

Find the exact coordinates of this point.

11 is meant by elastic deformation?

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

.....

[3]

11 curve with equation $y = \frac{2 - \sin x}{\cos x}$ has one stationary point in the interval $-\frac{1}{2}\pi < x < \frac{1}{2}\pi$.

Number of rooms occupied (x)	0	1	2	3	4	5	6	≥ 7
Number of nights	4	9	18	26	20	16	7	0

(e) (iii) de Moivre's theorem to show that
 the solution of the differential equation

.....

[8]

(ii) is suggested that these results are consistent with a distribution having probability density function f given by

$$\tan 4\theta = \frac{4 \tan \theta - 4 \tan^3 \theta}{1 - 6 \tan^2 \theta + \tan^4 \theta}$$

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

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[4]

- (a) (ii) are the amplitude and period of the wave?

Calculate the modulus of elasticity of the string.

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[5]

- (i) only one of the following two alternatives.

is suggested that the e.m.f. V is related to the number n of glass sheets by the equation

.....

[8]

- 9 Show that $\frac{dy}{dx} = \frac{1}{\sin \theta \cos^3 \theta}$.

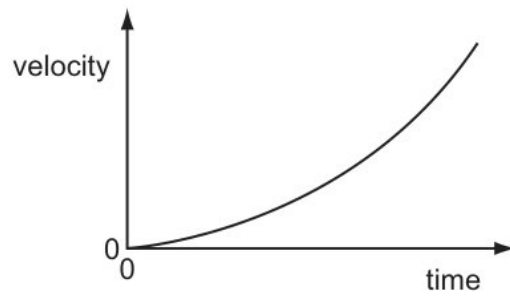
- (b) finding a cubic equation whose roots are α, β and γ , solve the set of simultaneous equations

a cartesian equation of the plane Π containing l_1 and l_2 .

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[4]

(a) (ii)



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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[6]

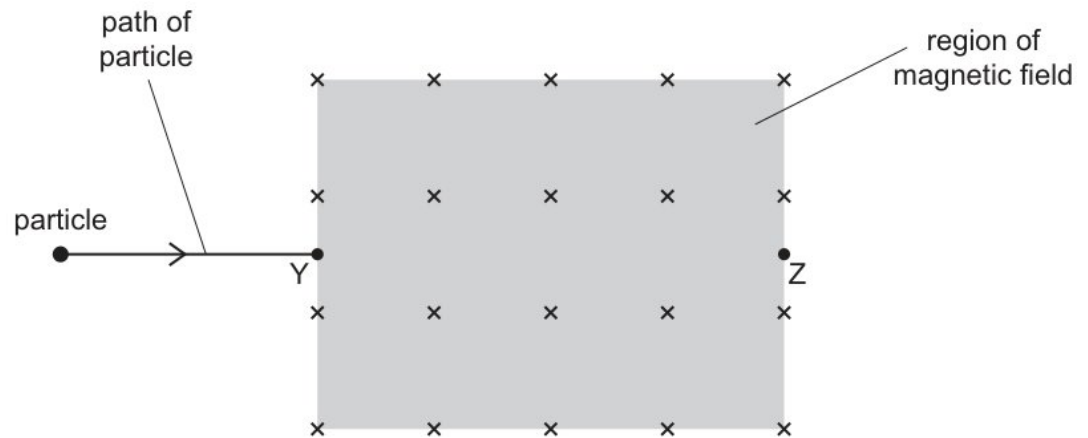
(i) P and Q collide and stick together.

is suggested that the e.m.f. V is related to the number n of glass sheets by the equation

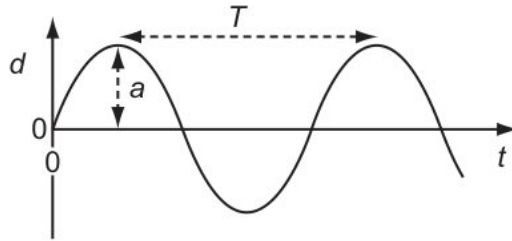
.....

[4]

(iv)



State the number of roots of the equation $p(2^y) = 0$, justifying your answer.



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[12]

- (c) (i) diagram shows a sketch of the curve $y = \frac{3}{\sqrt{9-x^3}}$ for values of x from -1.2 to 1.2 .
 7 men and 4 women are divided at random into a group of 6, a group of 3 and a group of 2 .

.....

velocity = el [6]

- (ii) the time from release until OP makes an angle $\frac{1}{2}\alpha$ with the downward vertical for the first time.

monochromatic plane wave of speed c and wavelength λ is diffracted at a small aperture.

.....

[5]

- (ix) Let $z = \cos \theta + i \sin \theta$. Show that $z - \frac{1}{z} = 2i \sin \theta$ and hence express $16 \sin^5 \theta$ in the form $\sin 5\theta + p \sin 3\theta + q \sin \theta$, where p and q are integers to be determined.

