{P}(\text{speed} < p)$ ***R1***

the region between p and q is not symmetrical ***AG***

METHOD 3 (Assumption of symmetry comparing speeds)

attempt to calculate area below q assuming distribution is symmetrical ***(M1)***

e.g. $\mathrm{P}(\text{speed} < q) = 0.82 + \frac{1}{2} \times 0.18 \quad (0.91)$

EITHER

$(q =)\ 72.9 \quad (72.9311\ldots)$ ***A1***

$72.9 < 74$ so 74 would not be in the region ***R1***

the region between p and q is not symmetrical ***AG***

OR

$\mathrm{P}(\text{speed} < 74) = 0.945 \quad (0.944670\ldots)$ ***A1***

$0.945 > 0.91$ so 74 would not be in the region ***R1***

the region between p and q is not symmetrical ***AG***

METHOD 4 (Assumption of symmetry comparing areas)

attempt to calculate symmetrical area with 74 as a boundary ***(M1)***

$\mathrm{P}(60.6 < \text{speed} < 74)$ **OR** Normal CDF(60.6, 74, 67.3, 4.2) **OR**

$\mathrm{P}(67.3 < \text{speed} < 74)$ **OR** Normal CDF(67.3, 74, 67.3, 4.2)

EITHER

$0.889 \quad (0.889340\ldots)$ ***A1***

$0.889 > 0.82$ so 74 would not be in the region ***R1***

the region between p and q is not symmetrical ***AG***

OR

$0.445 \quad (0.444670\ldots)$ ***A1***

$0.445 > 0.82 \div 2$ so 74 would not be in the region ***R1***

the region between p and q is not symmetrical ***AG***

[3 marks]

[Total: 5 marks]

Question 35

(a) H_0: X and Y are not (linearly) correlated **OR** $\rho = 0$ ***A1***

H_1: X and Y are (linearly) correlated **OR** $\rho \neq 0$ ***A1***

Note: Accept "independent" or "not associated" in place of "not correlated".
If H_0 and H_1 are reversed, then award ***A0A1***.

[2 marks]

(b) (i) $r = 0.849 \ (0.848886...)$ ***A1***

(ii) p-value $= 0.0325 \ (0.0325277...)$ ***A2***

Note: Award ***A1*** for p-value $= 0.033$ or p-value $= 0.03$.
Award ***FT*** for $\rho > 0$ or $\rho < 0$ in part (a), p-value $= 0.0163 \ (0.0162638\ldots)$
or p-value $= 0.984 \ (0.983736\ldots)$
Award the full marks for seeing the values of r and p-value from the markscheme when H_0 and H_1 are reversed in part (a).

[3 marks]

(c) $0.0325 < 0.05$ ***R1***

(so we reject H_0 in favour of H_1)

(there is sufficient evidence to suggest) X and Y are (linearly) correlated ***A1***

Note: Their conclusion must be consistent with their p-value and their hypotheses and it must be in context.

[2 marks]

[Total: 7 marks]

Question 36

(a) $H_0 : \mu_b = \mu_m$ ***A1***

$H_1 : \mu_b > \mu_m$ ***A1***

Note: Accept equivalent statements in words such as "the **mean** score of bilingual people equals the **mean** score of monolingual people".

[2 marks]

(b) $0.119 \ (0.119395\ldots)$ ***A2***

[2 marks]

(c) $0.119395\ldots > 0.05 \ \ (11.9395\ldots\% > 5\%)$ ***R1***

(fail to reject H_0) there is insufficient evidence to suggest that bilingual people have better memory retention than monolingual people ***A1***

Note: Do not award ***R0A1***.
The answer to part (c) MUST be consistent with **their** hypotheses and **their** p-value.

[2 marks]

[Total: 6 marks]

Question 37

(a) (i) 224 g (224.25 g) ***A1***

(ii) $[222.1, 226.4]$ ***A1A1***

Note: Award ***A1*** for each correct end of the interval. Accept open or closed (weak or strict) interval notation. Inequalities involving μ would also be accepted, but not involving $\bar{x}$.
Award ***A1A0*** for correct answers not given correct to 4 sf.

