

- 26 Find the  $x$ -coordinate of  $M$ .

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[10]

- 11 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?

number,  $x$ , of beech trees was counted in each of 50 randomly chosen regions of equal size in beech forests in country  $A$ . The number,  $y$ , of beech trees was counted in each of 40 randomly chosen regions of the same equal size in beech forests in country  $B$ . The results are summarised as follows.

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[5]

- 10 Find the cartesian equation of  $\Pi_1$ .

the particular solution of the differential equation

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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[8]

- 13 linear transformation  $T: \mathbb{R}^4 \rightarrow \mathbb{R}^4$  is represented by the matrix  $\mathbf{M}$ , where

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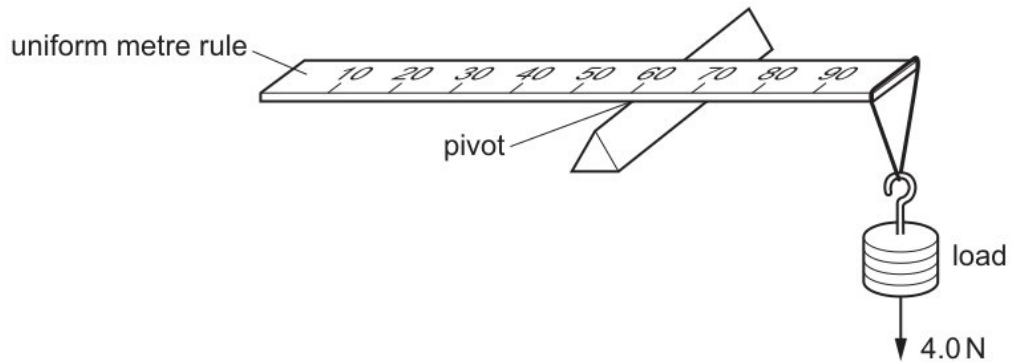
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[6]

- 24 verify that this equation has a root between 5 and 5.05.



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sample = ..... yn [5]

- 17 mean,  $\bar{x}$ , is 28.325 .

- (c) (i) potential divider consists of two resistors of resistances  $R_1$  and  $R_2$  connected in series across a source of potential difference (p.d.)  $V_{in}$ . The p.d. across  $R_1$  is  $V_{out}$ .  
 There will always be 9.0 V across the battery terminals.

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[2]

- (ii) the kinetic model of gases and Newton's laws of motion to explain how a gas exerts a pressure on the sides of its container.

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

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[6]

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

why Kieran is incorrect.

$A$  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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[12]

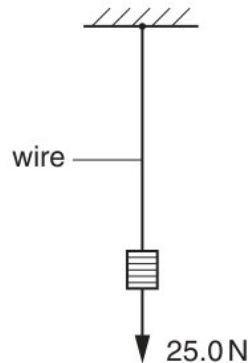
- (i) single change would double the value of this ratio?

the vertical and horizontal components of velocity at time  $t$ .

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taken, = .....  $xe$  [10]

- (ii)



student wishes to investigate projectile motion.

cube has volume  $V$  and is made of a material with resistivity  $\rho$ . The connections to the cube have negligible resistance.

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[5]

- (a) (ii) Find the probability that the die lands on 3 and the number of times the coin shows heads is 3 .

Hence obtain the expansion of  $\frac{5x-x^2}{(1+x)(2+x^2)}$  in ascending powers of  $x$ , up to and including the term in  $x^3$ .

$C$ , stating the coordinates of the intersections with the axes.

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ramp. = ....  $yd$  [10]

- (iv)  $x$  is in radians, has only one root for  $0 < x \leq \frac{1}{2}\pi$ .

1.1 lists some physical quantities. Identify with ticks ( $\checkmark$ ) which quantities are vectors and which are scalars.

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[5]

13 the period of small oscillations,

- (e) (iii)

	energy / J	time / s
A	3.0	2.0
B	3.0	8.0
C	48	2.0
D	48	8.0

plane  $\Pi_1$  passes through the points  $(1, 2, 1)$  and  $(5, -2, 9)$  and is parallel to the vector  $\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}$ .

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[8]

- (ii) Use a different object that has twice the density and the same volume as the original object.

that, for  $n \geq 2$ ,  $I_n = -1 + n(n-1)I_{n-2}$ .

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[6]

- (d) (vi) matrix  $\mathbf{A}$ , given by

Q hears a sound of decreasing frequency.

matrix  $\mathbf{A}$  is given by

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Each = .....  $nx$  [6]

- (ii) the exact volume of the solid generated

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

end of a light elastic string of natural length 0.4 m and modulus of elasticity 8 N is attached to a fixed point  $O$  on a smooth horizontal plane. The other end of the string is attached to a particle  $P$  of mass 0.2 kg which moves on the plane in a circular path with centre  $O$ . The speed of  $P$  is  $v \text{ m s}^{-1}$  and the extension of the string is  $x \text{ m}$ .

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[8]

activity of a radioactive sample.

- (f) 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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[2]

- 13 Find the values of  $p$  and  $q$ .

At a certain instant,  $P$  and  $Q$  are above the ground and  $3h_P = 8h_Q$ . Find the velocities of  $P$  and  $Q$  at this instant.

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[6]

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

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

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

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fixed = .....  $lm$  [10]

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

is given that  $\mu = 0.15$  and  $X = 20$ .

- (c)  $B$  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.

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

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[2]

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

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

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method = .....  $w_i$  [6]

- (d) (ii) Obtain a basis for the null space of  $T$ .

random sample of residents in a town took part in a survey. They were asked whether they would prefer the local council to spend money on improving the local bus service or on improving the quality of road surfaces. The responses are shown in the following table, classified according to the area of the town in which the residents live.

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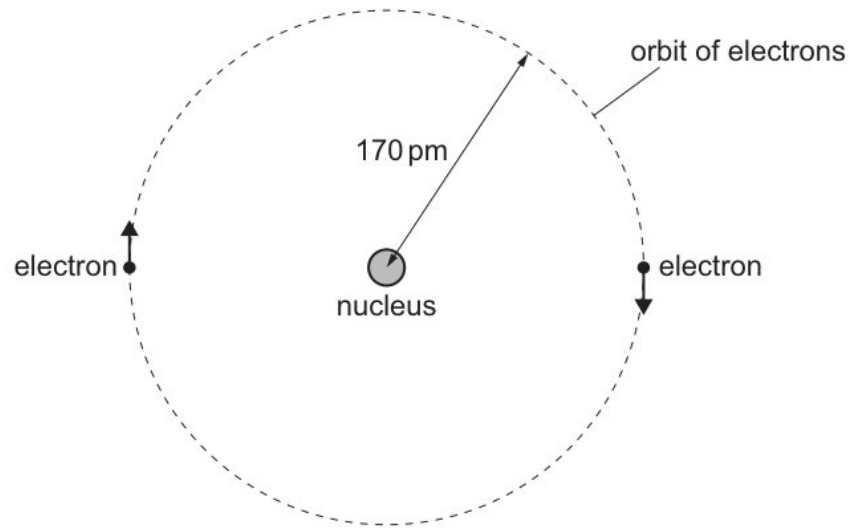
[8]

- (iii) child of weight 600 N stands in different positions on the plank.  
 object hangs by means of two cords around two rods, as shown.

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[6]

(v) down to antiup



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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[6]

- (b) (iii) potential difference across a resistor is  $12\text{ V}$ . The current in the resistor is  $2.0\text{ A}$ . random variable,  $X$ , has the distribution  $\text{Po}(31)$ . Use the normal approximation to the Poisson distribution to find  $P(X > 40)$ .

