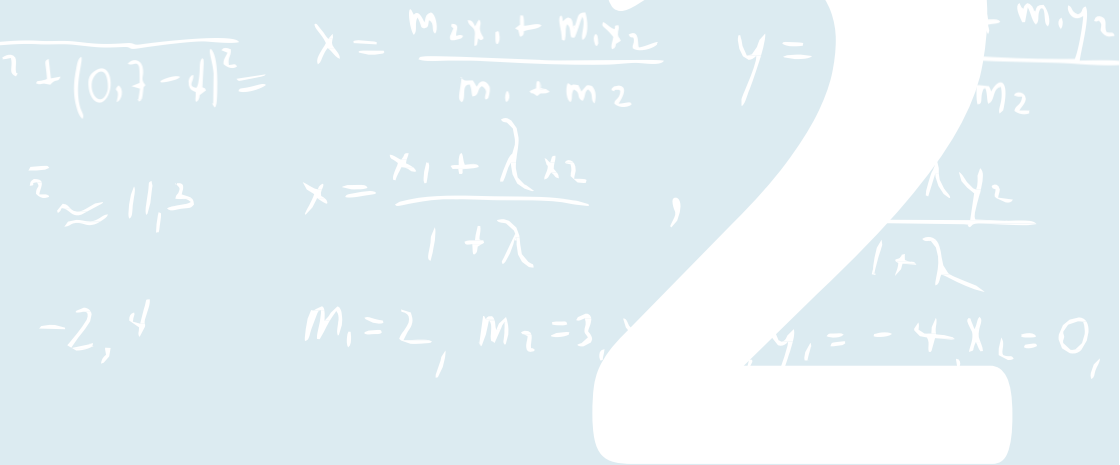


# Certified Actuarial Analyst Resource Guide

## Module 2 2017



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# Welcome to Module 2 - Statistics and Models of the Certified Actuarial Analyst qualification

The Certified Actuarial Analyst (CAA) is a professional qualification from CAA Global.

It is designed to provide you with a technical skills qualification if you:

- work alongside actuaries – in areas such as data analysis, pricing and marketing
- work in the wider financial services area – perhaps you already have other qualifications, and would like to develop a skill set that will mark you out in a competitive environment
- work in a service centre environment – the analytical skills you'll learn can then be added to your business knowledge
- have strong maths skills, and you want to and learn on the job rather than going to university.

The aim of the Module 2 Statistics and Models exam is to provide grounding in the aspects of statistics that are of relevance to actuarial work and in stochastic processes and survival models.

This Resource guide for Module 2 gives you the syllabus you will cover for the exam, and details of some online and other resources that will help you study for the Module 2 exam. There is also a specimen exam paper giving examples of the type of questions you will be asked.

Additional information about the Module 2 exam, including:

- How to enter for the exam
- What will happen at the exam centre

can be found in the:

- Student Actuarial Analyst Handbook

If you have any further questions contact the CAA Administration Team who will be happy

Email the team at:  
**enquiries@**  
**caa-global.org**

# The Certified Actuarial Analyst qualification

There are seven exams which you will need to complete for the qualification:

Module title	Assessed by
Fundamental Mathematics & Statistics – Module 0	2 hour Computer Based Assessment
Finance and Financial Mathematics – Module 1	2 hour Computer Based Assessment
<b>Statistics and Models – Module 2</b>	<b>2 hour Computer Based Assessment of 60 questions</b>
Long Term Actuarial Mathematics – Module 3	2 hour Computer Based Assessment
Short Term Actuarial Mathematics – Module 4	2 hour Computer Based Assessment
Models and Audit Trails – Module 5	3 hour examination
Online Professional Awareness Test (PAT)	90 minute examination

In addition to passing the above exams, you must complete at least one year of relevant work experience (Work-based skills).

# The syllabus for the Module 2 exam

The mathematical topics covered by the Module 2 exam are:

- The main features of the principal discrete and continuous distributions
- Moment generating function, cumulant generating function and simple cases of cumulants, and their uses to evaluate moments
- The concepts of independence, jointly distributed random variables and conditional distributions. The use of generating functions to establish the distribution of linear combinations of independent random variables
- The central limit theorem
- The concepts of random sampling, statistical inference and sampling distribution
- The main methods of estimation, the main properties of estimators, and their application
- Confidence intervals for unknown parameters
- Testing hypotheses
- Linear relationships between variables using correlation analysis and regression analysis
- The principles of actuarial modelling
- The general principles of stochastic processes, and their classification into different types
- Stochastic interest rate models
- Markov chain processes
- The Markov jump process
- The random lifetime survival model.

