NANYANG JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION

Higher 1

MATHEMATICS **8865/01**

Paper 1 **10 September 2018**

3 hours

Additional Materials: Cover Page
Answer Paper
List of Formulae (MF26)

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagram or graph.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** the questions.
Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.
You are expected to use a graphic calculator.
Unsupported answers from a graphic calculator are allowed unless a question specifically states otherwise.
Where unsupported answers from a graphic calculator are not allowed in a question, you are required to present the mathematical steps using mathematical notations and not calculator commands.
You are reminded of the need for clear presentation in your answers.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **7** printed pages.

Section A: Pure Mathematics [40 marks]

1 David went to a seafood restaurant on three different days to eat lobster, fish and crab. He observed that the price per kilogram of lobster and fish remained constant for all his three visits and the price per kilogram of crab was the same for his first two visits but increased by 20% on his third visit. In addition, the restaurant gave a fifty dollars discount for any bill exceeding $400. The mass of lobster, fish and crab that he ordered as well as the bill before discount for each visit are shown in the table below.

	First visit	Second visit	Third visit
Lobster (kg)	3.20	4.50	5.60
Fish (kg)	1.50	1.20	2.00
Crab (kg)	6.00	5.20	4.80
Bill before discount ($)	289.39	309.43	422.76

Find the price per kilogram of lobster, fish and crab during his first visit to the restaurant. [4]

2 The volume of a solid sphere is decreasing at a constant rate of $2\,\text{cm}^3\ \text{s}^{-1}$. Find the rate of change of its total surface area when its radius is 2 cm. [4]

[It is given that the surface area of a sphere is $4\pi r^2$ and the volume of a sphere is $\frac{4}{3}\pi r^3$, where r is the radius of the sphere.]

3 **(a)** Differentiate $\dfrac{\left(\mathrm{e}-\mathrm{e}^{-x}\right)^2}{\mathrm{e}^x}$ with respect to *x*. [3]

(b) Find $\displaystyle\int \frac{2}{\sqrt{5x-2}}\,\mathrm{d}x$, simplifying your answer. [2]

4 The curve *C* has equation $y=\mathrm{e}^{-2x+3}$.

(i) Sketch the graph of *C*, stating the exact coordinates of any points of intersection with the axes and the equations of any asymptotes. [2]

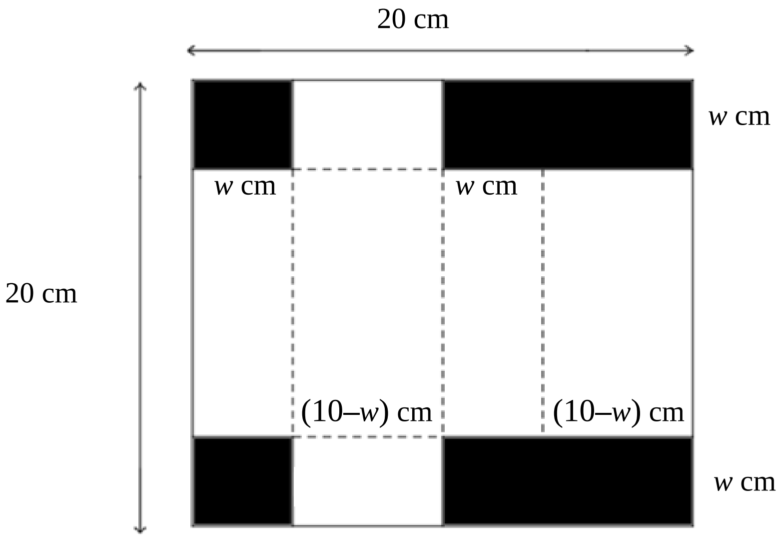
(ii) Find the equation of the tangent to *C* at the point $x=1$, giving your answer in the form $y=mx+c$, where *m* and *c* are exact constants to be determined. [3]

(iii) This tangent meets the *x*-axis at $x=p$. Find the exact area of the region bounded by *C*, the tangent, the line $x=2$ and the *x*-axis. [4]

(iv) Find the range of values of *k* for which *C* and $y=\dfrac{1}{k}\mathrm{e}^{-x+3}-\mathrm{e}^3$ do not intersect. [4]

Question 5 is printed on the next page

5



A cardboard, with negligible thickness, is in the shape of a square with side 20 cm. The shaded portions are to be cut off the cardboard and the remaining cardboard will be folded into a box with a top as shown in the diagram above. The volume of the box is V cm^3.