[3 marks]

(b) **EITHER**
the (population) weight of granules of Apollo coffee is normally distributed. ***R1***
OR
the readings are independent ***R1***

[1 mark]

(c) 226g lies within the confidence interval, ***R1***
so there is no evidence to dispute the claim on the label. ***A1***

Note: Do not award ***R0A1***.

[2 marks]
Total [6 marks]

Question 38

. (a) H_0 : there is no particular preference for any of the flavours ***A1***

H_1 : there is a particular preference for some of the flavours ***A1***

Note: Accept equivalent statements such as "H_0 : the population ratio of flavour preferences is $1:1:1:1$" or "H_0 : the population proportions are equal for each flavour" or "H_0 : the data is drawn from a uniform distribution".

[2 marks]

(b) **EITHER**

p-value $= 0.0629$ $(0.0629034...)$ ***A2***

$0.0629 > 0.05$ ***R1***

OR

$\chi^2_{calc} = 7.30$ ***A2***

$7.30 < 7.82$ ***R1***

Note: Award ***A2*** for either p-value $= 0.063$ or $\chi^2_{calc} = 7.3$ seen. Award ***R1*** for a correct comparison involve their p-value or χ^2_{calc}, and follow through for their conclusion.

THEN

so there is insufficient evidence to reject H_0, i.e.

there is no particular preference for any of the flavours. ***A1***

Note: Do not award ***R0A1***.

[4 marks]

Total [6 marks]

Question 39

(a)

Athlete	A	B	C	D	E	F	G	H
Age rank	7	6	3	5	4	2	8	1
Time rank	3.5	2	3.5	6	7	8	1	5

A1A1

Note: Award ***A1*** for each correct row.

[2 marks]

(b) $r_s = -0.671$ $(-0.670670...)$ ***A2***

Note: Only follow through from an incorrect table provided the ranks are all between 1 and 8.
Award ***A1*** for -0.67 **OR** for the omission of the negative sign, e.g. 0.671 $(0.670670...)$ or 0.67

[2 marks]

(c) (A value of $r_S = -0.671$) indicates a negative correlation between a person's age and the best time they take to run 100m. ***R1***

Note: Condone any comment that includes "weak" or "strong" etc. Accept an interpretation in words, but only if there is a general link described and not a rule: "The older a person gets, the faster they *tend to* run".
Answer must be in context.

[1 mark]

(d) *Award **R1** for any sensible reason:* ***R1***
The correlation, such that it is, is unlikely to be linear for this type of data.
Spearman's CC is less sensitive to outliers
Sung-Jin is not sure the data is drawn from a bivariate normal distribution
There are outliers/extreme data
Same time for two athletes with significantly different ages

[1 mark]

(e) (i) 0.264 $(0.263762...)$ ***A2***

Note: Award ***A1*** for 0.26 with no working. Given that the exact model is not specific in the question, accept correct r^2 values from other regression models: 0.631, 0.650, 0.759 and 0.256.

(ii) approximately 26% of the variability in the times taken can be explained by the runner's age. ***R1***

[3 marks]
Total [9 marks]

Question 40

(a) $(56 \times 0.86) = 48.2 \quad (48.16)$ ***A1***

Note: Accept 48.