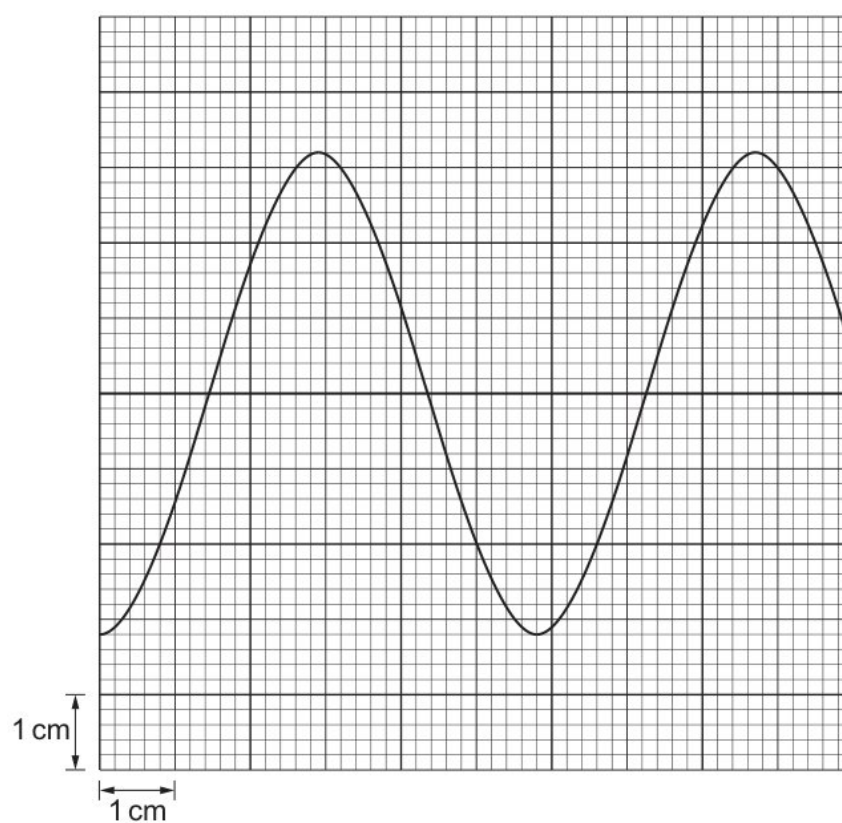
Find the coordinates of this stationary point, giving your answers correct to 3 decimal places.

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[6]



(i)



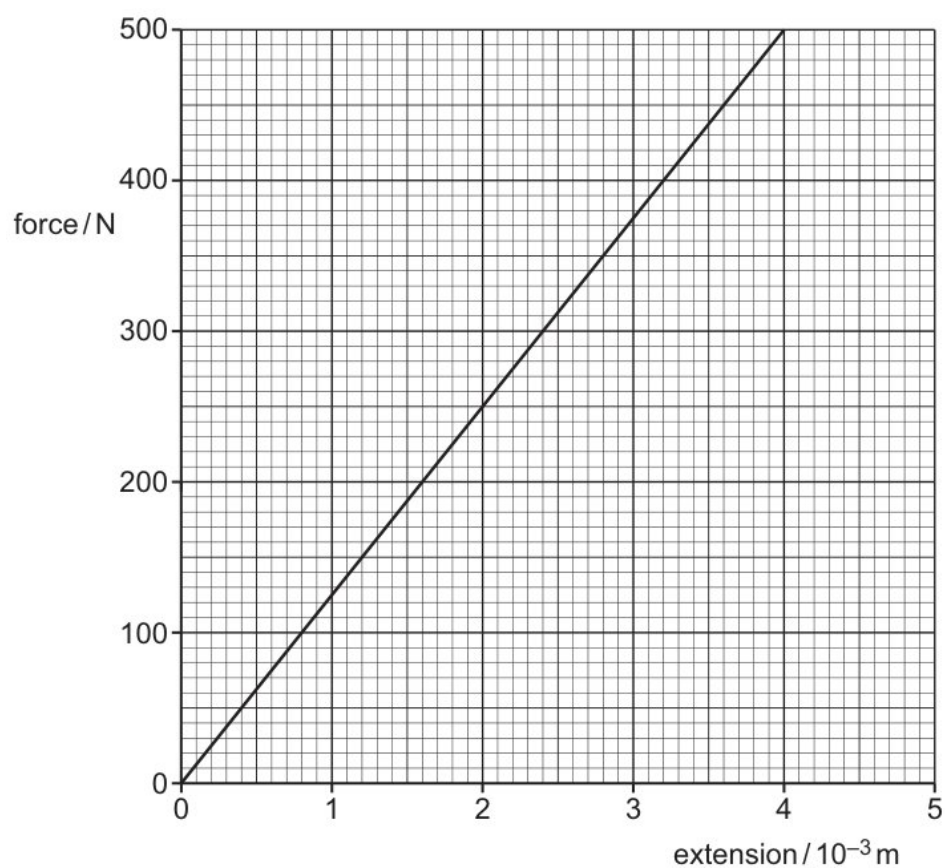
system is released from rest with  $OP$  making a small angle  $\alpha$  with the downward vertical. Find

diagram best represents the electric field surrounding the charges?

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[4]

(iv)



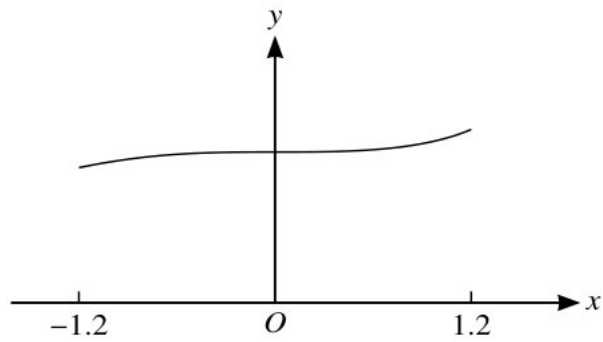
village hall has seats for 40 people, consisting of 8 rows with 5 seats in each row. Mary, Ahmad, Wayne, Elsie and John are the first to arrive in the village hall and no seats are taken before they arrive.

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[6]

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

- (c) (i) Find angle  $ABC$ .



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[1]

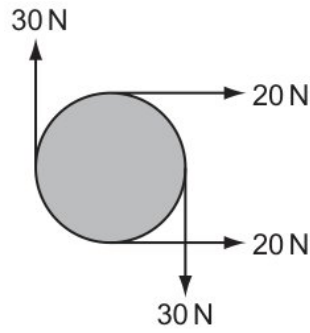
- (iii) statements about what person P and person Q hear during the motion of the car are correct?

quantities would be measured in order to determine  $E$  ?

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[3]

(a) (iii)



Draw up a probability distribution table for  $X$ .

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[4]

(ii)  $I_n = \int_0^1 (1-x)^n \sinh x \, dx$ , where  $n$  is a non-negative integer.  
exactly at point  $S$

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[5]

(e) (iii) Show that, for  $n > 2$ ,  
roots of the equation

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[12]

- (i) the value of  $\mu$ .

Find the value of  $x$ .

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[3]

- (ii) many different colour arrangements are there of the 10 books?

is the angle  $\theta$  ?

