

18 time taken by  $P$  to travel directly from  $L$  to  $M$  is 2 s .

- (b) (i) the type of each transformation, and make clear the order in which they are applied.  
is the phase difference between two points on the wave that are a distance of 0.50 m apart?

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[3]

- (iii) Find the area of the region enclosed by  $C$ .

$a$  is a positive constant. Sketch  $C_1$  and  $C_2$  on the same diagram.

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[6]

- (vi) child of weight 600 N stands in different positions on the plank.

the number of bags for which you would expect the mass of pasta to be more than 1.65 standard deviations above the mean.

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stop = ..... on [5]

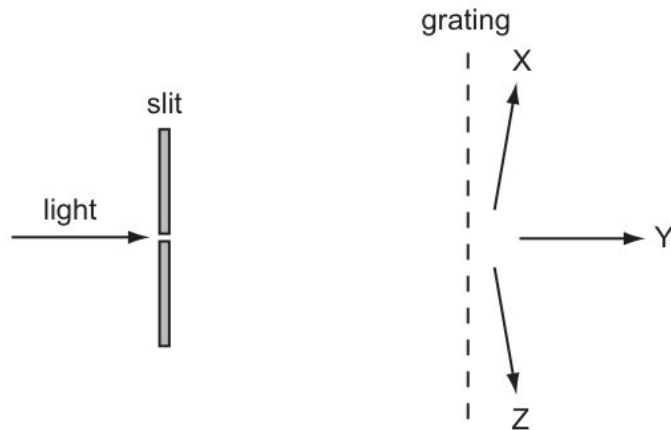
- (iv) variable resistor in (b) is fitted with a scale so that its resistance can be accurately determined.

When  $a$  and  $b$  have these values, factorise  $p(x)$  completely.

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[6]

(a) (i)



solid plastic cylinder floats in water. It is used to support one end of a horizontal uniform beam  $AB$  as shown in Fig. 2.1.

satellite in (b) is moved to an orbit in which the satellite remains at the same point above the surface of Mars.

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[5]

(ii) copper wire is 6.4 m long and has a resistance of  $0.92\Omega$ .

Using these values of  $p$  and  $q$ , find the value of the constant  $r$  for which the equation  $x^2 + px + q + r = 0$  has equal roots.

is given that  $f(n) = 3^{3n} + 6^{n-1}$ .

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[5]

- (v) two assumptions of the simple kinetic model of a gas.

Show that  $f(n+1) + f(n) = 28(3^{3n}) + 7(6^{n-1})$ .

that  $x^2y = z$ , show that

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[4]

- (iv) line  $l_1$  passes through the point with position vector  $8\mathbf{i} + 8\mathbf{j} - 7\mathbf{k}$  and is parallel to the vector  $4\mathbf{i} + 3\mathbf{j}$ . The line  $l_2$  passes through the point with position vector  $7\mathbf{i} - 2\mathbf{j} + 4\mathbf{k}$  and is parallel to the vector  $4\mathbf{i} - \mathbf{k}$ . The point  $P$  on  $l_1$  and the point  $Q$  on  $l_2$  are such that  $PQ$  is perpendicular to both  $l_1$  and  $l_2$ . In either order,

object of mass 8 kg slides down a line of greatest slope of an inclined plane. Its initial speed at the top of the plane is  $3 \text{ m s}^{-1}$  and its speed at the bottom of the plane is  $8 \text{ m s}^{-1}$ . The work done against the resistance to motion of the object is 120 J . Find the height of the top of the plane above the level of the bottom.

much work is done by the gas during this expansion?

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[5]

- 28 Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

the probability that both marbles chosen are the same colour.

time  $T$ , the particle strikes a smooth horizontal plane at a point which is a horizontal distance  $D$  from  $O$  and a vertical distance  $H$  below  $O$ .

ball of mass  $m$  kg is projected vertically upwards with initial speed  $U \text{ m s}^{-1}$  and moves under gravity. At time  $t$  s after projection, the ball has travelled a distance  $x$  m and its speed is  $v \text{ m s}^{-1}$ . There is a resistive force of magnitude  $mkv^2$  N, where  $k$  is a positive constant.

- (b) (iii) helium atom may be modelled as a nucleus surrounded by two electrons in diametrically opposite circular orbits, each of radius 170 pm, as shown in Fig. 2.1.

$$\sin 4y \frac{dy}{dx} = x \sin 2y \sin 3x$$

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[6]

- (iv)

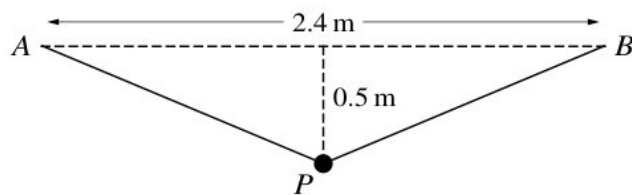
	direction of acceleration	separation of the plates
A	downwards	decrease
B	downwards	increase
C	upwards	decrease
D	upwards	increase

eigenvectors  $\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$ ,  $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$  and  $\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ . Find the eigenvalues of the matrix **AB**, and state corresponding eigenvectors.

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motion descends resistance = .....  $vq$  [2]

- (c) (iii) many images of the slit does he see?



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[12]

- (i) parametric equations of a curve are  
anywhere between point  $R$  and point  $S$

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[2]

- (a) (iii) farmer is investigating whether using a new fertiliser will increase the yield of tomato plants. The farmer selects 40 tomato plants at random and gives them the new fertiliser. The crop mass,  $x$  kg, of each of these 40 plants is recorded. The farmer selects a further 60 tomato plants at random and gives them a standard fertiliser. The crop mass,  $y$  kg, of each of these 60 plants is recorded. The results are summarised as follows.

Find the value of  $(\beta + \gamma)(\gamma + \alpha)(\alpha + \beta)$ .

car is accelerated by a constant resultant force of 300 N for 5.0 s .

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[4]

- (v) - coming to rest instantaneously on hitting the ground.

diagram shows the curve  $y = \sqrt{x} \sin 2x$  for  $0 \leq x \leq \frac{1}{2}\pi$ . The curve has a maximum point at  $M$ , where  $x = a$ .

three coplanar forces shown in the diagram act at a point  $P$  and are in equilibrium.

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[8]

- (d) (v) and N are two electromagnetic waves.

random variable  $Y$  is defined by  $Y = X^3$ . Find

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[6]

- (ii) When  $a$  and  $b$  have these values, factorise  $p(x)$  completely.

uniform solid hemisphere, of radius  $a$  and mass  $M$ , is placed with its curved surface in contact with a rough plane that is inclined at an angle  $\alpha$  to the horizontal. A particle  $P$  of mass  $m$  is attached to the rim of the hemisphere. The system rests in equilibrium with the rim of the hemisphere horizontal and  $P$  at the point on the rim that is closest to the inclined plane (see diagram). Given that the coefficient of friction between the plane and the hemisphere is  $\frac{1}{2}$ , show that

Given that, in fact, the mean concentration for patients taking the drug is 0.175, find the probability of a Type II error occurring in the test.

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[5]

- (i) wire is extended by a tensile force so that its deformation is elastic.

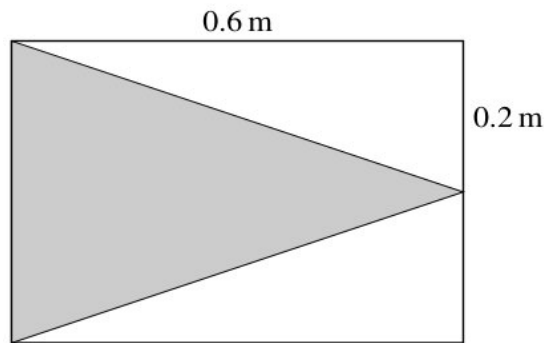
$$\frac{d^2z}{dx^2} + 4\frac{dz}{dx} + 4z = 8x^2$$

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[15]

- 11 by mathematical induction, that  $5^n + 3$  is divisible by 4 for all non-negative integers  $n$ .

- (a) (iii) Its speed decreases to a value greater than zero, then increases to  $20 \text{ ms}^{-1}$ .



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[5]

- (i) set of friends consists of 7 men and 4 women. Three of the men are brothers: Ali, Ben and Charlie.

P and Q form an isolated system.

Find the standard deviation of  $x$ .

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[5]

- (ii) the exact value of  $I_2$ .

gravitational potential at a point.

stationary firework explodes into three pieces. The masses and the velocities of the three pieces immediately after the explosion are shown.

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[6]

- (c) (iv)  $k$  is a positive constant. The relevant expected frequencies are given in the following table.

labels on the graphs are intended to show the wavelength  $\lambda$ , the period  $T$  and the amplitude  $a$  of the wave, but only one graph is correctly labelled.

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[3]

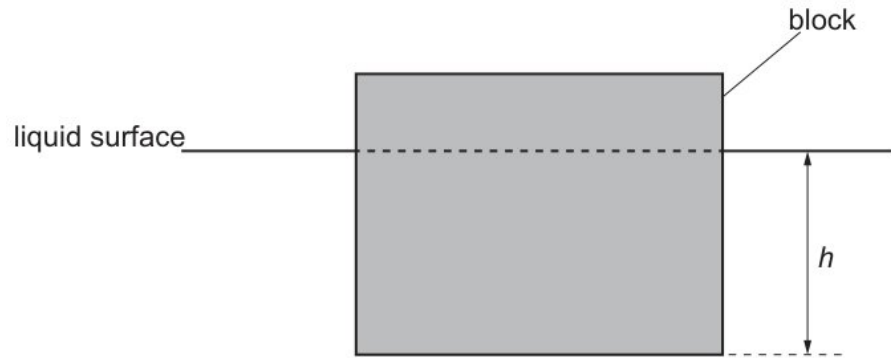
- (iii) procedure to be followed,

that the mean of these 40 values is 124.0 , find the value of  $k$ .

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moving = .....  $ea$  [3]

(ii)



parametric equations of a curve are

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[8]

- (d) (v) particle  $P$  of mass  $m$  is placed at the point  $Q$  on the outer surface of a fixed smooth sphere with centre  $O$  and radius  $a$ . The acute angle between  $OQ$  and the upward vertical is  $\alpha$ , where  $\cos \alpha = \frac{9}{10}$ . The particle is released from rest and begins to move in a vertical circle on the surface of the sphere. Show that  $P$  loses contact with the sphere when  $OP$  makes an angle  $\theta$  with the upward vertical, where  $\cos \theta = \frac{3}{5}$ , and find the speed of  $P$  at this instant.

Deduce that the cartesian equation of  $C$  is

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When = .....  $ns$  [3]

- (iv) Find the arc length of  $C$  between the point where  $\theta = 0$  and the point where  $\theta = \frac{1}{3}\pi$ .

greengrocer claims that his cabbages have a mean mass of more than 1.2 kg . In order to check his claim, he weighs 10 cabbages, chosen at random from his stock. The masses, in kg , are as follows.

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than = .....  $ao$  [5]

- (iii) changes to  $R_1$  and to  $R_2$  will increase the value of  $V_{\text{out}}$  ?

Draw up the probability distribution table for  $X$ .

1 and 2 only

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body. = .....  $ab$  [5]

- (i) Express  $\frac{5x-x^2}{(1+x)(2+x^2)}$  in partial fractions.

matrix  $\mathbf{M}$  represents a sequence of two geometrical transformations in the  $x - y$  plane

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[4]

- 9 Prove by mathematical induction that, for all positive integers  $n$ ,

uniform solid sphere with centre  $C$ , radius  $2a$  and mass  $3M$ , is pivoted about a smooth horizontal axis and hangs at rest. The point  $O$  on the axis is vertically above  $C$  and  $OC = a$ . A particle  $P$  of mass  $M$  is attached to the sphere at its lowest point (see diagram). Show that the moment of inertia of the system about the axis through  $O$  is  $\frac{84}{5}Ma^2$ .

- (iv) (a) Sound waves are transverse waves and light waves are longitudinal waves.

the probability that fewer than 10 of these customers bought a computer made by company  $F$ .

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[8]

- (b) that, when  $t = 0$ ,  $x = \frac{dx}{dt} = 0$ .

the expected value and variance of  $Y$ .

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[5]

- (f) will the powers to the resistors change when resistor  $W$  is removed?

graph shows how the acceleration of an object moving in a straight line varies with time.

are the amplitude and period of the wave?

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[8]

- (vi) (a) Use the trapezium rule with two intervals to find an approximation to the area of region  $A$ . Give your answer correct to 2 decimal places.

the range of  $f$ ,

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[6]

(c)

	wavelength	width of gap
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Find the value of  $x$  for which  $P$  reaches its maximum velocity, and calculate this maximum velocity.

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[10]

- (ii) (d) masses of the bags of rice made by a company are normally distributed with mean  $\mu$  kg and standard deviation 0.14 kg . The probability that the mass of a randomly chosen bag of this rice is less than 1.48 kg is 0.22 .

the quotient and remainder when  $x^3 + 5x^2 - 2x - 15$  is divided by  $x^2 - 3$ .

continuous random variable  $X$  has probability density function  $f$  given by

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[15]

- (b) child of weight 600 N stands in different positions on the plank.

is given that  $\sum x = 175.0$  and that the mean of  $y$  is 8.4 .

is given that  $a$  is a positive constant such that

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parallel = .....  $tb$  [5]

- (v) (c) function  $f$  is such that  $f(x) = 3 - 4 \cos^k x$ , for  $0 \leq x \leq \pi$ , where  $k$  is a constant.

that the object is on the point of toppling in its vertical plane about the vertex  $D$ , find the value of  $k$ .

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[5]

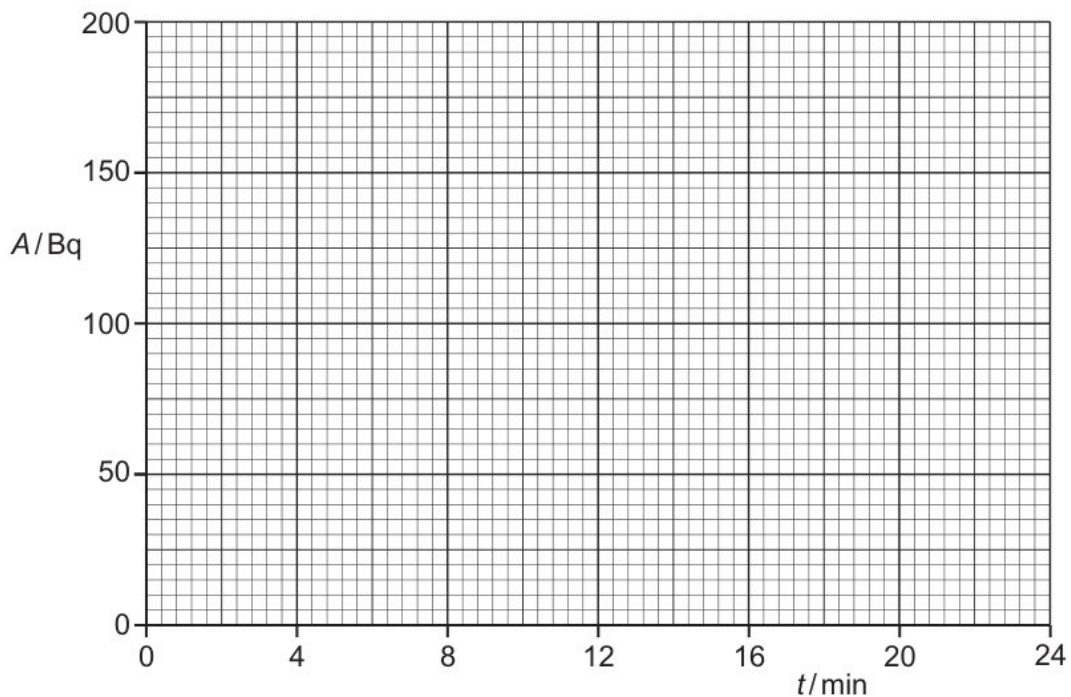
- (b) is the ratio  $\frac{\text{tension in wire } X}{\text{tension in wire } Y}$  ?

an antinode, what could be the ratio  $\frac{\text{displacement of the incident wave}}{\text{displacement of the reflected wave}}$  at any instant?

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[4]

- 9 Express  $u$  in the form  $x + iy$ , where  $x$  and  $y$  are real.



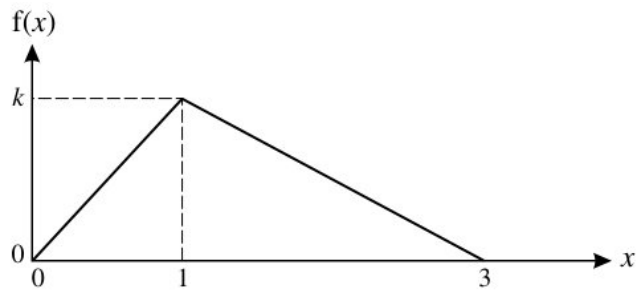
- (e) (i) much work is done by the gas during this expansion?

team of 4 is to be randomly chosen from 3 boys and 5 girls. The random variable  $X$  is the number of girls in the team.

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[6]

- (ii)



particle is moving in a circle of radius 2 m . At time  $t$  s its velocity is  $(t^2 - 12) \text{ ms}^{-1}$ . Find the magnitude of the resultant acceleration of the particle when  $t = 4$ .

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tank. smaller = .....  $zg$  [6]

- (c) (vi) in terms of  $a$ , the distance that  $P$  moves down the plane before coming to rest.  
 Show that  $x$  satisfies the equation

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[5]

- (iii) why the variation with time of the activity of a radioactive sample is exponential in nature.

$$y = \frac{3x - 9}{(x - 2)(x + 1)}$$

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[6]

- (g) (i) are the weight and the mass of the body when it is on the Moon?  
 the grid below, draw a box-and-whisker plot to summarise the information in the cumulative frequency graph.

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[10]

- (iii) Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point  $Z$ .  
 Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point  $Z$ .

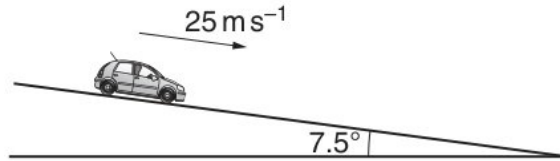
the exact value of the positive constant  $k$  for which

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[6]

18 the term isotope.

- (a) (v) block of mass 12 kg is placed on a rough plane inclined at an angle of  $\alpha$  to the horizontal, where  $\alpha = \tan^{-1} 0.5$ . A force of  $X$  N is applied to the block, directly up the plane (see diagram). The coefficient of friction between the block and the plane is  $\mu$ .



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[4]

- (iii) what is meant by centre of gravity.

people attempt a particular puzzle. The times taken, in minutes, to complete the puzzle are recorded. These times are represented in the cumulative frequency graph below.

mass of the liquid is  $0.36 \text{ kg} \pm 10\%$ .

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[15]

- (i) the principle of moments.

determine  $a$  correct to 3 decimal places. Give the result of each iteration to 5 decimal places.

determine the ratio  $\frac{V_1}{V_2}$  of the potential differences across  $R_1$  and  $R_2$ , a point is found on  $XY$  at which the lamp is off. This point is at a distance  $x$  from  $X$ .

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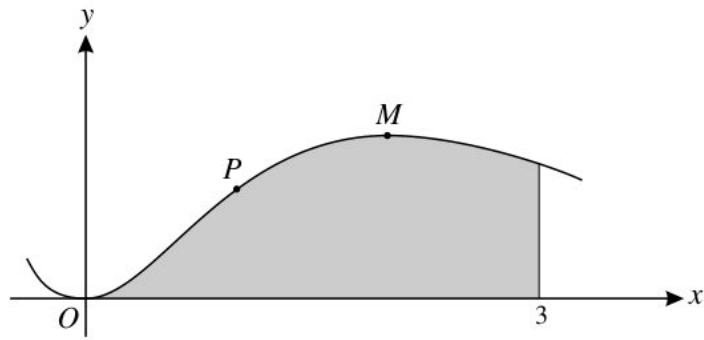
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[6]

(c) (ii)



$a, b$  and  $c$  are integers to be determined.

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[3]

(iii) suitable hypotheses, test at the 10% significance level whether there is any difference between the population means before and after the adjustments.

a result of the collision,  $A$  moves in a direction which is perpendicular to the line of centres.

Find the total work done against the resistance force as the car ascends the first ramp and descends the second ramp.

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value = .....  $cz$  [10]

16  $I_n = \int_0^1 (1-x)^n \sinh x \, dx$ , where  $n$  is a non-negative integer.

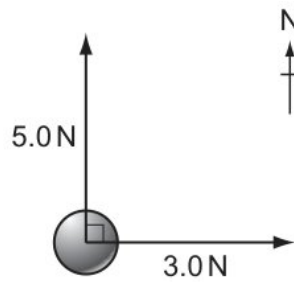
find the volume of the tetrahedron  $OABC$ , given that the volume of a tetrahedron is  $\frac{1}{3} \times$  area of base  $\times$  perpendicular height.

- (d) (i) parametric equations of a curve are  
 random variable  $Y$  is defined by  $Y = X^3$ . Find  
 sample of a radioactive substance emits particles that are positively charged and  
 have a continuous range of kinetic energies.

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[4]

(vi)

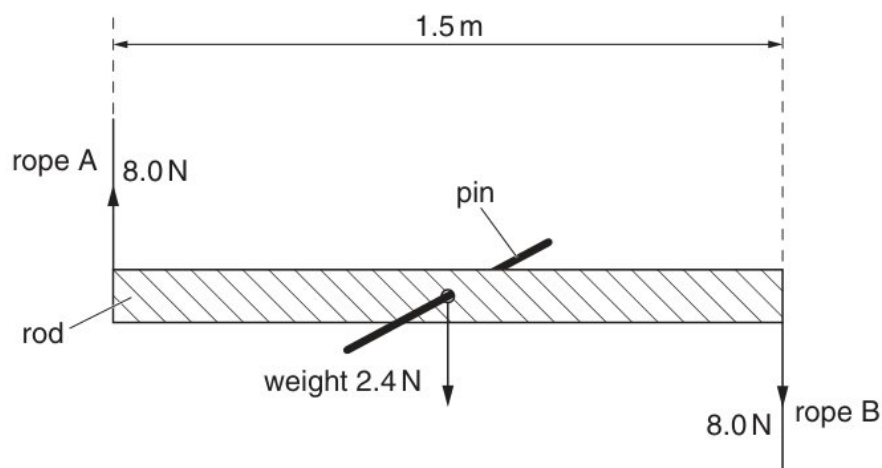


time to complete a crossword has a normal distribution with mean  $\mu$  minutes.  
 Calculate a 95% confidence interval for  $\mu$ .

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[6]

(ii)



The vector  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{A}$ , with corresponding eigenvalue  $\lambda$ , and is also an eigenvector of the matrix  $\mathbf{B}$ , with corresponding eigenvalue  $\mu$ . Show that  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{AB}$  with corresponding eigenvalue  $\lambda\mu$ .

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[12]

- (e) (i) a back-to-back stem-and-leaf diagram to represent this information, with Gulls on the left-hand side.

curves  $C_1$  and  $C_2$  have polar equations

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maintained = .....  $xe$  [4]

- (iii) the equation of the plane  $ABC$ , giving your answer in the form  $ax + by + cz = d$ .  
 are selected from these 20 to perform at a concert.

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[5]

- (ii) is the angle between the second-order maximum and the third-order maximum?

Calculate the gravitational potential  $\phi$  at the surface of Mars. Give a unit with your answer.

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through electric = .....  $wt$  [6]

- (c) (iv) Find the cartesian equation of  $\Pi_2$ .

Find the total distance travelled by the particle in the first 10 seconds of motion.

height of the orbit is increased to  $6.8 \times 10^6$  m above the surface. This increases the gravitational potential energy of the satellite by  $5.1 \times 10^8$  J.

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[3]

- (i) Saturday, 600 competitors took part. The times taken to complete the puzzle were normally distributed with mean 32.4 minutes and standard deviation 2.5 minutes.

random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

$$\int_0^a (1 + 2x + 3e^{3x}) \, dx = 250$$

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glucose = .....  $oe$  [8]

(v)  $\frac{\text{force}}{\text{length} \times \text{speed}}$

a value, to three significant figures, for the specific latent heat of fusion of water.

Find the equations of the asymptotes of  $C$ .

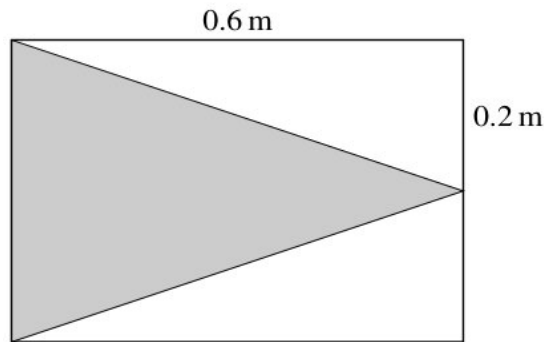
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[4]

17 object hangs by means of two cords around two rods, as shown.

Find the probability that a box is rejected.

(c) (ii) Show that  $b = 1 - a$ .



gas is enclosed inside a cylinder which is fitted with a frictionless piston.

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[4]

(i) circle is divided into 6 sectors in such a way that the angles of the sectors are in arithmetic progression. The angle of the largest sector is 4 times the angle of the smallest sector. Given that the radius of the circle is 5 cm , find the perimeter of the smallest sector.

is the magnitude of the net force acting on the ball?

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[5]

- (a) (i) is meant by elastic deformation?

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

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[12]

- (iii) the gradient of the curve

The total momentum is conserved provided that no external forces act.

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[8]

- (vi) labels on the graphs are intended to show the wavelength  $\lambda$ , the period  $T$  and the amplitude  $a$  of the wave, but only one graph is correctly labelled.

random sample of five metal rods produced by a machine is taken. Each rod is tested for hardness. The results, in suitable units, are as follows.

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[8]

- 9 1.1 shows a thin coil of cross-sectional area  $A$  and length  $l$  connected to a resistor of resistance  $S$  and two terminals.

- (c) (iii) variable resistor is used to control the current in a circuit, as shown in Fig. 5.1.  
 the probability that at least 2 of the marbles chosen are blue, given that at least 1 red marble and at least 1 blue marble are chosen.

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[8]

- (ii) Show that the kinetic energy of the electron before the collision is  $1.1 \times 10^{-15}$  J.  
the values of  $t$  such that the shortest distance between the lines  $AB$  and  $CD$  is  $\sqrt{2}$ .

four graphs represent a progressive wave on a stretched string. Graphs **A** and **B** show how the displacement  $d$  varies with distance  $x$  along the string at one instant. Graphs **C** and **D** show how the displacement  $d$  varies with time  $t$  at a particular value of  $x$ .

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[4]

- (iv) Find the values of  $a$  and  $b$ .

a laboratory experiment that uses a Hall probe to test the relationship between  $B$  and  $r$ . You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

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[3]

- (v) what is meant by the accuracy of a measured value.

Find the rank of **A** and show that  $\left\{ \begin{pmatrix} 2 \\ 2 \\ -1 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 3 \\ 0 \\ 1 \end{pmatrix} \right\}$  is a basis for the null

space of the transformation.

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[15]

- (d) (i) particle  $P$  of mass  $0.4 \text{ kg}$  is released from rest at a point  $O$  on a smooth plane inclined at  $30^\circ$  to the horizontal.  $P$  moves down the line of greatest slope through  $O$ . The velocity of  $P$  is  $v \text{ m s}^{-1}$  when its displacement from  $O$  is  $x \text{ m}$ . A retarding force of magnitude  $0.2v^2 \text{ N}$  acts on  $P$  in the direction  $PO$ .

The curve  $C$  has equation  $y = \sec^3 x$  for  $0 \leq x \leq \frac{1}{4}\pi$ . The region  $R$  is bounded by  $C$ , the  $x$ -axis, the  $y$ -axis and the line  $x = \frac{1}{4}\pi$ . Find the volume of revolution generated when  $R$  is rotated through  $2\pi$  radians about the  $x$ -axis.

Verify by calculation that this root lies between  $x = 1.1$  and  $x = 1.2$ .