[1 mark]

(b) recognizing binomial distribution (may be seen in (a)) ***(M1)***

e.g. $X \sim \mathrm{B}(56,\ 0.86)$

$\left(\mathrm{P}(X \geq 50) =\right)\ 0.316$ ***A2***

[3 marks]

(c) $\mathrm{P}(X \leq n) \geq 0.25$

$n = 46$ ***A2***

[2 marks]

Total [6 marks]

Question 41

(a) $X \sim \mathrm{N}(4, 0.25^2)$

EITHER

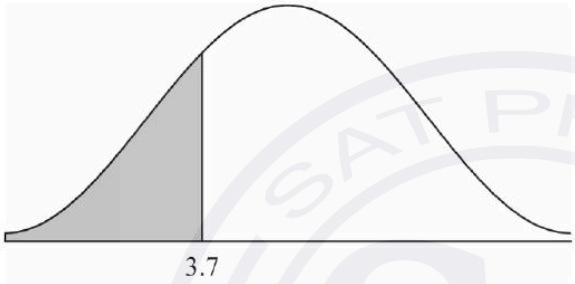
correct probability expression ***(M1)***

$\mathrm{P}(X < 3.7)$

Note: Accept a weak or strict inequality, and any label instead of X, e.g. length or L.

OR

normal curve with vertical line, left of mean, labelled 3.7, and shaded region ***(M1)***



THEN

0.115 $(0.115069\ldots, 11.5\%)$ ***A1***

Note: Award ***M1A0*** for 0.12 if no previous working.

[2 marks]

(b) **EITHER**

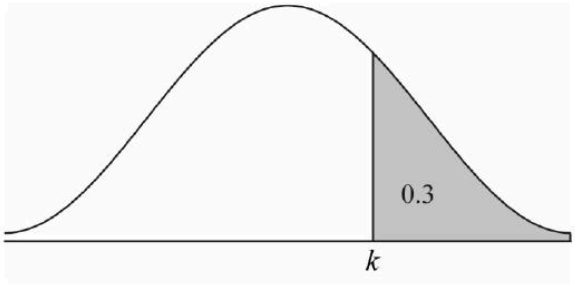
Correct probability expression ***(M1)***

$(\mathrm{P}(X < k) = 0.7$ **OR** $\mathrm{P}(X > k) = 0.3$

Note: Accept a weak or strict inequality, and any label instead of X *e.g.*, length or L.

OR

normal curve with vertical line to the right of the mean and shaded region, correctly labelled either 0.3 or 0.7 ***(M1)***



THEN

$(k =)\ 4.13\ (4.13110\ldots)$ ***A1***

Note: Award ***M1A0*** for 4.1 if no previous working.

[2 marks]

(c) **EITHER**

correct probability equation ***(M1)***

$\mathrm{P}(\text{length} < 4 + m) = 0.8$ **OR** $\mathrm{P}(\text{length} < 4 - m) = 0.2$

Note: Accept any letter instead of "length" *e.g.*, X or L.

OR

normal curve with vertical lines symmetrical about the mean line with a correct indication of an area of 0.6 or 0.2 or 0.8 ***(M1)***

THEN

$0.210\ (0.210405\ldots)$ ***A1***

Note: Award ***(M1)A0*** for an answer of 3.7895 or 4.2105 seen without working. Condone 0.21 seen and award ***(M1)A1***.

[2 marks]

Total [6 marks]

Question 42

(a) attempting to use $\mathrm{P}(R \cap S) = \mathrm{P}(R)\mathrm{P}(S)$ ***(M1)***

$0.2 = 0.8(0.2 + x)$ ***(A1)***

$x = 0.05$ ***A1***

[3 marks]

(b) $x + 0.2 + 0.6 + y = 1$ ***(M1)***

$y = 0.15$ ***A1***

[2 marks]

(c) **METHOD 1**

attempting to apply $\mathrm{P}(R' \mid S') = \dfrac{\mathrm{P}(R' \cap S')}{\mathrm{P}(S')}$ ***(M1)***

$\dfrac{0.15}{0.2}$

$= \dfrac{3}{4}$ ***A1***

METHOD 2

$\mathrm{P}(R' \mid S') = \mathrm{P}(R')$ (because R, S are independent) ***(M1)***

$= 1 - 0.25 = 0.75$ ***A1***

Note: ***FT*** from their values of x or y.

[2 marks]

Total [7 marks]

Question 43

(a) $11.0\ (11.0212\ldots)$ ***A2***

Note: Award ***A1*** for a final answer of 11 if no unrounded answer is seen.

