Cambridge AS & A Level · Mathematics 9709

Mathematics 9709 formulas and definitions: Probability & Statistics 2

All 36 formulas, facts and definitions to learn, by syllabus topic. Formulas the exam gives you are left out.

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6 Probability & Statistics 2

6.1 The Poisson distribution

Conditions: events occur singly, independently, at random, at a constant mean rate

λ is proportional to the length of the interval (rate $\times$ time)

$P(X = 0) = e^{-\lambda}$, $P(X \geqslant 1) = 1 - e^{-\lambda}$

$X \sim Po(\lambda), Y \sim Po(\mu)$ independent $\Rightarrow X + Y \sim Po(\lambda + \mu)$

$B(n, p) \approx Po(np)$ when $n > 50$ and $np < 5$

$Po(\lambda) \approx N(\lambda, \lambda)$ when $\lambda > 15$, with a continuity correction

Standardising: $z = \dfrac{x - \lambda}{\sqrt{\lambda}}$

6.2 Linear combinations of random variables

$E(aX + b) = aE(X) + b$

$\mathrm{Var}(aX + b) = a^2 \mathrm{Var}(X)$

$E(aX + bY) = aE(X) + bE(Y)$

$\mathrm{Var}(aX + bY) = a^2 \mathrm{Var}(X) + b^2 \mathrm{Var}(Y)$, for independent X and Y

$\mathrm{Var}(X - Y) = \mathrm{Var}(X) + \mathrm{Var}(Y)$ for independent X and Y

Total of n independent values: mean $n\mu$, variance $n\sigma^2$; one value times n: mean $n\mu$, variance $n^2\sigma^2$

X normal $\Rightarrow aX + b$ normal; X, Y independent normal $\Rightarrow aX + bY$ normal

$X \sim Po(\lambda), Y \sim Po(\mu)$ independent $\Rightarrow X + Y \sim Po(\lambda + \mu)$

Standardising: $z = \dfrac{x - \mu}{\sigma}$

6.3 Continuous random variables

$P(a < X < b) = \int_a^b f(x)\,dx$

$f(x) \geqslant 0$ for all x, and $\int f(x)\,dx = 1$ over the whole interval

$P(X = a) = 0$, so $<$ and $\leqslant$ give the same probability

Median m: $\int_{\text{start}}^{m} f(x)\,dx = \frac{1}{2}$; lower quartile $\frac{1}{4}$, upper quartile $\frac{3}{4}$

Graph symmetrical about $x = c$: $E(X) = c$ and median $= c$

$P(X > a) = 1 - P(X < a)$

$\int \cos(ax)\,dx = \dfrac{\sin(ax)}{a}$, $\int \sin(ax)\,dx = -\dfrac{\cos(ax)}{a}$

Triangle $\frac{1}{2}bh$, trapezium $\frac{1}{2}(a+b)h$, circle πr^2

6.4 Sampling and estimation

$E(\bar{X}) = \mu$, $\mathrm{Var}(\bar{X}) = \dfrac{\sigma^2}{n}$; exactly normal if X is normal

Coded data: $\bar{x} = a + \dfrac{\Sigma(x-a)}{n}$, and $s^2 = \dfrac{1}{n-1}\left(\Sigma(x-a)^2 - \dfrac{(\Sigma(x-a))^2}{n}\right)$

Confidence interval for μ: $\bar{x} \pm z\dfrac{\sigma}{\sqrt{n}}$ (use s for σ if unknown and n large)

Confidence interval for p: $\hat{p} \pm z\sqrt{\dfrac{\hat{p}(1-\hat{p})}{n}}$, with $\hat{p} = \dfrac{x}{n}$

z for an $\alpha\%$ interval: $\Phi(z) = \frac{1}{2}\left(1 + \frac{\alpha}{100}\right)$; level from z: $\alpha\% = 2\Phi(z) - 1$

Width $= 2 \times z \times$ standard error; centre $=$ the sample mean (or $\hat{p}$)

6.5 Hypothesis tests

Test statistic for a mean: $z = \dfrac{\bar{x} - \mu_0}{\sigma/\sqrt{n}}$

Critical value of $\bar{x}$: $\mu_0 - z\dfrac{\sigma}{\sqrt{n}}$ (lower tail) or $\mu_0 + z\dfrac{\sigma}{\sqrt{n}}$ (upper tail)

Two-tailed test: compare each tail with $\frac{\alpha}{2}$ (e.g. ± 1.96 at 5%)

Normal approximations: $B(n,p) \approx N\big(np, np(1-p)\big)$; $\mathrm{Po}(\lambda) \approx N(\lambda, \lambda)$ for $\lambda > 15$; with a continuity correction

$P(\text{Type I}) = P(\text{reject } H_0 \mid H_0 \text{ true}) := \alpha$ for a normal test, the rejection region's probability for a discrete one

$P(\text{Type II}) = P(\text{do not reject } H_0 \mid \text{the true value})$