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[10]

- (ii) that, when  $t = 0, x = 3$  and  $\frac{dx}{dt} = 0$ .

$$\sum_{r=1}^n \frac{1}{(2r+1)(2r+3)}$$

.....  
 .....  
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[12]

- (a) (ii) Use the iterative formula  $x_{n+1} = \frac{1}{\sin x_n}$  to determine this root correct to 2 decimal places. Give the result of each iteration to 4 decimal places.

that  $E(X) = \frac{47}{60}$ , find  $\text{Var}(X)$ .

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[8]

- (iii) random variable  $Y$  is defined by  $Y = X^3$ . Find  
 $X$  and  $Y$  are connected in series to a cell.

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[6]

- (i) weight of the parachutist is 850 N .

places the books in a row on her shelf. She is only interested in the arrangement of the colours.

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[6]

- (e) (iv)

	$v_1/\text{ms}^{-1}$	$v_2/\text{ms}^{-1}$
A	4.0	4.0
B	9.2	9.2
C	14	14
D	16	16

water is added to an insulated beaker, as shown in Fig. 2.1.

.....  
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village = .....  $xb$  [5]

- (iii) Brigville the weights, in kilograms, of boys aged 16 years have a normal distribution. 99% of the boys weigh less than 97.2 kilograms and 33% of the boys weigh less than 55.2 kilograms.

Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point  $Z$ .  
 Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point  $Z$ .

a large college, all students who study Science also study exactly one of Art or Drama or Music. 20% of these students study Art, 45% study Drama and 35% study Music.

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sides = .....  $pt$  [5]

- 13 (b) It limits the range of values obtained in repeated measurements.

(iii) State the name of this type of reaction.

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[6]

(ii) When  $a$  and  $b$  have these values, factorise  $p(x)$  completely.

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cherries = .....  $pw$  [8]

(c) and  $N$  are two electromagnetic waves.

curve  $C$  has polar equation  $r = 2a \cos(2\theta + \frac{1}{2}\pi)$  for  $0 \leq \theta < 2\pi$ , where  $a$  is a positive constant.

Show that the mass of  $P$  is 0.8 kg .

the rank of  $\mathbf{M}$  and a basis for the range space of  $T$  ,

(iv) matrix  $\mathbf{A}$  is given by

$$\mathbf{A} = \begin{pmatrix} \frac{3}{2} & 3 & 8 \\ 0 & 3 & 4 \\ 0 & 0 & -1 \end{pmatrix}.$$

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particle = .....  $az$  [4]

(ii) a matrix  $\mathbf{P}$  and a diagonal matrix  $\mathbf{D}$  such that  $\mathbf{A}^{-1} = \mathbf{PDP}^{-1}$ .

continuous random variable  $X$  has probability density function  $f$  given by

the probability that at least 2 and fewer than 8 of these competitors had times less than 36.0 minutes.

.....  
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[12]

- (iii) points  $A, B$  and  $C$  have position vectors  $2\mathbf{i} - \mathbf{j} + \mathbf{k}, 3\mathbf{i} + 4\mathbf{j} - \mathbf{k}$  and  $-\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}$  respectively.

$V$  increases because there is a p.d. across  $R$ .

.....  
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musician = .....  $uo$  [3]

- (e) Find the values of  $a$  and  $b$ .

The weight of the plank is causing a clockwise moment.

$$\mathbf{A} = \begin{pmatrix} 6 & -8 & 7 \\ 7 & -9 & 7 \\ 6 & -6 & 5 \end{pmatrix}$$

- (ii) Find the greatest height that  $P$  reaches above the level of  $O$ .

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[12]

- (i) long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

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[5]

- (iv)  $k$  is a positive constant. The relevant expected frequencies are given in the following table.

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[6]

- 7 It consists of two quarks that must both be the same flavour.

- (a) (iii) - falling freely with the parachute closed,

random sample of five metal rods produced by a machine is taken. Each rod is tested for hardness. The results, in suitable units, are as follows.

Show that the possible values of  $\alpha$  are 3 and 5 .

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[5]

- (vi) this question the use of a calculator is not permitted.

density of the water is  $\rho$ . The water does not rebound from the wall.

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[8]

- (i) Without using a calculator, find the exact values of isotopes of the element uranium are  ${}_{92}^{235}\text{U}$  and  ${}_{92}^{238}\text{U}$ .

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[2]

- (c) (i) your answer correct to 2 decimal places.

Find the arc length of  $C$  between the point where  $\theta = 0$  and the point where  $\theta = \frac{1}{3}\pi$ .

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[4]

- (ii) diagram shows four forces applied to a circular object.

aeroplane is flying horizontally. The aeroplane's engines are producing a constant power of 5500 kW , and the aeroplane experiences a constant horizontal resistance force of 25 kN .

light is passed through a narrow slit and the grating is placed so that its lines are parallel to the slit. Light passes through the slit and then the grating.

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[12]

- (vi) Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

with a reason, whether  $f$  has an inverse.

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with = ..... go [6]

- 17 car then travels up a slope at  $2^\circ$  to the horizontal, maintaining the same constant speed.

- (c) (i) State what is meant by the internal energy of a system.

Use your answer in (c)(i) to determine the half-life, in min, of the radioactive isotope.

Find the probability that the total number of cars sold in the two showrooms during 3 days is exactly 2 .

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[6]

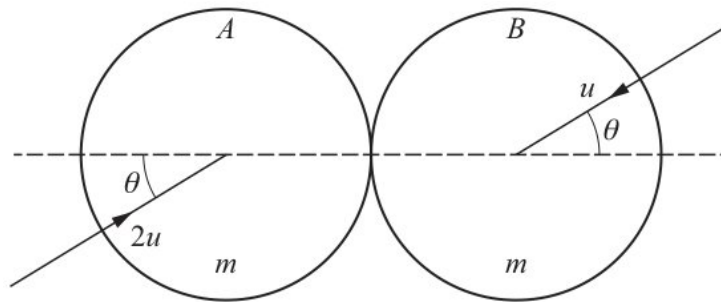
- (ii) Given that, in fact, the mean concentration for patients taking the drug is 0.175 , find the probability of a Type II error occurring in the test.

Express  $v$  in terms of  $x$ .

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[8]

- (iv)



respect to the origin  $O$ , the points  $A, B$  and  $C$  have position vectors given by

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[6]

- (d) (ii) that the eigenvalues of  $\mathbf{A}$  are  $-1, 1$  and  $5$  .

the time that it takes from when  $P$  is initially projected until the instant at which  $P$  collides with the combined particle

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standard = .....  $yx$  [2]

- (vii) Show that there is no point on  $C$  for which  $\frac{1}{3} < y < 3$ .

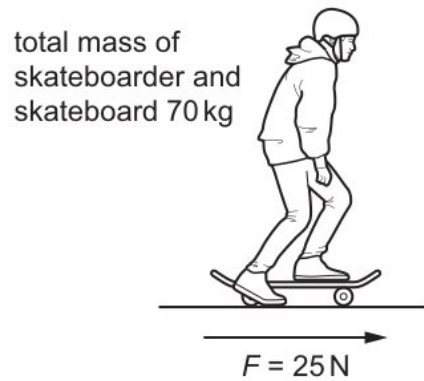
the value of  $\frac{d^2y}{dx^2}$  at  $P$ .

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[8]

- 7 the values of  $\omega z_1$  and  $\omega z_2$  Give your answers in the form  $re^{i\theta}$  where  $r > 0$  and  $-\pi < \theta \leq \pi$

- (a) (i) small ball is rolled with velocity  $v$  along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is  $p$  and the horizontal displacement of the ball is  $q$ , as shown in Fig 1.1.



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[3]

- (iii) polynomial  $ax^3 - 3x^2 - 11x + b$ , where  $a$  and  $b$  are constants, is denoted by  $p(x)$ . It is given that  $(x+2)$  is a factor of  $p(x)$ , and that when  $p(x)$  is divided by  $(x+1)$  the remainder is 12 .

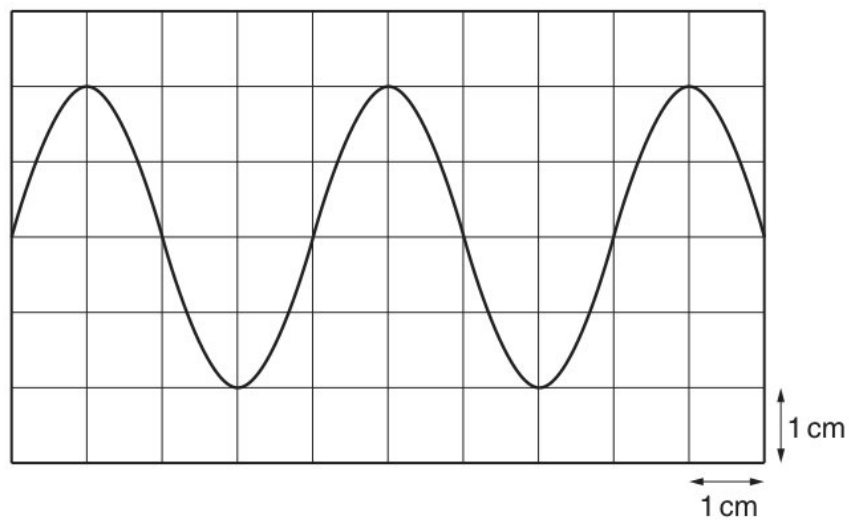
many electrons pass a point in the conductor in one minute?

circuit symbol does not represent an electric component that is designed to emit sound waves?

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[12]

(f) (v)



respect to the origin  $O$ , the points  $A$  and  $B$  have position vectors  $2\mathbf{i} + 4\mathbf{k}$  and  $5\mathbf{i} + \mathbf{j} + 6\mathbf{k}$  respectively. The line  $l_1$  passes through the points  $A$  and  $B$ .

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[5]

- (ii) a suitable approximation to find the probability that more than 50 of these competitors had times less than 36.0 minutes.

a cubic equation whose roots are  $\alpha^3 - 1, \beta^3 - 1, \gamma^3 - 1$

random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

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[6]

- (iii) 1 and 2 only

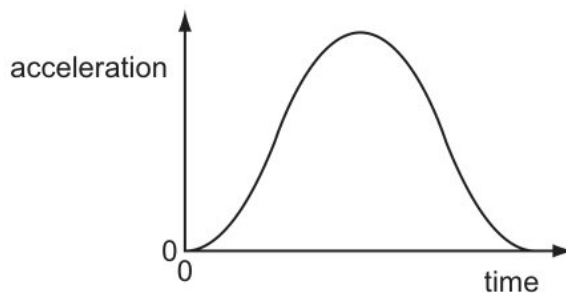
curve  $y = 4x^2 \ln x$  has one stationary point.

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 .....  
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[6]

13 Show that  $m = 0.9$ .

- (e) (iv)



by calculation that  $a$  lies between 2 and 2.1.

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[4]

- (ii) fair six-sided dice with faces labelled 1, 2, 3, 4, 5, 6 is thrown repeatedly until a 3 is obtained. The number of throws taken is denoted by the random variable  $X$ .

graph is correctly labelled?

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[8]

- (a) (v) Its speed decreases to zero, then increases to a value less than  $20 \text{ ms}^{-1}$ .

$$p(x) = 6x^3 + ax^2 + bx + 10$$

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[5]

- (i) then it converges to  $a$ .

the number of different arrangements of the 8 letters in the word KANGAROO in which the two As are together and the two Os are not together.

uniform solid hemisphere, of radius  $a$  and mass  $M$ , is placed with its curved surface in contact with a rough plane that is inclined at an angle  $\alpha$  to the horizontal. A particle  $P$  of mass  $m$  is attached to the rim of the hemisphere. The system rests in equilibrium with the rim of the hemisphere horizontal and  $P$  at the point on the rim that is closest to the inclined plane (see diagram). Given that the coefficient of friction between the plane and the hemisphere is  $\frac{1}{2}$ , show that

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[4]

(ii)



equation of a curve is  $xy + y^2e^{-x} = 4$ .

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Given time = ..... zu [4]

(vi) the exact value of  $\lim_{n \rightarrow \infty} \sum_{r=1}^n \frac{n}{n^2 + r^2}$ .

Find the constant speed that the tractor could maintain on the hill when working at this power.

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[6]

- (c) (ix) uniform metre rule of mass 100 g is supported by a pivot at the 40 cm mark and a string at the 100 cm mark. The string passes round a frictionless pulley and carries a mass of 20 g as shown in the diagram.

line  $l_3$  has equation  $\mathbf{r} = \mathbf{i} + 10\mathbf{j} + 3\mathbf{k} + v(2\mathbf{i} - 3\mathbf{j} + \mathbf{k})$ . Find the shortest distance between  $l_1$  and  $l_3$ .

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determined. = .....  $jj$  [4]

- (i) Find the value of  $a$ .

Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

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more coach = .....  $lb$  [12]

- 16 basic principle of note production in a horn is to set up a stationary wave in an air column.

$$\log_2(x + 5) = 5 - \log_2 x.$$

- (b) (i) find  $1^2 - 2^2 + 3^2 - 4^2 + \dots - (2n)^2$ , simplifying your answer.

Calculate the length  $AG$ .

observer views the slit through the grating at different angles, moving his head from  $X$  parallel to the grating, through  $Y$ , opposite the slit, to  $Z$  parallel to the grating on the opposite side.

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[4]

- (ii) a 5% significance level, test whether there is an association between the area lived in and preference for improving the local bus service or improving the quality of road surfaces.

two assumptions of the simple kinetic model of a gas.

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[8]

- (a) (i) one similarity and one difference between an electron and positron.

tension in the string when the particle is at  $Q$  is twice the tension in the string when the particle is at  $P$ .

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[3]

- (vi) P hears a sound of increasing frequency.

The resistor of resistance  $6.0\Omega$  is replaced with a filament lamp in the circuits of Fig. 5.1 and Fig. 5.3. State an advantage of using the circuit of Fig. 5.3, compared to the circuit of Fig 5.1, when using the circuits to vary the brightness of the filament lamp.

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[4]

- (c) (iv) the apparatus used to produce two sources of coherent waves that have circular wavefronts,

$\frac{1}{(2r+1)(2r+3)}$  in partial fractions and hence use the method of differences to find

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[5]

- (ii) is the effect of a systematic error on the measurement of a physical quantity?  
the subsequent motion find, in terms of  $r$ , the greatest height above  $O$  reached by the particle.

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[6]

- (iii) are the frequencies of the next two higher notes for this air column?

In some nuclear processes, mass-energy is not conserved.

Event  $X$  is 'exactly two of the selected balls have the same number'. Event  $Y$  is 'the ball selected from bag  $A$  has number 2'. Showing your working, determine whether events  $X$  and  $Y$  are independent or not.

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[6]

- 11 Find the modulus of elasticity of the string in terms of  $W$ .

point  $D$  is such that  $ABCD$  is a parallelogram.

- (c) (iv) the arc length of  $C$ ,

$$\frac{dy}{dx} - \frac{x+5}{x^2+10x+61}y = 1,$$

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[8]

- (ii) Use the trapezium rule with three intervals to estimate the value of  
random variable  $Y$  is defined by  $Y = \sqrt[3]{X}$

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[3]

- (iii) For this value of  $k$ , find the set of possible solutions, giving your answer in the form

car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.

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Kieran = ....  $zh$  [3]

- (b) (i) following table shows most of the corresponding expected frequencies, correct to 2 decimal places, using a Poisson distribution with mean 3.25.

is also known that the standard deviation of the times taken by all 50 runners is 1.38 seconds.

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[12]

- (ii)  $\frac{\text{mass}}{\text{length} \times (\text{time})^2}$

Calculate the acute angle between the planes.

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surface = .....  $di$  [3]

(a) (iii)

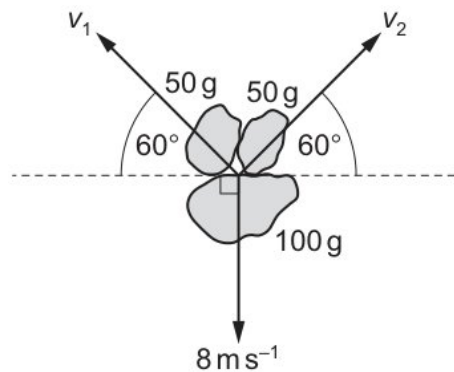
	pico (p)	giga (G)
A	$10^{-9}$	$10^9$
B	$10^{-9}$	$10^{12}$
C	$10^{-12}$	$10^9$
D	$10^{-12}$	$10^{12}$

an election 153 adults, from a random sample of 200 adults, said that they had voted. Using this information, an  $\alpha\%$  confidence interval for the proportion of all adults who voted in the election was found to be 0.695 to 0.835 , both correct to 3 significant figures. Find the value of  $\alpha$ , correct to the nearest integer.

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[10]

(ii) sample of 216 observations of the continuous random variable  $X$  was obtained and the results are summarised in the following table.



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metres results = .....  $ah$  [12]

(vi) Show that the kinetic energy of the electron before the collision is  $1.1 \times 10^{-15}$  J.  
 your answer in (b)(ii) to determine the distance of the star in (b) from the Earth.

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[6]

- 18 (c) The total momentum is conserved only in elastic collisions.

time-base setting on the oscilloscope should be used?

Length (cm)	5 – 9	10 – 14	15 – 19	20 – 24	25 – 29	30 – 39
Frequency	18	28	60	72	48	24

- (ii) analysis of the data,

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[1]

- (i) On a sketch of an Argand diagram, shade the region whose points represent complex numbers  $z$  satisfying both the inequalities  $|z - u| \leq 2$  and  $\operatorname{Re} z \geq 2$ , where  $\operatorname{Re} z$  denotes the real part of  $z$ .

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[5]

- (e) skateboarder and skateboard travel forwards a distance of 0.50 m before the skateboarder lifts her foot from the ground.
- (ii) why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

Find the exact value of the arc length of  $C$ .

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[4]

- (i) tree of mass 270 kg grows out of sloping ground and is supported by a post, as shown in Fig. 2.1.

is the speed of the projectile at this time?

tractor comes to a hill inclined at  $4^\circ$  above the horizontal. The power output is increased to 25 kW and the resistance to motion is unchanged.

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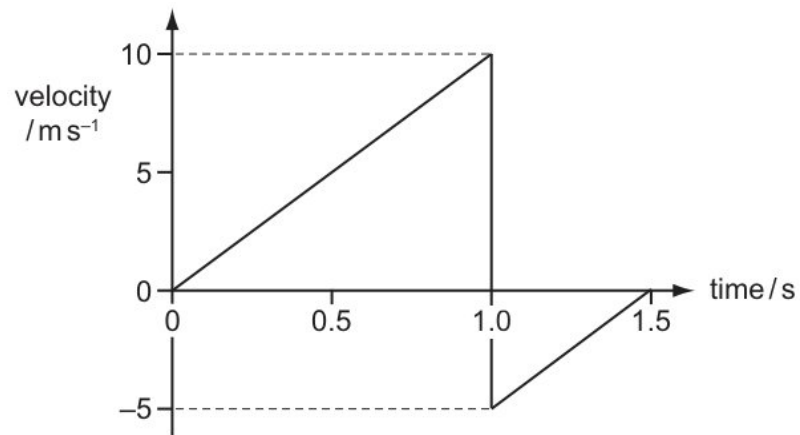
[6]

- (iv) up the probability distribution table for  $X$ .

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 .....  
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[8]

(a)



results for a random sample of 60 adults who completed the questionnaire this year are summarised as follows.

- (ix) Prove the identity  $\frac{\cos \theta}{\tan \theta(1-\sin \theta)} \equiv 1 + \frac{1}{\sin \theta}$ .

a period of time Julian finds that on long-distance flights he flies economy class on 82% of flights. On the rest of the flights he flies first class. When he flies economy class, the probability that he gets a good night's sleep is  $x$ . When he flies first class, the probability that he gets a good night's sleep is 0.9 .

the gas has a volume  $V_1$  and is in equilibrium with the external pressure  $p$ . The gas is then heated slowly so that it expands at constant pressure, pushing the piston back until the volume of the gas has increased to  $V_2$ .

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[10]

- (vi) Show that the kinetic energy of the electron before the collision is  $1.1 \times 10^{-15}$  J.

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[4]

- (iii)  $k$  is a positive constant. The relevant expected frequencies are given in the following table.

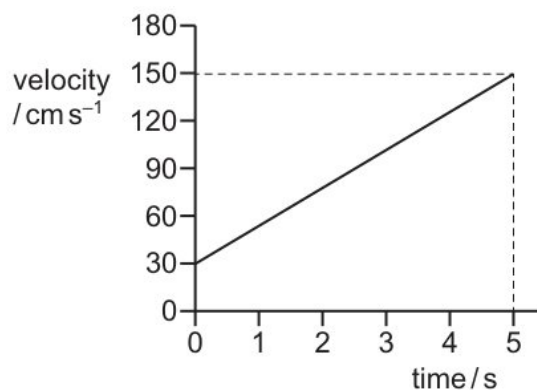
$$I_n + n(n-1)I_{n-2} = n \left( \frac{1}{2}\pi \right)^{n-1}$$

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[4]

- 15 (c) or otherwise solve the inequality  $|3x - 2a| < x + 5a$ .

- (v) For some nuclei, the nucleon number can be less than the proton number.



sub-multiples and multiples of units are indicated using a prefix to the unit. For example, the prefix milli ( m ) represents  $10^{-3}$ .

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[3]

- (i) a suitable approximation to find the probability that more than 50 of these competitors had times less than 36.0 minutes.

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positron = ..... *ts* [4]

- (iv) Calculate the distance of the centre of mass of the lamina from *A*.

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less = ..... *xr* [8]

- (iii) the probability that at least 1 of these students studies Drama.  
are selected from these 20 to perform at a concert.

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speed amplitude = .....  $fg$  [12]

- (d) parallel plates, a distance 25 mm apart, have a potential difference between them of 12 kV .

- (ii) by induction that  $u_n = 6^n - 1$  for all positive integers  $n$ .

a back-to-back stem-and-leaf diagram to represent this information, with Gulls on the left-hand side.

State one difference, which can be seen from the diagram, between the marks for History and Physics.

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[5]

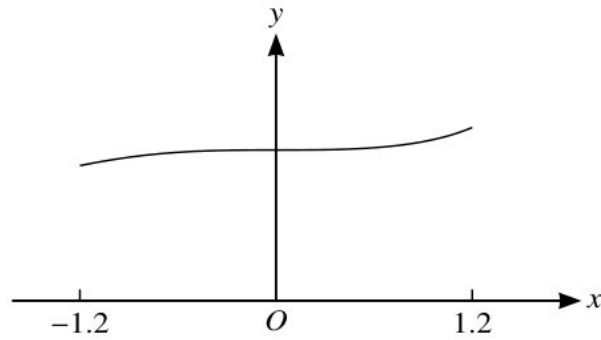
- (i) random sample of five metal rods produced by a machine is taken. Each rod is tested for hardness. The results, in suitable units, are as follows.

$$f(x) = \begin{cases} 0 & x < 1 \\ \frac{1}{2} & 1 \leq x \leq 3 \\ 0 & x > 3 \end{cases}$$

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[8]

- 20 Carry out a goodness of fit test at the 10% significance level.



electron moving at a speed of  $4.9 \times 10^7 \text{ ms}^{-1}$  collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

find  $1^2 - 2^2 + 3^2 - 4^2 + \dots - (2n)^2$ , simplifying your answer.

- (c) (ii) Carry out a goodness of fit test at the 10% significance level.

diagram shows part of the curve  $y = 4\sqrt{x} - x$ . The curve has a maximum point at  $M$  and meets the  $x$ -axis at  $O$  and  $A$ .

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chosen find find = .....  $vi$  [5]

- (iii) suitable hypotheses, test at the 10% significance level whether there is any difference between the population means before and after the adjustments.

lengths, in millimetres, of rods produced by a machine are normally distributed with mean  $\mu$  and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm .

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[6]

- (i) control of variables,

$$\log_2(x + 5) = 5 - \log_2 x.$$

Find the power output of the tractor's engine.

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[6]

- (b) (vi) that, at the point of  $C$  furthest from the initial line,

Obtain a basis for the null space of  $T$ .

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[8]

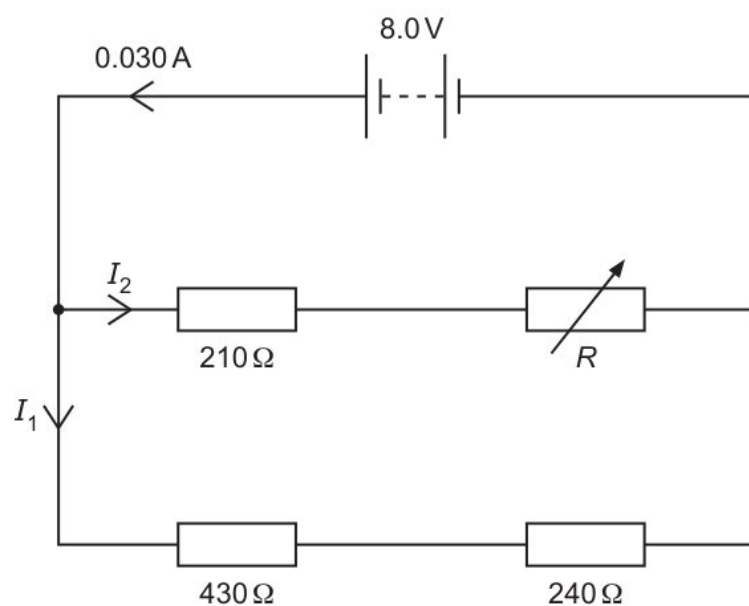
- (i) Find the modulus of elasticity of the string in terms of  $W$ .

copper wire is 6.4 m long and has a resistance of  $0.92\Omega$ .

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[2]

- (ii) the acute angle between the planes  $ABC$  and  $ABD$ .



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[12]

- 9 (b) up to antidown

- (iii) lowest mark was 17 and the highest mark was 74 .

Find the angle that the force acting on the rod at  $A$  makes with the horizontal.

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[6]

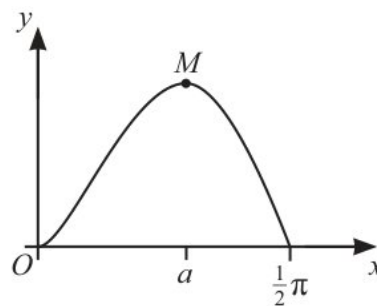
- (i) masses of small bags of pasta sold by the company are normally distributed with mean  $\mu$  kg and standard deviation  $\sigma$  kg. Tests show that 77% of these bags have masses greater than 1.26 kg and 44% have masses less than 1.35 kg.

Use the result for integrating  $\frac{1}{x^2+a^2}$  with respect to  $x$ , in the List of Formulae (MF10), to find the value of  $I_1$  and deduce that

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[5]

- (a) is given that  $k = 0.025$  and that  $U = 20$



quartile: 28, Median: 39, Upper quartile: 67.

State what happens to the electron and to the positron.

- (i) measurements to be taken,

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[8]

- (ii) the inequality  $|x + 2| > \left|\frac{1}{2}x - 2\right|$ .

Find the equation of the tangent to the curve at the point where  $\theta = \frac{1}{4}\pi$ , giving your answer in the form  $y = mx + c$ .

$$\sin 4y \frac{dy}{dx} = x \sin 2y \sin 3x$$

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[2]

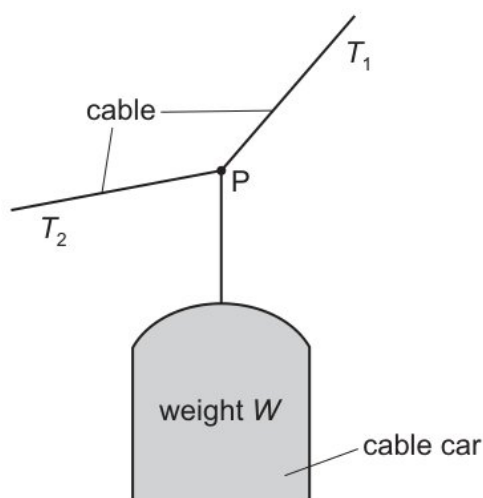
- (vi) random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

$B$  has speed  $38 \text{ m s}^{-1}$  immediately before it strikes the plane.

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[3]

(d)



how the difference in the densities of solids, liquids and gases may be related to the spacing of their molecules.

points  $A$ ,  $B$  and  $C$  have position vectors  $2\mathbf{i} - \mathbf{j} + \mathbf{k}$ ,  $3\mathbf{i} + 4\mathbf{j} - \mathbf{k}$  and  $-\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}$  respectively.