You can find the full Module 2 syllabus in Appendix 1 of this Resource guide

# Assessment of the Module 2 exam

The Module 2 exam is assessed by a 2 hour computer based exam containing 60 multiple choice questions.

Before you start your 2 hour exam you will have an extra 15 minutes for:

- reading the exam instructions, and
- working through some basic sample questions so that you become familiar with the format of the exam.

You will also need to sign a statement of confidentiality in relation to the exam materials.

Pass standards for the exam are set by CAA Global. Details of pass standards for CAA exams will be published in due course.



You can sit the exam at one of the many centres worldwide managed by Pearson VUE. You can find details of your local exam centre on their website by using their regional contact details: [www.pearsonvue.com/caaglobal](http://www.pearsonvue.com/caaglobal)

## Studying for the Module 2 exam

### Recommended study hours

We recommend that you spend 125-150 hours studying to prepare for the exam.

# 125-150

## Tuition

**BPP**  
ACTUARIAL EDUCATION



BPP Actuarial Education (ActEd),  
provides online study material for this exam.

Details of their training materials and services are available on their website.

Website: [www.bppacted.com](http://www.bppacted.com)

Email: [ActEd@bpp.com](mailto:ActEd@bpp.com)

Tel: +44 (0)1235 550 005

### Please note

Education providers are listed here for information purposes. CAA Global has not assessed the quality of the services provided.

## Free online resources

Listed below are samples of free web-based resources in which learning support links covering most, though not all, of the topics in Module 2 have been identified.

### Please note

The content of these websites has not been quality assured by CAA Global.  
The material should not be used as your primary learning resource, but may reinforce and/or supplement other sources.

### The following may be useful

**Topic 1** – The main features of the principal discrete and continuous distributions

<http://stattrek.com/probability-distributions/discrete-continuous.aspx>

<https://en.wikipedia.org>

[Use the search engine found at the top right hand corner of this site and search for: probability distribution]

<https://onlinecourses.science.psu.edu/stat414>

[See Sections 2 and 3 of this on-line module]

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**Topic 2** – Moment generating function, cumulant generating function and simple cases of cumulants, and their uses to evaluate moments

<http://www.twely.co.uk/article/lesson-15-moment-generating-functions/>

<http://onlinecourses.science.psu.edu/stat414>

[Lesson 10]

[http://en.wikipedia.org/wiki/Moment-generating\\_function](http://en.wikipedia.org/wiki/Moment-generating_function)

<http://mathworld.wolfram.com/>

[Use search engine to find 'moment generating function']

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**Topic 3** – The concepts of independence, jointly distributed random variables and conditional distributions. The use of generating functions to establish the distribution of linear combinations of independent random variables

<https://en.wikipedia.org>

[Search: marginal distribution, and for other terms in the Learning Objectives]

<http://onlinecourses.science.psu.edu/stat414>

[See Section 5]

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**Topic 4** – The central limit theorem. The concepts of random sampling, statistical inference and sampling distribution

<https://en.wikipedia.org>

[See Section 5, Lessons 26 and 27]

<https://en.wikipedia.org>

[Search: central limit theorem]

---

**Topic 5** – The main methods of estimation, the main properties of estimators, and their application

<http://onlinecourses.science.psu.edu/stat414>

[See Stat 415, Section 6]

<https://en.wikipedia.org>

[Search: Estimation Theory]

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**Topic 6** – Confidence intervals for unknown parameters

<http://onlinecourses.science.psu.edu/stat414>

[See Stat 415, Section 6, Lessons 30-33]

<https://en.wikipedia.org>

[Search: Confidence Intervals]

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**Topic 7** – Testing hypotheses

<http://onlinecourses.science.psu.edu/stat414>

[See Stat 415, Section 7]

<https://en.wikipedia.org>

[Search: Statistical hypothesis testing]

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**Topic 8** – Linear relationships between variables using correlation analysis and regression analysis