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

.....

[3]

22 - falling with constant speed with the parachute open,

- (e) block is released from rest at the top of a slope inclined at an angle to the horizontal. The slope has length L as shown in the diagram.

$$\text{power} = \text{force} \times \text{velocity}$$

.....

[3]

- (a) The speed of the car at the bottom of the first ramp is 14 m s^{-1} . Use an energy method to find the speed of the car when it reaches the bottom of the second ramp.

.....

[4]

(b) (iii) anywhere between point R and point S

continuous random variable X has probability density function f given by

.....

[8]

(ii)

	F_1/N	F_2/N
A	4.0	6.0
B	6.0	4.0
C	6.0	8.0
D	8.0	6.0

specific latent heat.

.....

[2]

(i) much charge passes a given point in wire R in a time of $5s$?

the set of values of p for which C has two distinct turning points.

.....

[3]

marble is now chosen at random from bag B .

20

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

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

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°C .

.....

[2]

the probability that all three cars are the same colour.

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

$$\frac{\text{wavelength of M}}{\text{wavelength of N}} = 10^5.$$

16 definition is correct and uses only quantities rather than units?

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

.....

asserts = be [4]

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.

25 only one of the following two alternatives.

.....

[4]

- 9 discrete random variable X has the following probability distribution.

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

525 520 522 524 518 520 519 525 527 516

- (a) (i) short time after passing point B truck R moves in a straight line on horizontal ground. The driver of the truck applies the brakes. Fig. 3.2 shows the variation with time of the momentum of the truck.

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

.....

[4]

- (iv) diagram shows a uniform thin rod AB of length $3a$ and mass $8m$. The end A is rigidly attached to the surface of a sphere with centre O and radius a . The rod is perpendicular to the surface of the sphere. The sphere consists of two parts: an inner uniform solid sphere of mass $\frac{3}{2}m$ and radius a surrounded by a thin uniform spherical shell of mass m and also of radius a . The horizontal axis l is perpendicular to the rod and passes through the point C on the rod where $AC = a$.

bolt is subjected to a tensile force, as shown.

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[5]

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

Use the confidence interval found in part (i) to comment on this claim.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \mathbf{a} + t\mathbf{b}$$

.....

[8]

- (iii) many electrons pass through a given cross-section of the wire in one second?

Find the value of I_2 .

.....

[10]

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

Show that $\text{ff}(x) = x$.

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.

.....

[6]

- (i) the exact value of a .

the number of different ways in which the 6 musicians can be selected if there must be at least 3 guitarists, at most 2 pianists and exactly 1 drummer.

.....

[5]

- (v) Use the iterative formula

the exact area of one loop of the curve.

.....

through block = df [3]

- (d) Given that the total number of cars sold during the 5 days is 5 , carry out the test.

.....

[4]

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

- 10 Given that there is no term in x^3 in the expansion of $(k + 2x) \left(1 - \frac{3}{2}x\right)^6$, find the value of the constant k .

is given that $k = 0.025$ and that $U = 20$

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[4]

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° above the horizontal, is applied to the block. Find the distance travelled by the block in the first 5 seconds of its motion.

- 7 velocity = acceleration \times time

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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[8]

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

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[4]

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

(ii) stationary nucleus has nucleon number A .

.....

[15]

(v) measurements to be taken,

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[4]

- 12 considering the sum of the areas of these rectangles, show that transmitted light has intensity $0.75I$.

	α -particles	γ -rays
A	least ionizing	least penetrating
B	least penetrating	most ionizing
C	most ionizing	most penetrating
D	most penetrating	least ionizing

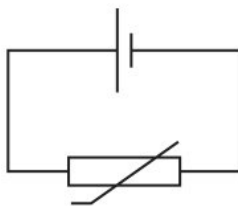
- (a) (ii) lifetime, in hours, of a 'Trulite' light bulb is a random variable T . The probability density function f of T is given by

$$\text{kinetic energy} = 1/2 \times \text{mass} \times (\text{speed})^2.$$

.....

[5]

- (iii) vertical and horizontal gridlines have a spacing of 1.0 cm . The voltage scaling is 4 V cm^{-1} and the time scaling is 5 ms cm^{-1} .



.....

[8]

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

State the name of this type of reaction.

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[6]

- (b) monochromatic plane wave of speed c and wavelength λ is diffracted at a small aperture.

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[10]

(c) (iii)

	transverse wave	longitudinal wave	can travel in free space	key 5* ✓ = property of an electromagnetic wave x = not a property of an electromagnetic wave
A	✓	x	✓	
B	✓	x	x	
C	x	✓	✓	
D	x	✓	x	

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

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[5]

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

continuous random variable X takes values in the interval $0 \leq x \leq 3$ only. For $0 \leq x \leq 3$ the graph of its probability density function f consists of two straight line segments meeting at the point $(1, k)$, as shown in the diagram. Find k and hence show that the distribution function F is given by

6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R .