- (i) Find the  $x$ -coordinate of the point  $P$  at which the tangent to the curve passes through the origin.

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[8]

- (iii) wires are extended with the same strain and obey Hooke's law.

Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

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[8]

- (e) the probability of a Type II error.

- (i) the values of  $a$  for which the system of equations

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[8]

- (iii) the average output power of the car during this time

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that = .....  $bg$  [6]

- 23 it is given that  $y = 2$  when  $x = 1$ . Solve the differential equation and obtain an expression for  $y$  in terms of  $x$ .

Use a different object that has twice the density and the same volume as the original object.

- (b) (i) considering the sum of the areas of these rectangles, show that

independent variables  $X$  and  $Y$  have distributions with the same variance  $\sigma^2$ . Random samples of  $N$  observations of  $X$  and  $2N$  observations of  $Y$  are taken, and the results are summarised by

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[5]

- (iii) The orbit has a period of 25 hours.

that  $\frac{d}{dt}(\operatorname{sech}^{-1} t) = -\frac{1}{t\sqrt{1-t^2}}$ .

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years = ..... *ub* [4]

- (ii) Fig. 7.1, complete the charge and mass of  $\alpha$ -particles,  $\beta$ -particles and  $\gamma$ -radiation. Give example speeds of  $\alpha$ -particles and  $\gamma$ -radiation emitted by a laboratory source.

a similar method to find, in terms of  $n$ , a lower bound for  $\sum_{r=1}^n \frac{1}{\sqrt{r}} e^{\sqrt{r}}$ .

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[4]

- (c) (ii) Determine the decay constant, in  $\text{min}^{-1}$ , of the radioactive isotope.

specific heat capacity of water is  $4.18 \text{ J g}^{-1}\text{C}^{-1}$ .

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[8]

- (iii) uniform small smooth spheres  $A$  and  $B$  have equal radii and each has mass  $m$ . Sphere  $A$  is moving with speed  $u$  on a smooth horizontal surface when it collides directly with sphere  $B$  which is at rest. The coefficient of restitution between the spheres is  $\frac{2}{3}$ . Sphere  $B$  is initially at a distance  $d$  from a fixed smooth vertical wall which is perpendicular to the direction of motion of  $A$ . The coefficient of restitution between  $B$  and the wall is  $\frac{1}{3}$ .

Explain why the observed wavelength and the emitted wavelength have different values.

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[4]

- (i) filter is rotated about the normal axis through an angle  $\theta$ .

complex number  $u$  is defined by  $u = \frac{5}{a+2i}$ , where the constant  $a$  is real.

$$\mathbf{A} = \begin{pmatrix} 1 & -1 & -1 & 1 \\ 2 & -1 & -4 & 3 \\ 3 & -3 & -2 & 2 \\ 5 & -4 & -6 & 5 \end{pmatrix}.$$

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following = .....  $x_j$  [12]

- (e) (ii) State, with a reason, whether the trapezium rule gives an under-estimate or an over-estimate of the true value of the integral in part (ii).

all solutions in the interval  $0^\circ \leq \theta \leq 180^\circ$ .

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variables = .....  $mn$  [12]

- (iv) bands will be selected from the original group of 20 musicians. Each band will consist of 3 guitarists, 1 pianist and 1 drummer. No musician can be in more than one band. The first band selected will play at a concert in France, the second band selected will play in Italy and the third band selected will play in Spain.

object weighs 6.0 N on Earth.

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[1]

- (i) How many possible arrangements are there of seating Mary, Ahmad, Wayne, Elsie and John assuming there are no restrictions?

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

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[5]

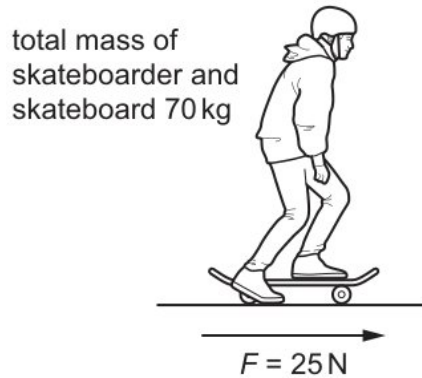
- (a) (ii) lifetime, in hours, of a 'Trulite' light bulb is a random variable  $T$ . The probability density function  $f$  of  $T$  is given by

Show that the possible values of  $\alpha$  are 3 and 5 .

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mass that = .....  $qt$  [5]

- (i)



nucleus decays by emitting a proton with speed  $v$  to form a new nucleus with speed  $u$ . The new nucleus and the proton move away from one another in opposite directions.

Find the probability that a box is rejected.

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[8]

16 row describes the momentum and kinetic energy of the two bodies after the collision?

a basis for the null space of  $T$ .

$I_n = \int_0^1 (1-x)^n \sinh x \, dx$  where  $n$  is a non negative integer

a matrix  $\mathbf{P}$  and a diagonal matrix  $\mathbf{D}$  such that  $\mathbf{A} - 2\mathbf{I} = \mathbf{P}\mathbf{D}\mathbf{P}^{-1}$ .

(a) (iv) which mark on the rule must a 50 g mass be suspended so that the rule balances?

line  $l_2$  has equation  $\mathbf{r} = 2\mathbf{i} + \mathbf{j} + 5\mathbf{k} + \mu(\mathbf{i} + 2\mathbf{j} + 3\mathbf{k})$ .

the probability that the mass of peaches sold on any given day is between 56 kg and 75 kg

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[6]

(iii) Show that  $\cos \theta = \frac{2}{3}$ .

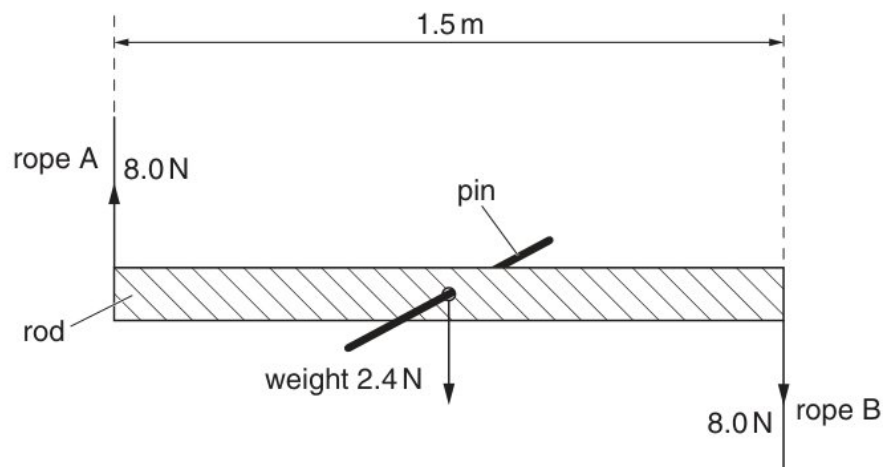
Find the area of the triangle  $ABC$ .

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[4]

- (ii) student determines the ratio  $\frac{\text{upthrust acting on the object}}{\text{weight of the object}}$ .

It is given that the determinant of  $\mathbf{A}$  is equal to the product of the eigenvalues of  $\mathbf{A}$ . Use this result to find the third eigenvalue of  $\mathbf{A}$ , and find also a corresponding eigenvector.



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[3]

- (e) (vi) variable resistor in (a) is now connected as a potential divider, as shown in Fig. 5.3.

Show that  $b = 1 - a$ .

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[4]

- (i) a group of 20 musicians, there are 9 guitarists, 6 pianists and 5 drummers.  
 cells are connected to a load resistor of resistance  $3.0\Omega$ . The electromotive force (e.m.f). and the internal resistance of each of the cells is shown.

to the origin  $O$ , the position vectors of the points  $A, B$  and  $C$  are given by

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[10]

- (iii) expression has the same SI base units as pressure?

the inequality  $|x| < |5 + 2x|$ .

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Fig. = .....  $dn$  [10]

- (c) (iii) Use the iterative formula

Given instead that  $\mu = 0$  and that the tension in the string is 0.48 N , calculate

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[10]

- (i) the distance  $AC$ .

diagram shows the force-extension graph produced.

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[8]

- 27 striking the horizontal plane,  $P$  rebounds with speed  $w$ . The coefficient of restitution between  $P$  and the plane is  $\frac{2}{3}$ .

Use de Moivre's theorem to show that

particle starts from a point  $O$  and moves in a straight line. The velocity of the particle at time  $t$  s after leaving  $O$  is  $v$  m s<sup>-1</sup>, where

Given that  $\tan 2\theta \cot \theta = 8$ , show that  $\tan^2 \theta = \frac{3}{4}$ .

- (i) (e) potential difference is applied between two metal plates that are not parallel.

Use de Moivre's theorem to show that

the probability that fewer than 6 rolls of this dice are required to obtain an A .

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[20]

- (b) Show that  $\cos \theta = \frac{2}{3}$ .

$$(n-1)I_n = 2^{\frac{1}{2}n-1} + (n-2)I_{n-2}.$$

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[2]

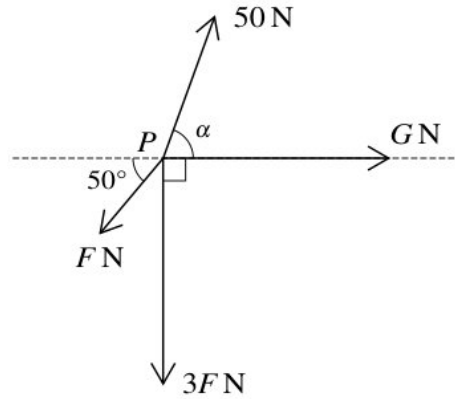
- (a) Under 25 178 181 183 192 203 209 223 231

State the name of this type of reaction.

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[4]

- (v) (b) statement about light waves and sound waves is correct?



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[5]

- (a) State, with a reason, whether the trapezium rule gives an under-estimate or an over-estimate of the true value of the integral in part (ii).

with a reason, whether  $f$  has an inverse.

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[6]

- 27 (c) Show that  $a = 19$  and find the values of  $b$  and  $c$ .

car then travels up a slope at  $2^\circ$  to the horizontal, maintaining the same constant speed.

- coming to rest instantaneously on hitting the ground.

- (ii) weight of 120 kN is placed on top of a metal column. The length of the column is compressed by 0.25 mm . The column obeys Hooke's law when compressed.

the jet of water hits the wall, it has horizontal velocity  $v$  and cross-sectional area  $A$ .

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random = .....  $yt$  [12]

- (i) The power to  $X$  will decrease and the powers to  $Y$  and  $Z$  will increase.

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[5]

- (a) polynomial  $3x^3 + pax^2 + 7a^2x + qa^3$  is denoted by  $f(x)$  where  $p, q$  and  $a$  are constants and  $a \neq 0$

- (iii) Solve the inequality  $|2x - 5| < |x + 3|$ .

$$\theta \cos \theta + \left(\frac{1}{8}\theta + 1\right) \sin \theta = 0$$

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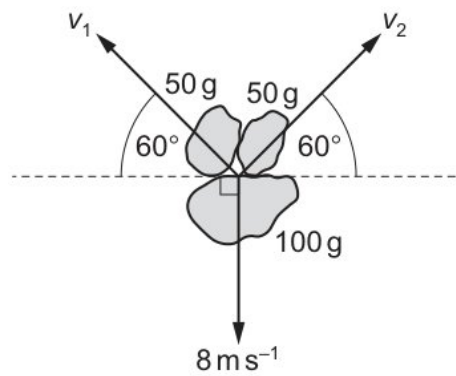
[6]

- (i) the values of  $a$  for which the system of equations

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[4]

(iv) the probability density function of  $Y$ ,



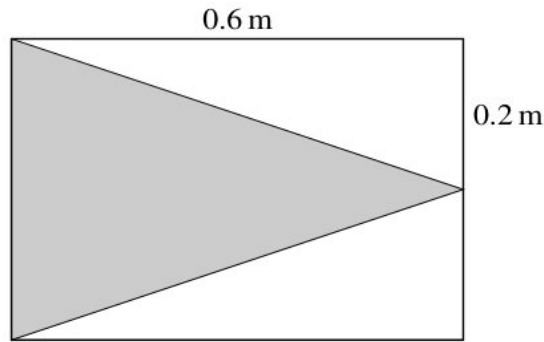
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[12]

- 12 is investigating the views of students at her school about the school sports facilities. She plans to give a survey to a sample of students.

row describes the relative ionizing power and the relative penetration power per unit length in air of  $\alpha$ -particles and  $\gamma$ -rays?

(b) (ii)



rigid body is made from uniform wire of negligible thickness and is in the form of a square  $ABCD$  of mass  $M$  enclosed within a circular ring of radius  $a$  and mass  $2M$ . The centres of the square and the circle coincide at  $O$  and the corners of the square are joined to the circle (see diagram). Show that the moment of inertia of the body about an axis through  $O$ , perpendicular to the plane of the body, is  $\frac{8}{3}Ma^2$ .

what can be deduced from this about the rotation of Mars on its axis.

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[8]

(v) is the charge, in terms of the elementary charge  $e$ , on a charm quark?

doctor is investigating the concentration of blood glucose in patients at risk of developing type 2 diabetes where blood glucose is measured in appropriate units The doctor claims that a particular intervention reduces the concentration by more than  $k$  units on average A group of 8 at risk patients is selected at random and each patient follows the intervention for six months The blood glucose concentrations before and after the intervention are given in the following table

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[3]

- (a) (v) potential difference is applied between two metal plates that are not parallel.  
a normal distribution, calculate a 95% confidence interval for the population mean.

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[8]

- (iv) waves are emitted from two sources.

particles  $A$  and  $B$  of masses 0.9 kg and 0.4 kg respectively are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the top of two inclined planes. The particles are initially at rest with  $A$  on a smooth plane inclined at angle  $\theta^\circ$  to the horizontal and  $B$  on a plane inclined at angle  $25^\circ$  to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes. A force of magnitude 2.5 N is applied to  $B$  acting down the plane (see diagram).

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[4]

- 29 Find the probability that the die lands on 4 and the number of times the coin shows heads is 2 .

It consists of three quarks that must all be the same flavour.

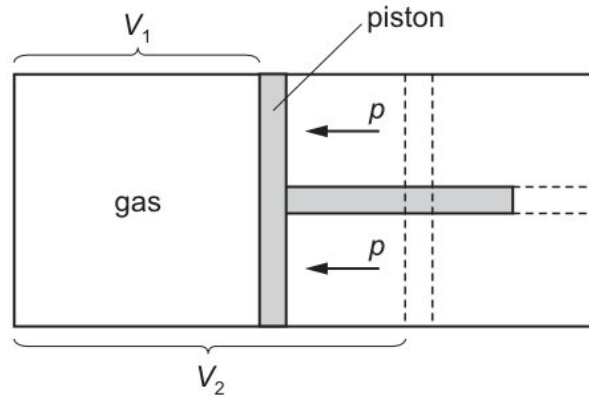
The weight of the plank is causing an anticlockwise moment.

the values of  $\omega z_1$  and  $\omega z_2$  Give your answers in the form  $re^{i\theta}$  where  $r > 0$  and  $-\pi < \theta \leq \pi$

Show that  $m = 0.9$ .

- (d) (ii) Draw up a probability distribution table for  $X$ .

values,  $x$ , in a particular set of data are summarised by



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[10]

- (iii) first coin is biased so that the probability of obtaining a head when it is thrown is  $\frac{1}{3}$ .

a laboratory experiment to determine the absorption coefficient of glass. You should

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[3]

- (i) statement is correct when  $S$  is changed from open to closed?

ages of a group of 12 people at an Art class have mean 48.7 years and standard deviation 7.65 years. The ages of a group of 7 people at another Art class have mean 38.1 years and standard deviation 4.2 years.

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horizontal = ..... es [6]

- (iv) the value of  $\sum_{r=1}^{\infty} \frac{1}{(2-3r)(5-3r)}$ .

object is free to rotate about the axis  $l$ . The object is held so that  $CA$  makes an angle  $\alpha$  with the downward vertical and is released from rest.

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[8]

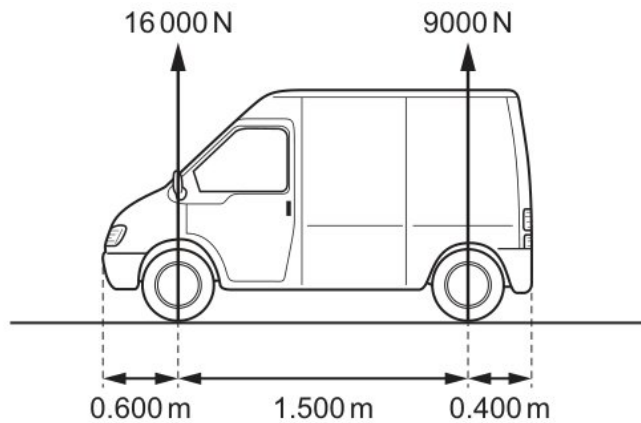
- (a) (i) waves are emitted from two sources.

$$\sum_{r=1}^n (2-3r)(5-3r) = an^3 + bn^2 + cn$$

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[5]

- (ii) Deduce the value of  $\sum_{r=1}^{\infty} \frac{2r+1}{r(r+1)(r+2)}$ .



$k$  is a positive constant. The relevant expected frequencies are given in the following table.

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[2]

- (iii) copper wire is 6.4 m long and has a resistance of  $0.92\Omega$ .

why the variation with time of the activity of a radioactive sample is exponential in nature.

matrix  $\mathbf{A}$  is given by

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either = .....  $tf$  [5]

- (b) (i) Sunday, teams of runners took part in a charity event. The time taken, in seconds, to run 50 m was recorded, correct to 1 decimal place, for each runner. The times recorded for 11 runners from each of the Gulls and the Herons are shown in the table.

much work is done by the gas during this expansion?

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They = .....  $lz$  [5]

- (ii) the complex numbers  $z$  for which  $\frac{z+5i}{z-5}$  is real and  $|z| = \sqrt{17}$  Give your answers in the form  $z = x + iy$  where  $x$  and  $y$  are real

equation  $x^3 + px + q = 0$  has a repeated root. Prove that  $4p^3 + 27q^2 = 0$ .

that  $x^2y = z$ , show that

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[4]

- (iii) Hence show that  $\sum_{r=1}^n \frac{2r+1}{r(r+1)(r+2)} = \frac{1}{2} \left\{ \frac{(2n+1)(2n+3)}{(n+1)(n+2)} - \frac{3}{2} \right\}$ .

small ball is dropped from rest from height  $h_1$  above the ground and falls vertically downwards. The ball collides with the ground and bounces back vertically upwards, reaching a maximum height  $h_2$ . Fig. 4.1 shows the ball just before and just after hitting the ground.

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[2]

- (c) (ii) the inequality  $|x| < |5 + 2x|$ .

a sketch of an Argand diagram with origin  $O$  show the points  $A, B, C$  and  $D$  representing the complex numbers  $z_1, z_2, \omega z_1$  and  $\omega z_2$  respectively

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radius, = .....  $zi$  [3]

- (i) team of 5 is chosen from 6 boys and 4 girls. Find the number of ways the team can be chosen if

4 astronauts are chosen to go on a mission. Each of these astronauts can take 3 personal possessions with him. How many different ways can these 12 possessions be arranged in a row if each astronaut's possessions are kept together?

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[10]

- (v) Find the median of  $X$ .

Hence find the exact value of  $\int_0^{\frac{1}{3}\pi} 16 \sin^5 \theta \, d\theta$ .

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[8]

- (iii) the expected value and variance of  $Y$ .

$$x = \frac{2}{5}t^{\frac{5}{2}} - 2t^{\frac{1}{2}}, \quad y = \frac{4}{3}t^{\frac{3}{2}}, \quad \text{for } 1 \leq t \leq 4.$$

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[12]

- 20 Express  $u$  in the form  $x + iy$ , where  $x$  and  $y$  are real.

- (a) (v) Use the equation of a suitable regression line to estimate the number of hours of sunshine on a day when the mid-day temperature is  $2^\circ\text{C}$ .

isolated stationary nucleus  $Q$  decays into nucleus  $R$  and an  $\alpha$ -particle. The  $\alpha$ -particle has speed  $1.5 \times 10^7 \text{ ms}^{-1}$ .

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[8]

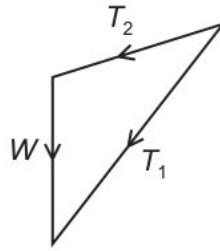
- (iv) a value, to three significant figures, for the specific latent heat of fusion of water.  
 an electron and an antineutrino

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[3]

- (ii) 8 Let  $I_n = \int_0^{\frac{1}{4}\pi} \sec^n x \, dx$  for  $n > 0$ .

curve  $C$  has polar equation  $r = a(1 + \sin \theta)$  for  $-\pi < \theta \leq \pi$ , where  $a$  is a positive constant.



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[5]

- (c) (v) cubic equation  $2x^3 - 3x^2 + 4x - 10 = 0$  has roots  $\alpha, \beta$  and  $\gamma$ .

Given that, in fact, the mean concentration for patients taking the drug is 0.175 , find the probability of a Type II error occurring in the test.

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[6]

- (iv)  $f(x) = \frac{3a-5x}{(3a+2x)(2a-x)}$  where  $a$  is a positive constant

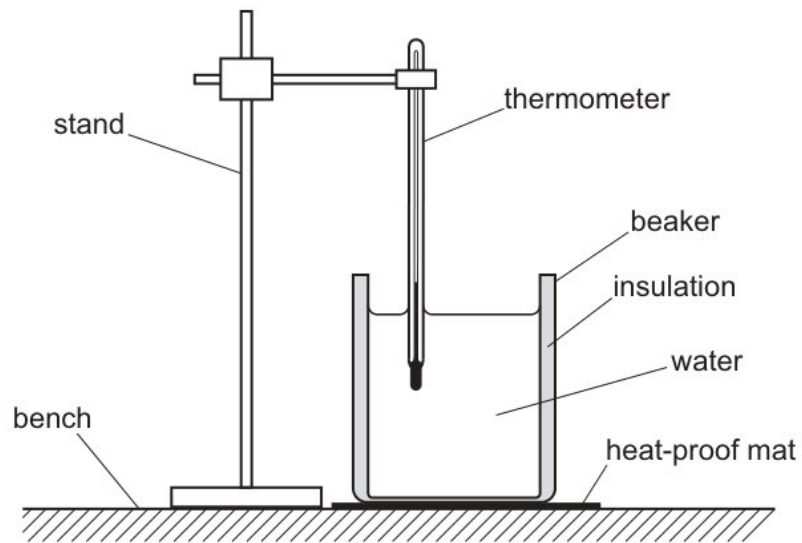
parametric equations of a curve are

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pushes = .....  $qy$  [5]

- 21 counts the number of emails,  $x$ , he receives each day and notes that, over a period of  $n$  days,  $\Sigma(x - 10) = 27$  and the mean number of emails is 11.5 . Find the value of  $n$ .

- (a) (iv) The potential difference across any component connected to the battery will be 9.0 V .



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[4]

- (iii) Show that the mean number of rooms that are occupied each night is 3.25 .  
 continuous random variable  $X$  has probability density function  $f$  given by

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[4]

- (i) random variables  $X$  and  $Y$  have the independent distributions  $N(44, 16)$  and  $N(30, 9)$  respectively.

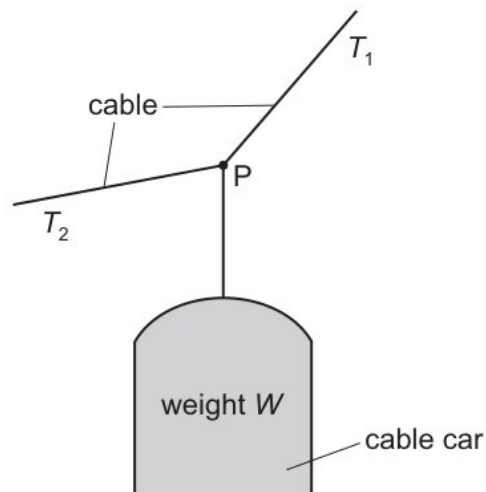
ball of mass  $m$  kg is projected vertically upwards with initial speed  $U$  m s<sup>-1</sup> and moves under gravity. At time  $t$  s after projection, the ball has travelled a distance  $x$  m and its speed is  $v$  m s<sup>-1</sup>. There is a resistive force of magnitude  $mkv^2$  N, where  $k$  is a positive constant.

resistors of equal value are connected as shown.

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[1]

- (d) (ii) The vector  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{A}$ , with corresponding eigenvalue  $\lambda$ , and is also an eigenvector of the matrix  $\mathbf{B}$ , with corresponding eigenvalue  $\mu$ . Show that  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{AB}$  with corresponding eigenvalue  $\lambda\mu$ .



row gives the sub-multiples or multiples represented by pico (p) and giga(G)?

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[4]

- (i) force is caused only by a pressure difference?  
does this mean?

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[5]

- (c) (iii) electron moving at a speed of  $4.9 \times 10^7 \text{ ms}^{-1}$  collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

potential divider consists of two resistors of resistances  $R_1$  and  $R_2$  connected in series across a source of potential difference (p.d.)  $V_{\text{in}}$ . The p.d. across  $R_1$  is  $V_{\text{out}}$ . Show that there is no point on  $C$  for which  $\frac{1}{3} < y < 3$ .

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rest string = ..... *bi* [5]

- (v) sample contains a single radioactive isotope that decays to form a stable isotope. that, when  $t = 0, x = \frac{dx}{dt} = 0$ .

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[1]

- 19 Hence, or otherwise, obtain an expression for  $f^{-1}(x)$ .

the number of different ways in which the 12 letters of the word STRAWBERRIES can be arranged

- (i) (b) does this mean?

$$f(x) = \frac{3a-5x}{(3a+2x)(2a-x)} \text{ where } a \text{ is a positive constant}$$

The matrix  $\mathbf{B}$  is given by  $\mathbf{B} = \mathbf{A} - 2\mathbf{I}$ , where  $\mathbf{I}$  is the  $3 \times 3$  identity matrix. Write down the eigenvalues of  $\mathbf{B}$ , and state a set of corresponding eigenvectors.

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[3]

- (a) that the eigenvalues of  $\mathbf{A}$  are  $-1, 1$  and  $5$ .

cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

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onto = ..... eh [6]

- (iv) (b) statement is correct when  $S$  is changed from open to closed?

Find the exact area of the shaded region.

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[6]

- (a)

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Observed frequency	1	3	15	31	59	107

the number of different ways in which these three bands can be selected.

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[15]

- (c) Find the  $x$ -coordinate of the maximum point  $M$  on the curve.

Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

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point determine = .....  $ge$  [10]

- (v) (b) particle of mass  $m$  and charge  $+Q$  moves at speed  $v$  into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

$$\int_{-1.2}^{1.2} \frac{3}{\sqrt{(9-x^3)}} dx$$

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[5]

- (g) that the area of the region bounded by the initial line, the arc of  $C_1$  from  $\theta = 0$  to  $\theta = \beta$ , and the arc of  $C_2$  from  $\theta = \beta$  to  $\theta = \frac{1}{4}\pi$  is

$$\omega^4 - \omega^3 + \omega^2 - \omega = -1$$

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[5]

- (ii) (d) volume of oil. Pressure is applied by a pump. The applied pressure is measured on a

$$\Sigma x = 18.7 \quad \Sigma x^2 = 106.43 \quad \Sigma y = 34.7 \quad \Sigma y^2 = 133.43 \quad \Sigma xy = 92.01$$

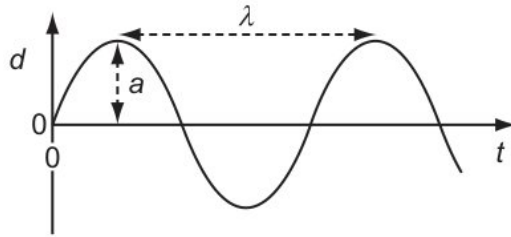
this compression, work  $W$  is done on the gas.

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[3]

(c) up to down

variables  $x$  and  $y$  satisfy the differential equation



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[15]

- 15 small ball  $B$  is projected from a point  $O$  which is  $h$  m above a horizontal plane. At time 2 s after projection  $B$  has speed  $18 \text{ m s}^{-1}$  and is moving in the direction  $30^\circ$  above the horizontal.