[2 marks]

(b) **EITHER**

$11.0 > 9.488\ (11.0212\ldots > 9.488\ )$ ***R1***

OR

$0.0263 < 0.05\ (0.0263264\ldots < 0.05\ )$ ***R1***

THEN

EITHER

(there is significant evidence to) reject H_0 ***A1***

OR

(there is significant evidence that) the (food) quality and the type of meal are not independent ***A1***

Note: Do not award ***R0A1.***

Award ***R1*** for $\chi^2_{\text{calc}} > \chi^2_{\text{crit}}$, provided the calculated value is explicitly seen in part (b).

Accept "p-value < significance level" provided their p-value is seen and their p-value is between 0 and 1.

[2 marks]

Total [4 marks]

Question 44

(a) Let X be the random variable number of shots taken in a 12 minute period

$X \sim \text{Po}(5)$ ***(A1)***

$\text{P}(X \leq 6) = 0.762 \ \ (= 0.762183...)$ ***A1***

[2 marks]

(b) $\text{P}(\text{less than 4 shots} \cap \text{success at least once})$

METHOD 1

$= \text{P}(\text{less than 4 shots}) - \text{P}(\text{less than 4 shots} \cap \text{zero success})$ ***(M1)***

Note: Might be communicated in Venn diagram.

attempt to multiply by different powers of 0.6 ***(M1)***

$= \text{P}(X \leq 3) - (\text{P}(X = 0) \times (0.6)^0 + \text{P}(X = 1) \times (0.6)^1 + \text{P}(X = 2) \times (0.6)^2 + \text{P}(X = 3) \times (0.6)^3)$ ***(A1)***

$= 0.414 \ \ (= 0.413845...)$ ***A1***

METHOD 2

attempt to multiply by different powers of 0.4 ***(M1)***

$= \text{P}(X = 1) \times (0.4)^1 + \text{P}(X = 2) \times \left((0.4)^2 + 2 \times 0.4 \times 0.6\right) + \text{P}(X = 3) \times \left((0.4)^3 + 3 \times 0.4^2 \times 0.6 + 3 \times 0.4 \times 0.6^2\right)$ ***(M1)(A1)***

Note: Award ***M1*** for recognizing the six different cases, e.g. $2 \times 0.4 \times 0.6$ (etc.) or equivalent seen, ***A1*** for completely correct expression.

$= 0.414 \ \ (= 0.413845...)$ ***A1***

[4 marks]

[Total 6 marks]

Question 45

(a) $M = 1000 \times t^{-0.6}$

$a = 1000 (= 999.972...)$ $\quad b = -0.600$ $(-0.599991...)$ **A1A1**

[2 marks]

(b) $y = -0.600x + 6.908$

$c = -0.600$ $\quad d = 6.908$ **A1A1**

Note: Long answer for c is $0.599991\ldots$ and for d is $6.90772\ldots$ If both answers are correct but not given to 3 decimal places award ***A1A0***.

[2 marks]

(c) **METHOD 1 (starting with the result in part (b))**

attempt to apply addition (or subtraction) log laws ***M1***

attempt to apply inverse log ***M1***

Note: These ***M1*** marks can be applied in either order depending on the approach.

e.g. $\ln M = \ln t^{-0.600} + \ln e^{6.908}$ then $\ln M = \ln \left(e^{6.908} \times t^{-0.600} \right)$

OR $\ln \dfrac{M}{t^{-0.600}} = 6.908$ then $\dfrac{M}{t^{-0.600}} = e^{6.908}$

$M = e^{6.908} t^{-0.600}$ ***A1***

$(M = 1000.24t^{-0.6})$

$M = 1000t^{-0.6}$ and hence (close enough to be) equivalent ***AG***

Note: The ***AG*** line (or something which approximates it) must be seen for the final ***A1*** to be awarded. If 3 sf answers are used from part (b), the coefficient is 1002; this can be condoned in the working, as it equals 1000 when rounded to 3 sf.

