## MATHEMATICAL TRIPOS: PART IA PROBABILITY

Lent 2017 JRN

#### Example Sheet 3 (of 4)

1. Let  $x_1, x_2, \ldots, x_n$  be positive real numbers.

(a) Show that their harmonic mean is no greater than their arithmetic mean, that is,

$$\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{x_{i}}\right)^{-1} \leq \frac{1}{n}\sum_{i=1}^{n}x_{i}.$$

(b) Show that, if y<sub>1</sub>,..., y<sub>n</sub> is any reordering of x<sub>1</sub>,...,x<sub>n</sub>, then

$$\frac{1}{n}\sum_{i=1}^n\frac{y_i}{x_i}\geq 1.$$

Let X be a random variable.

(a) Show that, for all p ∈ (0, ∞) and all x ∈ (0, ∞),

$$\mathbb{P}(|X| \ge x) \le \mathbb{E}(|X|^p)x^{-p}$$
.

(b) Show that, for all β ≥ 0,

$$\mathbb{P}(X \ge x) \le \mathbb{E}(e^{\beta X})e^{-\beta x}$$
.

Let X be a Poisson random variable of parameter λ ∈ (0, ∞).

(a) By optimizing the estimate of Question 2(b) over β, show that, for all x ≥ λ,

$$\mathbb{P}(X \ge x) \le \exp\{-x \log(x/\lambda) - \lambda + x\}.$$

(b) Show, on the other hand, that, for integers x, as x → ∞,

$$\mathbb{P}(X = x) \sim \frac{1}{\sqrt{2\pi x}} \exp\{-x \log(x/\lambda) - \lambda + x\}.$$

4. Consider a random sample  $X_1, \ldots, X_n$  taken from a distribution having mean  $\mu$  and variance  $\sigma^2 < \infty$ . Use Chebyshev's inequality to determine a sample size n that will be sufficient, whatever the distribution, for the probability to be at least 0.99 that the sample mean X will be within two standard deviations of  $\mu$ .

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