<http://onlinecourses.science.psu.edu/stat414>

[See Stat 414, Section 4]

<https://en.wikipedia.org>

[Search: bivariate data + other learning objectives]

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**Topic 9** – The principles of actuarial modelling

<https://www.qub.ac.uk/elearning/public/PrinciplesofActuarialModeling>

<https://en.wikipedia.org>

[Search: stochastic modelling]

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**Topic 10** – The general principles of stochastic processes, and their classification into different types

<https://en.wikipedia.org>

[Search: stochastic processes; Markov]

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**Topic 11** – Markov chain processes

<https://en.wikipedia.org>

[Search: stochastic processes; Markov chain]

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**Topic 12** – The Markov jump process

<https://en.wikipedia.org>

[Search: stochastic processes; Markov jump process model]

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**Topic 13** – The random lifetime survival model

**No free on-line resources available.**

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# Specimen exam paper

A specimen exam paper for Module 2, with sample exam questions, is given in Appendix 2. This will show you the types of questions which will be asked in the exam.

## Please note

Only 20 sample questions are given in the Specimen exam paper. There will be a total of 60 questions in the Module 2 exam you sit.

The questions found in the specimen paper will not be included in the Module 2 exam.

## Resources available at the exam centre

### Calculators

There is only one authorised calculator for all the CAA exams:

- **Texas Instruments TI-30 Multiview** (with or without suffix).

You should bring your own calculator with you to the exam. It will be checked by exam centre staff, and the memory will be cleared.

If you bring a different calculator model it must be left in the locker with your other personal belongings.

An on-screen scientific calculator will also be available for you to use during the exam. However, some students have reported that they found this on-screen calculator difficult or cumbersome to use, and so you may prefer to take your own TI-30 calculator to the exam with you.

The TI-30 Multiview calculator is available to buy from shops or online retailers.



### To clear the memory and reset the calculator:

**2nd** **[reset]** 2  
or  
**on** & **[clear]**

Resets the TI-30XS MultiView™ Calculator. Returns unit to default settings; clears memory variables, pending operations, all entries in history, and statistical data; clears the constant feature, K and Ans

## Making notes during the exam

You will be provided with an erasable note board at the centre to use during the exam.

You will only be given one board at a time but are entitled to as many as you need during the exam, and you will be able to keep these at your desk for the duration of the exam. You should ask the supervisor for more if needed. The Pearson VUE staff will not provide you with an eraser for the note boards.

The note boards will be collected by Pearson VUE staff at the end of the exam. On occasion you may instead be given scrap paper to make notes on.

## Formulae and Tables for actuarial examinations

The book of Formulae and Tables for examinations has been published to help students who sit actuarial exams.

The book gives you formulae for:

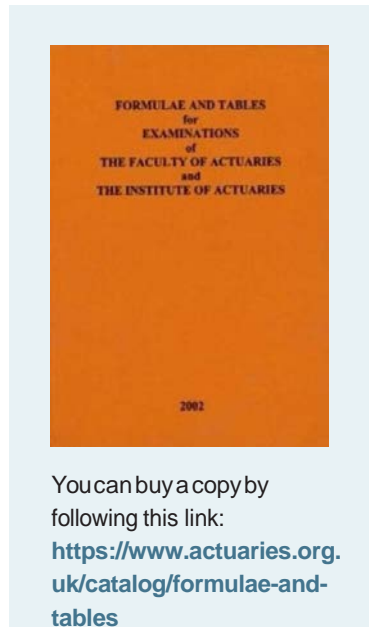
- selected mathematical and statistical methods,
- calculus, time series and economic models, and many other topics.

There are also tables for:

- compound interest calculations,
- selected statistical distributions, and
- other actuarial calculations.

You should make yourself familiar with these tables and formulae during your exam preparation.

You will not be able to use your own copy of the book during your exam, but a PDF copy will be available on your exam screen for you to use.



You can buy a copy by following this link:

<https://www.actuaries.org.uk/catalog/formulae-and-tables>

# Appendix 1

## Syllabus: Module 2 - Statistics and Models

### Aim

The aim of the Statistics and Models syllabus is to provide grounding in the aspects of statistics that are of relevance to actuarial work and in stochastic processes and survival models.