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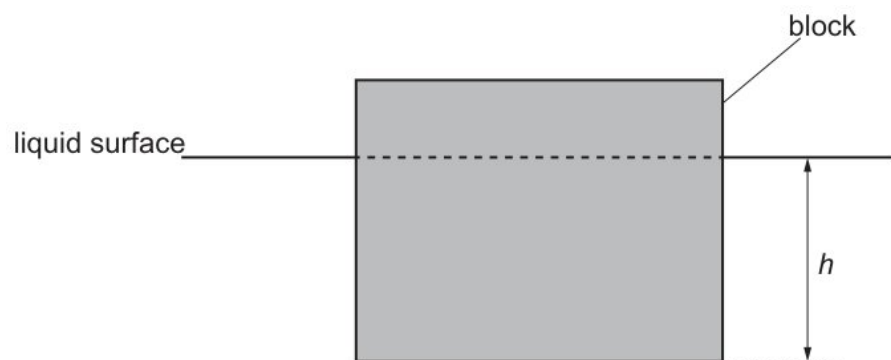
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[5]

- (iv) is the output power of the car's engine when travelling up the slope?



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[4]

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

(b) load on the lower end is increased from zero and then decreased again back to zero.

525 520 522 524 518 520 519 525 527 516

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[6]

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

- (d) 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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[12]

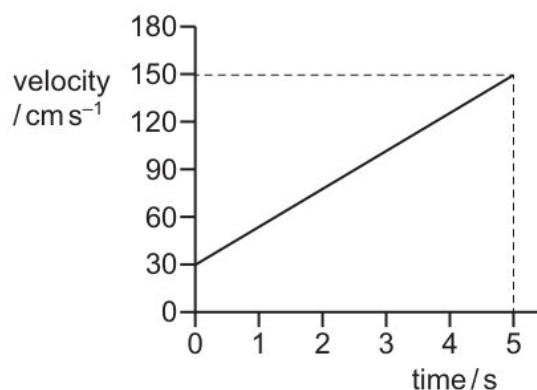
- 15 Find the modulus of elasticity of the string in terms of  $W$ .

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[20]

- 15 the solution of the differential equation

(c) (iv)



is given instead that the kinetic energy of  $P$  is twice the elastic potential energy stored in the string.

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[6]

- (i) how many ways can a team of 4 people be chosen from 10 people if 2 of the people, Ross and Lionel, refuse to be in the team together?

$$I = \frac{P}{4\pi r^2}$$

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[5]

- (a) (ii) Given that  $\begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}$  is an eigenvector of  $\mathbf{A}$ , find the corresponding eigenvalue.

$ABC$  is a uniform triangular lamina of weight 19 N , with  $AB = 0.22$  m and  $AC = BC = 0.61$  m. The plane of the lamina is vertical.  $A$  rests on a rough horizontal surface, and  $AB$  is vertical. The equilibrium of the lamina is maintained by a light elastic string of natural length 0.7 m which passes over a small smooth peg  $P$  and is attached to  $B$  and  $C$ . The portion of the string attached to  $B$  is horizontal, and the portion of the string attached to  $C$  is vertical (see diagram).

sequence  $x_1, x_2, x_3, \dots$  defined by

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[8]

- (vi) that  $\tan \theta = \frac{4}{3}$ , find  $\omega$  in terms of  $a$  and  $g$ .

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

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[6]



- 14 particles  $P$ ,  $Q$  and  $R$ , of masses 0.6 kg, 0.4 kg and 0.8 kg respectively, are at rest in a straight line on a smooth horizontal plane. The distance from  $P$  to  $Q$  is 3 m, and the distance from  $Q$  to  $R$  is also 3 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  $1.5 \text{ m s}^{-1}$ .

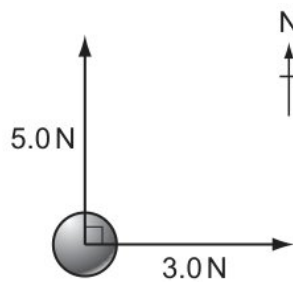
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[8]

- 7 is the change to the quark composition of a nucleus that takes place during  $\beta^+$  decay?  
 star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of  $4.62 \times 10^{-7} \text{ m}$ .

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

(f) (iv)



sample contains a single radioactive isotope that decays to form a stable isotope.  
 planes  $p$  and  $q$  have equations  $x + y + 3z = 8$  and  $2x - 2y + z = 3$  respectively.

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[4]

- (iii) 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.

particles  $P$ ,  $Q$  and  $R$ , of masses 0.6 kg, 0.4 kg and 0.8 kg respectively, are at rest in a straight line on a smooth horizontal plane. The distance from  $P$  to  $Q$  is 3 m, and the distance from  $Q$  to  $R$  is also 3 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  $1.5 \text{ m s}^{-1}$ .

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[12]

- (d) (i) the term ultimate tensile stress.

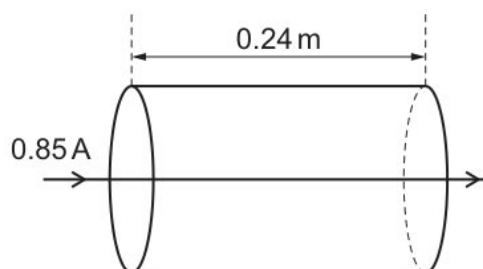
object is held in equilibrium by the forces  $F_1$  and  $F_2$ . The object weighs 10 N. There is negligible friction between the rods and cords. Angle  $\theta$  is  $90^\circ$ .

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[6]

- (ii) gas is compressed so that its temperature increases to  $3T$ .

Determine whether this point is a maximum or a minimum point.



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[4]

- 18 monochromatic plane wave of speed  $c$  and wavelength  $\lambda$  is diffracted at a small aperture.

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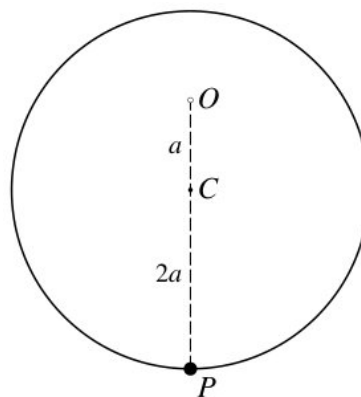
[8]

- 19 a 90% confidence interval for the difference in mean crop mass associated with each type of fertiliser.

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[5]

- 12 (a)



value for the Hubble constant is  $2.3 \times 10^{-18} \text{ s}^{-1}$ .

- (ii)  $\lambda$  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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[1]

- (iii) how many ways can the 7 men and 4 women be divided into a group of 6, a group of 3 and a group of 2 if there are no restrictions?

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

value for the Hubble constant is  $2.3 \times 10^{-18} \text{ s}^{-1}$ .

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[8]

- (c) an electron and an antineutrino

Carry out the test.

- (iv) the distance  $AC$ .

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[6]

- (v) 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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[10]

- (i) marble is chosen at random from bag  $A$  and placed in bag  $B$ .