(i) Show that $V = 2w^3 - 40w^2 + 200w$. [2]

(ii) Given that w can vary, using differentiation, find the exact length of w when the volume of the box is a maximum. [5]

A company manufactures the box for sandwiches and sells x (in thousands) of them per month. The monthly revenue $\$R$ is given by the equation $R = 10x - \dfrac{x^2}{10}$.

(iii) Sketch the graph of R against x, stating the coordinates of the intersections with the axes. [2]

(iv) State the maximum monthly revenue of the company and the number of sandwich boxes they must sell to achieve it. [2]

In addition, the monthly cost $\$C$ in producing x sandwich boxes (in thousands) is given by the equation $C = 50 + 2x$.

(v) Denoting the monthly profit receives by the company monthly be P, find an equation relating P and x. [1]

(vi) Justify whether maximum revenue and profit can be achieved at the same time by producing the same number of sandwich boxes. [2]

[Turn over

Section B: Statistics [60 marks]

6 Find the number of different arrangements of the eleven letters in the word 'PERSONALITY' if the arrangements are such that

(i) P, E and R are together, [2]

(ii) S, O and N are separated, [2]

(iii) P, E and R are together or S, O and N are separated. [3]

7 A manufacturer produces balloons of which 40% are oval and 60% are round. 20 balloons are randomly selected and packed into a packet.

(i) In a randomly selected packet of balloons, find the probability that

(a) 14 of them are round, [1]

(b) at least half of them are round. [2]

(ii) 6 packets of balloons are randomly selected. Find the probability that less than 4 of them have at least half of the balloons that are round. [2]

(iii) Instead of packing 20 balloons into one packet, the manufacturer decides to pack 80 balloons into one packet. 60 packets of balloons are randomly selected. Find the probability that on average, at most 49 balloons are round. [3]

Question 8 is printed on the next page

[Turn over

8 A recent study done on the graduates from *SSS* University aims to explore the relationship between their final grade point average (GPA) and their starting salaries. The starting salaries, y thousand dollars, of a random sample of 8 graduates from the university with GPA x are given in the following table.

x	3.2	4.8	2.3	3.6	1.8	4.5	2.7	3.4
y	4.1	5.2	3.5	4.3	3.2	5.8	3.4	4.7

(i) Give a sketch of the scatter diagram of the data. [2]

(ii) Find the product moment correlation coefficient and comment on its value in the context of the data. [2]

(iii) Find the equation of the regression line of y on x in the form $y = ax + b$. Sketch this line on your scatter diagram. [2]

(iv) Use the equation of your regression line to calculate an estimate of the starting salary for a graduate who have a GPA of 4.2. State two reasons why you would expect this to be a reliable estimate. [3]

9 A bag contains 3 red balls and 7 blue balls. Whenever a red ball is drawn, it will be replaced in the bag and whenever a blue ball is drawn, it is not replaced. 3 balls are drawn one after another. Construct a probability tree showing this information. [2]

Find the probability that

(i) all the balls are blue, [1]

(ii) at least one of the balls is blue, [2]

(iii) exactly two of the balls are blue. [2]

Given that exactly 2 of the 3 balls drawn are blue, find

(iv) the probability that the first ball drawn is blue. [3]