METHOD 2 (starting with the result in part (a))

attempt to apply log ***M1***

$\ln M = \ln (1000 \times t^{-0.6})$

attempt to apply addition (or subtraction) log laws ***M1***

$\ln M = \ln 1000 + \ln t^{-0.6}$

$\ln M = 6.90775... - 0.6 \ln t$ ***A1***

$(\ln M = y,\ \ln t = x)$

$y = -0.600x + 6.908$ and hence (close enough to be) equivalent ***AG***

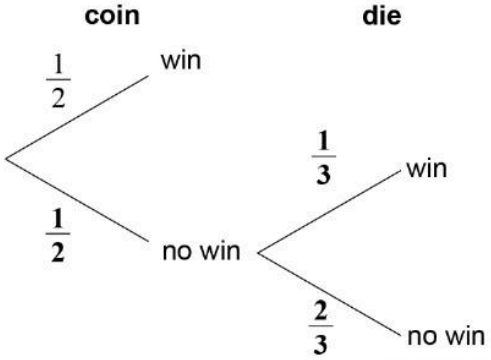
Note: The ***AG*** line (or something which approximates it) must be seen for the final ***A1*** to be awarded. Condone $b = -0.6$.

[3 marks]

[Total 7 marks]

Question 46

(a)



A1A1

Note: Award ***A1*** for completing first set of branches, ***A1*** for completing second set of branches.

[2 marks]

(b) attempt to multiply along the branches ***(M1)***

$\frac{1}{2}\times\frac{2}{3}$

$=\frac{1}{3}\ \ (=0.333...)$ ***A1***

[2 marks]

(c) **EITHER**

$$\frac{\frac{1}{2}}{\frac{1}{2}+\left(\frac{1}{2}\times\frac{1}{3}\right)}$$ ***M1A1***

Note: Award ***M1*** for recognizing conditional probability, ***A1*** for correct substitution.

OR

$$\frac{\frac{1}{2}}{1-\frac{1}{3}}$$ ***M1A1***

Note: Award ***M1*** for recognizing conditional probability, ***A1*** for correct substitution.

THEN

$=\frac{3}{4}$ ***A1***

[3 marks]
[Total 7 marks]

Question 47

(a) room temperature / the temperature below which the hot water will not cool **A1**

Note: Accept answers similar to "the temperature of the water in the cup after 25 minutes".

[1 mark]

(b) evidence of subtracting 25 from the temperature data **(M1)**

$a = 244\ (243.920...)$ and $b = -1.03\ (-1.02965...)$ **A1A1**

Note: Award ***M0A1A0*** for both answers $a = 116.764...$ and $b = -0.375218...$ seen, from not subtracting the 25.

[3 marks]

(c) $k = 61.1\ (61.0848...)$ and $c = 0.923\ (0.923029...)$ **A1**

Note: If not subtracting 25 was penalized in part (b), award ***A1*** for $k = 68.9023...$ and $c = 0.972506...$ seen in part (c).

[1 mark]

(d) *Award **R1** for any appropriate reason that supports Soo Min's model*
e.g.
EITHER
compare r^2 values: $0.76573583\ldots$ and $0.9233117\ldots$ **R1**

OR
consider value at $t = 0$ / "water cannot reach a temperature more than 100 degrees" **R1**

Note: If subtracting 25 was penalized in (b) then award ***R1*** for comparing r^2 values $0.904086\ldots$ and $0.994522\ldots$

Award ***R1*** for correct reasoning seen for the use of comparison of the sum of square residuals.