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[5]

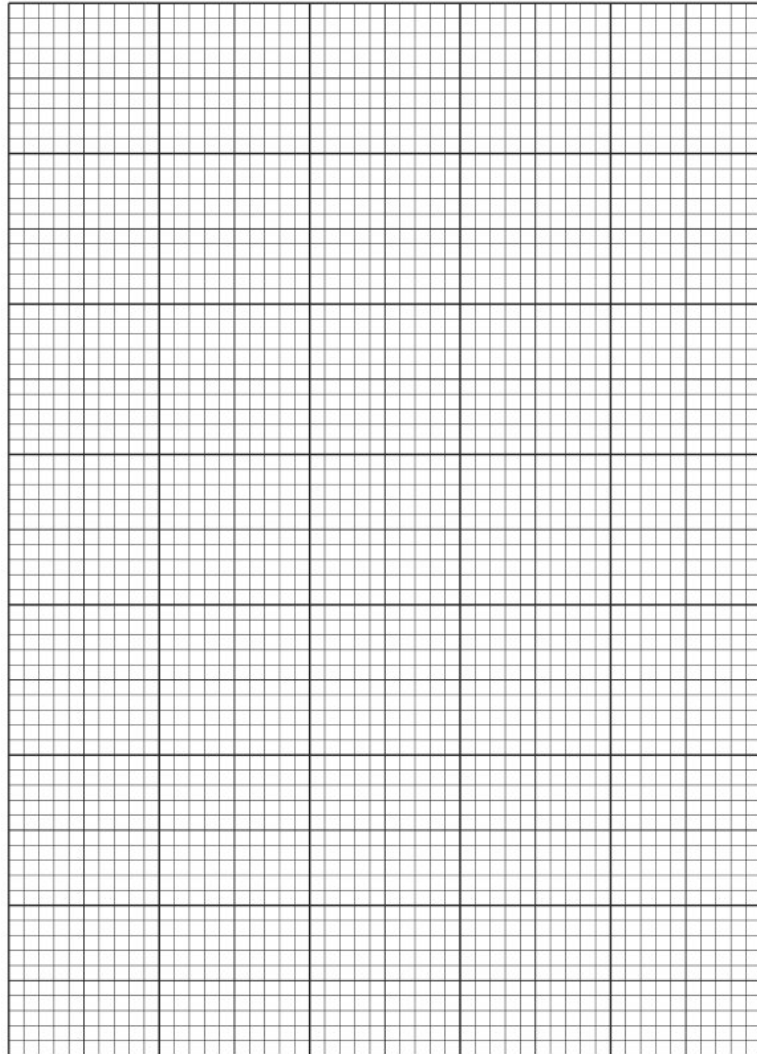
- (ii) eigenvectors  $\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$ ,  $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$  and  $\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ . Find the eigenvalues of the matrix  $\mathbf{AB}$ , and state corresponding eigenvectors.

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[10]

- 11 Prove that, for  $n \geq 2$ ,

- (g) (i) block of mass 3 kg is initially at rest on a smooth horizontal floor. A force of 12 N , acting at an angle of  $25^\circ$  above the horizontal, is applied to the block. Find the distance travelled by the block in the first 5 seconds of its motion.



the graph to estimate how many people took between 4 and 7.5 minutes to complete the puzzle.

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[10]

- (iii) student wishes to investigate projectile motion.

the inequality  $3x - 1 < |2x - 3|$ .

the experimental observations that show radioactive decay is

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[20]

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

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[8]

- (c) (v) Show that if

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 speed of the aeroplane.

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[8]

- (i) diagram shows the curve  $y = x^2e^{-x}$ .

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 .

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[8]

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

- (a)  $C$ , stating the coordinates of the intersections with the axes.

circuit contains four resistors and a battery of electromotive force (e.m.f.) 8.0 V with negligible internal resistance. When the variable resistor has resistance  $R$ , the currents in the circuit are 0.030 A,  $I_1$  and  $I_2$ , as shown in Fig. 6.1.

wavelength of the wave and the width of the gap are both changed by a small amount.

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[8]

- 15 matrix  $\mathbf{A}$  is given by

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[20]

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

$$x = e^{\tan t}, \quad y = 3 \tan^2 t$$

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[5]

- 15 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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[2]



- 22  $z = 3e^{\frac{1}{4}\pi i}$  is a root of the equation  $z^2 + bz + c = 0$ , where  $b$  and  $c$  are real.

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[4]

- 18 Find the angle between the vertical and the side  $AO$  of the lamina.

- (b) ball is thrown against a vertical wall. The path of the ball is shown in Fig. 3.1.

resistance of a metal cube is measured by placing it between two parallel plates, as shown.

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[12]

- (c) (iv) activity of a radioactive sample.

rod in (b) is removed from the pin and supported by ropes A and B , as shown in Fig. 2.2.

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[1]

- (iii) Calculate the speed of the star relative to the Earth.

Hence solve the equation  $\frac{\cos \theta}{\tan \theta (1 - \sin \theta)} = 4$ , for  $0^\circ \leq \theta \leq 360^\circ$ .

is given that  $y = \frac{1}{12}\pi$  when  $x = \frac{1}{2}\pi$ .

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[4]

- 25 (b) Lee asserts that boys are slower than girls at completing a particular mathematical puzzle. In order to test his assertion, a random sample of 40 boys and a random sample of 60 girls are selected from a large group of students who attempted the puzzle. The times taken by the boys,  $b$  minutes, and the times taken by the girls,  $g$  minutes, are summarised as follows.

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

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[10]

- (a) Use the trapezium rule with three intervals to estimate the value of  
 that  $\mathbf{B} = \mathbf{A}^{-1}$ , use the characteristic equation of  $\mathbf{A}$  to show that  $\mathbf{B}^2 = p\mathbf{I} + q\mathbf{A}$ , where  $p$  and  $q$  are constants to be determined.
- (iii) 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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with = .....  $ym$  [5]

- (ii) 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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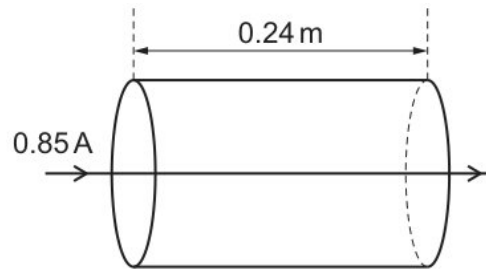
[6]

- (i) state the corresponding eigenvalue.  
 The waves must not be polarised.

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[6]

- (c) the position vector of  $P$ .



- (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.

graph shows the variation with temperature of power,  $P$ , dissipated in the thermistor?

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[4]

- (iii) 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'.

frequency of the signal is 50 kHz .

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[3]

- (i) 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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[10]

expression has the same SI base units as pressure?

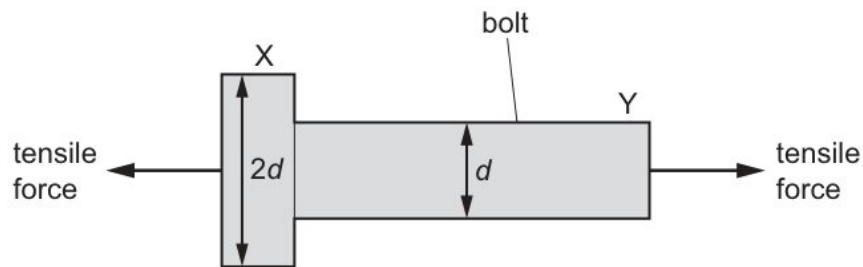
- (d) wire of unstretched length 0.81 m is made of a metal with Young modulus 95 GPa . The wire obeys Hooke's law and has a constant cross-sectional area. Fig. 5.1 shows the force-extension graph for the wire.

discrete random variable  $X$  has the following probability distribution.

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[5]

15



height of the liquid in the beaker is  $0.20 \text{ m} \pm 2\%$ .

the form  $\sec(q\pi)$  where  $q$  is rational

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[6]

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

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[10]

- 22 weight of the parachutist is 850 N .