10 The mean mass of cereal in a packet is printed as 475 grams on its packaging. The manager suspects that the mean mass may not be 475 grams. He took 30 randomly chosen packets and measured their mass and the data is summarized as follows.

$$\sum x = 14\,127, \qquad \sum x^2 = 6\,655\,913$$

(i) Find the unbiased estimates of the population mean and variance. [2]

(ii) Test at the 5% significance level whether the manager's suspicion is correct. [5]

(iii) State, with a reason, whether it is necessary to assume the mass of cereal in a packet has a normal distribution. [1]

(iv) The manager now wants to change the mean mass printed on the packaging to *m* grams. Based on the sample above and using 5% significant level, find the maximum mean mass in grams (to the nearest whole number) that should be printed so that it will not overstate the actual mass of the cereal. [6]

11 Every morning, a student needs to reach the bus stop at 7:30am to catch a bus to school. If he reaches school after 8:00am, he will be considered late. Assume that the waiting times for a bus is normally distributed with mean 8 minutes and variance 5 minutes^2, and the duration of the bus journey is normally distributed with mean 20 minutes and variance 4 minutes^2.

(i) On a randomly chosen day, find the probability that he will be late for school. [3]

(ii) In 20 days, what is the expected number of days he will be late for school? [1]

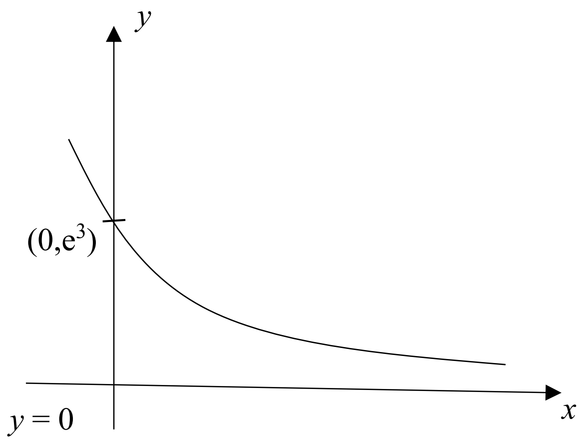
(iii) In order to reduce the probability of him being late for school, he has to reach the bus stop earlier than 7:30am. Find the latest time he needs to reach the bus stop for this probability to be less than 0.01. [3]

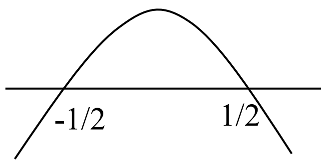
(iv) Find the probability that the mean time taken to travel from the bus stop (including waiting for the bus) to school in 40 days is between 28 and 29 minutes. [2]

(v) Bus fare is charged at \$0.085 per minute. Find the probability he has to pay more than \$8.60 for 5 days. [3]

