Mathematics Advanced

# MA-S1 Probability and Discrete Probability Distributions

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**Disclaimer**

This document is to be used to supplement the support teachers are offering students undertaking HSC Mathematics courses. Questions can be printed off for students individually, with or without solutions, or as an entire booklet. Questions have been sourced from various states across Australia and the source of each question has been referenced. Permission to use these resources was provided in June 2020. Solutions for each of the questions can be found at the end of the document.

**Outcomes**

All outcomes referred to in this booklet are from [Mathematics Advanced Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-mathematics/mathematics-advanced-2017) © 2017 NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales.

## Syllabus outcomes

The examination-style questions presented in this document refer to the following outcomes and syllabus content.

### Outcomes

A student:

* uses concepts and techniques from probability to present and interpret data and solve problems in a variety of contexts, including the use of probability distributions **MA11-7**
* provides reasoning to support conclusions which are appropriate to the context **MA11-9**

### Content

**S1.1: Probability and Venn diagrams**

* establish and use the rules:

 and  (ACMMM054) **AAM** 

* understand the notion of conditional probability and recognise and use language that indicates conditionality(ACMMM056)
* use the notation  and the formula ,  for conditional probability(ACMMM057) **AAM**
* understand the notion of independence of an event  from an event , as defined by (ACMMM058)
* use the multiplication law  for independent events  and  and recognise the symmetry of independence in simple probability situations (ACMMM059)

**S1.2: Discrete probability distributions**

* define and categorise random variables
* know that a random variable describes some aspect in a population from which samples can be drawn
* know the difference between a discrete random variable and a continuous random variable
* use discrete random variables and associated probabilities to solve practical problems(ACMMM142) **AAM**
* use relative frequencies obtained from data to obtain point estimates of probabilities associated with a discrete random variable(ACMMM137)
* recognise uniform discrete random variables and use them to model random phenomena with equally likely outcomes(ACMMM138)
* examine simple examples of non-uniform discrete random variables, and recognise that for any random variable, , the sum of the probabilities is 1 (ACMMM139)
* recognise the mean or expected value, , of a discrete random variable  as a measure of centre, and evaluate it in simple cases(ACMMM140)
* recognise the variance,, and standard deviation () of a discrete random variable as measures of spread, and evaluate them in simple cases(ACMMM141)
* use  for a random variable and  for a dataset
* understand that a sample mean, , is an estimate of the associated population mean , and that the sample standard deviation, , is an estimate of the associated population standard deviation, , and that these estimates get better as the sample size increases and when we have independent observations

## Supplementary resources

### Department of Education resources

#### Units of work

* [MA S1 Probability and discrete probability](https://education.nsw.gov.au/teaching-and-learning/curriculum/key-learning-areas/mathematics/stage-6/mathematics-advanced)

#### HSC Hub videos

* [Conditional probability](https://hschub.nsw.edu.au/mathematics-items/conditional-probability-2)
* [Discrete probability distributions Q19 NESA sample examination](https://hschub.nsw.edu.au/mathematics-items/discrete-probability-distributions-2)

### NESA resources

* [Mathematics Advanced – Sample examination materials (2020)](https://educationstandards.nsw.edu.au/wps/wcm/connect/ac7b6416-bf93-40ca-9b88-ff28fa0711a1/mathematics-advanced-sample-examination-materials-2020.pdf?MOD=AJPERES&CVID=)

### WOOTUBE resources

* [MA S1 Probability and Discrete probability distributions](https://www.youtube.com/playlist?list=PL5KkMZvBpo5BFwSEeNMH5keKPZGNdP0EE)

## Examination-style questions

### Sample question 1

**Question 7**

The discrete random variable has the following probability distribution:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |

The mean of is

Source: [© VCAA 2019 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 2

**Question 11**

 and are events from a sample space such that , where , and *.*

 and are independent events when

Source: [© VCAA 2019 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 3

**Question 12**

The discrete random variable has the following probability distribution:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 6 |
|  |  |  |  |  |  |

Let be the mean of

) is

Source: [© VCAA 2018 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 4

**Question 14**

Two events, and , are independent, where and

 is equal to

1. 0.1
2. 0.2
3. 0.3
4. 0.4
5. 0.5

Source: [© VCAA 2018 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 5

**Question 14**

The random variable has the following probability distribution, where

|  |  |  |  |
| --- | --- | --- | --- |
|  | -1 | 0 | 1 |
|  |  |  |  |

The variance of X is

Source: [© VCAA 2017 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 6

**Question 7**

The number of pets, , owned by each student in a large school is a random variable with the following discrete probability distribution.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  | 0.5 | 0.25 | 0.2 | 0.05 |