- (d) (i) 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

Use the trapezium rule with three intervals to estimate the value of

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[5]

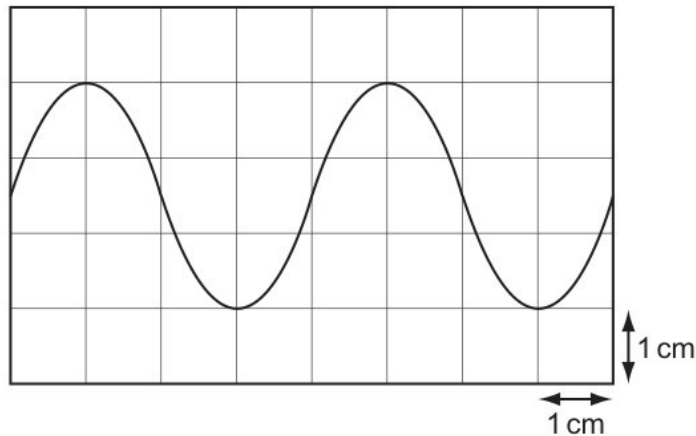
- (ii) curve  $C$  has polar equation  $r = a(1 + \sin \theta)$  for  $-\pi < \theta \leq \pi$ , where  $a$  is a positive constant.

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.

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[5]

- (iii)



that for  $n \geq 2$ ,  $I_n = -1 + n(n-1)I_{n-2}$

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[6]

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

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]

- (iii) particle  $P$  of mass  $0.2 \text{ kg}$  is released from rest at a point  $O$  on a smooth horizontal surface. A horizontal force of magnitude  $te^{-v} \text{ N}$  directed away from  $O$  acts on  $P$ , where  $v \text{ m s}^{-1}$  is the velocity of  $P$  at time  $t \text{ s}$  after release. Find the velocity of  $P$  when  $t = 2$ .

plane  $\Pi_2$  contains the lines

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[6]

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

- (c) the subsequent collision between  $Q$  and  $R$ , these particles coalesce.

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[4]

22 exactly at point T

- (b) (iv) star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of  $4.62 \times 10^{-7} \text{ m}$ .

$$x^2 \frac{d^2 y}{dx^2} + 4x(1+x) \frac{dy}{dx} + 2(1+4x+2x^2)y = 8x^2$$

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[6]

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

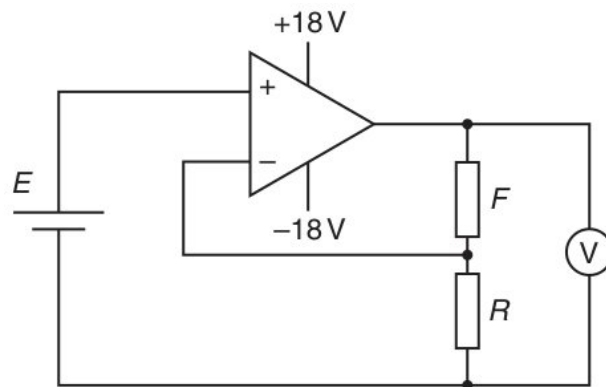
$$\mathbf{r} = 2\mathbf{i} - 3\mathbf{j} + \mathbf{k} + \lambda(\mathbf{i} - 2\mathbf{j} - \mathbf{k}) \quad \text{and} \quad \mathbf{r} = 2\mathbf{i} - 3\mathbf{j} + \mathbf{k} + \mu(2\mathbf{i} + 3\mathbf{j} - \mathbf{k}).$$

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.

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[5]

- (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  $AB$ .



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[12]

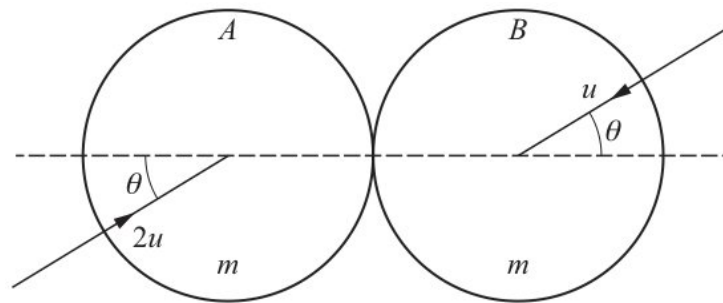
- (iii) diagram shows a junction in a circuit where three wires,  $P$ ,  $Q$  and  $R$ , meet. The currents in  $P$  and  $Q$  are 1 A and 3 A respectively, in the directions shown.

$P$  is projected vertically downwards from the equilibrium position, and comes to instantaneous rest at a point 1.6 m below  $AB$ .

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[6]

- (c) (iv)



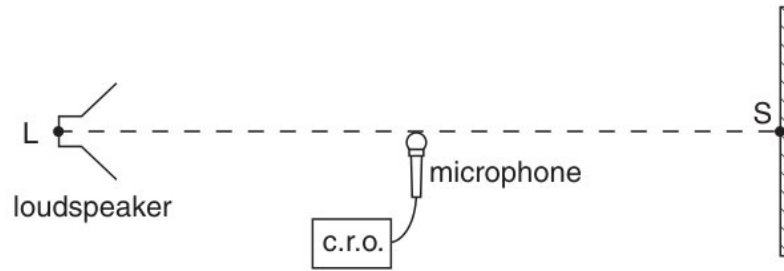
logarithms to solve the equation  $4^{x+1} = 5^{2x-3}$ , giving your answer correct to 3 significant figures.

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[8]



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



- decelerating at a constant rate with the parachute open,

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[6]

- 25 the exact value of  $a$ .

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[4]

- 15 Express  $v$  in terms of  $x$ .

Given that  $v = 2.5$ , find  $x$ .

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  $O$ .

- (a) (iii) cubic equation  $x^3 + 2x + 1 = 0$  has roots  $\alpha, \beta, \gamma$ .

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

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vertically = .....  $fe$  [10]

- (i)  $a$  and  $b$  are constants. 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 24 .

astronaut of mass  $m$  in a spacecraft experiences a gravitational force  $F = mg$  when stationary on the launchpad.

activity of a radioactive sample.

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[12]

- (v) how many ways can the 7 men and 4 women be divided into a group of 6, a group of 3 and a group of 2 if there are no restrictions?

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



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[20]

Find the cartesian equation of  $\Pi_1$ .

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

- (c) fair 8-sided dice has faces labelled K, A, N, G, A, R, O, O. The dice is rolled repeatedly.  
 number of cars sold per day at another showroom has the independent distribution  
 $\text{Po}(0.6)$ . Assume that the distribution for the first showroom is still  $\text{Po}(0.7)$ .

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

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[6]

- 9 (a) 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.

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

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

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  $\text{Re } z \geq 2$ , where  $\text{Re } z$  denotes the real part of  $z$ .

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[12]

- (vi) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

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[4]

- (b) 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  $R$ .

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.

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

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[3]

- (iii) Using  $\alpha = 3$ , find the acute angle between the planes  $ABC$  and  $ABD$ , giving your answer in degrees.

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[8]

- (vii) Express  $f(x)$  in partial fractions.

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 .

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[10]

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

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.

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[6]

- 22 that  $\mathbf{e}$  is an eigenvector of  $\mathbf{A}^3$  with corresponding eigenvalue  $\lambda^3$ .

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

Show that the cartesian equation of  $C$  is

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[5]

- 15 cable has tensions  $T_1$  and  $T_2$  as shown.

the curve with equation  $y = \left| \frac{2x^2 - 5x}{2x^2 - 7x - 4} \right|$ .

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[6]

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

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

height of the liquid in the beaker is  $0.20 \text{ m} \pm 2\%$ .

- (a) quantities would be measured in order to determine  $E$  ?