Solutions

1	Let x, y and z be the price per kilogram of the lobsters, fish and crabs respectively during his first visit. $3.20x+1.50y+6.00z=289.39$ $4.50x+1.20y+5.20z=309.43$ $5.60x+2.00y+4.80(1.2z)=422.76-50$ Using GC, $x=34.70, y=12.90, z=26.50$	B1: define x, y, z M1: 2 out of 3 equations correct M2: all equations correct A1
2	Let V, A, r be the volume, total surface area, radius of the hemisphere respectively. Given that $\frac{\mathrm{d}V}{\mathrm{d}t}=-2$, find $\frac{\mathrm{d}A}{\mathrm{d}t}$ when $r = 2$. $V=\frac{4}{3}\pi r^3 \quad \Rightarrow \quad \frac{\mathrm{d}V}{\mathrm{d}r}=4\pi r^2$ Since, $\frac{\mathrm{d}V}{\mathrm{d}t}=\frac{\mathrm{d}V}{\mathrm{d}r}\frac{\mathrm{d}r}{\mathrm{d}t}$ $-2=4\pi(2)^2\frac{\mathrm{d}r}{\mathrm{d}t}$ $\frac{\mathrm{d}r}{\mathrm{d}t}=-\frac{1}{8\pi}$ To find $\frac{\mathrm{d}A}{\mathrm{d}t}$: $A=4\pi r^2$ $\frac{\mathrm{d}A}{\mathrm{d}r}=8\pi r$ From $\frac{\mathrm{d}A}{\mathrm{d}t}=\frac{\mathrm{d}A}{\mathrm{d}r}\frac{\mathrm{d}r}{\mathrm{d}t}$ $\frac{\mathrm{d}A}{\mathrm{d}t}=8\pi(2)\left(-\frac{1}{8\pi}\right)=-2 \quad \text{cm}^2\text{s}^{-1}$ Hence, the surface area is decreasing at the rate of 2 cm^{2}s^{-1} when $r = 2$ cm.	M1: for $\frac{\mathrm{d}V}{\mathrm{d}r}=4\pi r^2$ M1: for $\frac{\mathrm{d}r}{\mathrm{d}t}=-\frac{1}{8\pi}$ M1: for $\frac{\mathrm{d}A}{\mathrm{d}r}=8\pi r$ A1: for correct answer $\frac{\mathrm{d}A}{\mathrm{d}t}=-2$
3	(a) $\frac{\mathrm{d}}{\mathrm{d}x}\frac{\left(\mathrm{e}-\mathrm{e}^{-x}\right)^2}{\mathrm{e}^x}$ $=\frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{e}^2-2\mathrm{e}^{1-x}+\mathrm{e}^{-2x}}{\mathrm{e}^x}$	M1: expanding M1: dividing

	$= \frac{\mathrm{d}}{\mathrm{d}x}(\mathrm{e}^{2-x} - 2\mathrm{e}^{1-2x} + \mathrm{e}^{-3x})$ $= -\mathrm{e}^{2-x} + 4\mathrm{e}^{1-2x} - 3\mathrm{e}^{-3x}$	correctly A1
	(b) $\int \frac{2}{\sqrt{5x-2}}\,\mathrm{d}x$ $= 2\int (5x-2)^{-\frac{1}{2}}\,\mathrm{d}x$ $= 2\frac{(5x-2)^{\frac{1}{2}}}{\frac{1}{2}(5)} + \mathrm{C}$ $= \frac{4}{5}\sqrt{5x-2} + \mathrm{C}$	M1: for integrating correctly A1
4	(a)(i)  	B1: shape of the graph (must cut the y axis) B1: equation of the asymptote and coordinates of y-intercept.
	(ii) $y = \mathrm{e}^{-2x+3}$ $\frac{\mathrm{d}y}{\mathrm{d}x} = -2\mathrm{e}^{-2x+3}$ When $x = 1$, $y = \mathrm{e}$ $\frac{\mathrm{d}y}{\mathrm{d}x} = -2\mathrm{e}$ $y - \mathrm{e} = -2\mathrm{e}(x-1)$ $y = \mathrm{e} - 2\mathrm{e}(x-1)$ $= -2\mathrm{e}x + 3\mathrm{e}$	M1: differentiate M1: correct values of y and $\frac{\mathrm{d}y}{\mathrm{d}x}$ A1
	(iii) $y = -2\mathrm{e}x + 3\mathrm{e}$ When $y = 0$, $x = p$	M1: $p = \frac{3}{2}$