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[5]

(d) is the phase difference between two points on the wave that are a distance of 0.50 m apart?

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

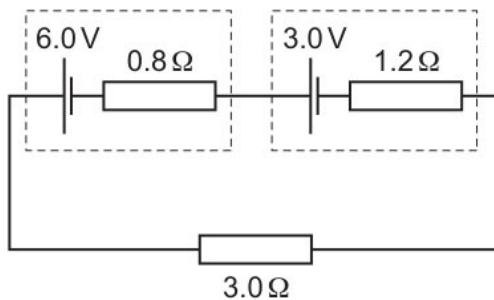
the coordinates of any stationary points on C .

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[15]

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

- (d) (i) row describes the momentum and kinetic energy of the two bodies after the collision?



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[3]

- (iii) λ 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.

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

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[10]

- (iv) cylindrical conductors, X and Y , are made from the same material. The conductors have equal lengths, but Y has a smaller diameter than X .

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

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

.....

[6]

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

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[5]

- 19 (d) Find the coordinates of the turning points of C .

$$\sec 5\theta = \frac{\sec^5 \theta}{5 \sec^4 \theta - 20 \sec^2 \theta + 16}$$

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[4]

- (a) random sample of 3 customers who each bought a computer from this store is chosen.

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[15]

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

25 this question the use of a calculator is not permitted.

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from = sg [6]

18 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.

circuit is set up as shown in Fig. 2.1.

the value of $\frac{d^2y}{dx^2}$ at the point $(4, \frac{1}{3})$.

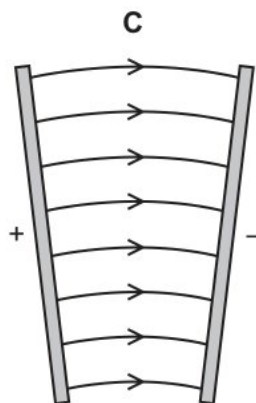
(a) (vi) graph is correctly labelled?

that the greatest height of B above the ground is 1.2 m , find the value of x .

.....

[3]

(ii)



Find the work done by the tension.

.....

[3]

- (iv) 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.

Express $\frac{dy}{dx}$ in terms of t .

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[4]

- (c) (v) Calculate the acute angle between the planes p and q .

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° above the horizontal, is applied to the block. Find the distance travelled by the block in the first 5 seconds of its motion.

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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[3]

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

the values of the constants k_1 and k_2 are to be determined.

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

.....

[10]

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

graph shows the variation with time of the velocity of the object?

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[12]

the value of c such that $P(-c < t < c) = \frac{1}{2}$.

Prove by mathematical induction that, for all positive integers n ,
the distance AC .

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

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[5]

13 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.

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

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

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[5]

(ii) mean, \bar{x} , is 28.325 .

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

.....

[12]

(iii) lines l_1 and l_2 have equations

- falling freely with the parachute closed,

.....

[3]

- (c) is an approximate value for the speed of sound in air?

frame consists of a horizontal rod XY and a rod YZ that is at an angle of 30° 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.

only one of the following two alternatives.

Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

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[6]

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

- (a) (iii) 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 .

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

.....

[5]

- (ii) the time that it takes for the block to move 2 m down the plane from rest.

the probability that more than 7 study Art or Music.

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

.....

[12]

- (i) are the amplitude and period of the wave?

state an eigenvector of the matrix \mathbf{CD} and give the corresponding eigenvalue.

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

.....

[5]

- (c) variables x and y satisfy the differential equation

Q always hears a sound of higher frequency than person P .

.....

[20]

- 28 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 $\frac{84}{5}Ma^2$.

- (d) car then travels up a slope at 2° to the horizontal, maintaining the same constant speed.

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[10]

- (b) 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 roots of the equation $z^3 = 27 - 27i$, giving your answers in the form $re^{i\theta}$, where $r > 0$ and $-\pi \leq \theta < \pi$.

a positron and a neutrino

Find $\frac{dy}{dx}$ and deduce that if C has two stationary points then $-\frac{3}{2} < \lambda < 1$.

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[20]

- (a) statement is correct?

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[6]

student investigates an electrical circuit.

- 12 8 Let $I_n = \int_0^{\frac{1}{4}\pi} \sec^n x \, dx$ for $n > 0$.

.....

less = pj [6]

- 30 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.

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 .

potential difference across a resistor is 12 V . The current in the resistor is 2.0 A .

- (c) \mathbf{A}^{2n} , where n is a positive integer.

.....

[10]

- (e) (ii) Use the iterative formula

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 ωz_2 respectively

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[5]

- (i) 1.1 shows two identical cylindrical metal conductors P and Q , each of length L and cross-sectional area A .

continuous random variable X has probability density function f given by

particle moves in a straight line. The velocity $v \text{ ms}^{-1}$ of the particle $t \text{ s}$ after leaving a fixed point O is given by $v = k(20 + pt - 6t^2)$, where k and p are constants. The acceleration of the particle at $t = 1$ is 42 ms^{-2} , and the displacement of the particle from O at $t = 1$ is 93 m .

