

CANDIDATE
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FURTHER MATHEMATICS

9231/22

Paper 2

May/June 2019

3 hours

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF10)

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO NOT WRITE IN ANY BARCODES.

Answer **all** the questions in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

Where a numerical value is necessary, take the acceleration due to gravity to be 10 m s^{-2} .

The use of a calculator is expected, where appropriate.

Results obtained solely from a graphic calculator, without supporting working or reasoning, will not receive credit.

You are reminded of the need for clear presentation in your answers.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

This document consists of **25** printed pages and **3** blank pages.



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- 1** A particle P moves along an arc of a circle with centre O and radius 2 m. At time t seconds, the angle POA is θ , where $\theta = 1 - \cos 2t$, and A is a fixed point on the arc of the circle.

(i) Show that the magnitude of the radial component of the acceleration of P when $t = \frac{1}{6}\pi$ is 6 m s^{-2} . [2]

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(ii) Find the magnitude of the transverse component of the acceleration of P when $t = \frac{1}{6}\pi$. [2]

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- 2** A particle P moves on a straight line in simple harmonic motion. The centre of the motion is O . The points A and B are on the line on opposite sides of O such that $OA = 3.5$ m and $OB = 1$ m. The speed of P when it is at B is twice its speed when it is at A . The maximum acceleration of P is 1 m s^{-2} .

(i) Find the speed of P when it is at O .

[4]

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

(ii) Find the time taken by P to travel directly from A to B .

[4]

[illegible]

- 3 Three uniform small spheres A , B and C have equal radii and masses $2m$, $4m$ and m respectively. The spheres are moving in a straight line on a smooth horizontal surface, with B between A and C . The coefficient of restitution between each pair of spheres is e . Spheres A and B are moving towards each other with speeds $2u$ and u respectively. The first collision is between A and B .

(i) Find the velocities of A and B after this collision. [3]

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Sphere C is moving towards B with speed $\frac{4}{3}u$ and now collides with it. As a result of this collision, B is brought to rest.

(ii) Find the value of e . [4]

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(iii) Find the total kinetic energy lost by the three spheres as a result of the two collisions. [3]

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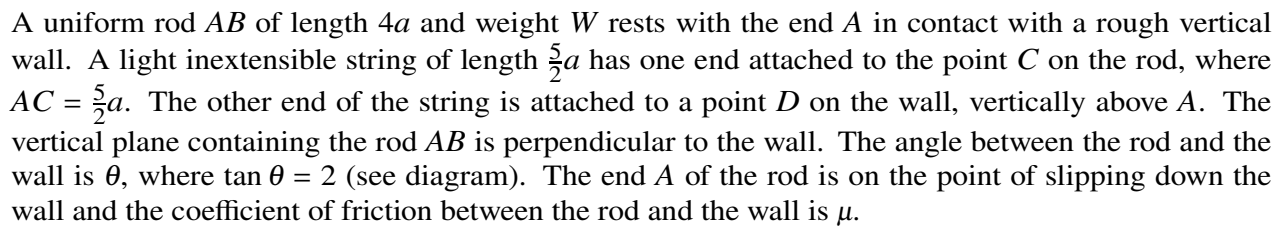
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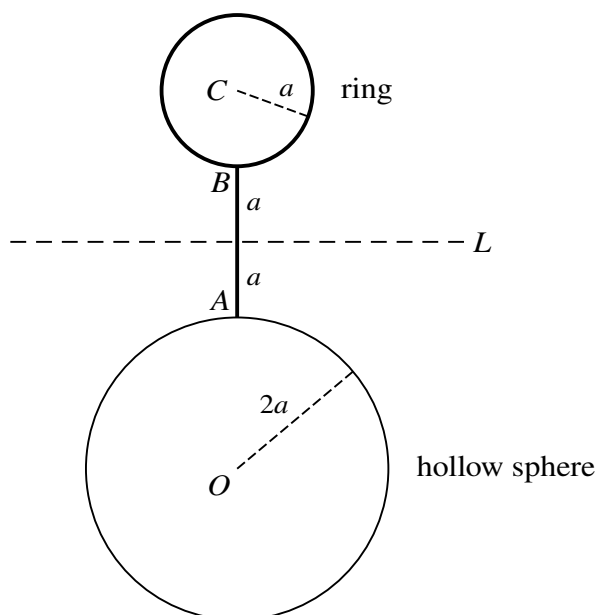
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[10]

This image shows a full page of white paper with horizontal dashed lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



A thin uniform rod AB has mass kM and length $2a$. The end A of the rod is rigidly attached to the surface of a uniform hollow sphere with centre O , mass kM and radius $2a$. The end B of the rod is rigidly attached to the circumference of a uniform ring with centre C , mass M and radius a . The points C, B, A, O lie in a straight line. The horizontal axis L passes through the mid-point of the rod and is perpendicular to the rod and in the plane of the ring (see diagram). The object consisting of the rod, the ring and the hollow sphere can rotate freely about L .