	$2\mathrm{e}p=3\mathrm{e}$ $p=\frac{3}{2}$ $\int_1^2 \mathrm{e}^{-2x+3}dx-\frac{1}{2}\left(\frac{3}{2}-1\right)(-2\mathrm{e}+3\mathrm{e})$ $=\left[\frac{\mathrm{e}^{-2x+3}}{-2}\right]_1^2-\frac{1}{2}\left(\frac{1}{2}\right)(\mathrm{e})$ $=-\frac{\mathrm{e}^{-1}}{2}+\frac{\mathrm{e}}{2}-\frac{\mathrm{e}}{4}$ $=-\frac{1}{2\mathrm{e}}+\frac{\mathrm{e}}{4}$	M1: integration and find the area of triangle M1: substituting the correct limits A1
	(b) For the 2 curve to intersect $\mathrm{e}^{-2x+3}=\frac{1}{k}\mathrm{e}^{-x+3}-\mathrm{e}^3$ $k\mathrm{e}^{-2x}\mathrm{e}^3=\mathrm{e}^{-x}\mathrm{e}^3-k\mathrm{e}^3$ $k\mathrm{e}^{-2x}=\mathrm{e}^{-x}-k$ Let $y=\mathrm{e}^{-x}$ $ky^2-y+k=0$ For y to have no solution so that they don't intersect $1-4(k)(k)<0$ $(1-2k)(1+2k)<0$ $k<-\frac{1}{2}$ *or* $k>\frac{1}{2}$  	M1: equate and simplify them M1: form equation M1: Discriminant < 0 A1: for both
5	(i) $V=(20-2w)(10-w)w$ $=2(10-w)^2 w$ $=2(100-20w+w^2)w$ $=200w-40w^2+2w^3$	M1: length x breadth M1: algebraic manipulation AG
	(ii)	M1: correct differentiation M1: find the 2 w values.

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$\frac{dV}{dw} = 6w^2 - 80w + 200$

$\frac{dV}{dw} = 0$

$6w^2 - 80w + 200 = 0$

$3w^2 - 40w + 100 = 0$

$(3w-10)(w-10) = 0$

$w = \frac{10}{3}$ or $w = 10$

When $w = \frac{10}{3}$,

<table>
<tr><td>w</td><td>$\left(\frac{10}{3}\right)^-$</td><td>$\frac{10}{3}$</td><td>$\left(\frac{10}{3}\right)^+$</td></tr>
<tr><td>Gradient</td><td>+ve</td><td>0</td><td>-ve</td></tr>
</table>

Hence, when $w = \frac{10}{3}$, it will give a maximum volume.

When $w = 10$,

<table>
<tr><td>w</td><td>$(10)^-$</td><td>10</td><td>$(10)^+$</td></tr>
<tr><td>Gradient</td><td>-ve</td><td>0</td><td>+ve</td></tr>
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Hence, when $w = 10$, it will give a minimum volume.

Therefore, $w = \frac{10}{3}$.

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B1: testing for one of the w values with correct conclusion.

B1: testing of the other w value.

A1

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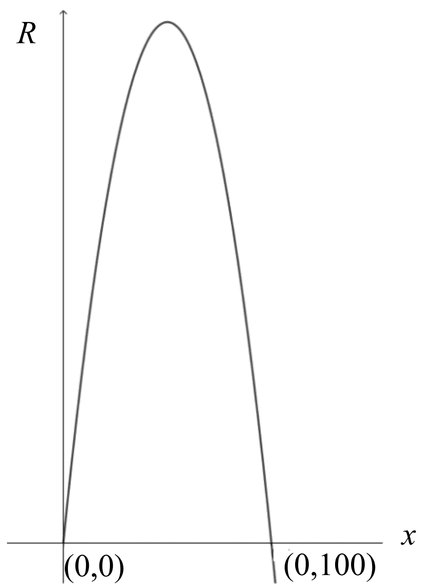
(iii)



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B1: shape only 1st and 4th Quadrant

B1: two x-intercepts coordinates. (in first quadrant)

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(iv)
number of sandwich boxes = 50 000
maximum revenue = $250