If two students are selected at random, the probability that they own the same number of pets is:

1. 0.3
2. 0.305
3. 0.355
4. 0.405
5. 0.8

Source: [© VCAA 2016 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 7

**Question 19**

Consider the discrete probability distribution with random variable shown in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | -1 | 0 |  |  | 4 |
|  |  |  |  |  |  |

The smallest and largest possible values of are respectively

1. -0.8 and 1
2. -0.8 and 1.6
3. 0 and 2.4
4. 0.2125 and 1
5. 0 and 1

Source: [© VCAA 2016 Mathematical Methods: Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 8

**Question 14**

Consider the following discrete probability distribution for the random variable, .

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 |
|  |  |  |  |  |  |

The mean of this distribution is

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### Sample question 9

**Question 14**

If is a random variable such that and , then
 is

Source: [© VCAA 2014 Mathematical Methods (CAS): Written examination 2](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 10

**Question 17**

and are events of a sample space.

Given that , and , is equal to

1.

Source: [© VCAA 2013 Mathematical Methods (CAS)](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx): Written examination 2

### Sample question 11

**Question 10**

For events and , and

If and are independent, then the value of is

1.

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### Sample question 12

**Question 6 (4 marks)**

Two boxes each contain four stones that differ only in colour.
Box 1 contains four black stones.
Box 2 contains two black stones and two white stones.
A box is chosen randomly and one stone is drawn randomly from it.

Each box is equally likely to be chosen, as is each stone.

1. What is the probability that the randomly drawn stone is black? **(2 marks)**
2. It is not known from which box the stone has been drawn.
Given that the stone that is drawn is black, what is the probability that it was drawn from Box 1? **(2 marks)**

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### Sample question 13

**Question 8 (5 marks)**

For events and from a sample space, andLet

1. Find in terms of **(1 mark)**
2. Find **(2 marks)**
3. Given that state the largest possible interval for **(2 marks)**

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### Sample question 14

**Question 7 (3 marks)**

A company produces motors for refrigerators. There are two assembly lines, Line A and Line B. 5% of the motors assembled on Line A are faulty and 8% of the motors assembled on Line B are faulty. In one hour, 40 motors are produced from Line A and 50 motors are produced from Line B. At the end of an hour, one motor is selected at random from all the motors that have been produced during that hour.

1. What is the probability that the selected motor is faulty? Express your answer in the form **(2 marks)**
2. The selected motor is found to be faulty.
What is the probability that it was assembled on Line A? Express your answer in the form **(1 mark)**

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### Sample question 15

**Question 8 (3 marks)**

For events A and B from a sample space, and

1. Calculate **(1 mark)**
2. Calculate , where A’ denotes the complement of A **(1 mark)**
3. If events and are independent, calculate **(1 mark)**

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### Sample question 16

**Question 9 (4 marks)**

An egg marketing company buys its eggs from farm and farm *B*. Let be the proportion of eggs that the company buys from farm . The rest of the company’s eggs come from farm . Each day, the eggs from both farms are taken to the company’s warehouse.

Assume that of all eggs from farm have white eggshells and of all eggs from farm have white eggshells.

1. An egg is selected at random from the set of all eggs at the warehouse.
Find, in terms of , the probability that the egg has a white eggshell. **(1 mark)**
2. Another egg is selected at random from the set of all eggs at the warehouse.
3. Given that the egg has a white eggshell, find, in terms of , the probability that it came from farm . **(2 marks)**
4. If the probability that this egg came from farm is, find the value of .
**(1 mark)**

Source: [© VCAA 2015 Mathematical Methods: Written examination 1](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx)

### Sample question 17

**Question 9 (6 marks)**

Sally aims to walk her dog, Mack, most mornings. If the weather is pleasant, the probability that she will walk Mack is , and if the weather is unpleasant, the probability that she will walk Mack is

Assume that pleasant weather on any morning is independent of pleasant weather on any other morning.

1. In a particular week, the weather was pleasant on Monday morning and unpleasant on Tuesday morning. Find the probability that Sally walked Mack on at least one of these two mornings. **(2 marks)**
2. In the month of April, the probability of pleasant weather in the morning was
3. Find the probability that on a particular morning in April, Sally walked Mack.
**(2 marks)**
4. Using your answer from **part b.i.**, or otherwise, find the probability that on a particular morning in April, the weather was pleasant, given that Sally walked Mack that morning. **(2 marks)**

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### Sample question 18

**Question 7 (6 marks)**

The probability distribution of a discrete random variable, , is given by the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 |
|  |  |  |  |  |  |

1. Show that **(3 marks)**
2. Let
3. Calculate **(2 marks)**
4. Find **(1 mark)**

Source: [© VCAA 2013 Mathematical Methods (CAS)](https://vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Mathematical-Methods.aspx): Written examination 1

### Sample question 19

**Question 10 (7 marks)**

A group of researchers conducted a study into the number of siblings of adult Australian citizens. They surveyed a total of 200 participants and recorded the number of siblings, , of each participant.