- (a) (iii) satellite of mass 122 kg is in orbit around Mars at a constant height of  $1.7 \times 10^6$  m above the surface of the planet.

uniform solid sphere with centre  $C$ , radius  $2a$  and mass  $3M$ , is pivoted about a smooth horizontal axis and hangs at rest. The point  $O$  on the axis is vertically above  $C$  and  $OC = a$ . A particle  $P$  of mass  $M$  is attached to the sphere at its lowest point (see diagram). Show that the moment of inertia of the system about the axis through  $O$  is  $\frac{84}{5}Ma^2$ .

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[12]

- (i) acceleration of free fall on Pluto is  $0.66 \text{ m s}^{-2}$ .

that, at the point of  $C$  furthest from the initial line,

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[5]

- (ii) points  $A, B$  and  $C$  have position vectors  $2\mathbf{i} - \mathbf{j} + \mathbf{k}, 3\mathbf{i} + 4\mathbf{j} - \mathbf{k}$  and  $-\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}$  respectively.

logarithms to solve the equation  $3^x = 2^{x+2}$ , giving your answer correct to 3 significant figures.

plank has a mass of 7.0 kg and has a pivot at its midpoint. The plank is horizontal and in equilibrium.

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[4]

- (c) (ix) is the force exerted on the wall by the water?

lengths, in millimetres, of rods produced by a machine are normally distributed with mean  $\mu$  and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm .

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[5]

- (vii)

	amplitude /V	period /ms
A	1.5	4
B	5.0	10
C	6.0	20
D	12.0	20

There will always be 9.0 V across the battery terminals.

.....  
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Elsie village = .... *gr* [4]

- (ii) Find the arc length of  $C$  between the point where  $\theta = 0$  and the point where  $\theta = \frac{1}{3}\pi$ .

Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point  $Z$ .

1.1 shows a thin coil of cross-sectional area  $A$  and length  $l$  connected to a resistor of resistance  $S$  and two terminals.

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along When = .....  $tz$  [4]

- 12 in exact form the set of values of  $x$  for which  $\left| \frac{2x^2-5x}{2x^2-7x-4} \right| < \frac{1}{9}$ .

- (e) (i) a time 8.4 minutes later, the activity is 120 Bq .

Hence find the largest integer  $y$  satisfying the inequality  $|2 \ln y - 5| < |\ln y + 3|$ .

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[8]

- (iii) the probability that at least 1 of these students studies Drama.

Draw a sketch of  $C$  for the case  $\lambda > 3$ .

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[3]

- (ii) uniform rod of length 1.5 m and weight 2.4 N is shown in Fig. 2.1.

researcher records the time,  $T$  seconds, taken by adults to complete a questionnaire.  
The waves must be coherent.

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[5]

- (c) (iv) continuous random variable  $X$  has probability density function  $f$  given by  
your answer in (b)(ii) to determine the distance of the star in (b) from the Earth.

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[3]

- (ii) region enclosed between the  $x$  axis and the curve is rotated through  $2\pi$  radians  
about the  $x$  axis

Use a different object that has half the volume and the same density as the original  
object.

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[15]

- (a) (ii) Show that the mean number of rooms that are occupied each night is 3.25 .

$$\log_2(x + 5) = 5 - \log_2 x$$

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[8]

- (i) State one other feature of this orbit.

$$f(x) = \frac{3a-5x}{(3a+2x)(2a-x)} \quad \text{where } a \text{ is a positive constant}$$

.....  
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[6]

- (iv) Find the solution of the equation  $\mathbf{Ax} = \begin{pmatrix} 3 \\ 7 \\ 18 \\ -7 \end{pmatrix}$  of the form  $\mathbf{x} = \begin{pmatrix} 4 \\ 9 \\ \alpha \\ \beta \end{pmatrix}$ , where

$\alpha$  and  $\beta$  are positive integers to be found.

Find the probability that exactly two of the selected balls have the same number.

.....  
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[2]

15 the equation for this decay.

- (c) (ii) transmitted light has intensity  $0.75I$ .

Show that  $x$  satisfies the equation

$$2 \tan \theta = -\tan 2\theta$$

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[6]

- (i) a normal distribution, calculate a 95% confidence interval for the population mean.

$$\text{Hence show that } \sum_{r=1}^n \frac{2r+1}{r(r+1)(r+2)} = \frac{1}{2} \left\{ \frac{(2n+1)(2n+3)}{(n+1)(n+2)} - \frac{3}{2} \right\}.$$

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[8]

- (iii) time  $T$ , the particle strikes a smooth horizontal plane at a point which is a horizontal distance  $D$  from  $O$  and a vertical distance  $H$  below  $O$ .

Using a 5% significance level, test whether there is non-zero correlation between the variables.

a value, to three significant figures, for the specific latent heat of fusion of water.

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[2]

- (b) (ii) other teams of runners, the Eagles and the Swifts, also took part in the event. The recorded times in seconds for 20 runners from the Eagles and 30 runners from the Swifts are denoted by  $x$  and  $y$  respectively.

lengths, in millimetres, of rods produced by a machine are normally distributed with mean  $\mu$  and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm .

is the gravitational force on the astronaut when the spacecraft is launched vertically upwards with an acceleration of  $0.2g$  ?

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[5]

- (v) Find the cartesian equation of the plane through  $A, B$  and  $C$ .

$$x = \tanh^{-1} t \quad \text{and} \quad y = t \operatorname{sech}^{-1} t, \quad \text{for } 0 < t < 1$$

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[12]

- (e) (ii) student is investigating a non-inverting operational amplifier (op-amp) circuit.  
Find the area of the triangle  $ABC$ .

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[4]

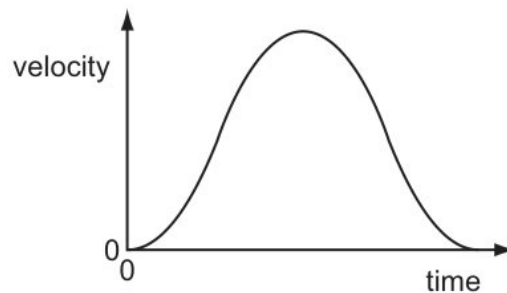
- (v) resistivity of copper is  $1.8 \times 10^{-8} \Omega \text{ m}$ .

The matrix  $\mathbf{B}$  is given by  $\mathbf{B} = \mathbf{A} - 2\mathbf{I}$ , where  $\mathbf{I}$  is the  $3 \times 3$  identity matrix. Write down the eigenvalues of  $\mathbf{B}$ , and state a set of corresponding eigenvectors.

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steel = .....  $ia$  [12]

- (iii)



de Moivre's theorem to prove that

truck R of mass 9400 kg moves with constant acceleration in a straight line down a slope, as illustrated in Fig. 3.1.

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bulbs that = .....  $rd$  [8]

18 the particular solution of the differential equation

- (b) (iii) Show that the kinetic energy of the electron before the collision is  $1.1 \times 10^{-15}$  J. with a reason, whether it was necessary to use the Central Limit Theorem in your answer to part (b).

Find  $\frac{d}{dx} \left( x (4 + x^2)^{-n} \right)$  and hence show that

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[2]

- (iv) Carry out the test.

identical uniform smooth spheres  $A$  and  $B$ , each with mass  $m$ , are moving on a horizontal surface with speeds  $2u$  and  $u$  respectively when they collide. Immediately before the collision, the spheres are moving parallel to each other in opposite directions such that their directions of motion each make an angle  $\theta$  with the line of centres (see diagram). As a result of the collision,  $B$  moves in a direction which is perpendicular to its initial direction of motion. The coefficient of restitution between the spheres is  $e$ .

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[6]

- (ii) particle of mass  $m$  and charge  $+Q$  moves at speed  $v$  into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

the complex numbers  $z$  for which  $\frac{z+5i}{z-5}$  is real and  $|z| = \sqrt{17}$  Give your answers in the form  $z = x + iy$  where  $x$  and  $y$  are real

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[4]

- (e) (ii) the probability that, when the 3 cars are selected, at least one car is white and at least one car is black.

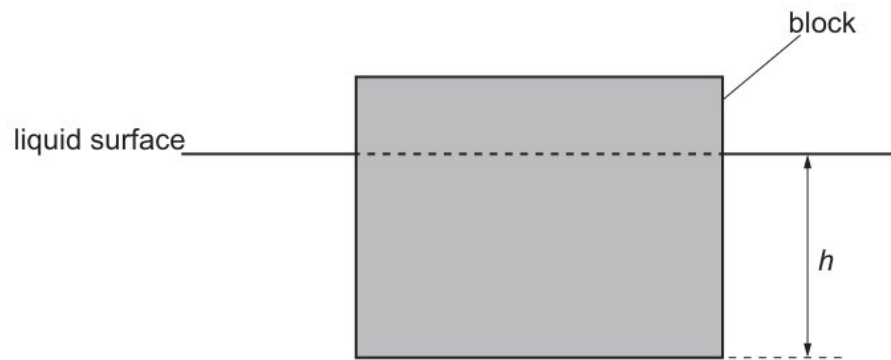
microphone connected to a cathode ray oscilloscope (c.r.o.) is positioned between L and S as shown in Fig. 6.1. The trace obtained on the c.r.o. is shown in Fig. 6.2.

Deduce that the cartesian equation of  $C$  is

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[5]

- (iv)



the probability of a Type I error.

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[4]

- (i)  $3 \times 3$  matrix  $\mathbf{A}$  has eigenvalues  $-1, 1, 2$ , with corresponding eigenvectors  
 is the value of the ratio  $\frac{V_1}{V_2}$  ?

.....  
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[15]

- (iii) Given instead that  $G = 0$  and the forces are in equilibrium, find the values of  $F$  and  $\alpha$ .

what is meant by the de Broglie wavelength.

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chosen number many = ..... *pu* [3]

22 the probability density function of  $Y$ ,

- (iii) (e) control of variables,

coplanar forces of magnitudes 40 N, 30 N and  $X$  N act at a point in the directions shown in the diagram.

$$\sum_{r=1}^n \frac{n}{n^2 + r^2} < \frac{1}{4}\pi$$

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springs = ..... *ew* [5]

- (c) Without using a calculator, find the exact values of

Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

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[3]

- (f) a vector equation for  $l$ .

the probability that the second A is obtained on the 6th roll of the dice.

de Moivre's theorem to prove that

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[15]

- (v) (a) sample contains a single radioactive isotope that decays to form a stable isotope.  
Use implicit differentiation to show that

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[5]

- (d) body travelling with a speed of  $10 \text{ ms}^{-1}$  has kinetic energy  $1500 \text{ J}$  .  
Find the deceleration of the tractor at the instant it begins to climb the hill.

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[6]

- (i) (a)  $V$  remains the same because the decrease of p.d. across  $r$  is balanced by the increase of p.d. across  $R$ .

Use the trapezium rule with two intervals to find an approximation to the area of region  $A$ . Give your answer correct to 2 decimal places.

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[8]

- (c) is the work done by  $F$  on the skateboarder and skateboard?  
is suggested that the e.m.f.  $V$  is related to the number  $n$  of glass sheets by the equation

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[5]

- (d) the value of  $\int_0^{\frac{2}{3}\pi} \sin\left(\frac{1}{2}x\right) dx$ .

is the gravitational force on the astronaut when the spacecraft is launched vertically upwards with an acceleration of  $0.2g$  ?

first artificial radioactive substance was made by bombarding aluminium,  ${}^{27}_{13}\text{Al}$ , with  $\alpha$ -particles. This produced an unstable isotope of phosphorus,  ${}^{30}_{15}\text{P}$ .

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[6]

24 Use de Moivre's theorem to show that

- (a) (vi) tractor of mass 3700 kg is travelling along a straight horizontal road at a constant speed of  $12 \text{ m s}^{-1}$ . The total resistance to motion is 1150 N .

considering the binomial expansion of  $\left(z - \frac{1}{z}\right)^5$ , where  $z = \cos \theta + i \sin \theta$ , use de Moivre's theorem to show that

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[4]

- (vii)  $V$  remains the same because the sum of the p.d.s across  $r$  and  $R$  is still equal to  $E$ .

a cubic equation whose roots are  $\alpha^3 - 1, \beta^3 - 1, \gamma^3 - 1$ .

a different investigation, Nikki uses another large random sample to calculate a 99% confidence interval and an  $x\%$  confidence interval.

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[15]

- (i) the nucleus of  ${}_{92}^{238}\text{U}$  absorbs a neutron, the nucleus decays, emitting an  $\alpha$ -particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the  $\alpha$ -particle.

Find the greatest height that  $P$  reaches above the level of  $O$ .

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[3]

- (b) (i) the method of differences to find  $\sum_{r=1}^n \frac{1}{(2-3r)(5-3r)}$  in terms of  $n$ .  
 equation  $x^3 + px + q = 0$  has a repeated root. Prove that  $4p^3 + 27q^2 = 0$ .

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[6]

- (iii) Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

the values of  $p$  and  $q$

Find the equation of the tangent to the curve at  $P$ .

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[5]

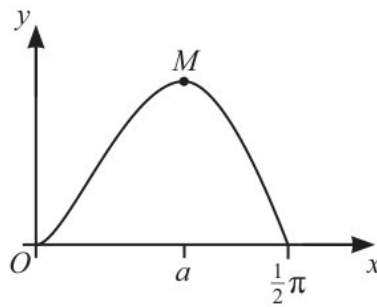
- (ii) curve  $C$  has equation  $y = \frac{2x^2-5x}{2x^2-7x-4}$ .

diagram shows two waves  $R$  and  $S$ .

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[5]

(c) (iv)



expression calculates the fractional uncertainty in the value of this speed?

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[6]

- (i) graph shows the variation with temperature of power,  $P$ , dissipated in the thermistor?

gas is enclosed inside a cylinder which is fitted with a frictionless piston.

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[8]

- (iii) de Moivre's theorem to show that

Given that the equilibrium is limiting, find the coefficient of friction between the bead and the rod.

helium atom may be modelled as a nucleus surrounded by two electrons in diametrically opposite circular orbits, each of radius 170 pm, as shown in Fig. 2.1.

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horizontal = .....  $yk$  [2]

- 20 Fig. 7.1, complete the charge and mass of  $\alpha$ -particles,  $\beta$ -particles and  $\gamma$ -radiation. Give example speeds of  $\alpha$ -particles and  $\gamma$ -radiation emitted by a laboratory source.

Stating suitable hypotheses and assuming a normal distribution, test the coach's belief at the 10% significance level.

- (a) (i) 1 and 2 only

Verify that  $\frac{2r+1}{r(r+1)(r+2)} = \frac{1}{2} \left\{ \frac{(2r+1)(2r+3)}{(r+1)(r+2)} - \frac{(2r-1)(2r+1)}{r(r+1)} \right\}$ .

is the total resistance between the two ends of the coil?

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[4]

- (iv) that  $\tan 2a = -4a$

that  $0 < y < \frac{1}{2}\pi$ , find the values of  $y$  when  $x = 0$ .

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[10]

- (ii) points  $A, B, C$  have position vectors

values,  $x$ , in a particular set of data are summarised by

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[8]

- (c) (v) random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

what time will some portion of the wavefront  $GH$  reach point  $P$ ?

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[8]

- (iii) Find also the exact value of the surface area generated when  $C$  is rotated through  $2\pi$  radians about the  $x$ -axis.

$$\mathbf{B} = \begin{pmatrix} 3 & 6 & 1 \\ 1 & -2 & -1 \\ 6 & 6 & -2 \end{pmatrix},$$

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[6]

- (iv) flows out of a pipe and hits a wall.  
 the values of the constants  $k_1$  and  $k_2$  are to be determined.

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[5]

- 20 sub-multiples and multiples of units are indicated using a prefix to the unit. For example, the prefix milli ( m ) represents  $10^{-3}$ .

- (e) (iii) Fig. 7.1, complete the charge and mass of  $\alpha$ -particles,  $\beta$ -particles and  $\gamma$ -radiation. Give example speeds of  $\alpha$ -particles and  $\gamma$ -radiation emitted by a laboratory source.

Given instead that  $G = 0$  and the forces are in equilibrium, find the values of  $F$  and  $\alpha$ .

three coplanar forces shown in the diagram act at a point  $P$  and are in equilibrium.

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[5]

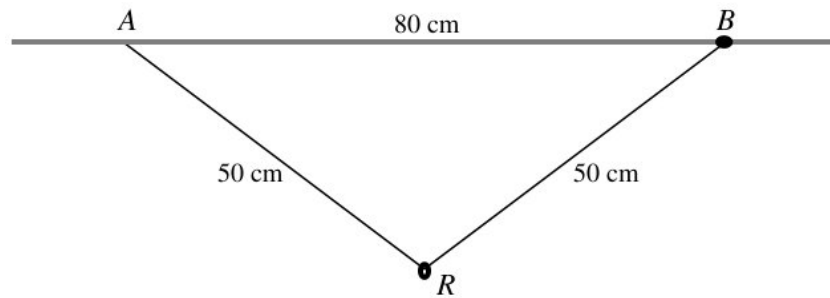
- (v) Show that  $\cos \theta = \frac{2}{3}$ .

how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

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[5]

- (c) (iii) the equations of the asymptotes of  $C$



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[8]

- (i) why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

Calculate the exact value of  $I_1$  and deduce the exact value of  $I_3$ .

moment of a force.

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[5]

- (ii) of these springs is placed in each corner of a horizontal square plate. The axis of each spring is in a vertical direction. These four springs support a total load of 160 N .

$$8nI_{n+1} = (2n - 1)I_n + 2 \times 8^{-n}$$

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[3]

- 21 (c) that  $y = 0$  when  $x = 0$ . Give your answer in an exact form.

- (iv) is given that  $\sum x = 175.0$  and that the mean of  $y$  is 8.4 .  
 the term elastic limit.

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[4]

- (iii) variation with time of the velocity, in  $\text{cms}^{-1}$ , of the car is shown.

uniform metre rule of weight 2.0 N is pivoted at the 60 cm mark. A 4.0 N load is suspended from one end, causing the rule to rotate about the pivot.

a laboratory experiment that uses a Hall probe to test the relationship between  $B$  and  $r$ . You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

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 .....  
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[5]

- (d) Given that, in fact, the mean concentration for patients taking the drug is 0.175 , find the probability of a Type II error occurring in the test.

- (i) village hall has seats for 40 people, consisting of 8 rows with 5 seats in each row. Mary, Ahmad, Wayne, Elsie and John are the first to arrive in the village hall and no seats are taken before they arrive.

.....  
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[8]

- (iv) the value of  $\frac{d^2y}{dx^2}$  at  $P$ .

State the gradient of the curve at the point  $(-1, 2)$  and sketch the curve.

time-base setting on the oscilloscope should be used?

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[3]

- (a) cells are connected to a load resistor of resistance  $3.0\Omega$ . The electromotive force (e.m.f). and the internal resistance of each of the cells is shown.

obtain the expansion of  $f(x)$  in ascending powers of  $x$ , up to and including the term in  $x^2$ .

- (ii) random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

	$F/N$ when child is at X	$F/N$ when child is at Y
A	600	0
B	600	150
C	750	0
D	750	150

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bounce = .....  $bq$  [8]

- (i) Its speed decreases to zero, then increases to  $20 \text{ m s}^{-1}$ .

Use a different object that has half the volume and the same density as the original object.

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[5]

- (v) system is released from rest with  $OP$  making a small angle  $\alpha$  with the downward vertical. Find

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[6]

- (iii) that the forces are in equilibrium, find the values of  $\theta$  and  $X$ .

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[12]

- 9 (c) Show that, for  $n > 2$ ,

Number of rooms occupied ( $x$ )	0	1	2	3	4	5	6	$\geq 7$
Observed frequency	4	9	18	26	20	16	7	0
Expected frequency	3.88	12.60	20.48	22.18	18.02	11.72		

- (vi) Find the value of  $x$ .

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[10]

- (iv) particle  $P$  starts from rest at a point  $O$  and travels in a straight line. The acceleration of  $P$  is  $(15 - 6x)\text{ms}^{-2}$ , where  $x$  m is the displacement of  $P$  from  $O$ .

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[10]

- (i) Show that  $\frac{ds}{dx} = \frac{1}{2}(e^x + e^{-x})$ , where  $s$  denotes the arc length of  $C$ , and find the surface area generated when  $C$  is rotated through  $2\pi$  radians about the  $x$ -axis.

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[6]

- (a) Explain why two gamma-ray photons are produced, rather than just one.  
 the probability generating function of  $Z$  to find  $E(Z)$ .
- (iii) why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

For a different value of  $\theta$ , the plane on which  $B$  rests is rough with coefficient of friction between the plane and  $B$  of 0.8 . The system is in limiting equilibrium with  $B$  on the point of moving in the direction of the 2.5 N force. Find the value of  $\theta$ .

student wishes to investigate projectile motion.

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[12]

- (i) the exact value of  $\int_{\frac{1}{5}\pi}^{\frac{1}{4}\pi} 3 \cos^2 5x \, dx$

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[5]

- (ii) is the speed of the block at the bottom of the slope?

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below water = ..... *ib* [2]

- (iv) Use your answer in (i) and an equation of motion to show that kinetic energy of a mass can be given by the expression

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[5]

- (b) a basis for the null space of  $T$ .

uniform rod  $AB$  of length  $3a$  and weight  $W$  is freely hinged to a fixed point at the end  $A$ . The end  $B$  is below the level of  $A$  and is attached to one end of a light elastic string of natural length  $4a$ . The other end of the string is attached to a point  $O$  on a vertical wall. The horizontal distance between  $A$  and the wall is  $5a$ . The string and the rod make angles  $\theta$  and  $2\theta$  respectively with the horizontal (see diagram). The system is in equilibrium with the rod and the string in the same vertical plane. It is given that  $\sin \theta = \frac{3}{5}$  and you may use the fact that  $\cos 2\theta = \frac{7}{25}$ .

- (iii) Find the magnitude and direction of the force exerted by the surface on the lamina at  $A$ .

mass of peaches sold per day in a supermarket is normally distributed with mean 65.8 kg and standard deviation 9.6 kg

students are selected at random from the students who study Science.

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[3]

- (vi) point  $D$  is the reflection of  $A$  in  $l$ .

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[6]

- 22 company sells bags of pasta. The masses of large bags of pasta are normally distributed with mean 2.50 kg and standard deviation 0.12 kg .

cubic equation  $x^3 + 2x + 1 = 0$  has roots  $\alpha, \beta, \gamma$ .

- (c) (iii) the probability generating function of  $Z$  to find  $E(Z)$ .

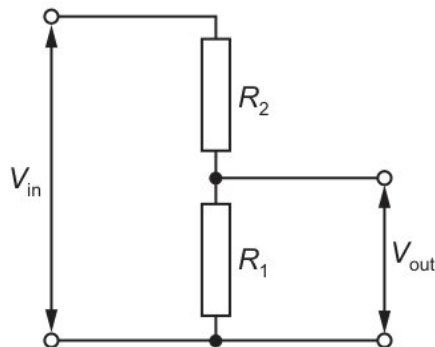
Use the iterative formula  $x_{n+1} = \tan^{-1}(x_n + \pi)$  to determine  $x$  correct to 2 decimal places. Give the result of each iteration to 4 decimal places.

( amplitude )<sup>2</sup>  $\propto \sqrt{\text{intensity}}$

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[6]

- (ii) Hence, or otherwise, prove by mathematical induction that  $f(n)$  is divisible by 7 for every positive integer  $n$ .



resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of  $15 \text{ ms}^{-1}$  to a final speed of  $30 \text{ ms}^{-1}$ .

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Find = ....  $dz$  [2]

- (d) (i) that  $x^2y = z$ , show that

Show how the expected value of 22.18, for  $x = 3$ , is obtained and find the expected values for  $x = 6$  and for  $x \geq 7$ .

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[10]

- (ii) body travelling with a speed of  $10 \text{ ms}^{-1}$  has kinetic energy 1500 J .

Find the equations of the asymptotes of  $C$ .

time-base setting on the oscilloscope should be used?

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[8]

- (iii) Find the magnitude and direction of the force exerted by the surface on the lamina at  $A$ .

curve  $C$  has equation  $y = x^{\frac{3}{2}}$ . Find the coordinates of the centroid of the region bounded by  $C$ , the lines  $x = 1, x = 4$  and the  $x$ -axis.

is the effect of a systematic error on the measurement of a physical quantity?

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[2]

- (a) (iv) the probability density function of  $Y$ ,

row of the table gives an angle  $\theta$  of  $90^\circ$  ?

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[5]

- (ii) Explain why two gamma-ray photons are produced, rather than just one.

that, at the point of  $C$  furthest from the initial line,

the nucleus of  ${}_{92}^{238}\text{U}$  absorbs a neutron, the nucleus decays, emitting an  $\alpha$ -particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the  $\alpha$ -particle.

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truck = .....  $nj$  [6]

- (i) polarised beam of light with intensity  $I$  is incident normally on a polarising filter. are selected from these 20 to perform at a concert.

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[4]

- 14 Given that  $E(X) = \frac{5}{2}$ , calculate  $\text{Var}(X)$ .

points  $A, B, C$  have position vectors

three coplanar forces shown in the diagram act at a point  $P$  and are in equilibrium.

- (a) (ii) manufacturer claims that the machine produces rods with mean length 300 mm . Find the cartesian equation of the plane through  $A, B$  and  $C$ .

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[10]

- (iii) adjustments are made to the machine. Assume that a normal distribution is still appropriate and that the population variance remains unchanged. A second random sample, this time of ten metal rods, is now taken. The results for hardness are as follows.

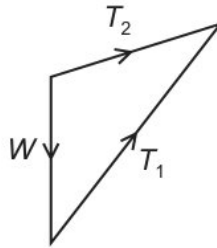
$$t^4 - 4t^3 - 6t^2 + 4t + 1 = 0,$$

what time will some portion of the wavefront  $GH$  reach point  $P$  ?

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[2]

- (b) (i)



that  $\frac{dy}{dx} = \frac{y^2 - ye^x}{xe^x + 2y}$ .

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[12]

- (ii)  $5 \sin \left( x + \frac{1}{6} \pi \right) - 4 \cos x$  in the form  $R \sin(x - \alpha)$ , where  $R > 0$  and  $0 < \alpha < \frac{1}{2} \pi$ . State the exact value of  $R$  and give the value of  $\alpha$  correct to 3 decimal places.

flows out of a pipe and hits a wall.

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[4]

- (d) (v) suitable hypotheses, test at the 10% significance level whether there is any difference between the population means before and after the adjustments.

weight, in grams, of pineapples is denoted by the random variable  $X$  which has a normal distribution with mean 500 and standard deviation 91.5. Pineapples weighing over 570 grams are classified as 'large'. Those weighing under 390 grams are classified as 'small' and the rest are classified as 'medium'.

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[8]

- (i) air resistance to be negligible, what will be the kinetic energy of the projectile when it reaches its highest point?

$V$  remains the same because the decrease of p.d. across  $r$  is balanced by the increase of p.d. across  $R$ .

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[10]

9 curve  $C$  with equation

- (d) (v) what is meant by the accuracy of a measured value.

Using  $\alpha = 3$ , find the shortest distance of the point  $D$  from the line  $AC$ , giving your answer correct to 3 significant figures.

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[12]

- (i) the other root and hence find the values of  $b$  and  $c$ .

the method of differences to find  $\sum_{r=1}^n \frac{1}{(2-3r)(5-3r)}$  in terms of  $n$ .

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[4]

- (b) (ii) resistivity of copper is  $1.8 \times 10^{-8} \Omega \text{ m}$ .

1.1 shows a thin coil of cross-sectional area  $A$  and length  $l$  connected to a resistor of resistance  $S$  and two terminals.

a similar method to find, in terms of  $n$ , a lower bound for  $\sum_{r=1}^n \frac{1}{\sqrt{r}} e^{\sqrt{r}}$ .

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[8]

- (i) that  $y = 0$  when  $x = 3$  Give your answer in an exact form

an approximate 95% confidence interval for the proportion of students who think that the sports facilities are good.

matrix  $\mathbf{M}$  represents a sequence of two geometrical transformations in the  $x - y$  plane

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[20]

- (ix) For a different value of  $\theta$ , the plane on which  $B$  rests is rough with coefficient of friction between the plane and  $B$  of 0.8 . The system is in limiting equilibrium with  $B$  on the point of moving in the direction of the 2.5 N force. Find the value of  $\theta$ .

continuous random variable  $X$  has probability density function  $f$  given by

.....  
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[12]

- 15 Explain why two gamma-ray photons are produced, rather than just one.