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[12]

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

the equation for this decay.

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[5]

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

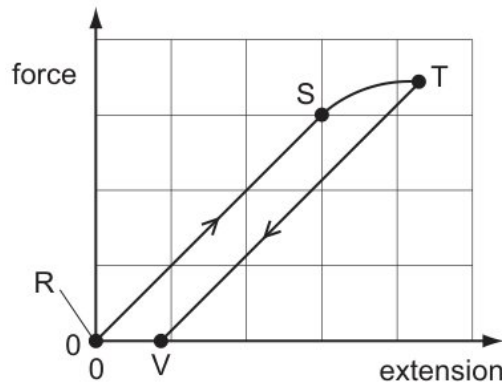
constant potential difference is applied between two horizontal metal plates. A charged oil droplet is held stationary by the electric field between the plates.

researcher claims that older people take longer to react to a sudden loud noise than younger people. To investigate this, the researcher randomly selects 6 people over 50 years old and 8 people under 25 years old and records their reaction times, in milliseconds, to a sudden loud noise. The reaction times are as follows.

.....

[12]

(ii)



cubic polynomial $p(x)$ is defined by

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[6]

(v) row describes the resultant force and resultant torque on the object?

Find the value of a and show that $b = -7$.

is given that λ is an eigenvalue of the non-singular square matrix \mathbf{A} , with corresponding eigenvector \mathbf{e} .

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[4]

(a) (iv) curve C has equation

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

curve C has equation

.....

[3]

- (vi) 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.

the term interference.

.....

[6]

22 the probability of a Type I error.

- (a) (ii) in either order the value of μ and the value of σ

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.

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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[6]

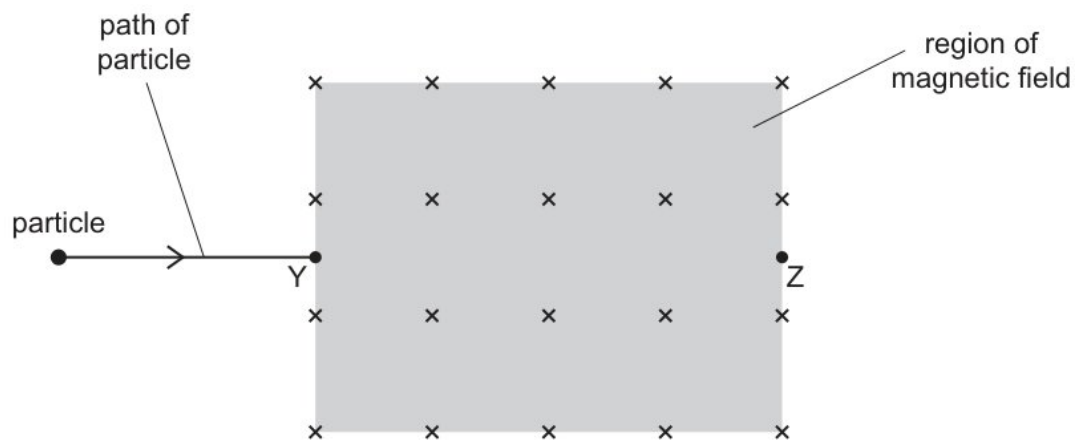
- (iii) potential divider consists of two resistors of resistances R_1 and R_2 connected in series across a source of potential difference (p.d.) V_{in} . The p.d. across R_1 is V_{out} .

524 526 520 523 530

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[1]

(c)



no digit can be repeated,

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[15]

(b) (i) state the corresponding eigenvalue.

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

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.....

1.35 mean = uq [4]

(ii) an instant during the motion the velocity of the load is 1.5 m s^{-1} .

an assumption necessary for the test in part (a) to be valid.

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[6]

- (vi) State the value of $E(X)$.

marks of the pupils in a certain class in a History examination are as follows.
the probability that a 3 is obtained for the second time before the 6th throw.

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.....
.....

[6]

- 24 (a) 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.

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[6]

- (f) Wavelength is proportional to amplitude.

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

- (iii) progressive wave of frequency 300 Hz is travelling with a speed of 600 m s^{-1} .

	first higher note /Hz	second higher note /Hz
A	113	150
B	150	225
C	150	300
D	225	375

Find the direction of motion of the particle 0.4 s after the instant of projection.

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.....
.....
.....

[6]

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

.....

flies first = zr [8]

- (v) ABC is a uniform triangular lamina of weight 19 N , with $AB = 0.22\text{ m}$ and $AC = BC = 0.61\text{ m}$. 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).

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

curves C_1 and C_2 intersect at the point with polar coordinates (a, β) . State the value of β .

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[12]

- (d) the probability that the mass of pasta in a randomly chosen large bag is less than 2.65 kg .