[1 mark]
[Total: 8 marks]

Question 48

(a) (i) let X be number of accidents per week $\Rightarrow X \sim \text{Po}(0.76)$
recognition cumulative Poisson distribution **(M1)**
$\text{P}(X \geq 2) = 1 - \text{P}(X \leq 1)$
$= 0.177\ (0.176907...)$ **A1**

(ii) let F be number of accidents per 4-week $\Rightarrow F \sim \text{Po}(3.04)$ **(M1)**
$\text{P}(Y = 3) = 0.224\ (0.223982...)$ **A1**

[4 marks]

(b) binomial model **A1**
with $p = 0.177$ **OR** $p = 1 - 0.177\ (= 0.823)$ and $n = 8$ **A1**

[2 marks]
[Total: 6 marks]

Question 49

(a) recognizing that only way to score 7 is to achieve a head and a 6 on die **(M1)**

e.g. $\frac{1}{6}$ and $\frac{1}{2}$ seen in an attempt to combine probabilities

$\left(\frac{1}{6}\times\frac{1}{2}=\right)\ \frac{1}{12}\ (0.0833333...)$ **A1**

Note: Condone 0.0835 from the use of 0.167.

[2 marks]

(b) there are two ways to score (e.g.) 5

achieve a head and a 4 on die, or a tail and a 5 on die **(M1)**

$\left(2\left(\frac{1}{6}\times\frac{1}{2}\right)=\right)\ \frac{2}{12}\quad\left(\frac{1}{6}, 0.167, 0.16666...\right)$ **A1**

Note: Award these marks for equivalent working for the 2, 3, 4 or 6 point scenarios.

Final Score	1	2	3	4	5	6	7
Probability	$\frac{1}{12}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{12}$

A1

Note: Award ***A1*** for a completely correct table. Award at most ***(M1)A1A0*** if their follow-through answer from part (a) leads to a total probability not equal to 1.

[3 marks]

(c) **EITHER**

multiplying at least two columns from their table **(M1)**

$1\times\frac{1}{12}+2\times\frac{1}{6}+...+6\times\frac{1}{6}+7\times\frac{1}{12}$

OR

recognizing the probabilities in the table are symmetric **(M1)**

OR *(for HL markscheme and/or removed from SL at publication)*

Considering the sum of two random variables **(M1)**

$\mathrm{E}(X+Y)=\mathrm{E}(X)+\mathrm{E}(Y)\ \ (=3.5+0.5)$

THEN

(expected value $=$) 4 **A1**

Note: Accept 4.01 $(4.00640\ldots)$ from use of their 3 sf values from (b).
Award at most ***M1A0*** if their final answer is not in the range 1 – 7

[2 marks]

[Total: 7 marks]

Question 50

(a) (i) recognition of binomial distribution (condone incorrect parameter) ***(M1)***
e.g. $M \sim \mathrm{B}(20, 0.04)$ **OR** $\mathrm{P}(M = 2) = \mathrm{binpdf}(20, 0.04, 2)$
$= 0.146 \ (0.145799...)$ ***A1***

(ii) recognition the cumulative probability required ***(M1)***
e.g. $\mathrm{P}(M \geq 3) = 1 - \mathrm{bincdf}(20, 0.04, 2)$ **OR** $\mathrm{bincdf}(20, 0.04, 3, 20)$
$= 0.0439 \ (0.0438627...)$ ***A1***

[4 marks]

(b) either one of two terms in expected value formula correct ***(M1)***
$50(20(0.96)) + 15(20(0.04))$
= 972 (pesos) ***A1***

[2 marks]
[Total: 6 marks]

Question 51

(a) $40 = 100 - 100 \times 2^{-t}$ ***(A1)***
0.737 (hours) $(0.736965\ldots)$ ***A1***

Note: Accept 44.2 minutes.

[2 marks]

(b) values of P are $50, 75, 87.5, 93.75$ ***(A1)***

$SS_{res} = (50 - 48)^2 + (75 - 74)^2 + (87.5 - 86)^2 + (93.75 - 91)^2$ ***(M1)(A1)***

$= 14.8 \ (14.8125)$ ***A1***

[4 marks]

(c) (i) The sum of the square residuals is smaller so it is a better fit ***R1***

(ii) *Accept a valid argument in favour of model P or against the quadratic model.* ***R1***

e.g. any one of the following:
quadratic has no asymptote
quadratic will begin to go down
quadratic will become negative
quadratic might not go through $(0, 0)$
model P is the manufacturer's model

[2 marks]
[Total 8 marks]

Question 52

(a) (i) attempt to rearrange to isolate C ***(M1)***
e.g., subtracting 32 or dividing the equation by 1.8

$C = \frac{5}{9}(F-32)$ $\left(C = \frac{F-32}{1.8},\ C = 0.556F - 17.8\right)$ ***A1***

Note: If the answer is not written as an equation, award at most ***M1A0***.