- (c) (iii) the distribution function of  $X$ .  
the Young modulus.

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[10]

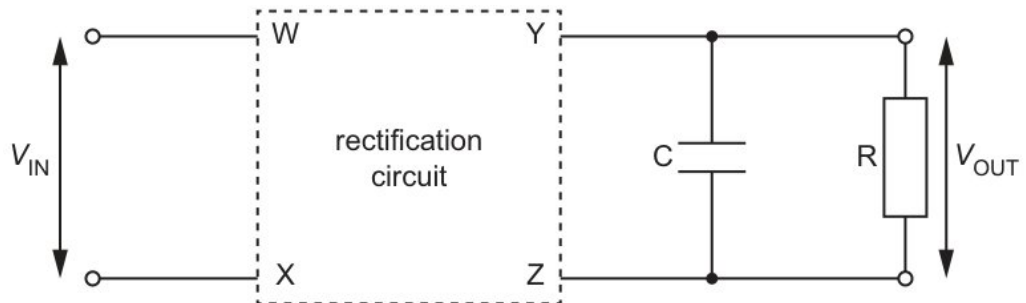
- (ii) row describes the resultant force and resultant torque on the object?  
resistors, each of resistance  $R$ , are connected as shown.

Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

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[4]

- (a) (iii) Calculate the density, in  $\text{kgm}^{-3}$ , of the material from which the paving slab is made.



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[2]

- (iv) uniform solid hemisphere, of radius  $a$  and mass  $M$ , is placed with its curved surface in contact with a rough plane that is inclined at an angle  $\alpha$  to the horizontal. A particle  $P$  of mass  $m$  is attached to the rim of the hemisphere. The system rests in equilibrium with the rim of the hemisphere horizontal and  $P$  at the point on the rim that is closest to the inclined plane (see diagram). Given that the coefficient of friction between the plane and the hemisphere is  $\frac{1}{2}$ , show that

beyond point  $S$  but before point  $T$

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circuit = .....  $bn$  [5]

- (ii)  $AOB$  is a uniform lamina in the shape of a quadrant of a circle with centre  $O$  and radius 0.6 m (see diagram).

variable resistor in (a) is now connected as a potential divider, as shown in Fig. 5.3.

the expected value and variance of  $Y$ .

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[20]

29 Use implicit differentiation to show that

- (a) (ii) masses of the bags of rice made by a company are normally distributed with mean  $\mu$  kg and standard deviation 0.14 kg. The probability that the mass of a randomly chosen bag of this rice is less than 1.48 kg is 0.22.

a cubic equation with roots  $\alpha, \beta$  and  $\gamma$ , given that

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[5]

- (ix) The waves must not be polarised.

team of 5 is chosen from 6 boys and 4 girls. Find the number of ways the team can be chosen if

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power distance = .....  $rk$  [8]

- (iii) cubic polynomial  $p(x)$  is defined by

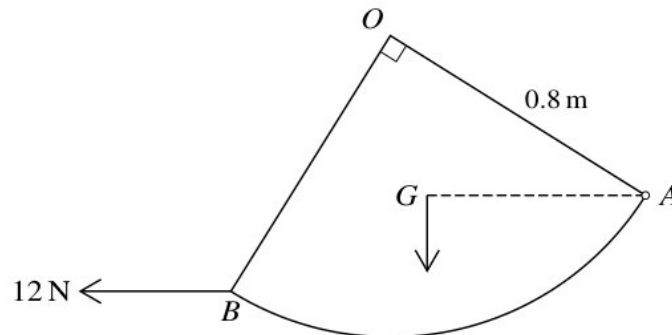
force = mass  $\times$  acceleration

Find the frictional and normal components of the contact force acting on  $B$ .

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[10]

- (b) (iii)



$191.5 \text{ m}^3$  of water is mixed with  $0.50 \text{ m}^3$  of alcohol. The density of water is  $1000 \text{ kg m}^{-3}$  and the density of alcohol is  $800 \text{ kg m}^{-3}$ .

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Trulite = .....  $ba$  [3]

- (i) State, with a reason, whether the trapezium rule gives an under-estimate or an over-estimate of the true value of the integral in part (ii).

diagram shows four forces applied to a circular object.

long, thin metal wire is suspended from a fixed support and hangs vertically.

Masses are suspended from its lower end.

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[6]

- (iv) a diagram, on page 3, showing the arrangement of your equipment. In your account

Calculate the gravitational potential  $\phi$  at the surface of Mars. Give a unit with your answer.

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[4]

- (g) (ii) system is released from rest with  $OP$  making a small angle  $\alpha$  with the downward vertical. Find

lifetime, in hours, of a 'Trulite' light bulb is a random variable  $T$ . The probability density function  $f$  of  $T$  is given by

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[6]

- (i) the grid below, draw a cumulative frequency graph to illustrate this information.  
 P and Q collide and stick together.

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[5]

- (c) (ii) is the total displacement of the ball from its original position after  $1.5s$  ?

an election 153 adults, from a random sample of 200 adults, said that they had voted. Using this information, an  $\alpha\%$  confidence interval for the proportion of all adults who voted in the election was found to be 0.695 to 0.835 , both correct to 3 significant figures. Find the value of  $\alpha$ , correct to the nearest integer.

Find the magnitude and direction of the force exerted by the surface on the lamina at  $A$ .

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over = ..... *me* [5]

- (i) Using  $\alpha = 3$ , find the shortest distance of the point  $D$  from the line  $AC$ , giving your answer correct to 3 significant figures.

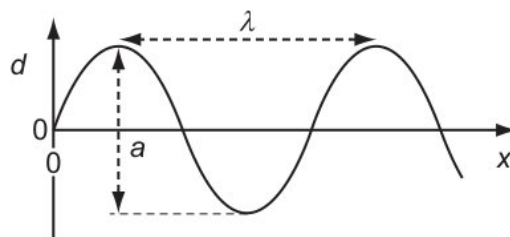
what can be deduced from this about the rotation of Mars on its axis.

524 526 520 523 530

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samples = ..... *cn* [8]

- (d) (iii) company sells bags of pasta. The masses of large bags of pasta are normally distributed with mean 2.50 kg and standard deviation 0.12 kg .



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follows. = ..... *bp* [6]

- (iv) is a general description of a baryon?  
the probability density function of  $Y$ ,

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[5]

- (i) particle is moving in a circle of radius 2 m . At time  $t$  s its velocity is  $(t^2 - 12) \text{ ms}^{-1}$ . Find the magnitude of the resultant acceleration of the particle when  $t = 4$ .

$$x^2 \sin y + \cos 3y = 4$$

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[3]

- 10 the area of the region bounded by  $C$  and the initial line, giving your answer in the form  $(p\pi^2 + q\pi + r) \text{e}^{\frac{1}{2}\pi} + s$ , where  $p, q, r$  and  $s$  are integers to be determined.

- (b) (i) body of mass  $m$  moves vertically through a distance  $h$  near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

Carry out the test.

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[8]

- (ii) has 10 different books from the series Squares and Circles. The books look similar except for their colour. There are 3 blue books, 2 red books, 2 yellow books, 1 orange book, 1 purple book and 1 green book.

order to test the effect of a drug, a researcher monitors the concentration,  $X$ , of a certain protein in the blood stream of patients. For patients who are not taking the drug the mean value of  $X$  is 0.185 . A random sample of 150 patients taking the drug was selected and the values of  $X$  were found. The results are summarised below.

adjustments are made to the machine. Assume that a normal distribution is still appropriate and that the population variance remains unchanged. A second random sample, this time of ten metal rods, is now taken. The results for hardness are as follows.

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[4]

- (c) (iii) a  $t$  test at the 5% significance level to find the range of values of  $k$  for which the result of the test is to reject the null hypothesis

the value of  $\frac{d^2y}{dx^2}$  at  $A$ .

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same = .....  $pf$  [4]

- (v) the acute angle between the planes  $ABC$  and  $ABD$ .

Stating your hypotheses, test at the 1% significance level whether there is a non-zero correlation between mid-day temperature and amount of sunshine.

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[5]

- (i) Find the total time which elapses between the initial projection of  $B$  and the instant when it strikes the plane for the second time.

Find the probability that a box is rejected.

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[12]

- 16 Find the mean and standard deviation of the weights of boys aged 16 years in Brigville.

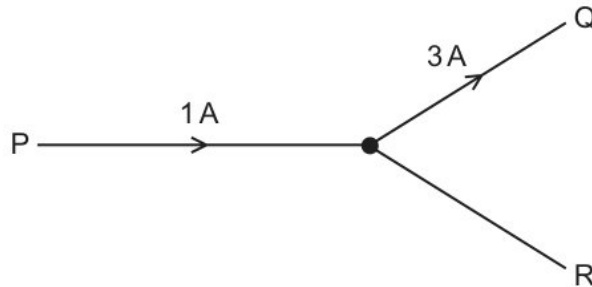
- (ii) (c) Use the equation of a suitable regression line to estimate the number of hours of sunshine on a day when the mid-day temperature is  $2^{\circ}\text{C}$ .

thermistor is connected to a cell with negligible internal resistance.

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[15]

- (f)



a positron and a neutrino

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[6]

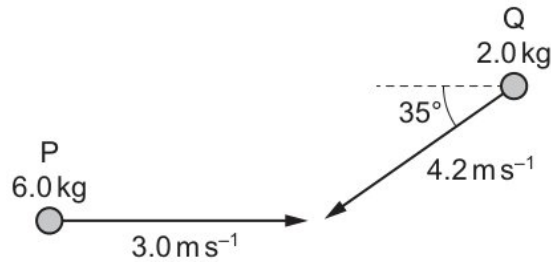
- (a) State the name of this type of reaction.

respect to the origin  $O$ , the points  $A$  and  $B$  have position vectors  $2\mathbf{i} + 4\mathbf{k}$  and  $5\mathbf{i} + \mathbf{j} + 6\mathbf{k}$  respectively. The line  $l_1$  passes through the points  $A$  and  $B$ .

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[8]

- (v) (c) the other root and hence find the values of  $b$  and  $c$ .

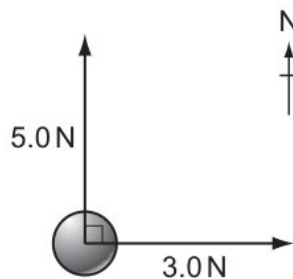


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[10]

- (b) Given also that  $-1$  is an eigenvalue of  $\mathbf{A}$ , find a corresponding eigenvector.

probability that Julian gets a good night's sleep on a randomly chosen flight is  $0.285$  .



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Sketch = ..... *pr* [4]

- 14 satellite of mass 122 kg is in orbit around Mars at a constant height of  $1.7 \times 10^6$  m above the surface of the planet.

could M and N be?

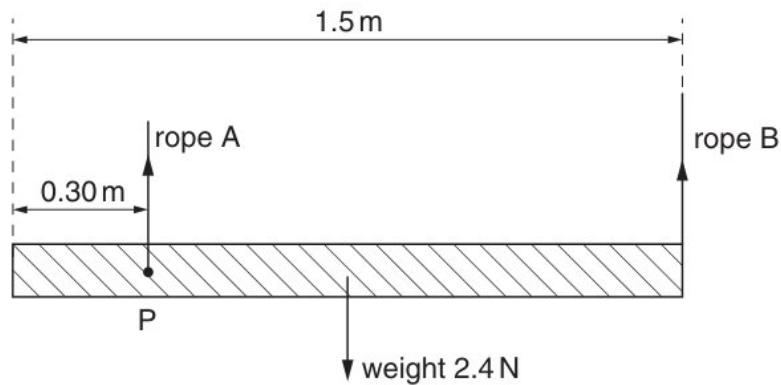
- (d) (v) Calculate the exact value of  $I_1$  and deduce the exact value of  $I_3$ .

positive charges and one negative charge, all of equal magnitude, are set at the corners of an equilateral triangle.

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correct = ..... *sx* [5]

- (i)



weights of letters posted by a certain business are normally distributed with mean 20 g . It is found that the weights of 94% of the letters are within 12 g of the mean.

a matrix  $\mathbf{P}$  and a diagonal matrix  $\mathbf{D}$  such that  $\mathbf{A} - 2\mathbf{I} = \mathbf{PDP}^{-1}$ .

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[6]

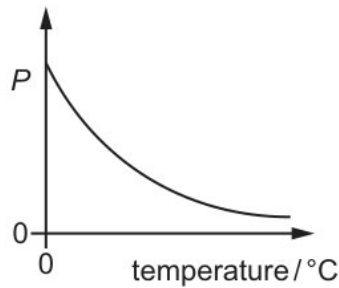
- (vi) car then travels up a slope at  $2^\circ$  to the horizontal, maintaining the same constant speed.

that  $T = \frac{U}{2g}(\sqrt{2} + \sqrt{6})$ .

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[10]

- (ii)



Show that  $\frac{dy}{dx} = \frac{3x^2y - 3y^3}{9xy^2 - x^3}$ .

region  $R$  is enclosed by  $C$  and  $l$ , and contains the pole. Find the area of  $R$ .

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[8]

- (f) (iii) uniform spheres  $A$  and  $B$ , of equal radius, are at rest on a smooth horizontal table. Sphere  $A$  has mass  $3m$  and sphere  $B$  has mass  $m$ . Sphere  $A$  is projected directly towards  $B$ , with speed  $u$ . The coefficient of restitution between the spheres is  $0.6$ . Find the speeds of  $A$  and  $B$  after they collide.

Show that the length of the arc of  $C$  from the pole to the point furthest from the pole is given by

the term ultimate tensile stress.

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[10]

- (i) suitable hypotheses, test at the 10% significance level whether there is any difference between the population means before and after the adjustments.

curve  $C$  has equation  $2x^3 + 3x^2y - 3y^3 - 16 = 0$ .

solve the equation  $5 \sin \left( 2\theta + \frac{1}{6}\pi \right) - 4 \cos 2\theta = \sqrt{7}$  for  $0 \leq \theta \leq \pi$ . Give your answers correct to 2 decimal places.

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[1]

- (c) (iv) an approximate 95% confidence interval for the proportion of students who think that the sports facilities are good.

lines  $l_1$  and  $l_2$  have equations

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particle = .....  $nq$  [8]

- (iii) random variables  $X$  and  $Y$  have the independent distributions  $N(44, 16)$  and  $N(30, 9)$  respectively.

$$\sin \frac{1}{5}\pi \sin \frac{2}{5}\pi \sin \frac{3}{5}\pi \sin \frac{4}{5}\pi \quad \text{and} \quad \sin^2 \left( \frac{1}{5}\pi \right) + \sin^2 \left( \frac{2}{5}\pi \right)$$

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[5]

- 23 curve  $C$  has equation  $x^3 - 3xy + y^2 = 4$ . Find the value of  $\frac{d^2y}{dx^2}$  at the point  $(0, 2)$  of  $C$ .

In the case where  $k = 2$ ,

The curve  $C$  has equation  $y = \sec^3 x$  for  $0 \leq x \leq \frac{1}{4}\pi$ . The region  $R$  is bounded by  $C$ , the  $x$ -axis, the  $y$ -axis and the line  $x = \frac{1}{4}\pi$ . Find the volume of revolution generated when  $R$  is rotated through  $2\pi$  radians about the  $x$ -axis.

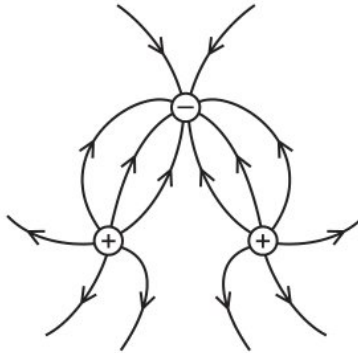
- (b) (iii) particles  $P$ ,  $Q$  and  $R$ , of masses  $0.6\text{ kg}$ ,  $0.4\text{ kg}$  and  $0.8\text{ kg}$  respectively, are at rest in a straight line on a smooth horizontal plane. The distance from  $P$  to  $Q$  is  $3\text{ m}$ , and the distance from  $Q$  to  $R$  is also  $3\text{ m}$  (see diagram).  $P$  is projected directly towards  $Q$  with speed  $3\text{ ms}^{-1}$ . After  $P$  and  $Q$  collide,  $P$  continues to move in the same direction with speed  $1.5\text{ m s}^{-1}$ .

Find the value of  $(\alpha + 1)(\beta + 1)(\gamma + 1)$ .

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[5]

- (iv)



$P$  and  $Q$  collide and stick together.

the acute angle between the planes  $ABC$  and  $ABD$ .

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[12]

- (ii) is given that

$$\frac{\text{force}}{\text{length} \times \text{time}}$$

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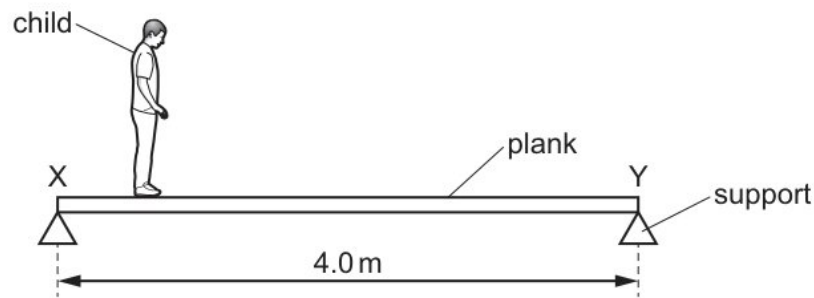
[5]

- (a) (iii) an estimate for the mean length of these 250 leaves.  
with a reason, whether  $f$  has an inverse.

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line = ..... oi [6]

(i)



Show that  $\cos \theta = \frac{2}{3}$ .

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[12]

- (d) (iii) Explain how an electric field can be used with the magnetic field to ensure that the particle in (b) now passes through point Z. particle in (b) now passes through point Z.

280 boxes are chosen randomly. Use an approximation to find the probability that at least 30 of these boxes are rejected.

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[8]

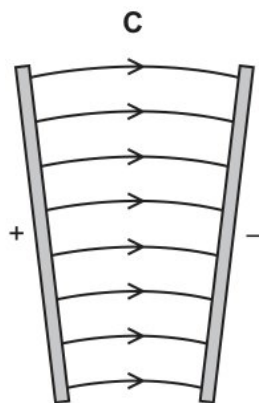
(ii) polynomial  $p(x)$  is defined by

the equation of the tangent to the curve at the point e 3 Give your answer in the form  $y = mx + c$  where  $m$  and  $c$  are exact

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[5]

(i)

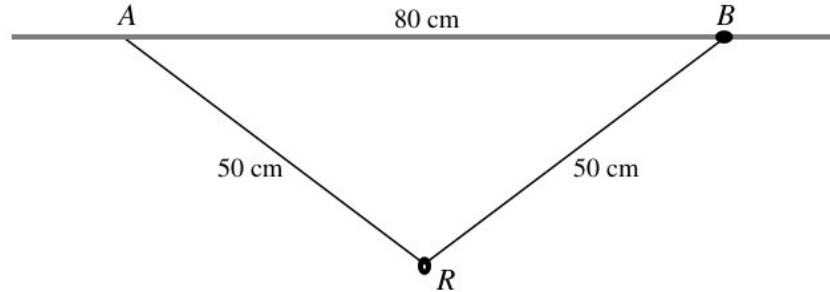


thermistor is connected to a cell with negligible internal resistance.

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[8]

- (v) light elastic string has natural length 2 m and modulus of elasticity 39 N . The ends of the string are attached to fixed points  $A$  and  $B$  which are at the same horizontal level and 2.4 m apart. A particle  $P$  of mass  $m$  kg is attached to the mid-point of the string and hangs in equilibrium at a point 0.5 m below  $AB$  (see diagram).



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[2]

- 25 Find the greatest height that  $P$  reaches above the level of  $O$ .

- (e) (i) the value of the constant  $k$ ,

$$\vec{OA} = \mathbf{i} + 2\mathbf{j}, \quad \vec{OB} = \mathbf{i} + 3\mathbf{j} - 2\mathbf{k} \quad \text{and} \quad \vec{OC} = 2\mathbf{i} - \mathbf{j} + 3\mathbf{k}$$

$5 \sin \left( x + \frac{1}{6}\pi \right) - 4 \cos x$  in the form  $R \sin(x - \alpha)$ , where  $R > 0$  and  $0 < \alpha < \frac{1}{2}\pi$ .  
 State the exact value of  $R$  and give the value of  $\alpha$  correct to 3 decimal places.

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[5]

- (ii) the solution of the differential equation

point  $D$  has position vector  $\mathbf{i} + t\mathbf{k}$ , where  $t \neq -2$ .

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[3]

(vi) is the current in the load resistor?

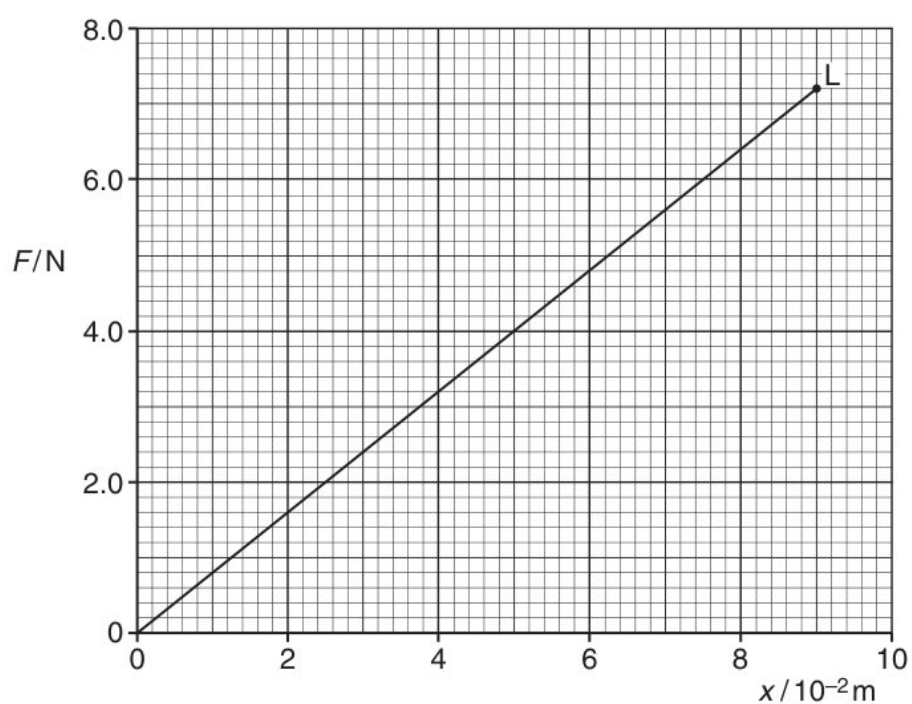
points  $A, B, C$  have position vectors

Find the coordinates of this stationary point, giving your answers correct to 3 decimal places.

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[1]

(b) (v)



the exact value of  $\operatorname{cosec}^2 15^\circ - \sec^2 15^\circ$ .

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[8]

- (ii) a different investigation, Nikki uses another large random sample to calculate a 99% confidence interval and an  $x\%$  confidence interval.

The waves must be polarised.

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[8]

- (iii) that, when  $t = 0$ ,  $x = 3$  and  $\frac{dx}{dt} = 0$ .

$$\overrightarrow{OA} = \begin{pmatrix} 2 \\ 3 \\ 5 \end{pmatrix}, \quad \overrightarrow{OB} = \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} \quad \text{and} \quad \overrightarrow{OC} = \begin{pmatrix} 10 \\ 0 \\ 6 \end{pmatrix}.$$

student wishes to investigate projectile motion.

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[3]

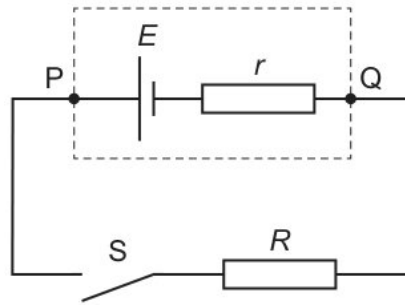
- (i) that  $\frac{dy}{dx} = -\sqrt{1-t^2} + (1-t^2) \operatorname{sech}^{-1} t$ .

uniform solid sphere with centre  $C$ , radius  $2a$  and mass  $3M$ , is pivoted about a smooth horizontal axis and hangs at rest. The point  $O$  on the axis is vertically above  $C$  and  $OC = a$ . A particle  $P$  of mass  $M$  is attached to the sphere at its lowest point (see diagram). Show that the moment of inertia of the system about the axis through  $O$  is  $\frac{84}{5}Ma^2$ .

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[8]

- (a) (i) Use the iterative formula



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[5]

- (ii) a laboratory experiment to determine the absorption coefficient of glass. You should

a crossword competition the times,  $x$  minutes, taken by a random sample of 6 entrants to complete a crossword are summarised as follows.

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[6]

- (iii)  $C$  in the case  $p = -1$ . Your sketch should indicate the coordinates of any intersections with the axes, but need not show the coordinates of any turning points.  
 planes  $p$  and  $q$  have equations  $x + y + 3z = 8$  and  $2x - 2y + z = 3$  respectively.  
 support at end  $X$  exerts a force  $F$  vertically upwards on the plank.

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[12]

- 17 skateboarder and her skateboard have a total mass of 70 kg . She pushes on the ground with her foot to create a forward force  $F$  of 25 N on herself and the skateboard, as shown in the diagram.

- (b) (iv) leptons are emitted from the sodium-21 nucleus during the decay?  
then it converges to  $a$ .

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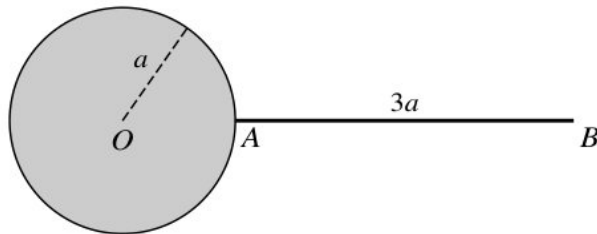
[6]

- (ii)  $\mathbf{A} = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$ . Prove by mathematical induction that, for every positive integer  $n$ ,  
marble is chosen at random from bag  $A$  and placed in bag  $B$ .

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[4]

- (a) (iii) the complex numbers  $z$  for which  $\frac{z+5i}{z-5}$  is real and  $|z| = \sqrt{17}$  Give your answers in the form  $z = x + iy$  where  $x$  and  $y$  are real



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[15]

- (iv) curve  $C$  has parametric equations

the de Broglie wavelength of an electron moving at a speed of  $4.9 \times 10^7 \text{ m s}^{-1}$ .

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[6]

- (e) (iii) Show that  $a = 19$  and find the values of  $b$  and  $c$ .

Draw a sketch of  $C$  for the case  $0 < \lambda < 1$ .

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mass = .....  $qe$  [6]

- (i) basic principle of note production in a horn is to set up a stationary wave in an air column.

Given also that  $-1$  is an eigenvalue of  $\mathbf{A}$ , find a corresponding eigenvector.

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[6]

- (ii) analysis of the data,



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also masses horizontal = .....  $bo$  [5]

- (f) (ii) the experimental observations that show radioactive decay is  
 which mark on the rule must a 50 g mass be suspended so that the rule balances?  
 in terms of  $m$  and  $g$ , the magnitude of the frictional force in this position.

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[8]

- (iii) Pressure is force per unit area.  
 Show that the cartesian equation of  $C$  is

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[12]

- 24 It consists of two quarks that do not need to be the same flavour.  
 if the 4 vowels A, E, E, I must all be together.

- (a) (i) the torque of a couple.

The weight of the plank is causing a clockwise moment.

the characteristic equation of  $\mathbf{A}$  to show that  $(\mathbf{A} - 2\mathbf{I})^3 = a\mathbf{A}^2 + b\mathbf{A} + c\mathbf{I}$  where  
 $a, b$  and  $c$  are constants to be determined.

