8.3 Piecewise densities and the uniform distribution

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

KEY WORDS continuous uniform distribution • variance

Piecewise densities and the uniform distribution

Objective

Normalise piecewise-linear densities by exact algebra (calculator-banned style), compute moments by integration, and use the uniform distribution's facts both directions (objectives 2.2, 2.4, 3.1).

1 Key knowledge and worked examples

Two shapes. A piecewise-linear pdf normalises to (usually) a perfect square in the join point k – factorise it. Uniform on $[a, b]$: density $\frac{1}{b-a}$, mean $\frac{a+b}{2}$, variance $\frac{(b-a)^2}{12}$, $E(X^2) = \text{Var} + \text{mean}^2$; probabilities are lengths over $b - a$; an interval probability gives $b - a$, the mean gives $a + b$.

Worked example – the two shapes (WST02 June 2025 Q5, Q6). (i) $f = \frac{2x}{21}$ on $[0, k]$ then $\frac{2(6-x)}{15}$ on $(k, 6]$: normalising gives $4k^2 - 28k + 49 = 0$, i.e. $(2k - 7)^2 = 0$, so $k = 3.5$; then $E(X) = \frac{19}{6}$ and (with $E(X^2) = \frac{277}{24}$) $\text{Var} = \frac{109}{72}$. (ii) Uniform with $P(2 < X < 5) = \frac{3}{16}$ and mean 6: $b - a = 16$, $a + b = 12 \to a = -2$, $b = 14$; variance $\frac{64}{3}$, $E(X^2) = \frac{172}{3}$, $P(\frac{3}{2}X - b > a) = P(X > 8) = \frac{3}{8}$.

2 Practice

2.1 X is uniform on $[3, 11]$. Write down the mean, the variance and $P(5 < X < 9)$. [3]

2.2 X is uniform on $[a, b]$ with mean 10 and variance $\frac{64}{3}$. Find a and b. [3]

2.3 $f(x) = \frac{x}{c}$ on $[0, 4]$. Find c and $E(X)$. [3]

3 Exam-style questions

3.1 *(Edexcel IAL WST02 June 2025 Q5.)* The continuous random variable X has probability density function $f(x) = \frac{2x}{21}$ for $0 \le x \le k$ and $f(x) = \frac{2(6-x)}{15}$ for $k < x \le 6$ (0 otherwise), where k is a positive constant. Given that $E(X^2) = \frac{277}{24}$: (a) show, with all working, that $k = 3.5$; (b) use algebraic integration to find $E(X)$; (c) find $\text{Var}(X)$. [11]

3.2 *(Edexcel IAL WST02 June 2025 Q6.)* The continuous random variable X is uniformly distributed on the interval $[a, b]$. Given that $P(2 < X < 5) = \frac{3}{16}$ and $E(X) = 6$: (a) find the value of a and the value of b; (b) find the value of the constant c for which $E(cX + 1) = 3$; (c) write down the exact value of $\mathrm{Var}(X)$; (d) find the exact value of $E(X^2)$; (e) find $P(\frac{3}{2}X - b > a)$. [10]