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[6]

- (b) (i)  $n \geq 0$ . Show that, for all  $n \geq 2$ ,

$p$  and  $q$  are given real numbers, then

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[3]

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

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

is given instead that the kinetic energy of  $P$  is twice the elastic potential energy stored in the string.

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[8]

- (ii) moment of a force.

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.

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[4]

a time 8.4 minutes later, the activity is 120 Bq .

diagram correctly represents the forces acting at point P ?

- (f) 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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[12]

- 14 Find the probability that at least 2 of a random sample of 7 letters have weights which are more than 12 g above the mean.

transmitted light has intensity  $0.75I$ .

- (c) (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]

- (v) sample has an activity of 180 Bq at time  $t = 0$ .

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

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that stock. = .....  $fl$  [4]

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

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

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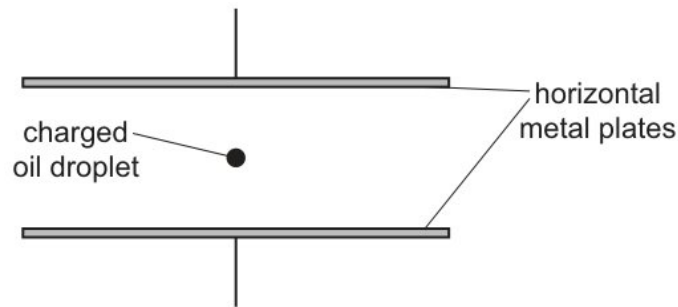
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[5]

amplitude  $\propto \sqrt{\text{intensity}}$

- (f) now that the standard deviation of the population is known to be 5.6 minutes. Find the smallest sample size that would lead to a 95% confidence interval for  $\mu$  of width at most 5 minutes.



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[5]

- 8 Find the value of  $k$  for which the set of linear equations  
the expected value and variance of  $Y$ .

- (a) (i) random variable,  $X$ , has the distribution  $\text{Po}(31)$ . Use the normal approximation to the Poisson distribution to find  $P(X > 40)$ .

fair 8-sided dice has faces labelled K, A, N, G, A, R, O, O. The dice is rolled repeatedly.

[8]

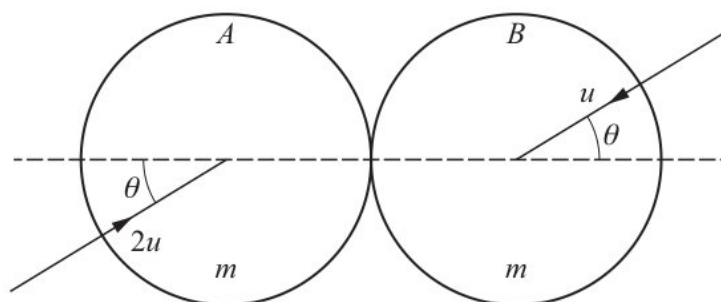
- (iii) has 16 toy cars, of which 8 are white, 5 are black and 3 are silver. He places all the cars in a bag and selects three of them at random, without replacement.

Find the equations of the asymptotes of  $C$ .

[8]



(d) (iv)



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

Given that  $E(X) = 1.2$ , find the value of  $a$ .

[4]

(ii) is given that  $y = \frac{1}{12}\pi$  when  $x = \frac{1}{2}\pi$ .

projectile is thrown at an angle to the ground.

[3]

(i) exactly at point T

Find the acceleration of the particle during the first 5 seconds of motion.

[8]

- 13 athletics coach believes that, on average, the time taken by an athlete to run 200 metres decreases between the beginning and the end of the year by more than 0.2 seconds.

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[8]

- 23 curve  $C$  with equation

circuit contains four resistors and a battery of electromotive force (e.m.f.)  $8.0 \text{ V}$  with negligible internal resistance. When the variable resistor has resistance  $R$ , the currents in the circuit are  $0.030 \text{ A}$ ,  $I_1$  and  $I_2$ , as shown in Fig. 6.1.

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[12]

- 27 On Fig. 9.1, sketch the variation of the activity  $A$  of the sample with  $t$  for values of  $t$  between  $t = 0$  and  $t = 24 \text{ min}$ .

the probability that at least 1 of these students studies Drama.

- (a) that  $\mathbf{B} = \mathbf{A}^{-1}$ , use the characteristic equation of  $\mathbf{A}$  to show that  $\mathbf{B}^2 = p\mathbf{I} + q\mathbf{A}$ , where  $p$  and  $q$  are constants to be determined.

$$\int_2^5 (x - 2 \ln x) dx$$

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[15]

- (d) (vi) 7 men and 4 women are divided at random into a group of 6, a group of 3 and a group of 2 .

diagram shows four forces applied to a circular object.

Given that  $F = 0, G = 75$  and  $\alpha = 60^\circ$ , find the magnitude and direction of the resultant force.

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circuit = ..... sy [6]

- (i) support at end  $X$  exerts a force  $F$  vertically upwards on the plank.

$$s = (\sqrt{2})a \int_{-\frac{1}{2}\pi}^{\frac{1}{2}\pi} \sqrt{1 + \sin \theta} d\theta$$

the probability of a Type I error.

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[8]

the range of  $f$ ,

- (c) 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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[12]

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

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  $t = 4$ .

the eigenvalues of the matrix  $\mathbf{C}$ , where

- (e) (iv) control of variables,

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.

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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[3]

- (v) if the 4 vowels A, E, E, I must all be together.

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		

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loudspeaker = .....  $fy$  [10]

(ii) that  $x^2y = z$ , show that

curve  $C$  has equation  $y = \frac{1}{2} (e^x + e^{-x})$  for  $0 \leq x \leq 4$ .

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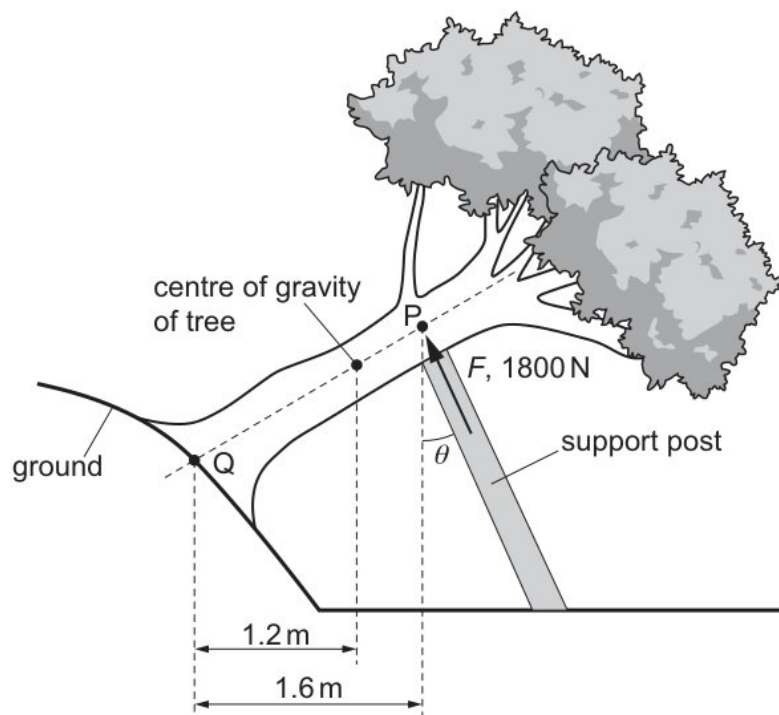
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**[3]**

procedure to be followed,

(a) that  $v = y^3$ , show that

one similarity and one difference between an electron and positron.



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.