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[8]

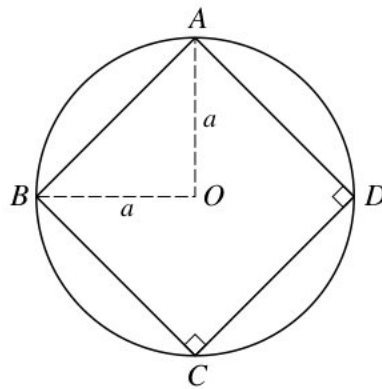
- (iv) the acute angle between the directions of  $l_1$  and  $l_2$ .

eigenvectors  $\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$ ,  $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$  and  $\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ . Find the eigenvalues of the matrix  $\mathbf{AB}$ , and state corresponding eigenvectors.

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[15]

- (c) (i) is the energy transferred in the resistor and the time taken for the charge to pass through the resistor?



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[3]

- (iv) stationary nucleus has nucleon number  $A$ .

$B$  now strikes a wall that is perpendicular to its path, rebounds and collides with  $A$  again. The coefficient of restitution between  $B$  and the wall is  $e$ . Given that the second collision between  $A$  and  $B$  brings  $A$  to rest, find  $e$ .

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matrix, = .....  $ro$  [6]

- (vii) the roots of the equation  $z^3 = 27 - 27i$ , giving your answers in the form  $re^{i\theta}$ , where  $r > 0$  and  $-\pi \leq \theta < \pi$ .

Find the direction of motion of the particle 0.4 s after the instant of projection.

Show that  $f(n+1) + f(n) = 28(3^{3n}) + 7(6^{n-1})$ .

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from grating from = .....  $mh$  [3]

- 24 Hence show that there are only two points on the curve at which the tangent is parallel to the  $x$ -axis and find the coordinates of these points.

The waves must be coherent.

van is 2.50 m long with the wheels at a distance of 0.600 m from the front of the van and 0.400 m from the rear of the van.

- (d) (i)  $V$  remains the same because the decrease of p.d. across  $r$  is balanced by the increase of p.d. across  $R$ .

time to complete a crossword has a normal distribution with mean  $\mu$  minutes.  
 Calculate a 95% confidence interval for  $\mu$ .

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[2]

- (ii) Find the matrix product  $\mathbf{A} \begin{pmatrix} -1 \\ 1 \\ -1 \\ 1 \end{pmatrix}$  and hence find the general solution of the

$$\text{equation } \mathbf{Ax} = \begin{pmatrix} 3 \\ 21 \\ 24 \\ 27 \end{pmatrix}.$$

$B$  bounces when it strikes the plane, and leaves the plane with speed  $20 \text{ m s}^{-1}$  but with its horizontal component of velocity unchanged.

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[8]

- (c) (ii) object is fired upwards from horizontal ground. The object has an initial velocity of  $20 \text{ ms}^{-1}$  at an angle of  $45^\circ$  to the horizontal. Air resistance is negligible.

is the energy transferred in the resistor and the time taken for the charge to pass through the resistor?

the probability that the 3 customers bought computers all made by different companies.

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$$\text{signal} = \dots\dots vd \quad [3]$$

- (vi) Hence factorise  $p(x)$  completely.

particles  $A$  and  $B$  of masses  $0.9 \text{ kg}$  and  $0.4 \text{ kg}$  respectively are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the top of two inclined planes. The particles are initially at rest with  $A$  on a smooth plane inclined at angle  $\theta^\circ$  to the horizontal and  $B$  on a plane inclined at angle  $25^\circ$  to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes. A force of magnitude  $2.5 \text{ N}$  is applied to  $B$  acting down the plane (see diagram).

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[4]

- (iv) For some nuclei, the nucleon number can be less than the proton number.

$$x^2 + y^2 = a(x + \sqrt{x^2 + y^2}).$$

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[3]

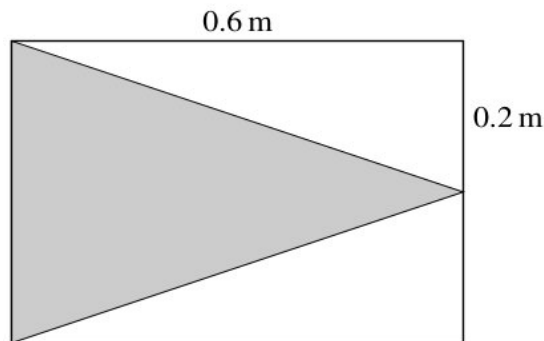
- (a) (ii) the differential equation, obtaining a relation between  $x$  and  $y$ .

momentum = mass  $\times$  velocity

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Random with taken, = .....  $ey$  [12]

- (i) points  $A, B, C$  have position vectors



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comes = .....  $bi$  [5]

- 13 the value of  $\theta$  for which the transformation represented by  $\mathbf{M}$  has a line of invariant points 7  
 the probability density function of  $Y$   
 is the speed of the block after falling this distance?

- (b) (i) planes have equations  $x + 2y - 2z = 7$  and  $2x + y + 3z = 5$ .

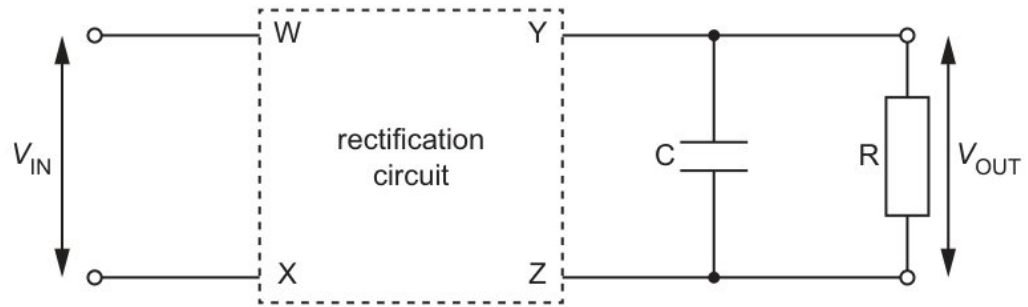
m.f. for  $n = 0$ .

the exact solutions of the equation  $f(x) = 1$ .

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[5]

(v)



labels on the graphs are intended to show the wavelength  $\lambda$ , the period  $T$  and the amplitude  $a$  of the wave, but only one graph is correctly labelled.

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when spheres = ..... *tb* [6]

(iv) - decelerating at a constant rate with the parachute open,

$$F(x) = \begin{cases} 0 & x \leq 0, \\ \frac{1}{3}x^2 & 0 < x \leq 1, \\ x - \frac{1}{2} - \frac{1}{6}x^2 & 1 < x \leq 3, \\ 1 & x > 3. \end{cases}$$

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[4]

(a) (iv) Find the greatest height that  $P$  reaches above the level of  $O$ .

the area of the region bounded by  $C$  and the initial line, giving your answer in the form  $(p\pi^2 + q\pi + r)e^{\frac{1}{2}\pi} + s$ , where  $p, q, r$  and  $s$  are integers to be determined.

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[6]

- (iii) Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

	$F_1/\text{N}$	$F_2/\text{N}$
A	4.0	6.0
B	6.0	4.0
C	6.0	8.0
D	8.0	6.0

Estimate the probability of throwing a 4.

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[5]

- (d) (ii) force is caused only by a pressure difference?

$OAB$  is a uniform lamina in the shape of a quadrant of a circle with centre  $O$  and radius 0.8 m which has its centre of mass at  $G$ . The lamina is smoothly hinged at  $A$  to a fixed point and is free to rotate in a vertical plane. A horizontal force of magnitude 12 N acting in the plane of the lamina is applied to the lamina at  $B$ . The lamina is in equilibrium with  $AG$  horizontal (see diagram).

Find the coordinates of  $A$  and  $M$ .

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[8]

- (v) that the distance travelled by the ball when it is moving upwards is  $x = \frac{1}{2k} \ln \left( \frac{g+kU^2}{g+kv^2} \right)$ .

frame consists of a horizontal rod  $XY$  and a rod  $YZ$  that is at an angle of  $30^\circ$  to the horizontal. Rod  $XY$  is attached to the wall by a hinge at  $X$  and has length 0.50 m . Assume that the weights of the rods are negligible.

the torque of a couple.

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[6]

- (iv) the time from release until  $OP$  makes an angle  $\frac{1}{2}\alpha$  with the downward vertical for the first time.

particle of mass  $m$  and charge  $+Q$  moves at speed  $v$  into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

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[8]

- (e) (ii) lamina is freely suspended at  $A$  and hangs in equilibrium.

radio-controlled toy car travels along a straight line for a time of 15 s .

has 10 different books from the series Squares and Circles. The books look similar except for their colour. There are 3 blue books, 2 red books, 2 yellow books, 1 orange book, 1 purple book and 1 green book.

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[6]

- (iii)  $a, b$  and  $c$  are integers to be determined.

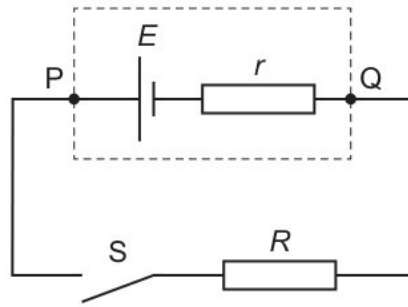
On Fig. 9.1, sketch the variation of the activity  $A$  of the sample with  $t$  for values of  $t$  between  $t = 0$  and  $t = 24$  min.

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[8]

20 Given that the total number of cars sold during the 5 days is 5 , carry out the test.

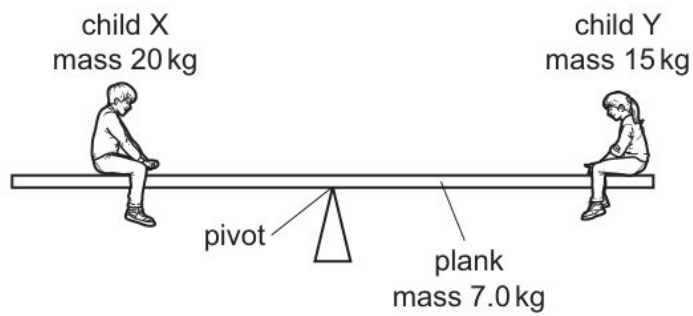
- (a) (i) Find the upward force on the parachutist due to the parachute, during the second stage.



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frictional = ..... oh [4]

- (iv) random variable  $T$  has probability density function given by



In the case where  $k = 1$ ,

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[5]

- (d) (iii) region enclosed between the  $x$  axis and the curve is rotated through  $2\pi$  radians about the  $x$  axis

Show how the expected value of 22.18 , for  $x = 3$ , is obtained and find the expected values for  $x = 6$  and for  $x \geq 7$ .

the speed of  $Q$  after the collision.

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light point smooth = ....  $ib$  [5]

- (iv) How many possible arrangements are there of seating Mary, Ahmad, Wayne, Elsie and John if Mary and Ahmad sit together in the front row and the other three sit together in one of the other rows?

1.26 1.24 1.17 1.23 1.18 1.25 1.19 1.20 1.21 1.18

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[4]

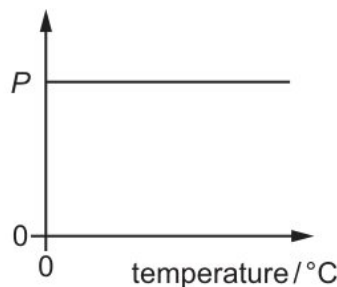
- (i) Find the value of  $x$  for which  $P$  reaches its maximum velocity, and calculate this maximum velocity.

Derive an expression for  $v$  in terms of  $B$  and the electric field strength  $E$ .

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Art, = .....  $gn$  [8]

25 (c)



the Young modulus.

- (ii) metal electrical conductor has a resistance of  $5.6\text{k}\Omega$ . A potential difference (p.d.) of  $9.0\text{ V}$  is applied across its ends.

a vector equation for the line  $l_1$ .

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[4]

- (i) positive charges and one negative charge, all of equal magnitude, are set at the corners of an equilateral triangle.

The total momentum of each object in the system is the product of its mass and velocity.

the distance  $AC$ .

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there = ..... zz [5]

- (a) Prove that  $\sin^2 2\theta (\operatorname{cosec}^2 \theta - \sec^2 \theta) \equiv 4 \cos 2\theta$ .

$$\mathbf{D} = \begin{pmatrix} 1 & -1 & 1 \\ -6 & -3 & 4 \\ -9 & -3 & 7 \end{pmatrix},$$

- (ii) measurements to be taken,

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[6]

- (iii) Show that the kinetic energy of the electron before the collision is  $1.1 \times 10^{-15}\text{ J}$ .

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[4]

- (v) from the definitions of  $\tanh$  and  $\operatorname{sech}$  in terms of exponentials, prove that thermistor is connected to a cell with negligible internal resistance.

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[8]

33 that  $a = \exp\left(\frac{1}{6}\left(\frac{5}{a^2} + 3\right)\right)$  where  $\exp(x)$  denotes  $e^x$

- (d) (ii) A ductile material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension  $x$  of the stretching force  $F$ .

only one of the following two alternatives.

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[6]

- (i) Find the work done by the tension.

curve  $C$  has parametric equations  $x = e^t \cos t, y = e^t \sin t$ , for  $0 \leq t \leq \pi$ . Find the arc length of  $C$ .

the time that it takes for the block to move 2 m down the plane from rest.

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[10]

- (a) (v) Find the  $x$ -coordinate of the point  $P$  at which the tangent to the curve passes through the origin.

times taken to run 200 metres at the beginning of the year and at the end of the year are recorded for each member of a large athletics club. The time taken, in seconds, at the beginning of the year is denoted by  $x$  and the time taken, in seconds, at the end of the year is denoted by  $y$ . For a random sample of 8 members, the results are shown in the following table.

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[3]

- (i) rod in (b) is removed from the pin and supported by ropes A and B , as shown in Fig. 2.2.

$\mathbf{a} \times \mathbf{b}$  and deduce the area of the triangle  $OAB$ .

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fields = .....  $ht$  [12]

- (iv) the lowest note produced by a horn, a node is formed at the mouthpiece and the antinode is formed at the bell. The frequency of this note is 75 Hz .

1 Which quantity is a scalar quantity?

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mass = .....  $ig$  [6]

- (iii) man has a mass of 80 kg . He ties himself to one end of a rope which passes over a single fixed pulley. He pulls on the other end of the rope to lift himself up at an average speed of  $50 \text{ cm s}^{-1}$ .

company sells bags of pasta. The masses of large bags of pasta are normally distributed with mean 2.50 kg and standard deviation 0.12 kg .

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[4]

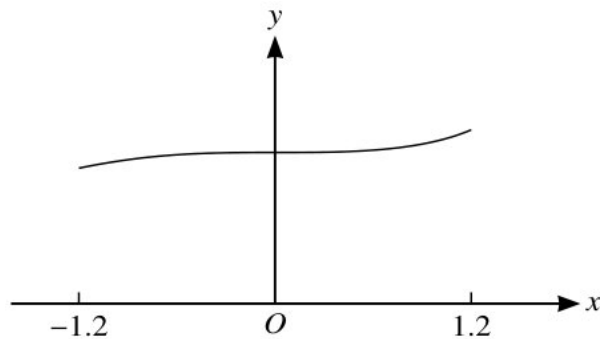
- (c) (ii) Show that  $P(X = 3) = \frac{1}{15}$ .

filter is rotated about the normal axis through an angle  $\theta$ .

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[4]

- (iii)



It consists of three quarks that must all be the same flavour.

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[4]

- 12 Find the mean and standard deviation of the weights of boys aged 16 years in Brigville.  $C$ , stating the coordinates of the intersections with the axes.

(d) (i)

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Expected frequency	1	7	$a$	$b$	$c$	91

is a planet that may be considered to be an isolated uniform sphere of radius  $3.4 \times 10^6$  m.

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[4]

(ii) the graph to estimate how many people took between 4 and 7.5 minutes to complete the puzzle.

the de Broglie wavelength of an electron moving at a speed of  $4.9 \times 10^7$  m s<sup>-1</sup>.

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[5]

(a) (iii) Show that the total distance fallen is 1048 m .

restaurant manager buys 160 of these large bags of pasta.

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[12]

(i) diagram, showing these three forces to scale, is correct?

verify that this equation has a root between 5 and 5.05.

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[8]

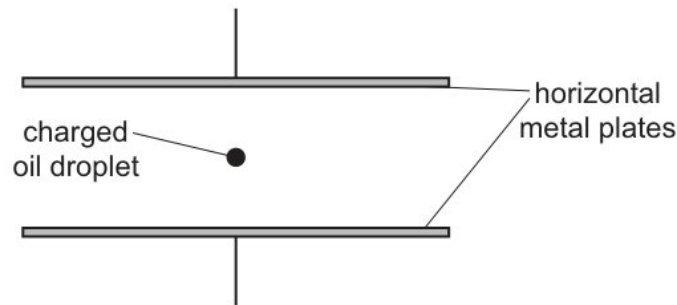
- (ii) Hence show that there are only two points on the curve at which the tangent is parallel to the  $x$ -axis and find the coordinates of these points.

$$g(t) = \begin{cases} \frac{1}{2} \cos t & -\frac{1}{2}\pi \leq t \leq \frac{1}{2}\pi \\ 0 & \text{otherwise} \end{cases}$$

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[3]

- (b) (v) team of 5 is chosen from 6 boys and 4 girls. Find the number of ways the team can be chosen if



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[2]

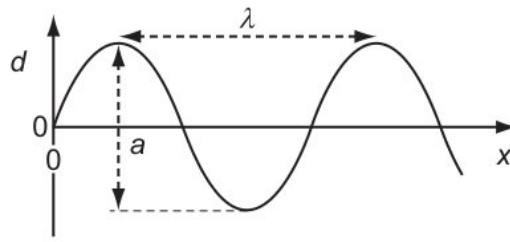
- (i) Express  $f(x)$  in partial fractions.  
 standard results from the list of formulae (MF19) to show that

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[3]

16 paving slab has a mass of 68 kg and dimensions 50 mm  $\times$  600 mm  $\times$  900 mm.

(a) (iii)



Show that  $x$  satisfies the equation

graph shows the variation with temperature of power,  $P$ , dissipated in the thermistor?

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[15]

- (i) is suggested that these results are consistent with a distribution having probability density function  $f$  given by

a crossword competition the times,  $x$  minutes, taken by a random sample of 6 entrants to complete a crossword are summarised as follows.

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[6]

- (c) (iv) electromagnetic wave phenomenon is needed to explain the spectrum produced when white light falls on a diffraction grating?

$A$  contains 4 balls numbered 2, 4, 5, 8. Bag  $B$  contains 5 balls numbered 1, 3, 6, 8, 8. Bag  $C$  contains 7 balls numbered 2, 7, 8, 8, 8, 8, 9. One ball is selected at random from each bag.

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[5]

- (i) random sample of five metal rods produced by a machine is taken. Each rod is tested for hardness. The results, in suitable units, are as follows.

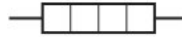
complex number  $1 - (\sqrt{3})i$  is denoted by  $u$ .

would this object weigh on Pluto?

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[6]

- (b) (i) tension in the string of the pendulum is  $T$ . The weight of the pendulum bob is  $W$ . The string is held at an angle of  $30^\circ$  to the vertical.



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[6]

- (iv) the value of  $\mu$ .  
 is the value of  $R$  ?

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[8]

10 continuous random variable  $X$  has probability density function  $f$  given by

- (a) (i) random variables  $X$  and  $Y$  have the independent distributions  $N(44, 16)$  and  $N(30, 9)$  respectively.

Length (cm)	5 – 9	10 – 14	15 – 19	20 – 24	25 – 29	30 – 39
Frequency	18	28	60	72	48	24

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[5]

- (iv) the equation  $2 \ln(2x) - \ln(x + 3) = \ln(3x + 5)$ .

many different colour arrangements are there of the 10 books?

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[6]

- (ii) up the probability distribution table for  $X$ .

star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of  $4.62 \times 10^{-7}$  m.

it is given that  $y = 2$  when  $x = 1$ . Solve the differential equation and obtain an expression for  $y$  in terms of  $x$ .

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[6]

- (e) (i) transmitted light has intensity  $0.75I$ .

beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

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[6]

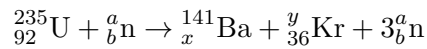
- (vi) function  $f$  is defined by  $f: x \mapsto \frac{x+3}{2x-1}, x \in \mathbb{R}, x \neq \frac{1}{2}$ .

which mark on the rule must a 50 g mass be suspended so that the rule balances?

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[6]

(iii) the value of  $\frac{dy}{dx}$  at  $P$ ,



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[3]

(c) (ii) gas is then cooled at constant volume so that its temperature decreases to  $2T$ .  
 random variable  $X$  is the number of heads obtained.

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[10]

(ix) the value of  $\mu$  and the value of  $X$  for which the block is on the point of moving up the plane.

that if a sequence of values given by the iterative formula

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particle length = ..... oq [4]

13 the distribution function of  $X$ .

polynomial  $ax^3 - 3x^2 - 11x + b$ , where  $a$  and  $b$  are constants, is denoted by  $p(x)$ . It is given that  $(x + 2)$  is a factor of  $p(x)$ , and that when  $p(x)$  is divided by  $(x + 1)$  the remainder is 12 .

bolt is subjected to a tensile force, as shown.

- (c) (iii) Calculate the acute angle between the planes.

	amplitude /cm	period /ms
A	2	10
B	2	90
C	4	10
D	4	90

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[8]

- (ii) the number of different selections if the 4 books include at least 1 red book, at most 1 blue book and exactly 1 yellow book.

	$R_1$	$R_2$
A	doubled	doubled
B	doubled	halved
C	halved	doubled
D	halved	halved

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[4]

- (b) (vi) the subsequent motion,  $B$  does not reach the pulley. When  $A$  reaches the ground, it comes to rest.

State the value of  $E(X)$ .

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[5]

- (ii) student is being weighed. The student, of weight  $W$ , stands 0.30 m from end A of a uniform plank AB, as shown in Fig. 3.1.

1.26 1.24 1.17 1.23 1.18 1.25 1.19 1.20 1.21 1.18

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Squares = ....  $mx$  [6]

- (e) (i) bag contains 10 marbles, of which 4 are red and 6 are blue. Four marbles are selected from the bag at random, without replacement. The random variable  $X$  denotes the number of blue marbles selected.

Use the trapezium rule, with two intervals, to estimate the value of

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[6]

- (iii) Find the modulus of elasticity of the string in terms of  $W$ .

$$\mathbf{D} = \begin{pmatrix} 1 & -1 & 1 \\ -6 & -3 & 4 \\ -9 & -3 & 7 \end{pmatrix},$$

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[5]

- (g) (vi)  $AOB$  is a uniform lamina in the shape of a quadrant of a circle with centre  $O$  and radius 0.6 m (see diagram).

Use a different object that has twice the density and the same volume as the original object.

that  $0 < y < \frac{1}{2}\pi$ , find the values of  $y$  when  $x = 0$ .

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[6]

- (i) is the work done by  $F$  on the skateboarder and skateboard?

aeroplane then ascends 300 m in 50 s , while maintaining the same speed. The resistance force is no longer constant, and the work done against the resistance force in ascending the 300 m is 270000 kJ . The mass of the aeroplane is 60000 kg .

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[5]

- (ii) circle is divided into 6 sectors in such a way that the angles of the sectors are in arithmetic progression. The angle of the largest sector is 4 times the angle of the smallest sector. Given that the radius of the circle is 5 cm , find the perimeter of the smallest sector.

variables  $x$  and  $y$  satisfy the differential equation

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[6]

- 17 student is investigating a non-inverting operational amplifier (op-amp) circuit.

flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

- (a) (iii) Stating suitable hypotheses and assuming a normal distribution, test the coach's belief at the 10% significance level.

random variable  $Z$  is the sum of the number of red balls and the number of different colours present in Kieran's selection. Kieran claims that the probability generating function of  $Z$  is equal to  $G_X(t) \times G_Y(t)$ .

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[5]

- (i) 4 astronauts are chosen from a certain number of candidates. If order of choosing is not taken into account, the number of ways the astronauts can be chosen is 3876 . How many ways are there if order of choosing is taken into account?

potential divider consists of two resistors of resistances  $R_1$  and  $R_2$  connected in series across a source of potential difference (p.d.)  $V_{\text{in}}$ . The p.d. across  $R_1$  is  $V_{\text{out}}$  .

ball is released from rest at time zero. After 1.0 s it bounces inelastically from a horizontal surface and rebounds, reaching the top of its first bounce after 1.5 s .

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[6]

- (ii) curve  $C$  has equation  $\tan y = x$ , for  $x > 0$ .

is given that  $P$  remains at rest in this new position.

How many possible arrangements are there of seating Mary, Ahmad, Wayne, Elsie and John if Mary and Ahmad sit together in the front row and the other three sit together in one of the other rows?

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[15]

- (h) (ii) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Show that if

is suggested that the strength  $B$  of the magnetic field at the centre of a flat circular coil is inversely proportional to the radius  $r$  of the coil.

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[20]

- (i) the values of  $a$  for which the system of equations

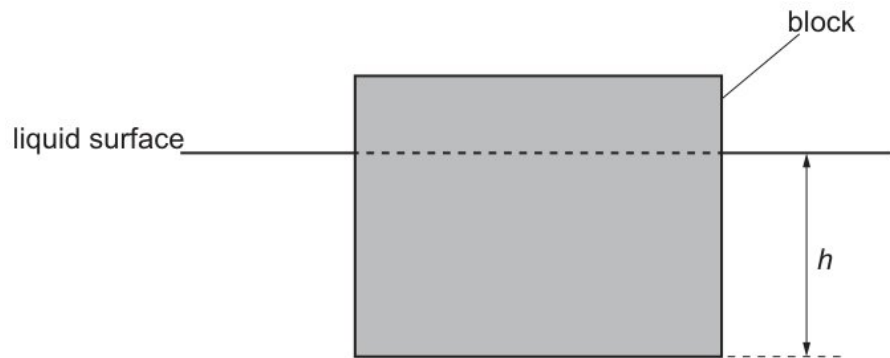
Find the total distance travelled by the particle in the first 10 seconds of motion.

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[20]

- (vi) Find the matrix product  $\mathbf{A} \begin{pmatrix} -1 \\ 1 \\ -1 \\ 1 \end{pmatrix}$  and hence find the general solution of the

equation  $\mathbf{Ax} = \begin{pmatrix} 3 \\ 21 \\ 24 \\ 27 \end{pmatrix}$ .



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[5]

- (c) (iii) is the mass of the car?

the values of  $p$  and  $q$

the experimental observations that show radioactive decay is

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[12]

- (i) a similar method to find a lower bound for  $\sum_{r=1}^n \frac{n}{n^2+r^2}$ . Give your answer in terms of  $n$  and  $\pi$ .

Find the value of  $a$  for which  $\arg(u^*) = \frac{3}{4}\pi$ , where  $u^*$  denotes the complex conjugate of  $u$ .

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without = .....  $az$  [8]

- (b) (iii) the distribution function of  $X$ .

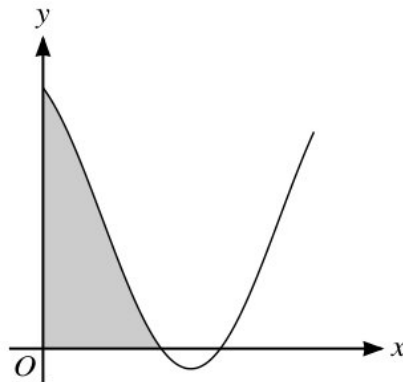
the value of  $\sum_{r=1}^{\infty} \frac{1}{(2-3r)(5-3r)}$ .

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[6]

- (iv) the value of  $\alpha$ .