.....

[8]

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

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° to the vertical.

- 21 The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

the value of θ .

.....

[5]

- 33 the process by which α -particles lose energy when they pass through air.

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

researcher claims that older people take longer to react to a sudden loud noise than younger people. To investigate this, the researcher randomly selects 6 people over 50 years old and 8 people under 25 years old and records their reaction times, in milliseconds, to a sudden loud noise. The reaction times are as follows.

.....

[5]

- (iii) curve with equation $y = \frac{2-\sin x}{\cos x}$ has one stationary point in the interval $-\frac{1}{2}\pi < x < \frac{1}{2}\pi$.

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

.....

[8]

- (d) (i) Hence find the value of $\frac{d^2y}{dx^2}$ at the point $(1, \frac{1}{4}\pi)$ on C .

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

.....

matrix = tv [5]

- (ii) random variable X has the distribution $Po(1.5)$.

force is caused only by a pressure difference?

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[5]

row compares the number of charge carriers per unit time passing through X and through Y and compares the average drift speed of the charge carriers in X and in Y ?

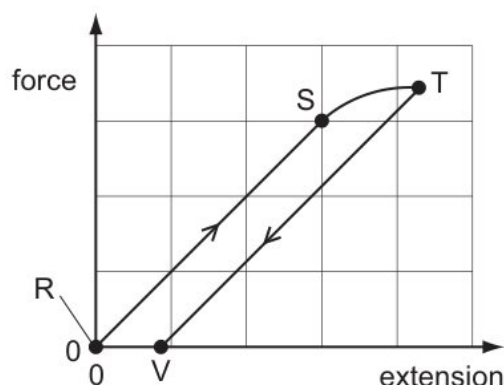
- 21 Use your answer in (i) and an equation of motion to show that kinetic energy of a mass can be given by the expression

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[3]

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

28



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

.....

[8]

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

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

.....

[10]

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

.....

[8]

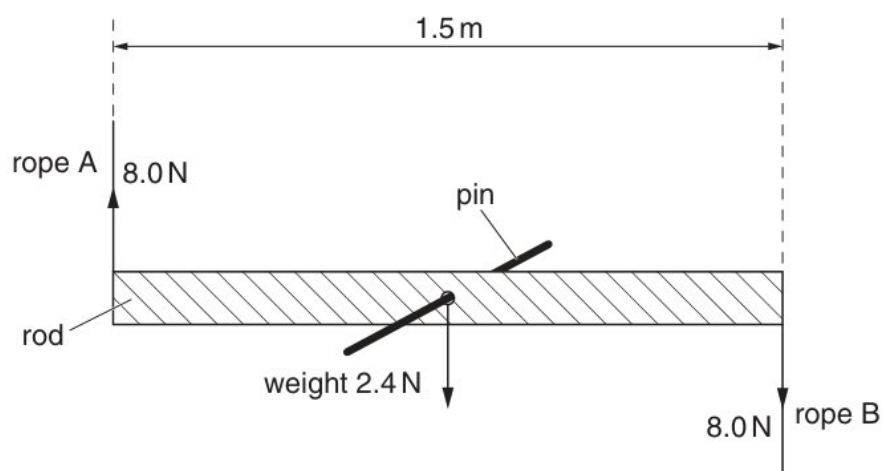
- (e) (ii) has 10 different books from the series Squares and Circles. The books look similar except for their colour. There are 3 blue books, 2 red books, 2 yellow books, 1 orange book, 1 purple book and 1 green book.

Given also that C has a turning point when $x = 2$, find the value of c .

.....

[3]

(i)



Find the value of t when the particle is instantaneously at rest.

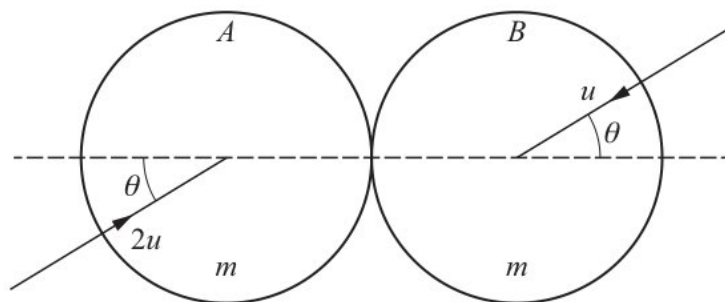
diagram shows a uniform thin rod AB of length $3a$ and mass $8m$. The end A is rigidly attached to the surface of a sphere with centre O and radius a . The rod is perpendicular to the surface of the sphere. The sphere consists of two parts: an inner uniform solid sphere of mass $\frac{3}{2}m$ and radius a surrounded by a thin uniform spherical shell of mass m and also of radius a . The horizontal axis l is perpendicular to the rod and passes through the point C on the rod where $AC = a$.

.....

[10]

out a Wilcoxon rank-sum test at the 5% significance level to test the researcher's claim.

