A-LEVEL MATHS (EDEXCEL 9MA0) · STATISTICS YEAR 2 · CHAPTER 3: THE NORMAL DISTRIBUTION · A* EXAM PRACTICE

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The normal distribution: A* questions

80 marks

Date

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X A* exam questions

A to A*

Extended Edexcel-style questions. Show every step. The hints are at the end of the sheet. Use one at a time.

X1 The masses, in grams, of a type of pear are normally distributed. The curve of the distribution has its points of inflection at 142 g and 166 g. A pear is small if its mass is under 140 g. A shop packs pears at random into boxes of n. Find the least value of n for which the probability that a box holds at least one small pear is more than 0.9. [9 marks]

Answer .....

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X2 $X \sim \mathrm{N}(\mu, \sigma^2)$. $\mathrm{P}(X > \mu + 5) = 0.2$ and $\mathrm{P}(X < 40 \mid X < \mu) = 0.3$.

(a) Find σ. [3 marks]

Answer .....

(b) Find μ. [4 marks]

Answer .....

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(c) Three independent observations of X are all less than μ. Find the probability that exactly one of them is less than 40. [3 marks]

Answer .....

Total for X2: 10 marks

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X3 $X \sim \mathrm{B}(200, p)$. A normal approximation, with a continuity correction, gives $\mathrm{P}(X \geqslant 73) = 0.02688$. Find p, to 2 decimal places. Show clearly why you reject any other value. [9 marks]

Answer .....

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X4 The lengths, in mm, of bolts are normally distributed with standard deviation 4. A test of $\mathrm{H}_0 : \mu = 50$ against $\mathrm{H}_1 : \mu > 50$ at the 5% level uses the mean of a random sample of n bolts. In fact the mean length has risen to 51 mm. Find the least n for which the probability that the test rejects H_0 is at least 0.9. [10 marks]

Answer .....

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X5 A machine fills bags of flour. The masses, x grams, are normally distributed and the machine is set to a mean of 500 g with standard deviation 6 g. A quality controller weighs a random sample of 40 bags and records $y = x - 500$ for each. She finds $\sum y = -62$ and $\sum y^2 = 1500$.

(a) Find the mean mass of the sample. [2 marks]

Answer .....

(b) Test, at the 5% level, whether the mean mass is different from 500 g. Assume the standard deviation is 6 g. [6 marks]

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(c) Find the p-value of the test in (b). [2 marks]

Answer .....

(d) Use the sample to check whether a standard deviation of 6 g is reasonable. [2 marks]

Total for X5: 12 marks

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X6 A council thinks 40% of residents support a new cycle lane. A campaign group believes support is higher. They ask a random sample of n residents, where n is even, and will test $\mathrm{H}_0 : p = 0.4$ against $\mathrm{H}_1 : p > 0.4$ at the 5% level, using a normal approximation.

(a) Show that, if exactly half of the sample support the lane, H_0 is rejected when $0.1n - 0.5 > 1.6449\sqrt{0.24n}$. [3 marks]

Answer .....

(b) Hence find the least even value of n for which half of the sample in support would lead to H_0 being rejected. [4 marks]

Answer .....

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(c) For $n = 76$ and 38 in support, find the exact probability $\mathrm{P}(X \geqslant 38)$ and say whether the exact test gives the same conclusion. [3 marks]

Total for X6: 10 marks

X7 The waiting times, t minutes, of 80 patients at a clinic are recorded. $\sum t = 1040$ and $\sum t^2 = 18\,500$. The shortest wait is 1 minute and the longest is 41 minutes. A manager models the waiting time by $T \sim \mathrm{N}(\mu, \sigma^2)$, using the mean and standard deviation of the sample.

(a) Find μ and σ. [3 marks]

Answer .....

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(b) Find $\mathrm{P}(T < 0)$ and $\mathrm{P}(T > 41)$ under the model. [3 marks]

Answer .....