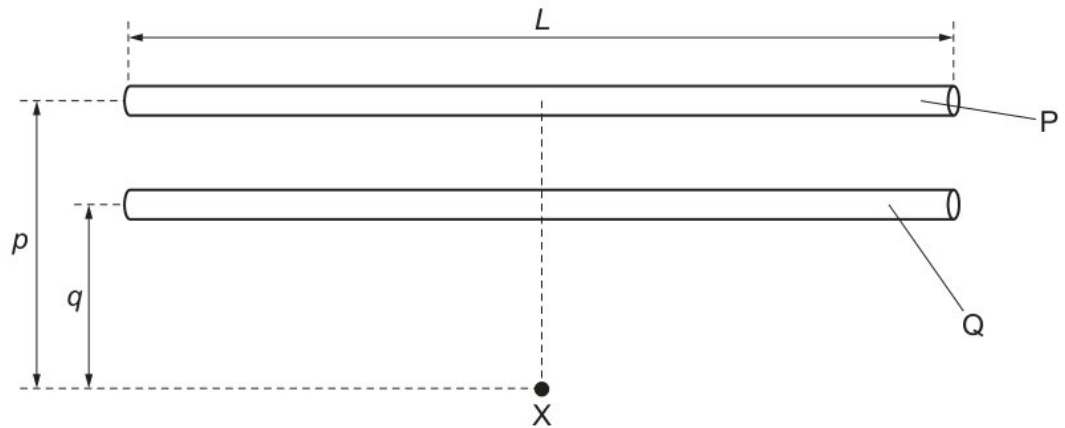
Prove that, for  $n \geq 2$ ,



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[6]

- 15 (c) continuous random variable,  $X$ , has probability density function given by



- (iv) smooth spheres  $P$  and  $Q$ , of equal radius, have masses  $m$  and  $3m$  respectively. They are moving in the same direction in the same straight line on a smooth horizontal table. Sphere  $P$  has speed  $u$  and collides directly with sphere  $Q$  which has speed  $ku$ , where  $0 < k < 1$ . Sphere  $P$  is brought to rest by the collision. Show that the coefficient of restitution between  $P$  and  $Q$  is  $\frac{3k+1}{3(1-k)}$ .

random sample of five metal rods produced by a machine is taken. Each rod is tested for hardness. The results, in suitable units, are as follows.

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[8]

- (i) particle of mass  $m$  and charge  $+Q$  moves at speed  $v$  into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

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$$y^2 + 5 = \dots\dots\dots\text{ks} \quad [6]$$

- (a) a positron and an antineutrino

- (iii) The point  $A$  on the line of intersection of  $p$  and  $q$  has  $y$ -coordinate equal to 2 . Find the equation of the plane which contains the point  $A$  and is perpendicular to both the planes  $p$  and  $q$ . Give your answer in the form  $ax + by + cz = d$ .

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[4]

- (ii) Find a vector equation for the line of intersection of the planes.

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vector eigenvector with = .....  $bg$  [6]

- (b) this Saturday's event, 60% of the competitors had times less than 36.0 minutes.

- (i) Use the information in (d)(iv) to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

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[3]

- (ii) only one of the following two alternatives.

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[10]

(vi) that  $\frac{d}{dt}(\operatorname{sech}^{-1} t) = -\frac{1}{t\sqrt{1-t^2}}$ .

are two marks on the tube. The top mark is positioned at  $115 \pm 1$  mm on the adjacent rule and the lower mark at  $385 \pm 1$  mm. The ball passes the top mark at  $1.50 \pm 0.02$  s and passes the lower mark at  $3.50 \pm 0.02$  s.

by mathematical induction, that  $\sum_{r=1}^n r \ln\left(\frac{r+1}{r}\right) = \ln\left(\frac{(n+1)^n}{n!}\right)$  for all positive integers  $n$ .

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[5]

16 the term isotope.

$$\tan 3\theta = \frac{3 \tan \theta - \tan^3 \theta}{1 - 3 \tan^2 \theta}.$$

(c) (ii) diagram shows the graph of the probability density function,  $f$ , of a random variable  $X$ . The graph is a straight line from  $(0, a)$  to  $(2, b)$ , where  $a$  and  $b$  are positive constants. Elsewhere,  $f(x) = 0$ .

$$(\text{amplitude})^2 \propto \sqrt{\text{intensity}}$$

$$\alpha + \beta + \gamma = -6, \quad \alpha^2 + \beta^2 + \gamma^2 = 38, \quad \alpha\beta\gamma = 30$$

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[4]

(iii) Find the value of  $\alpha$  correct to 3 decimal places. Show your working, giving each calculated value of the sequence to 5 decimal places.

believes that 20% of the students at his college are left-handed. His friend believes that the true proportion,  $p$ , is less than 20%. Amir plans to use the binomial distribution to test the null hypothesis,  $H_0 : p = 0.2$ , against the alternative hypothesis,  $H_1 : p < 0.2$ .

results for a random sample of 60 adults who completed the questionnaire this year are summarised as follows.

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[4]

- (a) (iii) It limits the range of values obtained in repeated measurements.

of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

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[8]

- (iv) resistor of resistance  $240\Omega$  is now replaced by a new resistor X of unknown resistance. A galvanometer is connected as shown in Fig. 6.2.

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Observed frequency	1	3	15	31	59	107

Find the angle that this tangent makes with the  $x$ -axis.

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appropriate = .....  $xz$  [10]

- (i) sample of a radioactive substance emits particles that are positively charged and have a continuous range of kinetic energies.

that  $y = 0$  when  $x = 0$ . Give your answer in an exact form.

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with eigenvector = .....  $fh$  [8]

- (b) (iii) are the amplitude and the period of wave  $S$  ?

measurements to be taken,

counts the number of emails,  $x$ , he receives each day and notes that, over a period of  $n$  days,  $\Sigma(x - 10) = 27$  and the mean number of emails is 11.5 . Find the value of  $n$ .

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[6]

- (v) source of sound of constant power  $P$  is situated in an open space. The intensity  $I$  of sound at distance  $r$  from this source is given by

support at end  $X$  exerts a force  $F$  vertically upwards on the plank.

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[4]

- 29 Explain why the observed wavelength and the emitted wavelength have different values.

For boys aged 16 years in Jimpuri, 25% have a weight between 65 kilograms and  $k$  kilograms, where  $k$  is greater than 65 . Find  $k$ .

Nucleon numbers of nuclei are unchanged by the emission of  $\beta$ -particles.

- (c) (i) is a planet that may be considered to be an isolated uniform sphere of radius  $3.4 \times 10^6$  m.

how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

[12]

- (ii) ice cube of mass 37.0 g at temperature  $0.0^{\circ}\text{C}$  is placed in a beaker containing water of mass 208 g at temperature  $26.4^{\circ}\text{C}$ .

uniform solid sphere with centre  $C$ , radius  $2a$  and mass  $3M$ , is pivoted about a smooth horizontal axis and hangs at rest. The point  $O$  on the axis is vertically above  $C$  and  $OC = a$ . A particle  $P$  of mass  $M$  is attached to the sphere at its lowest point (see diagram). Show that the moment of inertia of the system about the axis through  $O$  is  $\frac{84}{5}Ma^2$ .

[5]

- (iii)  $\lambda$  is a positive constant. Given that the mean lifetime of Trulite bulbs is 2000 hours, find the probability that a randomly chosen Trulite bulb has a lifetime of at least 1000 hours.

is given that  $P$  remains at rest in this new position.

[12]

- (d) (ii)  $p$  and  $q$  are given real numbers, then  
the speed of the aeroplane.

[5]

- (iii) curve  $C$  has equation

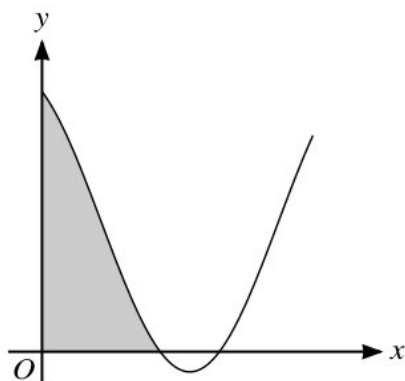
fair six-sided dice with faces labelled 1, 2, 3, 4, 5, 6 is thrown repeatedly until a 3 is obtained. The number of throws taken is denoted by the random variable  $X$ .

that  $\frac{d}{dt}(\operatorname{sech}^{-1} t) = -\frac{1}{t\sqrt{1-t^2}}$ .

[8]

- 8 the curve with equation  $y = \left| \frac{2x^2-5x}{2x^2-7x-4} \right|$ .

- (a) (vi) particle  $P$  of mass  $m$  is attached to one end of a light inextensible string of length  $a$ . The other end of the string is attached to a fixed point  $O$ . The particle moves in a horizontal circle with constant angular speed  $\omega$  and with the string inclined at an angle of  $\theta$  to the downward vertical.



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[8]

- (iv) all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is  $10.3^{\circ}\text{C}$ .

a diagram, on page 3, showing the arrangement of your equipment. In your account

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[6]

- (g)(vii) small smooth ring  $R$ , of mass  $0.6 \text{ kg}$ , is threaded on a light inextensible string of length  $100 \text{ cm}$ . One end of the string is attached to a fixed point  $A$ . A small bead  $B$  of mass  $0.4 \text{ kg}$  is attached to the other end of the string, and is threaded on a fixed rough horizontal rod which passes through  $A$ . The system is in equilibrium with  $B$  at a distance of  $80 \text{ cm}$  from  $A$  (see diagram).

is a planet that may be considered to be an isolated uniform sphere of radius  $3.4 \times 10^6 \text{ m}$ .

marks of the pupils in a certain class in a History examination are as follows.

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[6]

- (ii)  $f(x)$  is divided by  $(x+2a)$  the remainder is  $-22a^3$  When  $f(x)$  is divided by  $(3x-a)$  the remainder is  $-a^3$

the characteristic equation of  $\mathbf{A}$  to show that  $(\mathbf{A} - 2\mathbf{I})^3 = a\mathbf{A}^2 + b\mathbf{A} + c\mathbf{I}$  where  $a, b$  and  $c$  are constants to be determined.

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[6]

- (e) (iv) particles  $P, Q$  and  $R$ , of masses  $0.6 \text{ kg}, 0.4 \text{ kg}$  and  $0.8 \text{ kg}$  respectively, are at rest in a straight line on a smooth horizontal plane. The distance from  $P$  to  $Q$  is  $3 \text{ m}$ , and the distance from  $Q$  to  $R$  is also  $3 \text{ m}$  (see diagram).  $P$  is projected directly towards  $Q$  with speed  $3 \text{ ms}^{-1}$ . After  $P$  and  $Q$  collide,  $P$  continues to move in the same direction with speed  $1.5 \text{ m s}^{-1}$ .

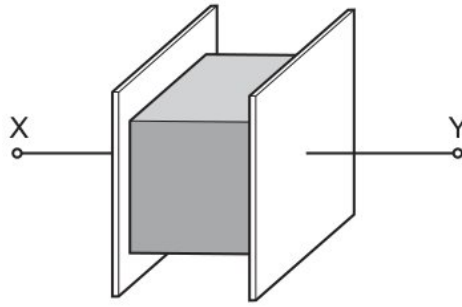
$$\mathbf{i} + \mathbf{j} + 3\mathbf{k}, \quad 3\mathbf{i} - \mathbf{j} + 5\mathbf{k}, \quad 3\mathbf{i} - \mathbf{j} + \mathbf{k}, \quad 5\mathbf{i} - 5\mathbf{j} + \alpha\mathbf{k},$$

car of mass  $1400 \text{ kg}$  is travelling on a straight, horizontal road at a constant speed of  $25 \text{ m s}^{-1}$ . The output power from the car's engine is  $30 \text{ kW}$ .

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[2]

(ii)



stationary loudspeaker emits sound of constant frequency. A microphone is placed near to the loudspeaker and connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

the time that it takes from when  $P$  is initially projected until the instant at which  $P$  collides with the combined particle

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[12]

16 that the greatest height of  $B$  above the ground is 1.2 m , find the value of  $x$ .

(b) (i) weight of 120 kN is placed on top of a metal column. The length of the column is compressed by 0.25 mm . The column obeys Hooke's law when compressed.

random variable,  $X$ , has the distribution  $Po(31)$ . Use the normal approximation to the Poisson distribution to find  $P(X > 40)$ .

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[8]

- (iii) diagram illustrates successive wavefronts.

$$C_1 : r = a$$

$$C_2 : r = 2a \cos 2\theta, \text{ for } 0 \leq \theta \leq \frac{1}{4}\pi$$

many different colour arrangements are there of the 10 books in which the 3 blue books are together, but the 2 yellow books are not next to each other?

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residents = .....  $js$  [10]

- (iv) wavelength of the wave and the width of the gap are both changed by a small amount.

row describes the relative ionizing power and the relative penetration power per unit length in air of  $\alpha$ -particles and  $\gamma$ -rays?

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[10]

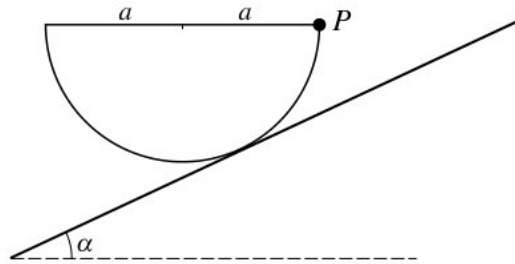
- (d) (vi) in either order the value of  $\mu$  and the value of  $\sigma$

the curve with equation  $y = \left| \frac{2x^2 - 5x}{2x^2 - 7x - 4} \right|$ .

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[20]

- (i) Calculate the speed of the star relative to the Earth.



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[4]

- (a) (i) Deduce an approximation to the area of region  $B$  and explain why this approximation under- estimates the true area of region  $B$ .

roots of the equation

system is released from rest with  $OP$  making a small angle  $\alpha$  with the downward vertical. Find

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[3]

- (iii) random variables  $X$  and  $Y$  have the independent distributions  $N(44, 16)$  and  $N(30, 9)$  respectively.

particle oscillates in simple harmonic motion with centre  $O$ . When its distance from  $O$  is 3 m its speed is  $16 \text{ m s}^{-1}$ , and when its distance from  $O$  is 4 m its speed is  $12 \text{ m s}^{-1}$ . Find the period and amplitude of the motion.

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[8]

- (ii) Find the deceleration of the tractor at the instant it begins to climb the hill.

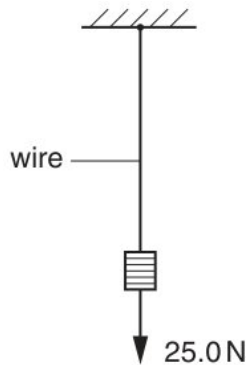
$$(\text{amplitude})^2 \propto \sqrt{\text{intensity}}$$

measurements to be taken,

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[5]

- (c) (v)



team of 4 is to be randomly chosen from 3 boys and 5 girls. The random variable  $X$  is the number of girls in the team.

Find the value of  $a$  for which  $\arg(u^*) = \frac{3}{4}\pi$ , where  $u^*$  denotes the complex conjugate of  $u$ .

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such = .....  $fu$  [2]

- (i) if the 4 vowels A, E, E, I must all be together.

neutron decays to form a proton.

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 .....  
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[8]

- (iv) the solution of the differential equation

find the probability that in 15 throws the number of 4 s obtained is 2 or more.

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string = .....  $mf$  [10]

20 sample of an ideal gas at thermodynamic temperature  $T$  has internal energy  $U$ .

	$\alpha$ -particles	$\gamma$ -rays
A	least ionizing	least penetrating
B	least penetrating	most ionizing
C	most ionizing	most penetrating
D	most penetrating	least ionizing

- (a) (i) Different isotopic nuclei have different proton numbers.

Carry out a goodness of fit test at the 10% significance level.

Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

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[20]

- (ii) was the by-product of this reaction?

single change would double the value of this ratio?

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[12]

- (c) (ii) in exact form the set of values of  $x$  for which  $\left| \frac{2x^2-5x}{2x^2-7x-4} \right| < \frac{1}{9}$ .

why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

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[3]

- (iii) variable resistor in (a) is now connected as a potential divider, as shown in Fig. 5.3.

single change would double the value of this ratio?

would this object weigh on Pluto?

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[8]

16 the term ultimate tensile stress.

- (b) (ii) the probability that at least 1 of these students studies Drama.

$x$  is in radians, has only one root for  $0 < x \leq \frac{1}{2}\pi$ .

numbers of barrels of oil, in millions, extracted per day in two oil fields  $A$  and  $B$  are modelled by the independent random variables  $X$  and  $Y$  respectively, where  $X \sim N(3.2, 0.4^2)$  and  $Y \sim N(4.3, 0.6^2)$ . The income generated by the oil from the two fields is \$90 per barrel for  $A$  and \$95 per barrel for  $B$ .

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[10]

- (i) a similar method to find a lower bound for  $\sum_{r=1}^n \frac{n}{n^2+r^2}$ . Give your answer in terms of  $n$  and  $\pi$ .

Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

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matrix = ..... *bo* [8]

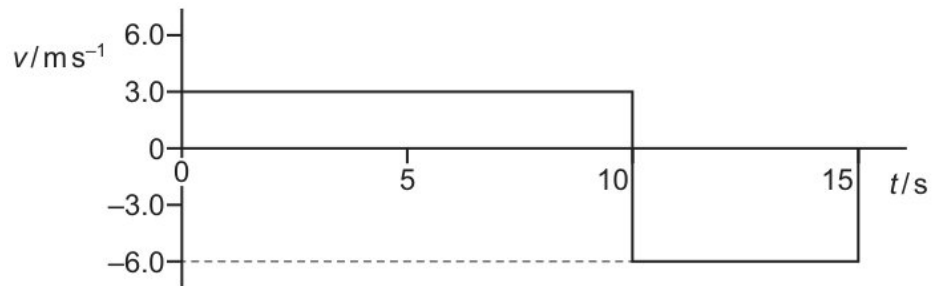
- (iii) the average power of the aeroplane's engines.

$$\begin{pmatrix} 0 \\ 1 \\ -1 \end{pmatrix}, \quad \begin{pmatrix} -1 \\ 0 \\ 1 \end{pmatrix}, \quad \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix},$$

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same = ..... *lh* [6]

- (v)



forces, of magnitudes  $F$  N,  $3F$  N,  $G$  N and  $50$  N, act at a point  $P$ , as shown in the diagram.

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[5]

- (e) (v) bolt has a circular cross-section. At end X , the diameter is  $2d$ . At end Y , the diameter is  $d$ .

By using the substitution  $y = \frac{1}{x^2}$ , find the cubic equation with roots  $\frac{1}{\alpha^2}$ ,  $\frac{1}{\beta^2}$  and  $\frac{1}{\gamma^2}$ .

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origin. = ..... oh [2]

- (vii) row best specifies the correct  $I - V$  graphs for the lamp and the diode?

the data to carry out a goodness of fit test at the 5% significance level to test the scientist's claim.

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[6]

- (iii) determine the ratio  $\frac{V_1}{V_2}$  of the potential differences across  $R_1$  and  $R_2$ , a point is found on  $XY$  at which the lamp is off. This point is at a distance  $x$  from  $X$ .

constant potential difference is applied between two horizontal metal plates. A charged oil droplet is held stationary by the electric field between the plates.

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[2]

- 13 the acute angle between the planes  $ABC$  and  $ABD$ .

- (b) (ii) the value of  $\int_0^{\frac{2}{3}\pi} \sin\left(\frac{1}{2}x\right) dx$ .

considering the binomial expansion of  $\left(z - \frac{1}{z}\right)^5$ , where  $z = \cos \theta + i \sin \theta$ , use de Moivre's theorem to show that

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[5]

- (iii) that, when  $t = 0$ ,  $x = 3$  and  $\frac{dx}{dt} = 0$ .

Find the probability that the total income produced by the two fields in a day is at least \$670 million.

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[6]

- (i) internal diameter of the beaker is  $0.05 \text{ m} \pm 3\%$ .

relationship is used in the derivation of the equation shown?

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[6]

- (g) (v) in terms of  $a$ , the distance that  $P$  moves down the plane before coming to rest.  
 the jet of water hits the wall, it has horizontal velocity  $v$  and cross-sectional area  $A$ .

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[8]

- (vi) activity of a radioactive sample.

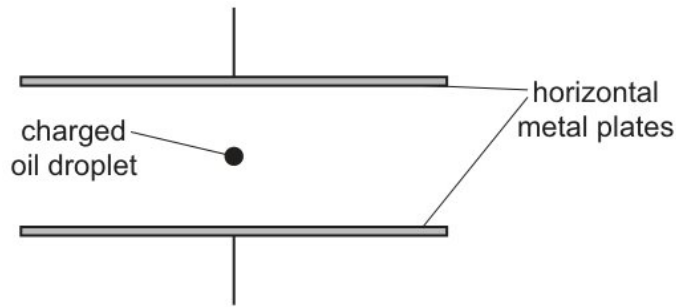
the vertical and horizontal components of velocity at time  $t$ .

will the powers to the resistors change when resistor W is removed?

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[10]

- (f) (ii) aeroplane is flying at a constant speed.



is also known that the standard deviation of the times taken by all 50 runners is 1.38 seconds.

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[6]

- (iii) no digit can be repeated,  
 cubic equation  $2x^3 - 3x^2 + 4x - 10 = 0$  has roots  $\alpha, \beta$  and  $\gamma$ .

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[12]

- (i) the nucleus of  ${}_{92}^{238}\text{U}$  absorbs a neutron, the nucleus decays, emitting an  $\alpha$ -particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the  $\alpha$ -particle.

width of the 99% confidence interval is double the width of the  $x\%$  confidence interval.

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[10]

- (c) (ii) no unique solution.

plank has a mass of 7.0 kg and has a pivot at its midpoint. The plank is horizontal and in equilibrium.

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[6]

- (iv) the number of different selections if the 4 books include at least 1 red book, at most 1 blue book and exactly 1 yellow book.

$$a^2 \left( \frac{1}{6}\pi - \frac{1}{8}\sqrt{3} \right)$$

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[10]

- 9 bolt has a circular cross-section. At end X , the diameter is  $2d$ . At end Y , the diameter is  $d$ .

- (v) (b) values,  $x$ , in a particular set of data are summarised by  
 continuous random variable  $X$  has probability density function  $f$  given by

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[5]

- (a) value for the Hubble constant is  $2.3 \times 10^{-18} \text{ s}^{-1}$ .

$$x = e^{\tan t}, \quad y = 3 \tan^2 t$$

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[4]

- (vi) (c) copper wire is 6.4 m long and has a resistance of  $0.92\Omega$ .  
by calculation that  $a$  lies between 2 and 2.1.

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[15]

- (e)  $\frac{1}{(2r+1)(2r+3)}$  in partial fractions and hence use the method of differences to find

$$\tan 4\theta = \frac{4 \tan \theta - 4 \tan^3 \theta}{1 - 6 \tan^2 \theta + \tan^4 \theta}$$

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[4]

- 16 wires  $X$  and  $Y$  are made of different metals. The Young modulus of wire  $X$  is twice that of wire  $Y$ . The diameter of wire  $X$  is half that of wire  $Y$ .

- (b) (ii) magnetic flux density.

lifetime, in hours, of a 'Trulite' light bulb is a random variable  $T$ . The probability density function  $f$  of  $T$  is given by

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[12]

- (v) planes  $p$  and  $q$  have equations  $x + y + 3z = 8$  and  $2x - 2y + z = 3$  respectively.

diagram shows the curve with equation  $y = \frac{1}{\sqrt{x}}e^{\sqrt{x}}$  for  $x \geq 1$ , together with a set of  $n - 1$  rectangles of unit width. of unit width.

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[8]

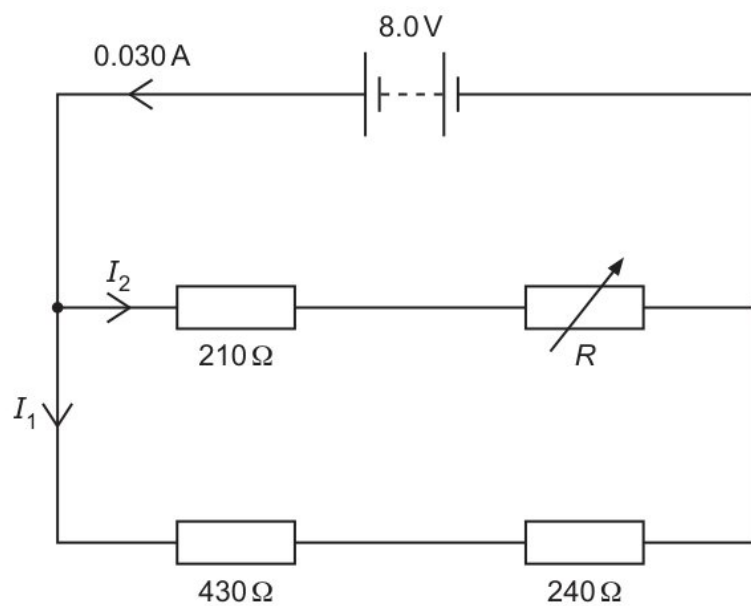
- (i) variation with extension  $x$  of the force  $F$  for a spring A is shown in Fig. 6.1.

of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of  $4.91 \times 10^{-7}$  m.

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[5]

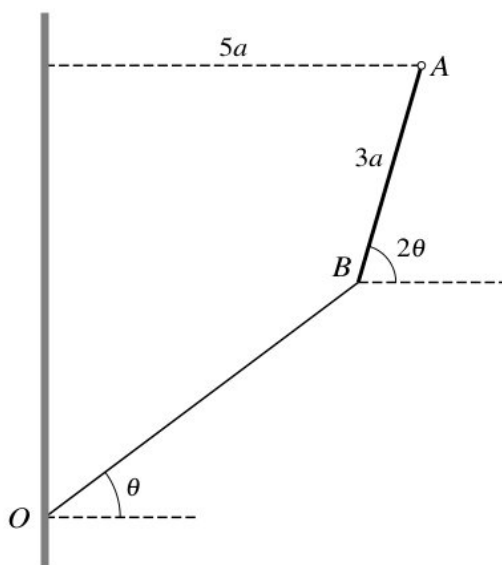
- (d) (ii) 1 and 2 only



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[4]

(iv) could M and N be?



why the variation with time of the activity of a radioactive sample is exponential in nature.

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[2]

12 (b)  $V$  increases because there is a p.d. across  $R$ .

(iii) wavelength of light is 550 nm .

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[12]

(i) the exact value of  $\int_{\frac{1}{5}\pi}^{\frac{1}{4}\pi} 3 \cos^2 5x \, dx$

state the corresponding eigenvalue.

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[2]

- (vi) is suggested that these results are consistent with a distribution having probability density function  $f$  given by

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[3]

- (e) Find the mean age of all 19 people.

Prove that  $\sin^2 2\theta (\operatorname{cosec}^2 \theta - \sec^2 \theta) \equiv 4 \cos 2\theta$ .

- (iii) amplitude  $\propto$  intensity

plank rests on fixed supports at its ends  $X$  and  $Y$ .

State the equation of the other asymptote.

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[4]

- (i) 6.1 shows a circuit that rectifies an alternating input voltage  $V_{\text{IN}}$  and produces an output voltage  $V_{\text{OUT}}$  across a resistor  $R$ .

diagram shows a car travelling at a constant speed in a straight line between person P and person Q from point X to point Y .

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[10]

- 15 (e) Find the volume obtained when the shaded region is rotated through  $360^\circ$  about the  $x$ -axis, giving your answer in terms of  $\pi$ .

- (ii) The vector  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{A}$ , with corresponding eigenvalue  $\lambda$ , and is also an eigenvector of the matrix  $\mathbf{B}$ , with corresponding eigenvalue  $\mu$ . Show that  $\mathbf{e}$  is an eigenvector of the matrix  $\mathbf{AB}$  with corresponding eigenvalue  $\lambda\mu$ .

flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

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[12]

- (iv) object consists of a uniform lamina with a particle attached. The uniform lamina  $ABCEFD$  of mass  $m$  is formed from a rectangle  $ABCD$  and an isosceles triangle  $CEF$ , where  $F$  is the midpoint of  $CD$ . The rectangle has sides  $AB = 2a$  and  $AD = a$ . The triangle  $CEF$  has base  $a$  and height  $2a$ . The particle of mass  $km$  is attached to the lamina at  $E$ . The object rests in a vertical plane with its edge  $AD$  on horizontal ground (see diagram).

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[4]

- (a) Given that exactly two of the selected balls have the same number, find the probability that they are both numbered 2 .

$$\tan 3\theta = \frac{3 \tan \theta - \tan^3 \theta}{1 - 3 \tan^2 \theta}.$$

- (ii) Calculate the initial speed and the angle of projection of  $P$ .

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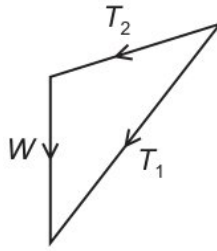
[2]

- (iii) Find the rank of  $\mathbf{M}$ .