### Topic 1

#### The main features of the principal discrete and continuous distributions

Indicative study and assessment weighting 15%

# 1

### Learning objectives

- (i) Define the discrete distributions: geometric, binomial, negative binomial, poisson and uniform.
- (ii) Apply the discrete distributions: geometric, binomial, negative binomial, poisson and uniform.
- (iii) Define the continuous distributions: normal, lognormal, exponential, gamma, chi-square,  $t$ ,  $F$ , beta and uniform.
- (iv) Apply the continuous distributions: normal, lognormal, exponential, gamma, chi-square,  $t$ ,  $F$ , beta and uniform.

## Topic 2

### Moment generating function, cumulant generating function and simple cases of cumulants, and their uses to evaluate moments

Indicative study and assessment weighting 5%

# 2

#### Learning objectives

- (i) Determine the moment generating function (MGF) of random variable.
- (ii) Determine the cumulant generating function and the cumulants for a random variable.
- (iii) Determine using generating functions, the moments and cumulants of random variables, by expansion as a series or by differentiation, as appropriate.
- (iv) Describe the applications for which a moment generating function, a cumulant generating function and cumulants are used.
- (v) State the reasons why moment generating functions, cumulant generating functions and cumulants are used.

## Topic 3

### The concepts of independence, jointly distributed random variables and conditional distributions. The use of generating functions to establish the distribution of linear combinations of independent random variables

Indicative study and assessment weighting 5%

# 3

#### Learning objectives

- (i) Obtain marginal distributions and conditional distributions from jointly distributed random variables.
- (ii) Define the probability function/density function of a marginal distribution and of a conditional distribution.
- (iii) State the conditions under which random variables are independent.
- (iv) State and calculate the mean and variance of a function of two jointly distributed random variables, and the covariance and correlation coefficient between two such variables.

- (v) Determine the probability function/density function of a function of independent random variables, using MGFs.
- (vi) State the mean and variance of linear function of independent random variables.

## Topic 4

### The central limit theorem. The concepts of random sampling, statistical inference and sampling distribution

Indicative study and assessment weighting 10%

# 4

#### Learning objectives

- (i) State the central limit theorem for a sequence of independent, identically distributed random variables.
- (ii) Apply the central limit theorem to establish normal approximations to other distributions, and to calculate probabilities.
- (iii) Explain a continuity correction when using a normal approximation to a discrete distribution.
- (iv) Apply a continuity correction when using a normal approximation to a discrete distribution.
- (v) Explain what is meant by a sample, a population and statistical inference.
- (vi) Define a random sample from a distribution of a random variable.
- (vii) Explain what is meant by a statistic and its sampling distribution.
- (viii) Determine the mean and variance of a sample mean and the mean of a sample variance in terms of the population mean, variance and sample size.
- (ix) State and use the basic sampling distributions for:
  - the sample mean where the population variance is known
  - the sample mean where the population variance is unknown
  - the sample variancefor random samples from a population that follows a normal distribution.

## Topic 5

### The main methods of estimation, the main properties of estimators, and their application

Indicative study and assessment weighting 10%

# 5

#### Learning objectives

- (i) Describe the method of moments for constructing estimators of population parameters.
- (ii) Apply the method of moments for constructing estimators of population parameters.
- (iii) Describe the method of maximum likelihood for constructing estimators of population parameters for exact data samples.
- (iv) Apply the method of maximum likelihood for constructing estimators of population parameters for exact data samples.
- (v) Define the terms: efficiency, bias, consistency and mean squared error.
- (vi) Calculate the bias and mean square error of an estimator and use them to compare estimators.

## Topic 6

### Confidence intervals for unknown parameters

Indicative study and assessment weighting 5%

# 6

#### Learning objectives

- (i) Define in general terms a confidence interval for an unknown parameter of a distribution based on a random sample.
- (ii) Calculate a confidence interval for an unknown parameter using a given sampling distribution for example the mean and variance of a normal distribution.
- (iii) Calculate confidence intervals for a binomial probability and a Poisson mean, using the normal approximation in both cases.
- (iv) Calculate confidence intervals for two-sample situations involving either the normal distribution, or the normal approximation to the binomial and Poisson distributions.