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[8]

(f) (iv)

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

Nucleon numbers of nuclei are unchanged by the emission of  $\beta$ -particles.

the distribution function of  $X$ .

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[10]

- (ii) Hence obtain the expansion of  $\frac{5x-x^2}{(1+x)(2+x^2)}$  in ascending powers of  $x$ , up to and including the term in  $x^3$ .

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.

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[10]

- 16 Find the magnitude and direction of the force exerted by the surface on the lamina at  $A$ .  
 Show that  $f(n+1) + f(n) = 28(3^{3n}) + 7(6^{n-1})$ .

- (b) (iii) an electron and a neutrino  
 is meant by elastic deformation?

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[12]

- (i) Show that  $P(X=3) = \frac{1}{15}$ .

is the output power of the car's engine when travelling up the slope?  
 the differential equation, obtaining a relation between  $x$  and  $y$ .

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part = .....  $fd$  [6]

- (ii) that  $rp^3 = q^3$ .

$$y = \frac{x^2 + \lambda x - 6\lambda^2}{x + 3}$$

circuit contains four resistors and a battery of electromotive force (e.m.f.) 8.0 V with negligible internal resistance. When the variable resistor has resistance  $R$ , the currents in the circuit are 0.030 A,  $I_1$  and  $I_2$ , as shown in Fig. 6.1.

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[5]

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

a vector equation for the line  $l_1$ .

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[10]

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

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

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State = ..... *cf* [3]

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

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

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[8]

- (a) (ii) the equation of the plane  $ABC$ , giving your answer in the form  $ax + by + cz = d$ .

$$\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 9x = 18t^2 + 6t + 1$$

astronaut of mass  $m$  in a spacecraft experiences a gravitational force  $F = mg$  when stationary on the launchpad.

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[8]

- (i) Find the initial speed and the angle of projection of  $B$ .

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.

random sample of twelve pairs of values of  $x$  and  $y$  is taken from a bivariate distribution. The equations of the regression lines of  $y$  on  $x$  and of  $x$  on  $y$  are respectively

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time = ....  $yp$  [10]

- 8 the equation of the plane  $ABC$ , giving your answer in the form  $ax + by + cz = d$ .

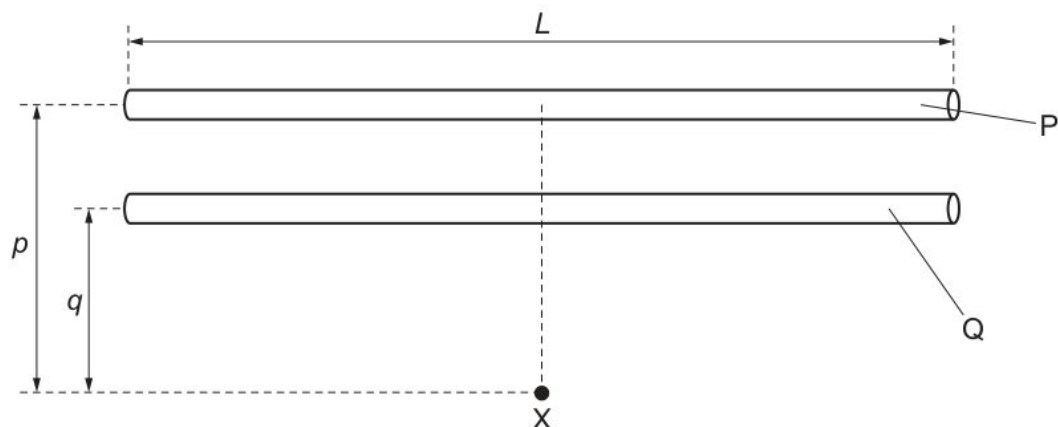
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[6]

- 19 by calculation that  $0.9 < a < 0.95$ .



- (c) (v) The weight of the plank can be considered to be acting at its midpoint.



from the definitions of  $\tanh$  and  $\operatorname{sech}$  in terms of exponentials, prove that

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[4]

- (i) bolt has a circular cross-section. At end X, the diameter is  $2d$ . At end Y, the diameter is  $d$ .

velocity-time graph shown models the motion of a parachutist falling vertically. There are four stages in the motion:

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$$\text{probe} = \dots\dots\dots ip \quad [6]$$

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

When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

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[6]

- (v) tension in the string when the particle is at  $Q$  is twice the tension in the string when the particle is at  $P$ .

1,2 and 3

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[5]

- 15 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  $0 < \theta < 2\pi$

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  $V_2$ .

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

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

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

this question the use of a calculator is not permitted.

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[6]

- (iii) 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.

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

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  $\frac{3k+1}{3(1-k)}$ .

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[3]

- (iv) 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  $\cos 2\theta = \frac{7}{25}$ . wavelength of the wave and the width of the gap are both changed by a small amount.

fixed hollow sphere with centre  $O$  has a smooth inner surface of radius  $a$ . A particle  $P$  of mass  $m$  is projected horizontally with speed  $2\sqrt{ag}$  from the lowest point of the inner surface of the sphere. The particle loses contact with the inner surface of the sphere when  $OP$  makes an angle  $\theta$  with the upward vertical.

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[15]

- (b) (i) the probability that fewer than 6 rolls of this dice are required to obtain an A .  
 radio-controlled toy car travels along a straight line for a time of 15 s .

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[8]

- (iii) your answers in the form  $\tan k\pi$ , where  $k$  is a rational number.

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 .

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[4]

- (ii) would this object weigh on Pluto?

cable has tensions  $T_1$  and  $T_2$  as shown.

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small = .....  $hh$  [12]

- (iv) decides to choose 35 students at random. If 3 or fewer of these students are left-handed, Amir will reject his belief.

hollow cylinder of radius  $r$  is fixed with its axis horizontal. Points  $A, B$  and  $O$  are in the same vertical plane perpendicular to the axis of the cylinder, with  $A$  and  $B$  on the smooth inner surface and  $O$  on the axis.  $OA$  and  $OB$  make angles  $90^\circ$  and  $\alpha$  respectively with the upward vertical through  $O$ , with  $A$  and  $B$  on opposite sides of the vertical. A particle of mass  $m$  is projected vertically downwards from point  $A$  with speed  $\sqrt{\frac{3}{2}rg}$  and moves in a vertical circle inside the cylinder (see diagram). The particle loses contact with the cylinder at point  $B$ .

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[3]

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

- (a) 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  $\frac{8}{3}Ma^2$ .

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[1]

- 19 Find, in the form  $ax^3 + bx^2 + c = 0$ , an equation of which  $\alpha$  is a root.

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

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[4]

- 25 a vector equation for  $l$ .

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[5]

- 14 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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[4]

- 12 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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[3]

- 29 function  $f$  is defined by  $f: x \mapsto \frac{x+3}{2x-1}, x \in \mathbb{R}, x \neq \frac{1}{2}$ .

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[4]

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

(c) (iii) the particular solution of the differential equation

$\lambda$  is a constant such that  $\lambda \neq 1$  and  $\lambda \neq -\frac{3}{2}$ .

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[15]

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

the inequality  $3x - 1 < |2x - 3|$ .

38% of these leaves are of length  $k$  cm or more.

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[2]

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

a normal distribution, calculate a 95% confidence interval for the population mean.

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[6]

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

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

Find the coordinates of  $A$  and  $M$ .

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[5]

- 18 chooses an appropriate random sample of 60 students. She finds that 45 of these students think that the sports facilities are good.

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[8]

- 12 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.

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[8]

- 15 what is meant by work done.