(ii) $C = \left(\frac{77-32}{1.8} =\right)\ 25\ (^{\circ}\text{C})$ ***A1***

[3 marks]

(b) (i) $(1.8\times 17 + 32 =)\ 62.6\ (^{\circ}\text{F})$ ***A1***

(ii) recognizing that the "+32" does not affect the SD ***(M1)***
$(1.8\times 9 =)\ 16.2\ (^{\circ}\text{F})$ ***A1***

Note: Award ***M0A0*** for $1.8\times 9 + 32\ (= 48.2)$.

[3 marks]
[Total 6 marks]

Question 53

(a) (i) $r = 0.995\ (0.994705\ldots)$ ***A2***

Note: Award ***A1*** for 0.99.

(ii) $m = 10.6t + 43.9\ (10.6032...t + 43.8780...)$ ***A1A1***

Note: Second ***A1*** is for the correct variables.

[4 marks]

(b) **EITHER**
$10.6032...\times 1.5$ ***(M1)***
OR
$(10.6032...(t+1.5) + 43.8780...) - (10.6032...(t) + 43.8780...)$ ***(M1)***
THEN
15.9 (marks) $(15.9048\ldots)$ ***A1***

Note: Accept 16.

[2 marks]

(c) *Accept any valid reason* ***R1***
e.g:
The students in the sample might not be of equal ability / she has not controlled for ability

She might have originally obtained close to full marks so an extra 15.9 would not be possible.

[1 mark]
[Total: 7 marks]

Question 54

(a) normal distribution **A1**
Mean = 15 (cm) **A1**
Standard deviation = 0.4 (cm) **OR** variance = 0.16 (cm^2) **A1**
[3 marks]

(b) $E(W) = 3$ ***(A1)***
$Var(W) = 0.4^2 + 0.25^2$ ***(A1)***
$= 0.223 \ (0.2225)$ ***(A1)***
W is normally distributed ***(M1)***
$(P(W < 2.5) =) \ 0.145 \ (0.144572\ldots)$ ***A1***

Note: Accept $P(0 < W < 2.5)$.

[5 marks]
[Total 8 marks]

Question 55

(a) recognizing need to find $P(W > 3.5)$ **OR** $1 - P(W < 3.5)$ ***(M1)***

$(P(W > 3.5) =) \ 0.994 \ (0.993790\ldots)$ ***A1***

Note: Award ***M1A0*** for an answer of 0.99 with no working.

[2 marks]

(b) (i) appropriate use of the GDC to find either a or b seen in either (b)(i) or (b)(ii) ***(M1)***
$a = 3.99 \ (3.98737\ldots)$ ***A1***

(ii) $b = 5.01 \ (5.01262\ldots)$ ***A1***

Note: The working for ***(M1)*** may be seen and awarded in part (b)(ii) if part (b)(i) has not been answered.

[3 marks]

(c) multiplying two identical probabilities ***(M1)***
$P(W < 3.5) \times P(W < 3.5)$ **OR** $(1 - \text{their (a)}) \times (1 - \text{their (a)})$

Note: Accept a lower bound of zero for W, given the context.

$(0.00620967)^2$
$0.0000386 \ (0.0000385601\ldots$ **OR** $3.86 \times 10^{-5})$ ***A1***

Note: Award ***M0A0*** for an answer greater than 1 such as 3.86.
Award ***M1A0*** for 3.86E-5.

[2 marks]
[Total: 7 marks]