## Topic 7

### Testing hypotheses

Indicative study and assessment weighting 10%

# 7

#### Learning objectives

- (i) Explain what is meant by the terms null and alternative hypotheses, simple and composite hypotheses, critical region, level of significance and probability-value of a test.
- (ii) Apply basic tests for the one-sample and two-sample situations involving the normal, binomial and Poisson distributions.
- (iii) Apply a basic test for paired data.
- (iv) Apply a chi-square test to test the hypothesis that a random sample is from a particular distribution, including cases where parameters are unknown.

## Topic 8

### Linear relationships between variables using correlation analysis and regression analysis

Indicative study and assessment weighting 5%

# 8

#### Learning objectives

- (i) Interpret scatterplots for bivariate data.
- (ii) Define the correlation coefficient for bivariate data.
- (iii) Explain the interpretation of the correlation coefficient for bivariate data and perform statistical inference as appropriate.
- (iv) Calculate the correlation coefficient for bivariate data.
- (v) Explain what is meant by response and explanatory variables.
- (vi) Define the usual simple regression model (with a single explanatory variable).
- (vii) Calculate  $R^2$  (coefficient of determination).



- (viii) Describe the use of  $R^2$  to measure the goodness of fit of a linear regression model.
- (ix) Use a fitted linear relationship to predict a mean response or an individual response.

## Topic 9

### The principles of actuarial modelling

Indicative study and assessment weighting 5%

# 9

#### Learning objectives

- (i) Describe why and how actuarial models are used.
- (ii) Explain the benefits and limitations of modelling.
- (iii) Explain the difference between a stochastic and a deterministic model, and identify the advantages/disadvantages of each.
- (iv) Describe, in general terms, how to decide whether a model is suitable for any particular application.
- (v) Explain the difference between the short-run and long-run properties of a model, and how this may be relevant in deciding whether a model is suitable for any particular application.
- (vi) Describe, in general terms, how to analyse the potential output from a model, and explain why this is relevant to the choice of model.
- (vii) Describe the process of sensitivity testing of assumptions and explain why this forms an important part of the modelling process.
- (viii) Explain the factors that must be considered when communicating the results following the application of a model.

## Topic 10

### The general principles of stochastic processes, and their classification into different types. Stochastic interest rate models

Indicative study and assessment weighting 5%

# 10

#### Learning objectives

- (i) Define in general terms a stochastic process and in particular a counting process.

- (ii) Describe a stochastic process according to whether it:
- operates in continuous or discrete time
  - has a continuous or a discrete state space
  - is a mixed type
- and give examples of each type of process.
- (iii) Describe possible applications of mixed processes.
- (iv) Explain what is meant by the Markov property in the context of a stochastic process.
- (v) Explain the concept of a stochastic interest rate model and the fundamental distinction between this and a deterministic model.
- (vi) Derive algebraically, for the model in which the annual rates of return are independently and identically distributed and for other simple models, expressions for the mean value and the variance of the accumulated amount of a single premium.

## Topic 11

### Markov chain processes

Indicative study and assessment weighting 10%

11

#### Learning objectives

- (i) State the essential features of a time-homogeneous Markov chain model.
- (ii) Calculate the stationary distribution for a Markov chain model in simple cases.
- (iii) Describe a system of frequency based experience rating in terms of a Markov chain model and describe other simple applications.
- (iv) Demonstrate how Markov chains can be used as a tool for modelling.

## Topic 12

### The Markov jump process

Indicative study and assessment weighting 10%

# 12

#### Learning objectives

- (i) State the essential features of a Markov jump process model.
- (ii) Define time-homogeneous and time-inhomogeneous Markov jump process models of transitions between discrete states, state the distribution of the holding time in a particular state, and apply these results.
- (iii) Define the Poisson process, state the distribution of the number of events in a given time interval, state the distribution of inter-event times, and apply these results.
- (iv) Define the two-state survival model, sickness models and other example multiple state models in terms of Markov jump processes.
- (v) Define the jump chain model associated with a Markov jump process model, and apply the results.
- (vi) Demonstrate how Markov jump processes can be used as a tool for modelling.

## Topic 13

### The random lifetime survival model

Indicative study and assessment weighting 5%

# 13

#### Learning objectives

- (i) Describe the model of lifetime or failure time from age  $x$  as a random variable.
- (ii) State the consistency condition between the random variable representing lifetimes from different ages.
- (iii) Define the distribution and density functions of the random future lifetime, the survival function, the force of mortality or hazard rate, and state the relationships between them.
- (iv) Define the actuarial symbols  ${}_t p_x$  and  ${}_t q_x$  and state integral formulae for them.