24



any assumption that you make, test at the 10% significance level whether the greengrocer's claim is supported by this evidence.

.....

[8]

will the powers to the resistors change when resistor W is removed?

- 29 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.

.....

[3]

- 12 The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

that $\tan 2a = -4a$

is the reading on the ammeter?

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

$$525 \quad 520 \quad 522 \quad 524 \quad 518 \quad 520 \quad 519 \quad 525 \quad 527 \quad 516$$

.....

[8]

- (vi) Frequency is inversely proportional to wavelength.

Show that the total distance fallen is 1048 m .

.....

particular = vn [8]

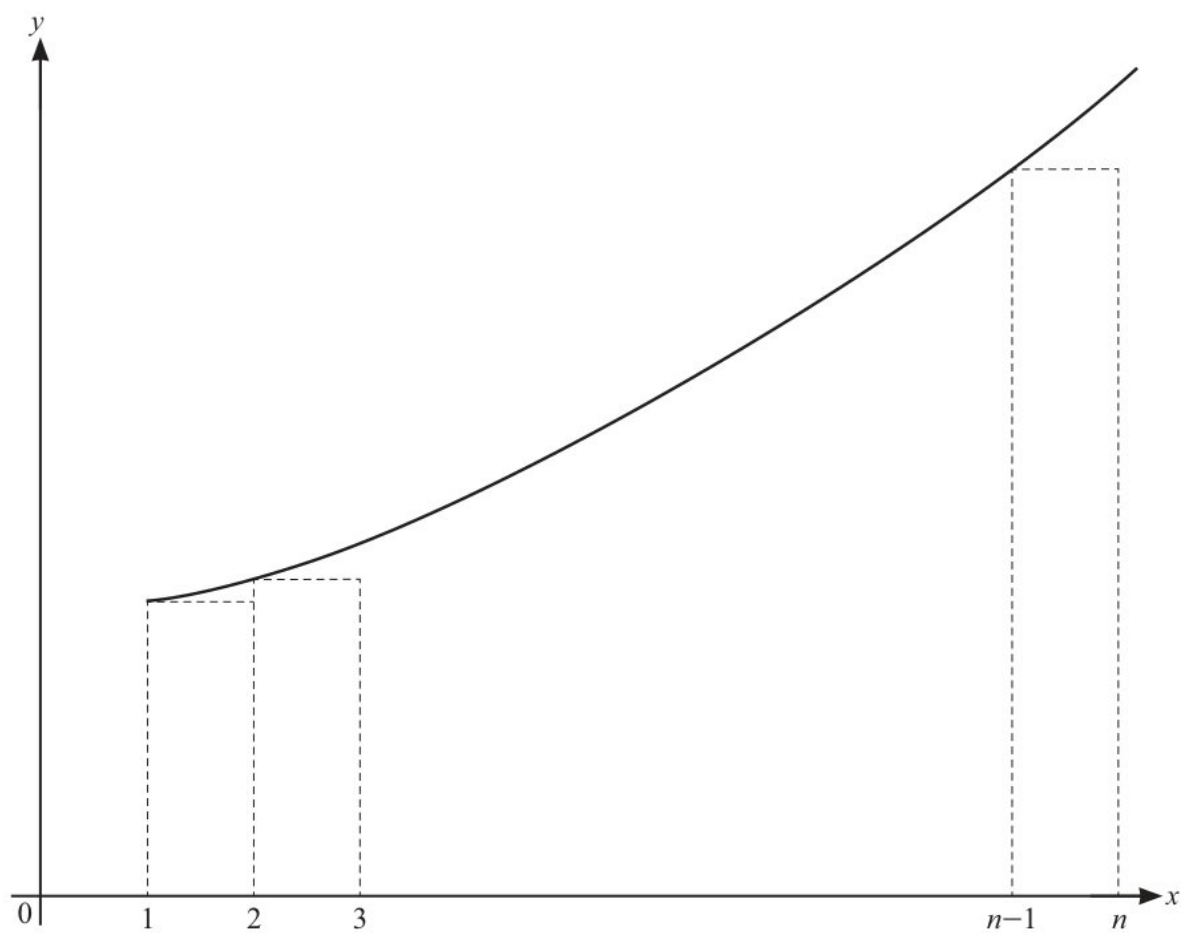
- (e) selects 4 books from her 10 different books from the series Squares and Circles.

.....

[5]

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

(b) (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.

.....

[4]

- (iii) the solution of the differential equation

$$\int_0^k e^{4x} dx = \int_0^{2k} e^x dx$$

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, $f(x) = 0$.

.....

[12]

- (i) Find the values of a and b .

Find the interquartile range of X .

.....

[4]

- (iv) the term interference.

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.

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

.....

[8]

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

.....

[4]

- (e) (ii) Find the acute angle between Π_1 and Π_2 .

Show that the tension in the string is 10 N .