- (i) Show that the moment of inertia of the object about L is $\frac{3}{2}(8k + 3)Ma^2$. [6]

[illegible]

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- This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

- 6** A fair six-sided die is thrown until a 3 or a 4 is obtained. The number of throws taken is denoted by the random variable X .

(i) State the mean value of X . [1]

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(ii) Find the probability that obtaining a 3 or a 4 takes exactly 6 throws. [1]

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(iii) Find the probability that obtaining a 3 or a 4 takes more than 4 throws. [2]

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- (iv) Find the greatest integer n such that the probability of obtaining a 3 or a 4 in fewer than n throws is less than 0.95. [3]

This image shows a full page of a handwriting practice worksheet. It consists of approximately 20 horizontal rows. Each row is defined by two parallel dotted lines, creating a series of uniform gaps for letter height. The entire page is otherwise blank, with no margins, text, or other markings.

7 The continuous random variable X has probability density function f given by

$$f(x) = \begin{cases} \frac{3}{4x^2} + \frac{1}{4} & 1 \leq x \leq 3, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Find the distribution function of X .

[3]

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

- (ii) Find the exact value of the interquartile range of X .

[5]

This image shows a full page of white paper with horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

- 8** A large number of runners are attending a summer training camp. A random sample of 6 runners is chosen and their times to run 1500 m at the beginning of the camp and at the end of the camp are recorded. Their times, in minutes, are shown in the following table.

Runner	A	B	C	D	E	F
Time at beginning of camp	3.82	3.62	3.55	3.71	3.75	3.92
Time at end of camp	3.72	3.55	3.52	3.68	3.54	3.73

The organiser of the training camp claims that a runner's time will improve by more than 0.05 minutes between the beginning and end of the camp. Assuming that differences in time over the two runs are normally distributed, test at the 10% significance level whether the organiser's claim is justified. [8]

[illegible]

It is required to test the goodness of fit of the distribution with probability density function f given by

The relevant expected frequencies, correct to 2 decimal places, are given in the following table.

(i) Show how the expected frequency for $1.6 \leq x < 2.4$ is obtained. [3]

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[7]

[illegible]

- 10** The values from a random sample of five pairs (x, y) taken from a bivariate distribution are shown below.

x	3	4	4	6	8
y	5	7	q	6	7

The equation of the regression line of x on y is given by $x = \frac{5}{4}y + c$.

- (i) Given that q is an integer, find its value. [5]

This image shows a full page of a handwriting practice worksheet. It consists of multiple sets of three horizontal dashed lines, providing a guide for letter height and placement. The lines are evenly spaced across the entire page, which is otherwise blank.

(ii) Find the value of c .

[3]

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(iii) Find the value of the product moment correlation coefficient.

[3]

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A particle P , of mass m , is able to move in a vertical circle on the smooth inner surface of a sphere with centre O and radius a . Points A and B are on the inner surface of the sphere and AOB is a horizontal diameter. Initially, P is projected vertically downwards with speed $\sqrt{\left(\frac{21}{2}ag\right)}$ from A and begins to move in a vertical circle. At the lowest point of its path, vertically below O , the particle P collides with a stationary particle Q , of mass $4m$, and rebounds. The speed acquired by Q , as a result of the collision, is just sufficient for it to reach the point B .

- [illegible]

In its subsequent motion, P loses contact with the inner surface of the sphere at the point D , where the angle between OD and the upward vertical through O is θ .

(ii) Find $\cos \theta$.

[5]

[illegible]

OR

A farmer grows two different types of cherries, Type *A* and Type *B*. He assumes that the masses of each type are normally distributed. He chooses a random sample of 8 cherries of Type *A*. He finds that the sample mean mass is 15.1 g and that a 95% confidence interval for the population mean mass, μ g, is $13.5 \leq \mu \leq 16.7$.

- (i) Find an unbiased estimate for the population variance of the masses of cherries of Type *A*. [3]

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The farmer now chooses a random sample of 6 cherries of Type *B* and records their masses as follows.

12.2 13.3 16.4 14.0 13.9 15.4

- (ii) Test at the 5% significance level whether the mean mass of cherries of Type *B* is less than the mean mass of cherries of Type *A*. You should assume that the population variances for the two types of cherry are equal. [9]

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