- (v) Define the curtate future lifetime from age  $x$  and state its probability function.
- (vi) Define the expected value and variance of the complete and curtate future lifetimes and state expressions for them. Define the symbols  $e_x$  and  $e_x^o$  and state an approximate relationship between them.
- (vii) Compare the random lifetime survival model with the two state Markov jump process survival model.

## END OF SYLLABUS

# Appendix 2

## Specimen Examination Paper: Module 2 – Statistics and Models

### Please note:

- This Specimen Examination Paper acts as an example of the types of questions that will appear in the Module 2 Exam Paper.
- Although only 20 sample questions are listed in this specimen paper, there will be a total of 60 questions in the actual Module 2 examination.
- The questions found in the Module 2 Specimen Examination Paper will not be included in the actual Module 2 examination.

1. A random variable  $X$  is distributed according to the following probability distribution, with parameters  $k$  and  $\theta$ :

$$P(X = x) = \binom{x-1}{k-1} \theta^k (1-\theta)^{x-k}, \quad x = k, k+1, \dots; \quad 0 < \theta < 1$$

**Identify** this probability distribution.

- A. Negative Binomial
- B. Binomial
- C. Poisson
- D. Uniform (discrete version)

Answer: **A**

---

2 The random variable  $X$  follows a Geometric distribution with parameter  $p=0.2$ .

**Calculate** the mean and standard deviation of  $X$ , correct to two decimal places.

- A. mean=0.20, standard deviation=0.20
- B. mean=0.20, standard deviation=0.04
- C. mean=5.00, standard deviation=20.00
- D. mean=5.00, standard deviation=4.47

Answer: **D**

---

3 A random variable  $X$  follows a Gamma distribution with mean=1.5 and variance=0.75.

**Identify** the form of the probability density function (PDF) for the random variable  $X$ .

- A.  $[2x\exp(-x)]^2$
- B.  $8x^3\exp(-2x)$
- C.  $x^1\exp(-x)$
- D.  $4x^2\exp(-3x)$

Answer: **A**

---

4 A random variable  $X$  follows a Binomial  $(n, \theta)$  distribution.

**Identify** the form of the moment generating function for  $X$ .

- A.  $(\theta e^t + \theta)^n$
- B.  $[1 + \theta(e^t - 1)]^n$
- C.  $\exp[\theta(e^t - 1)]$
- D.  $\exp(\theta t + \frac{1}{2}\theta^2 t^2)$

Answer: **B**

---

- 
- 5  $X$  and  $Y$  are random variables and the covariance of  $X$  and  $Y$  is 6.

**Calculate** the covariance of the terms  $(3X + 2)$  and  $(5Y + 1)$

- A. 9
- B. 15
- C. 18
- D. 90

Answer: **D**

---

- 6 In a large population 45% of people have blood group A. A random sample of 300 individuals is chosen from this population.

**Calculate** an approximate value for the probability that more than 125 of the sample have blood group A, correct to two decimal places.

Use a normal approximation without a continuity correction.

- A. 0.12
- B. 0.14
- C. 0.86
- D. 0.88

Answer: **C**

---

- 7 A random sample of size 16 is taken from a Normal distribution with mean  $\mu = 25$  and variance  $\sigma^2 = 4$ .

The sample mean is denoted  $\bar{x}$ .

**Calculate** the probability that  $\bar{x}$  is greater than 26, correct to two decimal places.

- A. 0.02
- B. 0.15
- C. 0.31
- D. 0.98

Answer: **A**

---

- 
- 8 The percentage return on an investment over a period of one year is to be modelled as a Normal random variable  $X$  with mean  $\mu$  and variance 1.

A potential investor is interested in the chance that the return over a year on such an investment will exceed 9%.

A random sample of ten such returns (in %) contains the values:

7.3, 8.9, 8.3, 6.2, 9.8, 7.7, 9.4, 7.9, 9.1, and 7.4.

**Calculate** the estimate of  $\theta = P(X > 9)$  based on the maximum likelihood estimate of  $\mu$ , correct to three decimal places.