A few days later the lead researcher discovered that the survey data had been misplaced. Fortunately, one of the research assistants had been doing some rough calculations on a whiteboard and the lead researcher was able to recover the following information about the probability distribution for and the mean .

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |

The letters and have been used to denote unknown probabilities.

1. i. Write two independent equations for and . **(2 marks)**

ii. Hence solve for the unknown probabilities. **(2 marks)**

Later that day the research assistant found the complete probability distribution in their records and discovered that they had made an error in their original calculation of the mean. The correct probability distribution is given in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |

1. i. Given that there were 200 participants in the study, complete the table below to show the number of participants with 0, 1, 2 and 3 siblings. **(1 mark)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |
|  |  |  |  |  |

ii. Determine the correct mean and standard deviation of the number of siblings . **(2 marks)**

Source: [© WA SCSA 2019 Mathematics Methods – Section 2](https://senior-secondary.scsa.wa.edu.au/further-resources/past-atar-course-exams/mathematics-methods-past-atar-course-exams): Calculator assumed

### Sample question 20

**Question 4 (4 marks)**

Ten shop owners in a coastal resort were asked how many extra staff they intended to hire for the next holiday season. Their responses are shown below:

3, 0, 2, 1, 2, 1, 1, 0, 2, 1

If = number of additional staff,

1. complete the probability distribution of below. **(2 marks)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |

1. what is the mean number of staff the shop owners intend to hire? **(2 marks)**

Source: [© WA SCSA 2018 Mathematics Methods – Section 1](https://senior-secondary.scsa.wa.edu.au/further-resources/past-atar-course-exams/mathematics-methods-past-atar-course-exams): Calculator free

### Sample question 21

**Question 13 (9 marks)**

Ravi runs a dice game in which a player throws two standard six-sided dice and the sum of the uppermost faces is calculated. If the sum is less than five, the player wins $20. If the sum is greater than eight, the player wins $10. Otherwise the player receives no money.

1. Complete the table below. **(2 marks)**

|  |  |  |  |
| --- | --- | --- | --- |
| Amount won |  |  |  |
| Probability |  |  |  |

1. What is the expected amount of money won by a player each time they play?
**(2 marks)**
2. Liu Yang decides to play the game. If Ravi charges her $5 to roll two dice, who is likely to be better off in the long-term? Explain. **(3 marks)**
3. If Ravi wants to make a long-term profit per game of 20% of what he charges, what should he charge a player to roll the two dice? **(2 marks)**

Source: [© WA SCSA 2017 Mathematics Methods – Section 2: Calculator assumed](https://senior-secondary.scsa.wa.edu.au/further-resources/past-atar-course-exams/mathematics-methods-past-atar-course-exams)

### Sample question 22

**Question 15 (6 marks)**

A tetrahedral die has the numbers 1 to 4 on each face. When thrown, each side is equally likely to land facedown. Let be defined as the sum of the numbers on the facedown side when the die is thrown twice.

1. Complete the following table **(1 mark)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Roll two |  |  |  |
|  | Sum of two rolls | 1 | 2 | 3 | 4 |
| Roll One | 1 | 1 + 1 = 2 | 3 |  |  |
|  | 2 | 3 |  |  |  |
|  | 3 |  | 5 |  |  |
|  | 4 |  |  |  |  |

1. i. Hence, or otherwise, complete the probability distribution of , which is given by the following table. **(1 mark)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|  |  |  |  |  |  |  |  |

ii. Calculate the probability of obtaining a sum of five or less **(2 marks)**

iii. Determine the mean and standard deviation for **(2 marks)**

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## Solutions

### Sample question 1

**Question 7**

 =

Correct answer = D

### Sample question 2

**Question 11**

If A and B are independent

 and

So,

Correct answer = A

### Sample question 3

**Question 12**

Correct answer = E

### Sample question 4

**Question 14**

Correct = B (disregard 1.3 as probability cannot be greater than 1)

### Sample question 5

**Question 14**

Correct answer= D

### Sample question 6

**Question 7**

Correct answer = C

### Sample question 7

**Question 19**

Substitute

The smallest value for is 0 and the largest value is 1.