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B1
B1

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<td>(v)</td>
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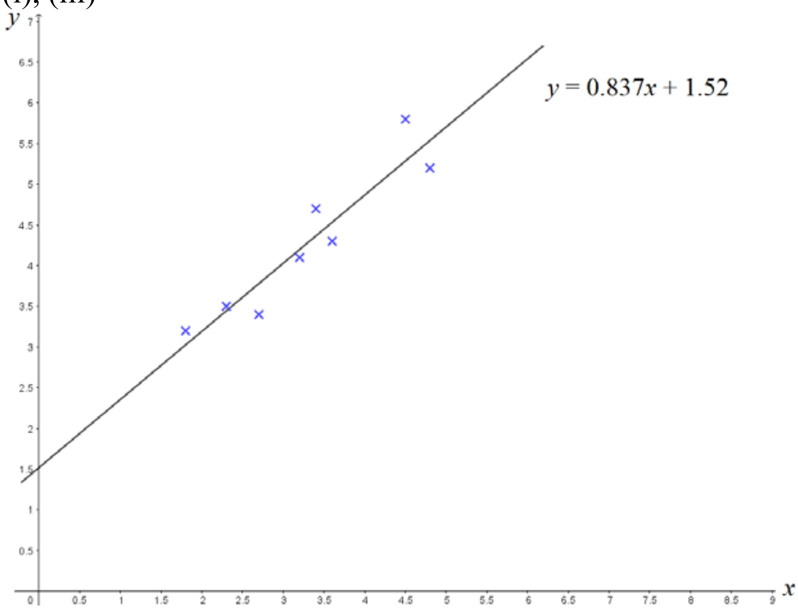
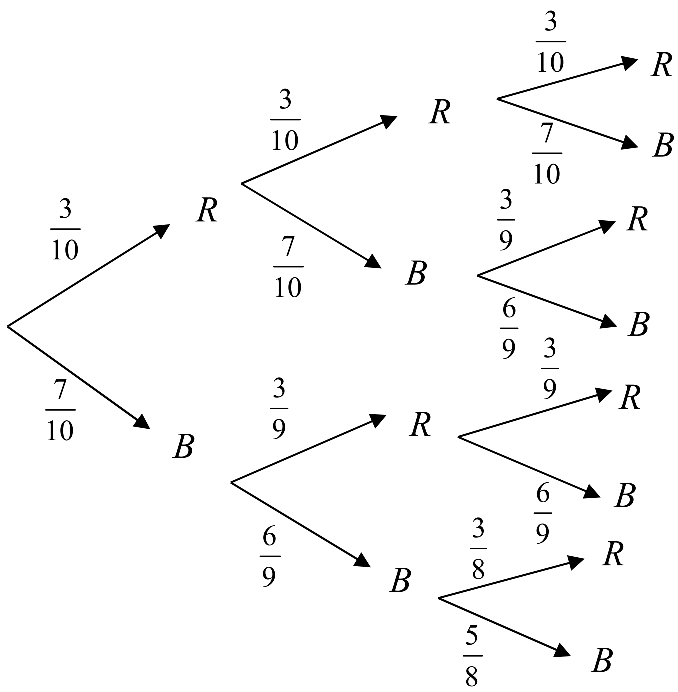
[Turn over

	$P=10x-\frac{x^2}{10}-(50+2x)$ $=8x-\frac{x^2}{10}-50$	B1
	(vi) $P=8x-\frac{x^2}{10}-50$ $\frac{\mathrm{d}P}{\mathrm{d}x}=8-\frac{x}{5}$ For maximum profit, $\frac{\mathrm{d}P}{\mathrm{d}x}=0$ $8-\frac{x}{5}=0$ $x=40$ Maximum profit happens when the company has to produce 40 000 boxes. Since the company has to produce 50 000 sandwich boxes to attain maximum revenue and produce 40 000 sandwich boxes to attain maximum profit, the level of production is not the same to produce maximum revenue and maximum profit.	B1 B1 (for explaining the not the same)
6	(i) No. of ways = 3! 9! = 2 177 280 (ii) No. of ways = 8! ${}^9C_3$ 3! = 20 321 280 (iii) No. of ways where P, E and R are together and S, O and N are separated = 3! 6! ${}^7C_3$ 3! = 907 200 $\therefore$ No. of ways P, E and R are together or S, O and N are separated = No. of ways P, E and R are together + No of ways S, O and N are separated – No. of ways where P, E and R are together and S, O and N are separated = 2 177 280 + 20 321 280 – 907 200 = 2 1591 360	M1 A1 M1 A1 M1 M1 A1
7	(i)(a) Let X be the random variable denoting the number of balloons out of 20 that are round. $X \sim \mathrm{B}(20, 0.6)$ $\mathrm{P}(X=14)=0.12441=0.124$	B1
	(i)(b) $\mathrm{P}(X \geq 10)$ $=1-\mathrm{P}(X \leq 9)$ $=0.87249$ $=0.872$	M1 A1
	(ii) Let Y be the random variable denoting the number of packets out of 6 with at	