- A. 0.212
- B. 0.300
- C. 0.700
- D. 0.788

Answer: **A**

---

- 9 A statistical model is being considered for the observed amount of claims,  $X$ , which occur in one year on a class of policies. Only policies on which claims actually arise are considered.

One of the possible models for  $X$ , based on the parameter  $\theta$ , is:

$$P(X = x) = \frac{1 - \theta^x}{\log(1 - \theta)}, \quad x = 1, 2, 3, \dots; \quad 0 < \theta < 1$$

The data available consists of a random sample of 12 claims with sample mean £5,214.

**Identify** which of the following expressions is proportional to the log-likelihood of the data.

- A.  $-12 \log \{-\log(\theta)\} + 62,568 \log(1 - \theta)$
- B.  $-12 \log \{-\log(1 - \theta)\} + 5,214 \log(\theta)$
- C.  $-12 \log \{-\log(1 - \theta)\} + 62,568 \log(\theta)$
- D.  $-12 \log \{-\log(\theta)\} + 5,214 \log(1 - \theta)$

Answer: **C**

---



- 
- 10 In a survey conducted by a restaurant, 172 customers from a random sample of 200 indicated that they were highly satisfied with the meal they ate in the restaurant.

**Calculate** an approximate 95% confidence interval for the proportion of the restaurant's customers who are highly satisfied with their meal.

- A. (0.797, 0.923)
- B. (0.812, 0.908)
- C. (0.858, 0.862)
- D. (0.859, 0.861)

Answer: **B**

---

- 11 Past data for two household claims assessors, *A* and *B*, is being investigated. The following table shows the assessors' initial estimates of the cost (in units of £100) of meeting each flood damage claim:

<b>A:</b>	4.6	6.6	2.8	5.8	2.1	5.2	5.9	3.4	7.8	3.5	1.6	8.6	2.7
<b>B:</b>	5.7	3.4	4.7	3.6	6.5	3.3	3.8	2.4	7.0	4.0	4.4		

For the *A* data:  $n_A = 13$ ,  $\sum x = 60.6$  and  $\sum x^2 = 340.92$

For the *B* data:  $n_B = 11$ ,  $\sum x = 48.8$  and  $\sum x^2 = 236.80$

Let  $\mu_A$  denote the mean initial estimate for this type of flood damage for assessor *A* and  $\mu_B$  denote the mean initial estimate for this type of flood damage for assessor *B*.

The insurance company wishes to test the hypothesis:  $H_0: \mu_A = \mu_B$  vs  $H_1: \mu_A \neq \mu_B$

**Calculate** the value of the test statistic under  $H_0$ .

- A. 0.12 with 22 degrees of freedom
- B. 0.12 with 24 degrees of freedom
- C. 0.29 with 22 degrees of freedom
- D. 0.29 with 24 degrees of freedom

Answer: **C**

---

- 
- 12 A random sample of size 10 is taken from a Normal population with standard deviation  $\sigma = 15$  and the sample standard deviation,  $s$ , is calculated.

**Calculate** the value  $k$  such that  $P(S > k) = 0.95$ , correct to two decimal places.

- A. 6.59
- B. 9.12
- C. 9.92
- D. 20.57

Answer: **B**

---

- 13 As part of an investigation into whether mortality rates can be used to predict sickness rates, data on standardised mortality rates and standardised sickness rates were collected for a sample of 10 regions. The results are shown in the table below:

Region	Mortality rate $m$ (per 10,000)	Sickness rate $s$ (per 1,000)
1	125.2	206.8
2	119.3	213.8
3	125.3	197.2
4	111.7	200.6
5	117.3	189.1
6	100.7	183.6
7	108.8	181.2
8	102.0	168.2
9	104.7	165.2
10	121.1	228.5

Data summaries:

$$\sum m = 1136.1, \sum m^2 = 129,853.03, \sum s = 1934.2, \sum s^2 = 377,700.62, \sum ms = 221,022.58$$

**Calculate** the value of the correlation coefficient between the mortality rates and the sickness rates, correct to three decimal places.

- A. 0.236
- B. 0.365
- C. 0.583
- D. 0.764

Answer: **D**

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**14 Identify** which of the following statements is NOT true:

- A. a stochastic model is sometimes better than a deterministic model.
- B. a deterministic model is sometimes better than a stochastic model.
- C. fixed inputs to a deterministic model always give a fixed output.
- D. fixed inputs to a stochastic model always give a variable output.