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[5]

(c)



three quantities that are conserved during the decay.

- (vii) nucleus  $X$  has 14 nucleons and  $p$  protons. The ratio of charge to mass for nucleus  $X$  is  $4.1 \times 10^7 \text{Ckg}^{-1}$ .

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[2]

- (i) airline has found that, on average, 1 in 100 passengers do not arrive for each flight, and that this occurs randomly. For one particular flight the airline always sells 403 seats. The plane only has room for 400 passengers, so the flight is overbooked if the number of passengers who do not arrive is less than 3 . Use a suitable approximation to find the probability that the flight is overbooked.

Find the distance of  $B$  from the wall when it collides with  $A$  for the second time.

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[6]

- (ii) matrix  $\mathbf{M}$  is given by  $\mathbf{M} = \begin{pmatrix} 1 & 2 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix}$  where  $0 < \theta < 2\pi$

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purple = ..... oq [5]

- (d) Show that  $P(X = 3) = \frac{1}{15}$ .

mid-day temperature,  $x^{\circ}\text{C}$ , and the amount of sunshine,  $y$  hours, were recorded at a winter holiday resort on each of 12 days, chosen at random during the winter season. The results are summarised as follows.

electromagnetic wave phenomenon is needed to explain the spectrum produced when white light falls on a diffraction grating?

- (iii) Find, in the form  $ax^3 + bx^2 + c = 0$ , an equation of which  $\alpha$  is a root.

counts the number of emails,  $x$ , he receives each day and notes that, over a period of  $n$  days,  $\Sigma(x - 10) = 27$  and the mean number of emails is 11.5 . Find the value of  $n$ .

diagram shows a semicircle  $ACB$  with centre  $O$  and radius  $r$ . The tangent at  $C$  meets  $AB$  produced at  $T$ . The angle  $BOC$  is  $x$  radians. The area of the shaded region is equal to the area of the semicircle.

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[4]

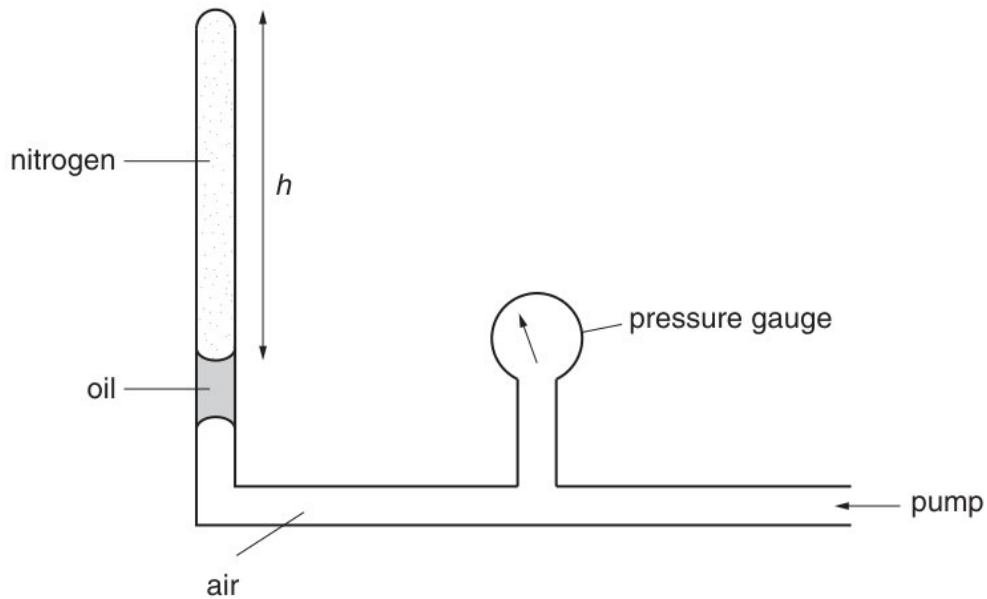
- (i) the complex numbers  $z$  for which  $\frac{z+4}{z+4i}$  is real and  $|z| = \sqrt{10}$ . Give your answers in the form  $z = x + iy$ , where  $x$  and  $y$  are real.

the exact value of the positive constant  $k$  for which

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[5]

- 18 weights of letters posted by a certain business are normally distributed with mean 20 g . It is found that the weights of 94% of the letters are within 12 g of the mean.
- aeroplane is flying at a constant speed.



point  $D$  has position vector  $\mathbf{i} + t\mathbf{k}$ , where  $t \neq -2$ .

- (a) (iii) masses of small bags of pasta sold by the company are normally distributed with mean  $\mu$  kg and standard deviation  $\sigma$  kg Tests show that 77% of these bags have masses greater than 1.26 kg and 44% have masses less than 1.35 kg
- the subsequent collision between  $Q$  and  $R$ , these particles coalesce.

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[6]

- (vii) specific heat capacity of water is  $4.18 \text{ J g}^{-1}\text{°C}^{-1}$ .

particles  $P$  and  $Q$  are projected vertically upwards from horizontal ground at the same instant. The speeds of projection of  $P$  and  $Q$  are  $12 \text{ m s}^{-1}$  and  $7 \text{ m s}^{-1}$  respectively and the heights of  $P$  and  $Q$  above the ground,  $t$  seconds after projection, are  $h_P$  m and  $h_Q$  m respectively. Each particle comes to rest on returning to the ground.

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[6]

- (c) (i) weight of 120 kN is placed on top of a metal column. The length of the column is compressed by 0.25 mm . The column obeys Hooke's law when compressed.

the apparatus used to produce two sources of coherent waves that have circular wavefronts,

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[10]

(ii)

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Observed frequency	1	3	15	31	59	107

is given that  $\sum x^2 = 1823.0$ .

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 .....

[6]

(iv)

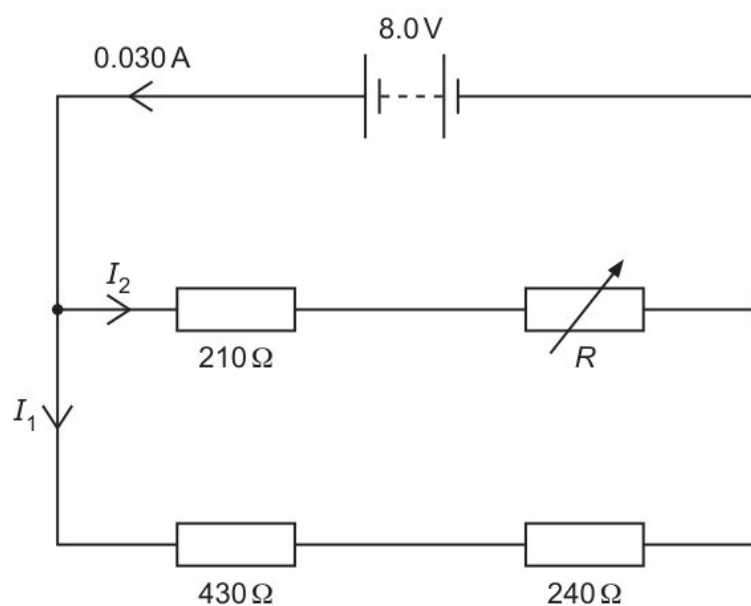
A	mass of stretching load	original length of wire	diameter of wire	extension of wire
B	mass of stretching load	new length of wire	cross-sectional area of wire	diameter of wire
C	mass of wire	original length of wire	cross-sectional area of wire	new length of wire
D	mass of wire	new length of wire	diameter of wire	extension of wire

Given that on a particular flight Julian does not get a good night's sleep, find the probability that he is flying economy class.

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[12]

(iii)



current-carrying coil produces a magnetic field.

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[10]

- 15 Show that  $\frac{ds}{dx} = \frac{1}{2}(e^x + e^{-x})$ , where  $s$  denotes the arc length of  $C$ , and find the surface area generated when  $C$  is rotated through  $2\pi$  radians about the  $x$ -axis.

(a) (i) how the pattern of interfering waves may be observed.

the team contains more boys than girls.

that  $\frac{dy}{dx} = -\sqrt{1-t^2} + (1-t^2) \operatorname{sech}^{-1} t$ .

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[3]

- (iii) Calculate the greatest deceleration of  $P$ .

Nucleus  $X$  undergoes  $\beta^-$  decay to form nucleus  $Z$ .

Explain why the observed wavelength and the emitted wavelength have different values.

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[5]

- (c) (ii) is the work done by  $F$  on the skateboarder and skateboard?

variables  $x$  and  $y$  satisfy the differential equation

is the work done by  $F$  on the skateboarder and skateboard?

.....

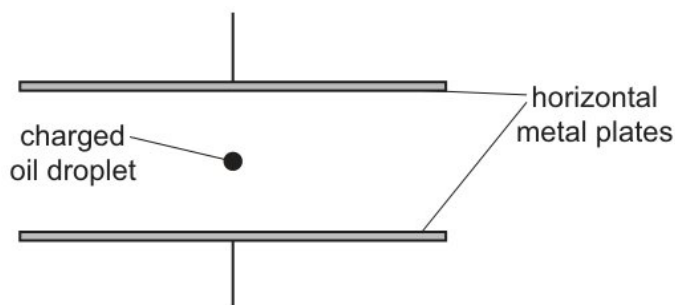
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[6]

- (i) all necessary working, solve the equation  $2 \log_2 x = 3 + \log_2(x + 1)$ , giving your answer correct to 3 significant figures.



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[8]

- (iii) Find the area of the sector of  $C$  between  $\theta = 0$  and  $\theta = \frac{1}{3}\pi$ .

Find the probability density function of  $Y$ .

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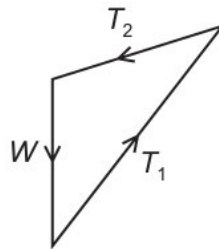
[5]

- (g) (iv) by mathematical induction that, for all positive integers  $n$ ,  
 is a general description of a baryon?

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frequency = .....  $gf$  [12]

- (i)



Use the equation of a suitable regression line to estimate the number of hours of  
 sunshine on a day when the mid-day temperature is  $2^{\circ}\text{C}$ .

the principle of superposition.

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[6]

- (b) (ii) only one of the following two alternatives.

uniform solid hemisphere, of radius  $a$  and mass  $M$ , is placed with its curved surface in contact with a rough plane that is inclined at an angle  $\alpha$  to the horizontal. A particle  $P$  of mass  $m$  is attached to the rim of the hemisphere. The system rests in equilibrium with the rim of the hemisphere horizontal and  $P$  at the point on the rim that is closest to the inclined plane (see diagram). Given that the coefficient of friction between the plane and the hemisphere is  $\frac{1}{2}$ , show that

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[6]

- (v) that  $\frac{d}{dt}(\operatorname{sech}^{-1} t) = -\frac{1}{t\sqrt{1-t^2}}$ .

bag contains 7 red balls and 3 blue balls. Kieran selects 2 balls at random, without replacement. The number of red balls selected by Kieran is denoted by  $X$ , and the number of different colours present in Kieran's selection is denoted by  $Y$ .

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[15]

- 10 Show that  $v^2 = u^2 + \frac{14}{5}ag$ .

State the name of this type of reaction.

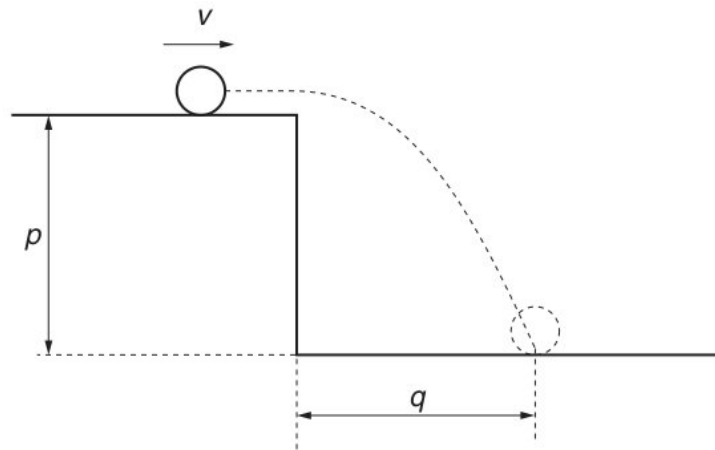
- (b) (v) sequence  $x_1, x_2, x_3, \dots$  defined by

graph shows the variation with temperature of power,  $P$ , dissipated in the thermistor?

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[4]

- (i) It limits the precision of the measured value.



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[4]

- (c) (iii) is now given that the true value of  $p$  is 0.05 .

points  $A, B$  and  $C$  have position vectors  $2\mathbf{i} - \mathbf{j} + \mathbf{k}$ ,  $3\mathbf{i} + 4\mathbf{j} - \mathbf{k}$  and  $-\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}$  respectively.

For this value of  $k$ , find the set of possible solutions, giving your answer in the form

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[8]

- (iv) equation gives  $v$  in terms of  $A$  and  $u$  ?

Find the terms in  $x^2$  and  $x^3$  in the expansion of  $(1 - \frac{3}{2}x)^6$ .

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[3]

12 that  $\mathbf{e}$  is an eigenvector of  $\mathbf{A}^3$  with corresponding eigenvalue  $\lambda^3$ .

- (iii) (a) and explain whether the nuclei in the sample are undergoing  $\alpha$ -decay,  $\beta^+$  decay or  $\beta^-$  decay.

Use the trapezium rule with three intervals to estimate the value of

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[6]

- (c) the values of  $p$  and  $q$

Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

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inclined = .....  $ym$  [8]

- (e) Given also that  $-1$  is an eigenvalue of  $\mathbf{A}$ , find a corresponding eigenvector.

out a Wilcoxon rank-sum test at the 5% significance level to test the researcher's claim.



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[10]

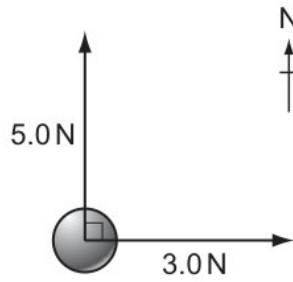
- (b) the probability that, in a randomly chosen week, the first day on which less than 59.1 kg of cherries are sold is the fifth day of the week.

standard results from the list of formulae (MF19) to show that

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[8]

(iv) (b)



why the variation with time of the activity of a radioactive sample is exponential in nature.

point  $D$  is such that  $ABCD$  is a parallelogram.

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straight = .....  $dl$  [5]

(c) definition is correct and uses only quantities rather than units?

what can be deduced from this about the rotation of Mars on its axis.

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[8]

(d) is the work done by  $F$  on the skateboarder and skateboard?

Find the frictional and normal components of the contact force acting on  $B$ .

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[5]

- (a) small smooth ring  $R$ , of mass  $0.6\text{ kg}$ , is threaded on a light inextensible string of length  $100\text{ cm}$ . One end of the string is attached to a fixed point  $A$ . A small bead  $B$  of mass  $0.4\text{ kg}$  is attached to the other end of the string, and is threaded on a fixed rough horizontal rod which passes through  $A$ . The system is in equilibrium with  $B$  at a distance of  $80\text{ cm}$  from  $A$  (see diagram).

Find the least tension in the string during the motion.

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[4]

- (ii) (d) on the graph would the elastic limit be found?

sample of 216 observations of the continuous random variable  $X$  was obtained and the results are summarised in the following table.

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[10]

- (e) a 90% confidence interval for the difference in mean crop mass associated with each type of fertiliser.

is the reading on the ammeter?

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[5]

- (b) Use de Moivre's theorem to show that

$\lambda$  is a positive constant. Given that the mean lifetime of Trulite bulbs is 2000 hours, find the probability that a randomly chosen Trulite bulb has a lifetime of at least 1000 hours.

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[20]

- (i) (a) masses of the bags of rice made by a company are normally distributed with mean  $\mu$  kg and standard deviation 0.14 kg . The probability that the mass of a randomly chosen bag of this rice is less than 1.48 kg is 0.22 .

expression has the same SI base units as pressure?

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[4]

- (b) curve has equation  $y = \frac{4}{3x-4}$  and  $P(2, 2)$  is a point on the curve.  
 is now given that the true value of  $p$  is 0.05 .

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[3]

- 10 particle  $P$  is projected from a point  $O$  on horizontal ground. 0.4 s after the instant of projection,  $P$  is 5 m above the ground and a horizontal distance of 12 m from  $O$ .

is suggested that the strength  $B$  of the magnetic field at the centre of a flat circular coil is inversely proportional to the radius  $r$  of the coil.

- (c) (i)

	wavelength	width of gap
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

$B$  has speed  $38 \text{ m s}^{-1}$  immediately before it strikes the plane.

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[8]

- (ii) By using the substitution  $y = \frac{1}{x^2}$ , find the cubic equation with roots  $\frac{1}{\alpha^2}$ ,  $\frac{1}{\beta^2}$  and  $\frac{1}{\gamma^2}$ .

	weight/N	mass/kg
A	9.85	1.00
B	9.85	6.00
C	58.9	1.00
D	58.9	6.00

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straight, = .....  $lh$  [3]

- (b) (i) light elastic string of natural length 1.2 m and modulus of elasticity 24 N is attached to fixed points  $A$  and  $B$  on a smooth horizontal surface, where  $AB = 1.2$  m. A particle  $P$  is attached to the mid-point of the string.  $P$  is projected with speed  $0.5 \text{ m s}^{-1}$  along the surface in a direction perpendicular to  $AB$  (see diagram).  $P$  comes to instantaneous rest at a distance 0.25 m from  $AB$ .

the arc length of  $C$ ,

region  $R$  is enclosed by  $C$  and  $l$ , and contains the pole. Find the area of  $R$ .

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[5]

- (iv) On Fig. 9.1, sketch the variation of the activity  $A$  of the sample with  $t$  for values of  $t$  between  $t = 0$  and  $t = 24$  min.

light is incident on the front of a photocell, an e.m.f. is generated in the photocell.

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[5]

(ii) Find the general solution of (\*), giving  $y$  in terms of  $x$ .

- falling with constant speed with the parachute open,

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[8]

(g) (v) a digit can be repeated and the number made is even.

first coin is biased so that the probability of obtaining a head when it is thrown is  $\frac{1}{3}$ .

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[2]

(ii) sample has an activity of 180 Bq at time  $t = 0$ .

the median value of  $X$ .

statement about light waves and sound waves is correct?

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[8]

(iii) Its speed decreases to zero, then increases to a value less than  $20 \text{ ms}^{-1}$ .

the geometric effects of multiplying  $z_1$  and  $z_2$  by  $\omega$

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[8]

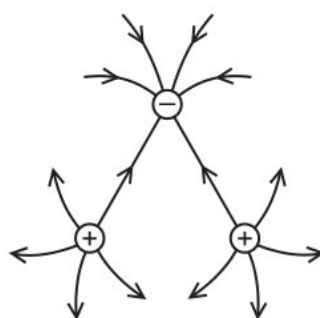
(iv) is the total elastic potential energy stored in the four springs?

resistance of a metal cube is measured by placing it between two parallel plates, as shown.

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[6]

(a) (iii)  $V$  remains the same because the decrease of p.d. across  $r$  is balanced by the increase of p.d. across  $R$ .

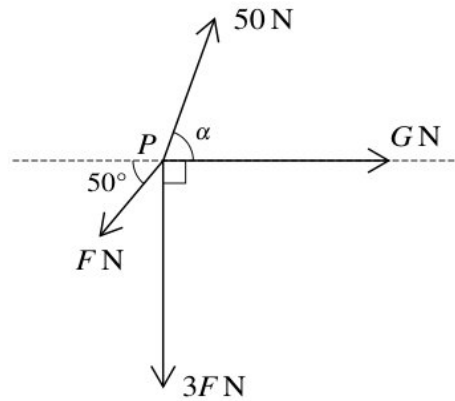


Both light waves and sound waves show the Doppler effect.

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[6]

- (v) the probability that, in a randomly chosen week, the first day on which less than 59.1 kg of cherries are sold is before the fifth day of the week.



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[6]

- (i) Show that  $\frac{d^{n+1}}{dx^{n+1}} (x^{n+1} \ln x) = \frac{d^n}{dx^n} (x^n + (n+1)x^n \ln x)$ .

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Observed frequency	1	3	15	31	59	107

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[5]

- (ii) the solution of the differential equation

$$\tan 4\theta = \frac{4 \tan \theta - 4 \tan^3 \theta}{1 - 6 \tan^2 \theta + \tan^4 \theta}$$

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[12]

- 12 that  $0 < y < \frac{1}{2}\pi$ , find the values of  $y$  when  $x = 0$ .

curve  $C$  has polar equation  $r = 3 + 2 \cos \theta$ , for  $-\pi < \theta \leq \pi$ . The straight line  $l$  has polar equation  $r \cos \theta = 2$ . Sketch both  $C$  and  $l$  on a single diagram.

Show that  $r = -2a \sin 2\theta$  and sketch  $C$ .

the number of different ways in which the 12 letters of the word STRAWBERRIES can be arranged

Find the cartesian equation of the plane through  $A, B$  and  $C$ .

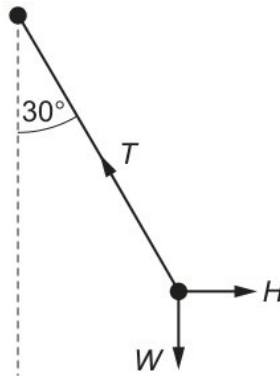
- (h) (ix) specific heat capacity of water is  $4.18 \text{ J g}^{-1}\text{°C}^{-1}$ .

Show by calculation that  $a$  lies between 2 and 4 .

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[4]

- (i)



Saturday, a particular community holds a 'Puzzle' event to raise money for a new Leisure Centre. Competitors attempt to solve a puzzle as quickly as possible.

set of friends consists of 7 men and 4 women. Three of the men are brothers: Ali, Ben and Charlie.

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[2]

- (vi) aeroplane then ascends 300 m in 50 s , while maintaining the same speed. The resistance force is no longer constant, and the work done against the resistance force in ascending the 300 m is 270000 kJ . The mass of the aeroplane is 60000 kg .

the probability that at least 1 of these students studies Drama.

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[5]

- (b) (ii) State what is meant by the internal energy of a system.

the probability of a Type I error.

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[3]

- (iv) point  $P$  is the foot of the perpendicular from  $A$  to  $l$ .

Hence show that the differential equation

$$\sin 5\theta = 5 \sin \theta - 20 \sin^3 \theta + 16 \sin^5 \theta$$

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[8]

- (v) the distribution function of  $X$ .

the de Broglie wavelength of an electron moving at a speed of  $4.9 \times 10^7 \text{ m s}^{-1}$ .

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[3]

- (c) (i) much charge passes a given point in wire  $R$  in a time of  $5s$  ?  
process does not require energy to be supplied?

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[8]

- (iv) a positron and an antineutrino

an experiment to demonstrate two-source interference of light, a beam of light is split into two beams using two slits  $0.50\text{ mm}$  apart. These two beams are incident on a laboratory wall at a distance of  $4.0\text{ m}$  .

logarithms to solve the equation  $3^x = 2^{x+2}$ , giving your answer correct to 3 significant figures.

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[1]

- (ii) student determines the ratio  $\frac{\text{upthrust acting on the object}}{\text{weight of the object}}$  .

probability that Julian gets a good night's sleep on a randomly chosen flight is  $0.285$  .

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[5]

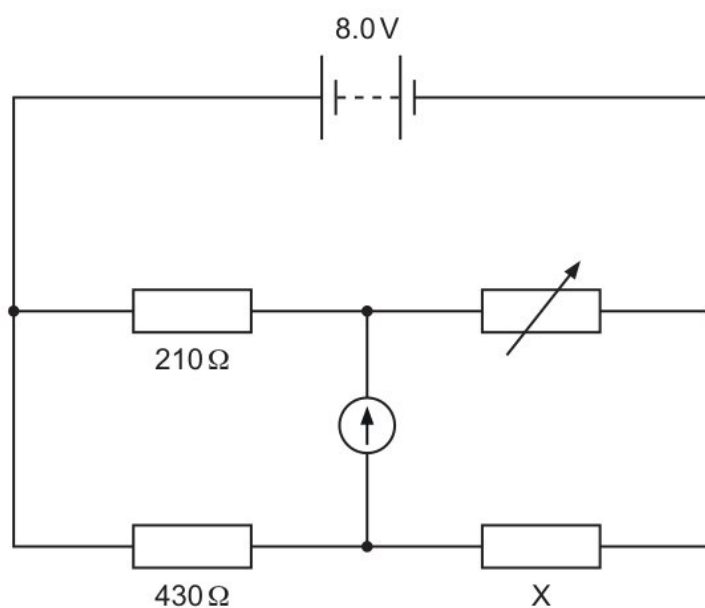
- (v) bag contains 10 marbles, of which 4 are red and 6 are blue. Four marbles are selected from the bag at random, without replacement. The random variable  $X$  denotes the number of blue marbles selected.

Show that  $a = \frac{1}{3} \ln(251 - a - a^2)$ .

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[6]

(a) (iv)



matrix **A** is given by

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[4]

(iii)

	$A$	$n$	$v$	$q$
A	area of cross-section	number of free electrons	voltage	charge of each molecule
B	area of cross-section	number of free electrons per unit volume	average drift speed of electrons	charge of each electron
C	current	number of free electrons	average drift speed of electrons	charge of each molecule
D	current	number of free electrons per unit volume	voltage	charge of each electron

is a planet that may be considered to be an isolated uniform sphere of radius  $3.4 \times 10^6$  m.

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[8]

- (ii) Sound waves are transverse waves and light waves are longitudinal waves.

A	mass of stretching load	original length of wire	diameter of wire	extension of wire
B	mass of stretching load	new length of wire	cross-sectional area of wire	diameter of wire
C	mass of wire	original length of wire	cross-sectional area of wire	new length of wire
D	mass of wire	new length of wire	diameter of wire	extension of wire

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[3]

- 16 Find the value of  $k$  for which the set of linear equations

- (d) (i) particle  $P$  of mass  $0.4 \text{ kg}$  is released from rest at a point  $O$  on a smooth plane inclined at  $30^\circ$  to the horizontal.  $P$  moves down the line of greatest slope through  $O$ . The velocity of  $P$  is  $v \text{ m s}^{-1}$  when its displacement from  $O$  is  $x \text{ m}$ . A retarding force of magnitude  $0.2v^2 \text{ N}$  acts on  $P$  in the direction  $PO$ .

Find the coordinates of  $A$  and  $M$ .

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moves = .....  $mx$  [8]

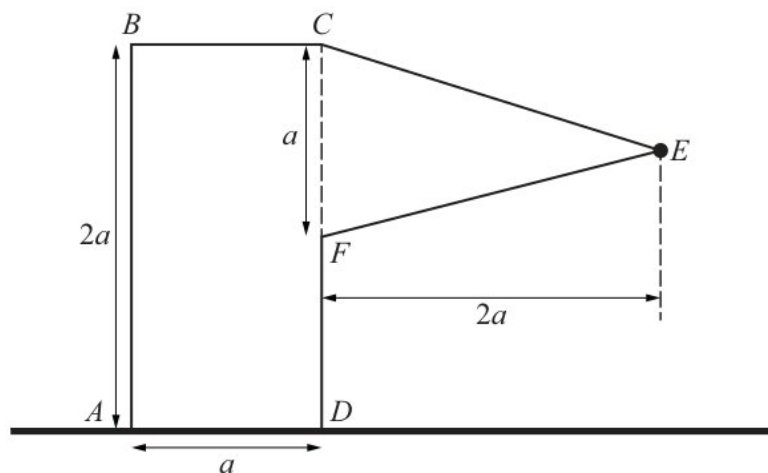
- (iv) Given that  $F = 0, G = 75$  and  $\alpha = 60^\circ$ , find the magnitude and direction of the resultant force.

are no resistive forces acting on the block.

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[12]

(b) (iii)



the data to carry out a goodness of fit test at the 5% significance level to test the scientist's claim.

competitors who took part in this Saturday's event are selected at random.

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[10]

(ii) the solution of the differential equation

curve  $C$  has polar equation  $r = 2a \cos(2\theta + \frac{1}{2}\pi)$  for  $0 \leq \theta < 2\pi$ , where  $a$  is a positive constant.

Show that the mass of Mars is  $6.4 \times 10^{23}$  kg.

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[4]