.....

[10]

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

the other root and hence find the values of b and c .

the probability density function of Y

.....

mass they = em [6]

- (i) the exact volume of the solid generated

Find $\frac{dy}{dx}$ and deduce that if C has two stationary points then $-\frac{3}{2} < \lambda < 1$.

.....

[6]

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

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

.....
.....
.....
.....

[5]

- 17 the median value of X .

is the magnitude of F when the child stands at X and when the child stands at Y ?

- (c) (i) the grid below, draw a cumulative frequency graph to illustrate this information.

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

.....
.....
.....
.....

[5]

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

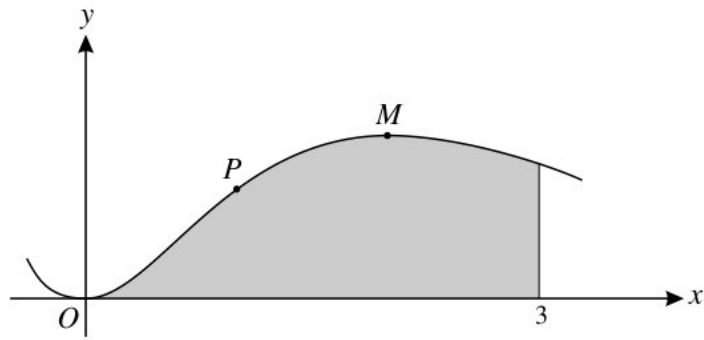
Find the exact area of the shaded region.

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

.....
.....
.....
.....

string = bb [8]

(b) (ii)



the speed of the combined particle after this collision.

$$\int_0^k e^{4x} dx = \int_0^{2k} e^x dx$$

.....

[4]

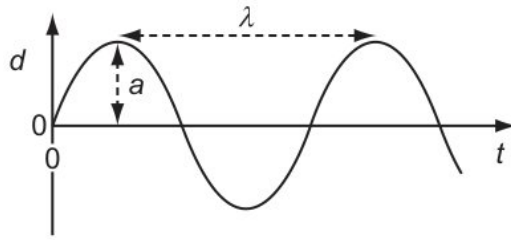
(vi) curves C_1 and C_2 intersect at the point with polar coordinates (a, β). State the value of β .

are the frequencies of the next two higher notes for this air column?

.....

[12]

(iv)



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

.....

[10]

(d) Find the area of the sector of C between $\theta = 0$ and $\theta = \frac{1}{3}\pi$.

.....

other three = ld [8]

(a) The speed of the car at the bottom of the first ramp is 14 m s^{-1} . Use an energy method to find the speed of the car when it reaches the bottom of the second ramp.

.....

[6]

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

17

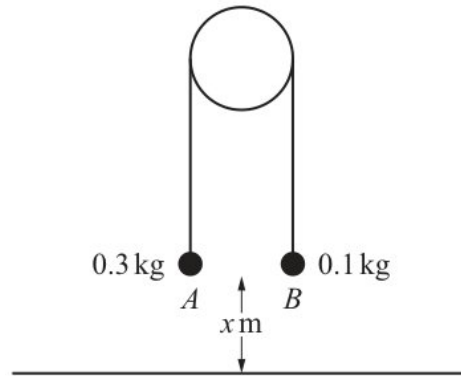


diagram shows the curve with equation $y = \frac{1}{\sqrt{x}}e^{\sqrt{x}}$ for $x \geq 1$, together with a set of $n - 1$ rectangles of unit width. of unit width.

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

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

.....

amplitude harmonic speed = jd [3]

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

- 16 Find the interquartile range of X .

.....

[8]

- 26 the exact area of one loop of the curve.

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.

- (b) (ii) exactly at point T

the solution of the differential equation

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

.....

[5]

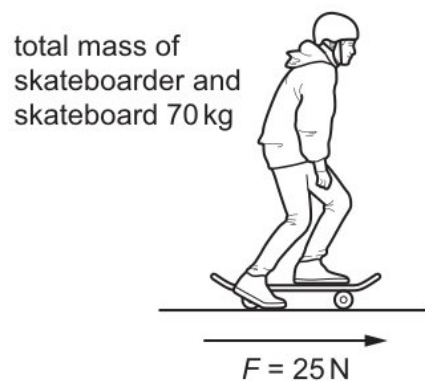
- (v) stationary loudspeaker emits sound of constant frequency. A microphone is placed near to the loudspeaker and connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

Hence find the solutions of the equation

.....

small = xe [6]

(i)



an electron and a neutrino

.....

.....

.....

.....

[5]

(c) cylindrical copper wire P of length 0.24 m is shown in Fig. 6.1.

.....

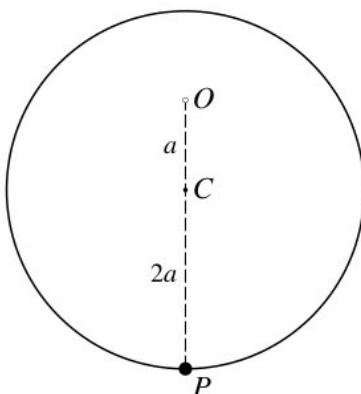
.....