	least half of the balloons round. $Y \sim \mathrm{B}(6, 0.87249)$ $\mathrm{P}(Y < 4)$ $= \mathrm{P}(Y \le 3)$ $= 0.030738$ $= 0.0307$	M1 A1
	(iii) Let W be the random variable denoting the number of balloons (in a packet) out of 80 that are round. $W \sim \mathrm{B}(80, 0.6)$ $\overline{W} = \dfrac{W_1 + W_2 + \ldots + W_{60}}{60}$ Since n = 60 is large, by Central Limit Theorem, $\overline{W} \sim \mathrm{N}(80(0.6), \dfrac{80(0.6)(0.4)}{60})$ approximately. $\mathrm{P}(\overline{W} \le 49)$ $= 0.96145$ $= 0.961$	B1: CLT M1: correct expectation and variance A1
8	(i), (iii) 	(i) B1: axes and appropriate scale B1: correct data points (iii) B1: regression line y on x
	(ii) $r = 0.936$ As the GPA increases, the starting salary increases in a strong linear correlation	B1: correct r value B1: comment on r value
	(iii) $y = 0.837x + 1.52$	B1: correct equation
	(iv) $y = 0.837(4.2) + 1.52 = 5.0354$ Starting salary = \$5035.40	B1: correct answer B1

[Turn over

	The r value of 0.936 is close to 1. $x = 4.2$ is within the data range.	B1
9	Let R denote the event "a red ball is drawn" and B denote the event "a blue ball is drawn".	A2: for all correct A1: for 1 mistake A0: for more than 1 mistake



	(i) P(all the balls are blue) = $\frac{7}{10} \times \frac{6}{9} \times \frac{5}{8} = \frac{7}{24}$ or 0.291 (to 3 sig fig)	B1
	(ii) P(at least one of the balls is blue) = 1 – P(all balls are red) $= 1 - \frac{3}{10} \times \frac{3}{10} \times \frac{3}{10}$ $= \frac{973}{1000}$ or 0.973	 M1 A1
	(iii)	

	P(exactly two of the balls are blue) = P(RBB) + P(BRB) + P(BBR) $=\left(\frac{3}{10}\times\frac{7}{10}\times\frac{6}{9}\right)+\left(\frac{7}{10}\times\frac{3}{9}\times\frac{6}{9}\right)+\left(\frac{7}{10}\times\frac{6}{9}\times\frac{3}{8}\right)$ $=\frac{847}{1800}$ or 0.471 (to 3 sig fig)	M1 A1
	(iv) P(the first ball drawn is blue | exactly 2 of the 3 balls drawn are blue) $=\frac{\text{P(the first ball drawn is blue AND exactly 2 of the 3 balls drawn are blue)}}{\text{P(exactly 2 of the 3 balls drawn are blue)}}$ $=\frac{\text{P(BRB)+P(BBR)}}{\text{P(exactly 2 of the 3 balls drawn are blue)}}$ $=\frac{\left(\frac{7}{10}\times\frac{3}{9}\times\frac{6}{9}\right)+\left(\frac{7}{10}\times\frac{6}{9}\times\frac{3}{8}\right)}{\frac{847}{1800}}$ $=\frac{85}{121}$ or 0.702	M1: numerator M1:denominator A1
10	(i) $n = 30$, $\overline{x}=\frac{\sum x}{n}=\frac{14127}{30}=470.9=471$ (to 3 sig. fig) $s^2=\frac{1}{n-1}\left(\sum x^2-\frac{\left(\sum x\right)^2}{n}\right)=\frac{1}{29}\left(6655913-\frac{(14127)^2}{30}\right)=120.99=121$ (to 3 sig fig)	B1 B1
	(b)	