(c) Use your answers to (b), and the data, to comment on whether the normal model is suitable. [3 marks]

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(d) The clinic wants to state that 90% of patients are seen within k minutes. Find k using the model, and explain why k should be taken from the data instead. [2 marks]

Total for X7: 11 marks

X8 A test of $\mathrm{H}_0 : \mu = 80$ against $\mathrm{H}_1 : \mu \neq 80$ at the 5% level uses the mean $\bar{X}$ of a random sample of n observations from a normal population with standard deviation 9. The critical region is $\bar{X} \leqslant 77.06$ or $\bar{X} \geqslant 82.94$.

(a) Find the standard deviation of $\bar{X}$, and hence find n. [4 marks]

Answer .....

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(b) Find the critical region for the same test at the 1% level. [2 marks]

Answer .....

(c) The sample mean is 83.5. Find the p-value, and state the conclusions at the 5% and the 1% levels, in context of the population mean. [3 marks]

Total for X8: 9 marks

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F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can find μ and σ from the curve, from conditions or from summary statistics, and judge whether a normal model fits.	○	○	○
I can use a normal approximation with a continuity correction, forwards and backwards.	○	○	○
I can test a population mean with coded data, and find its p-value and critical regions at different levels.	○	○	○
I can find the sample size a test needs, using inequalities and logarithms.	○	○	○

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Hints

Use one hint at a time. Cover the ones below it with a sheet of paper.

X1

- **Hint 1** — The points of inflection are one standard deviation either side of the mean.
- **Hint 2** — "At least one" is $1 - \mathrm{P}(\text{none})$, and the pears are independent.
- **Hint 3** — Take logarithms. $\ln$ of a number less than 1 is negative, so the inequality turns.

X2

- **Hint 1** — $\mu + 5$ is 5 above the mean: write its z value in terms of σ.
- **Hint 2** — $\mathrm{P}(X < \mu) = 0.5$, so the condition halves the probability: find $\mathrm{P}(X < 40)$ first.
- **Hint 3** — For (c) the condition is already given, so each observation is less than 40 with probability 0.3: this is binomial with $n = 3$.

X3

- **Hint 1** — Write the approximating distribution in terms of p, and use 72.5 for $X \geqslant 73$.
- **Hint 2** — Standardise, set it equal to the z value for an upper tail of 0.02688, and square to clear the square root.
- **Hint 3** — Squaring adds a root. For a small upper tail, 72.5 must be above the mean $200p$.

X4

- **Hint 1** — First find the critical value c of $\bar{X}$ in terms of n. It is worked out with the mean in H_0.
- **Hint 2** — Then find the probability that $\bar{X} > c$ when the mean is 51. The standard deviation of $\bar{X}$ is still $\frac{4}{\sqrt{n}}$.
- **Hint 3** — The z value with 0.9 above it is -1.2816. The $\frac{4}{\sqrt{n}}$ terms combine to give $\sqrt{n}$ alone.

X5

- **Hint 1** — Undo the coding: the mean of x is 500 plus the mean of y.
- **Hint 2** — "Different" means two tails. The standard deviation of the sample mean is $\frac{6}{\sqrt{40}}$.
- **Hint 3** — For (d), subtracting 500 does not change the standard deviation. Use $\frac{\sum y^2}{n} - \bar{y}^2$.

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X6

Hint 1 Use $\mathrm{N}(np, np(1-p))$ with $p = 0.4$, and the continuity correction for $X \geqslant 0.5n$.

Hint 2 Put $u = \sqrt{n}$ to get a quadratic inequality in u.

Hint 3 n must be even. Check the even numbers either side of your boundary in the original inequality.

X7

Hint 1 Use $\sigma^2 = \frac{\sum t^2}{n} - \bar{t}^2$.

Hint 2 A waiting time cannot be negative. Compare $80 \times \mathrm{P}(T > 41)$ with what was seen.

Hint 3 The mean is 13 but the longest wait is 28 minutes above it and the shortest only 12 below it.

X8

Hint 1 The two ends of the critical region are 1.96 standard deviations of $\bar{X}$ from 80.

Hint 2 The standard deviation of $\bar{X}$ is $\frac{9}{\sqrt{n}}$.

Hint 3 For a two-tailed test, the p-value is twice the tail beyond the observed mean.

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