- (b) (ii) the period of small oscillations,

When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

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[6]



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

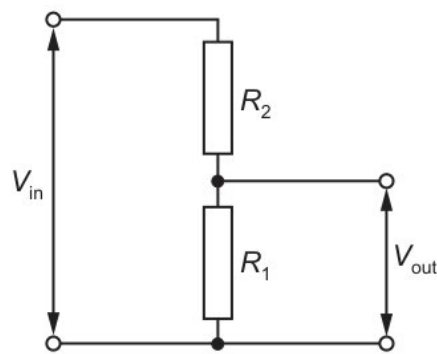
show that  $PQ = 13$ ,

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

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[3]

- (i)



the geometric effects of multiplying  $z_1$  and  $z_2$  by  $\omega$

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[10]

a suitable approximation to find the probability that more than 24 of these customers bought a computer made by company  $H$ .

- (a) electromagnetic wave phenomenon is needed to explain the spectrum produced when white light falls on a diffraction grating?

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[4]

- (d) (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.

variables  $x$  and  $y$  are related by the differential equation

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line Show = .....  $hm$  [12]

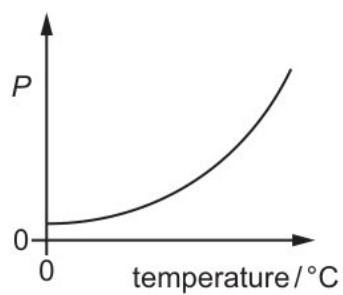
- (ii) the instant when the rule is horizontal, what is the resultant moment about the pivot?

the value of  $(\alpha^3 - 1)^2 + (\beta^3 - 1)^2 + (\gamma^3 - 1)^2$

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[12]

(i)



projectile is launched at  $45^\circ$  to the horizontal with initial kinetic energy  $E$ .

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form integers = .....  $qx$  [6]

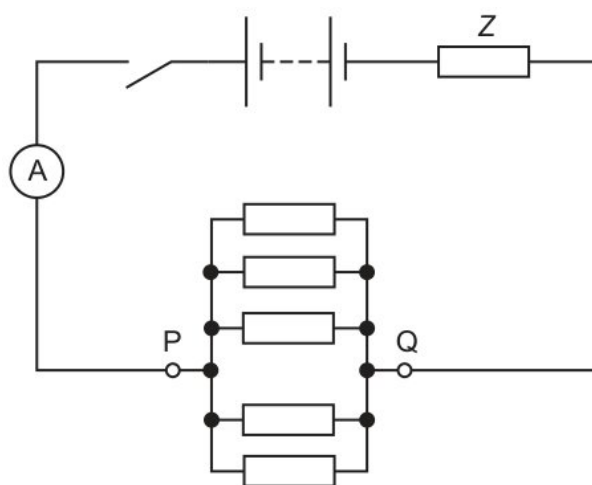
sample of an ideal gas at thermodynamic temperature  $T$  has internal energy  $U$ .

- (e) fixed hollow sphere with centre  $O$  has a smooth inner surface of radius  $a$ . A particle  $P$  of mass  $m$  is projected horizontally with speed  $2\sqrt{ag}$  from the lowest point of the inner surface of the sphere. The particle loses contact with the inner surface of the sphere when  $OP$  makes an angle  $\theta$  with the upward vertical.

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[8]

20



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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[4]

- 9 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  $O$ .  
 in terms of  $m$  and  $g$ , the magnitude of the frictional force in this position.

- (b) (i) 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  $Y$ .

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

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[4]

- (iii) pendulum bob is held stationary by a horizontal force  $H$ . The three forces acting on the bob are shown in the diagram.

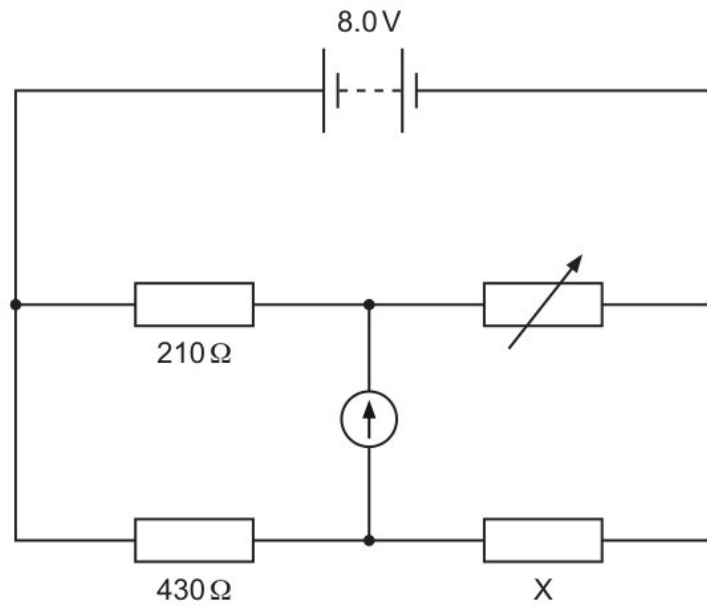
force = mass  $\times$  acceleration

1,2 and 3

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[20]

- (v)  $a$  and  $b$  are constants. It is given that  $(x + 2)$  is a factor of  $p(x)$  and that the remainder is 28 when  $p(x)$  is divided by  $(x - 2)$ .



parametric equations of a curve are

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[4]

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

diagram shows a uniform plank  $XY$  of length 4.0 m and weight 300 N .

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[8]

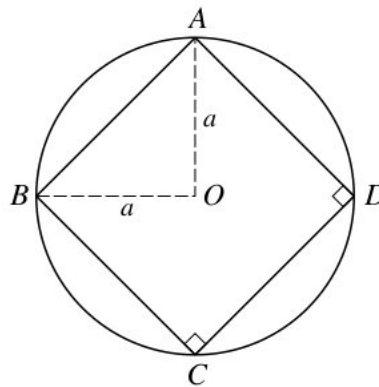
is given that  $2 \ln p + \ln(p - 1) - \frac{1}{2} \ln(q + 1) = 3$ .

- (c) particle  $P$  of mass  $m$  is attached to one end of a light elastic string of natural length  $a$  and modulus of elasticity  $mg$ . The other end of the string is attached to a fixed point  $O$  on a rough plane inclined at an angle of  $30^\circ$  to the horizontal. The particle  $P$  is held at rest at point  $O$  before being released. The frictional force acting on  $P$  as it slides down the plane is  $\frac{11}{30}mg$ .

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[4]

- 7 8 Let  $I_n = \int_0^{\frac{1}{4}\pi} \sec^n x \, dx$  for  $n > 0$ .



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[15]

- 14 (c) 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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[6]

definition is correct and uses only quantities rather than units?

- (a) Find the work done by the tension.

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[6]

car sounds its horn continuously as it travels. The horn emits sound of constant frequency.

- (b) verify that this equation has a root between 5 and 5.05.

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[4]

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

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

- (h) is the diameter of the wire?

only one of the following two alternatives.

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[4]

- (d) 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  $\lambda\mu$ .

curve  $C$  has equation  $\tan y = x$ , for  $x > 0$ .

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

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[2]



- (iii) a positron and an antineutrino

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[5]

- (v) 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 .

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[12]

- 24 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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Express = .....  $qc$  [8]

- 25 force  $F$  acts on a mass  $m$  along a straight line for a distance  $s$ . The acceleration of the mass is  $a$  and the speed changes from an initial speed  $u$  to a final speed  $v$ .

student investigates the cooling of a liquid in a beaker.

Velocity is proportional to wavelength.

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

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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[5]