Correct answer = E

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### Sample question 8

**Question 14**

=

Correct = D

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### Sample question 9

**Question 14**

If is a continuous random variable, then

Correct = E

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### Sample question 10

**Question 17**

Correct = D

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### Sample question 11

**Question 10**

If A and B are independent events

 =

Correct = C

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### Sample question 12

**Question 6a**

Several approaches were possible using a tree diagram or a counting argument.

 =

 =

Since choosing either box is equally likely and choosing any stone is equally likely and there are 8 stones, 6 of which are black, P(Black) =

This question was generally well answered. Many students showed their reasoning via a tree diagram or some written explanation. Some students overworked the problem by trying to use the binomial distribution

**Question 6b**

=

Students generally recognised the conditional probability (reduced sample space). Some students incorrectly worked P(Black | Box 1), resulting in a probability greater than 1, which is not feasible.

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### Sample question 13

**Question 8a**

This questions was generally answered well. The most common errors included solving for , and incorrectly transposing to yield

**Question 8b**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Or,

And

Students who scored highly usually used a table or a Venn diagram to arrive at their answer. There were various misconceptions of the connection between conditional probabilities and Many students assumed that events A and B were independent, hence incorrectly used

**Question 8c**

If

 , thus

Most students identified that Only a few students identified the correct interval because students did not consider that in this case . Common incorrect answers included (allowing negative probabilities) and

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### Sample question 14

**Question 7a**



While a tree was not required to answer the question, it may have assisted some students to determine the two required cases. Many students stated probabilities greater than 1.

**Question 7b**

In general the conditional probability was recognised but not the reduced sample space. Often the instruction regarding the form of the final answer was overlooked.

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### Sample question 15

**Question 8a**

**Question 8b**

**Question 8c**

If A and B are independent, then P(A\B) = P(A) =

Many students made little headway into solving this problem due to their lack of understanding of independent events. The additional rule was then applied using an incorrect value for P(A), resulting in final answers well outside the interval [0,1]. Students must note that a probability must lie with [0,1] and is never a negative answer.

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### Sample question 16

**Question 9a**

Many students made good use of a tree diagram in their formulation of a solution. Some students left their answer unsimplified as a sum of two products. A significant number of students offered a final expression not in terms of p.

**Question 9bi**

While most students recognised that this question involved conditional probability, many could not apply it within the context of the specific question. Algebraic fractions were not handled well.

**Question 9bii**

Many students missed the specific connection of this part with the previous part.

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### Sample question 17

**Question 9a**

, OR

A tree diagram or listing the sample space were the best options to solve this problem.

**Question 9bi**



Many students made a good attempt at this question. Most students correctly identified the required sum of two products; however, made errors in the evaluation of the final fraction.

**Question 9bii**

Many students were able to identify the conditional probability and use their answer to part bi. in the denominator, however, used an incorrect numerator

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### Sample question 18

**Question 7a**

 OR

This question presented a range of fundamental problems for students: mixed operations with fractions and decimals, factorising and solving quadratics, using substitution to ‘show’ and not eliminate or determine other possible solutions, and poor notation.

**Question 7bi**

Many students had difficulty adding decimals and fractions to give an answer

**Question 7bii**

Many students gave 0.5 as the answer

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### Sample question 19

**Question 10ai.**

Probabilities add to 1

Calculation of the mean

**Question 10aii.**

From first equation

Substituting into the second equation

**Question 10bi.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |
|  |  |  |  |  |

**Question 10bii.**

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### Sample question 20

**Question 4a**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 |
|  |  |  |  |  |

**Question 4b**

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### Sample question 21

**Question 13a**

|  |  |  |  |
| --- | --- | --- | --- |
| Amount won | 20 | 10 | 0 |
| Probability |  |  |  |

**Question 13b**

Let the random variable X be the amount of money won by a player:

**Question 13c**

Expected payout = 6.11 – 5 = 1.11

Lui Yang is better off in the long term.

In the long term Liu Yang will likely win $1.11 per game.

**Question 13d**

Let amount to be paid be $P

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### Sample question 22

**Question 15a**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Roll two |  |  |  |
|  | Sum of two rolls | 1 | 2 | 3 | 4 |
| Roll One | 1 | 1 + 1 = 2 | 3 | **4** | **5** |
|  | 2 | 3 | **4** | **5** | **6** |
|  | 3 | **4** | 5 | **6** | **7** |
|  | 4 | **5** | **6** | **7** | **8** |

**Question 15bi**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|  |  |  |  |  |  |  |  |

**Question 15bii**

**Question 15biii**

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