Answer: **D**

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**15 Identify** which of the following correctly describes the nature of the state space and time space of a Poisson process.

- A. discrete state space and continuous time space
- B. discrete state space and discrete time space
- C. continuous state space and continuous time space
- D. continuous state space and discrete time space

Answer: **A**

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**16** A motor insurer offers a No Claims Discount scheme.

The discount levels are {0%, 25%, 50%, 60%}.

Following a claim-free year a policyholder moves up one discount level (or stays at the maximum discount). After a year with one or more claims the policyholder moves down two discount levels (or moves to or stays in the 0% discount level).

**Identify** the nature of this stochastic process.

- A. irreducible and aperiodic
- B. irreducible and not aperiodic
- C. not irreducible and aperiodic
- D. not irreducible and not aperiodic

Answer: **A**

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- 17 Consider the time-homogeneous two-state Markov chain with the following transition matrix:

$$\begin{pmatrix} 1-a & a \\ b & 1-b \end{pmatrix}$$

It is required that this is a valid Markov chain that is both irreducible and periodic.

**Identify** the values that  $a$  and  $b$  can take for these conditions to be satisfied.

- A.  $0 < a \leq 1$  and  $0 < b \leq 1$   
B.  $0 < a \leq 1$  and  $b = 1$   
C.  $a = 1$  and  $0 < b \leq 1$   
D.  $a = 1$  and  $b = 1$
- 
- 18 A firm hires out cars and operates from three locations — the Airport, the Beach and the City. Customers may return vehicles to any of the three locations.

The company estimates that the probability of a car being returned to each location, based on the location where it was hired from, behaves according to the following matrix:

Car hired from	Car returned to		
	Airport	Beach	City
Airport	0.50	0.25	0.25
Beach	0.25	0.75	0.00
City	0.25	0.25	0.50

**Calculate** the value of the stationary distribution  $\pi$  in this case.

- A. Airport 1/3, Beach 1/2, City 1/6  
B. Airport 1/2, Beach 1/4, City 1/4  
C. Airport 1/3, Beach 0, City 2/3  
D. Airport 1/2, Beach 1/6, City 1/3

Answer: **A**

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- 19 At a certain airport, taxis for the city centre depart from a single terminus. The taxis are all of the same make and model, and each can seat four passengers (not including the driver). The terminus is arranged so that empty taxis queue in a single line, and passengers must join the front taxi in the line. As soon as it is full, each taxi departs.

A strict environmental law forbids any taxi from departing unless it is full. Taxis are so numerous that there is always at least one taxi waiting in line.

Passengers arrive at the terminus according to a Poisson process with a rate  $\beta$  per minute.

**Calculate** the expected time a passenger arriving at the terminus will have to wait until his or her taxi departs.

- A.  $1/\beta$  minutes
- B.  $1.5/\beta$  minutes
- C.  $2.5/\beta$  minutes
- D.  $3/\beta$  minutes

Answer: **B**

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- 20 The mortality of a certain species of fish has been studied. It is known that at ages over five years the force of mortality for the fish,  $\mu$ , is constant. However the variation in mortality for fish below five years of age is not well understood. The proportion of the fish that survive to exact age five years, from birth, is denoted as  ${}_5P_0$ .

**Derive** the expression for the proportion of all newly born fish that are expected to die between exact ages 10 and 15 years.

- A.  ${}_5P_0 e^{-10\mu}$
- B.  ${}_5P_0 e^{-5\mu}$
- C.  ${}_5P_0 (e^{-5\mu} - e^{-10\mu})$
- D.  ${}_5P_0 (e^{-10\mu} - e^{-5\mu})$

Answer: **C**

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## US OFFICE

475 N. Martingale Road  
Suite 600  
Schaumburg, IL 60173  
USA

**Tel:** +1-847-273-8890  
1-844-839-1679 (Toll Free)

## UK OFFICE

7th Floor, Holborn Gate,  
326 - 330 High Holborn,  
London, WC1V 7PP  
United Kingdom

**Tel:** +44 01865 268266

**E:** [enquiries@caa-global.org](mailto:enquiries@caa-global.org)

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