	Let μ denote the population mean mass of packets of cereals H_0: $\mu = 475$ H_1: $\mu \neq 475$ Under H_0, $\bar{X} \sim \mathrm{N}\left(475, \frac{120.99}{30}\right)$ by Central Limit Theorem. $Z = \frac{\bar{X} - 475}{\sqrt{\frac{120.99}{30}}} \sim \mathrm{N}(0,1)$ At 5% significant level, reject H_0 if p-value ≤ 0.05 Using GC, p-value $= 0.041192 \leq 0.05$ Reject H_0 and conclude that 5% significance level, there is sufficient evidence to suggest that the manager's suspicion is correct, i.e. a packet of cereal may not be 475 grams.	M1:Test & Definition M1: For Correct values M1: rejection level A1: for p value M1:Conclusion
	(c) It is not necessary to assume that the weight of packets of cereals have a normal distribution because the sample size is large, the distribution of the sample mean is approximately normal by the Central Limit Theorem.	B1
	(d) H_0: $\mu = m$ H_1: $\mu < m$ Under H_0, $\bar{X} \sim \mathrm{N}\left(m, \frac{120.99}{30}\right)$ by Central Limit Theorem. $Z = \frac{\bar{X} - m}{\sqrt{\frac{120.99}{30}}} \sim \mathrm{N}(0,1)$ At 1% significant level, reject H_0 if p-value ≤ 0.05 Since we do not want to reject H_0 $P(\bar{X} \leq 470.9) \geq 0.05$ $P(Z \leq \frac{470.9 - m}{\sqrt{\frac{120.99}{30}}}) \geq 0.05$ $\frac{470.9 - m}{\sqrt{\frac{120.99}{30}}} \geq -1.64485$	M1: Test M1: Statement M1:Correct p formula M1: standardizing A1: Correct InvNorm

	$m \le 474.2$ The packaging should indicate 474 grams.	A1
11	(i) Let W and J denote the average waiting time and journey time $W \sim N(8,5)$ $J \sim N(20,4)$ Let T denote the sum of the waiting and journey time $T \sim N(28,9)$ $P(T > 30) = 0.25249 = 0.252$ (to 3 sig fig)	B1 M1, A1
	(ii) Expected number of days late $= 20 \times 0.25249 = 5.05$ (to 3 sig fig)	A1
	(iii) Let t be the time that is exceeded by less than 1% of his waiting and journey time $P(T > t) < 0.01$ $P(T < t) > 0.99$ $t > 34.98$ To nearest minutes $t = 35$ minutes So the latest time he can be at the bus stop is 7:25am if he is to have less than 1% chance of being late.	M1 A1 A1: 7:25am
	(iv) Let $\overline{T}$ be the mean traveling time for 40 days $\overline{T} \sim N(28, \frac{9}{40})$ $P(28 < \overline{T} < 29) = 0.48249 = 0.482$ (to 3 sig fig)	B1 A1
	(v) Let F denote the bus fare per day so $F = 0.085J$ $F \sim N(0.085 \times 20, 0.085^2 \times 4)$ $F \sim N(1.7, 0.0289)$ For 5 days $F_1 + ... + F_5 \sim N(8.5, 0.1445)$ $P(F_1 + ... + F_5 > 8.6) = 0.39625 = 0.396$ (to 3 sig fig)	M1 M1 A1