.....

.....

[10]

- (d) (v) curve has equation $x^2 + 2y^2 + 5x + 6y = 10$. Find the equation of the tangent to the curve at the point $(2, -1)$. Give your answer in the form $ax + by + c = 0$, where a, b and c are integers.



.....

above = bk [6]

- (iv) the Maclaurin s series for $e^{\left(\frac{1}{x+2}\right)}$ up to and including the term in x^2
 a normal distribution, calculate a 95% confidence interval for the population mean.

.....

[3]

- (iii) Write down matrices \mathbf{P} and \mathbf{D} such that $\mathbf{P}^{-1}\mathbf{A}\mathbf{P} = \mathbf{D}$, where \mathbf{D} is a diagonal matrix, and hence find the matrix \mathbf{A}^n in terms of n , where n is a positive integer.

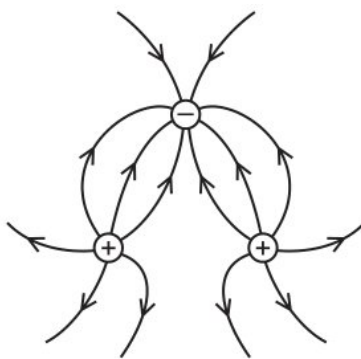
$$\mathbf{a} = 3\mathbf{i} + 2\mathbf{j} - \mathbf{k}, \quad \mathbf{b} = 4\mathbf{i} - 3\mathbf{j} + 2\mathbf{k}, \quad \mathbf{c} = 3\mathbf{i} - \mathbf{j} - \mathbf{k}$$

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

.....

[3]

(ii)



support at end X exerts a force F vertically upwards on the plank.

.....

[8]

- (e) 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 .

Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

Express v in terms of x .

.....

[5]

sample has an activity of 180 Bq at time $t = 0$.

29 by calculation that $0.9 < a < 0.95$.

$$x^3 - 2y^3 = 3xy.$$

.....

present Kieran balls = ew [2]

the speed of Q after the collision.

- 16 Find the value of a for which $\arg(u^*) = \frac{3}{4}\pi$, where u^* denotes the complex conjugate of u .
It consists of three quarks that do not need to be the same flavour.
the ratio $H : D$.

.....
.....
.....
.....

[4]

- 16 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.

Find the x -coordinate of the maximum point M on the curve.

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

- (c) The acceleration of the particle between $t = 6$ and $t = 10$ is 7.5 m s^{-2} . When $t = 10$ the velocity of the particle is $V \text{ m s}^{-1}$. Find the value of V .

a basis for the null space of T .

.....
.....
.....
.....

[10]

- (b) (iii) 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.

In the case where $k = 2$,

line l passes through B and C .

.....
.....
.....
.....

[5]

- (iv) is the force on an electron when it is in the uniform electric field between the plates?

by calculation that $0.9 < a < 0.95$.

at the 2% significance level whether the population mean time for this year is less than 62.4 seconds.

.....

[4]

- (i) 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 ω and with the string inclined at an angle of θ to the downward vertical.

diagram best represents the electric field surrounding the charges?

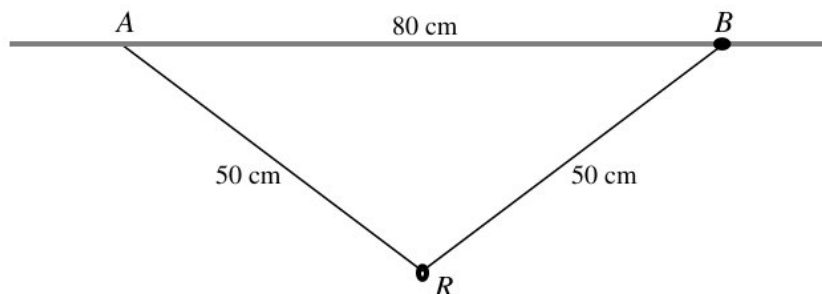
.....

[3]

wires are extended with the same strain and obey Hooke's law.

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

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



[6]

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

- (a) 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.

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.

.....

[4]

- (b) m.f. for $n = 0$.

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 $ax + by + cz = d$.

.....

[2]

- 8 gravitational potential at a point.

- (e) molecule of mass m travelling horizontally with velocity u hits a vertical wall at right-angles to its velocity. It then rebounds horizontally with the same speed.

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.

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).

.....

[10]

- (c) (ii) Find the coordinates of the turning points of C .

is given that λ is an eigenvalue of the non-singular square matrix \mathbf{A} , with corresponding eigenvector \mathbf{e} .

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

.....

that Assume = tf [5]

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

the period of small oscillations,

.....

[4]

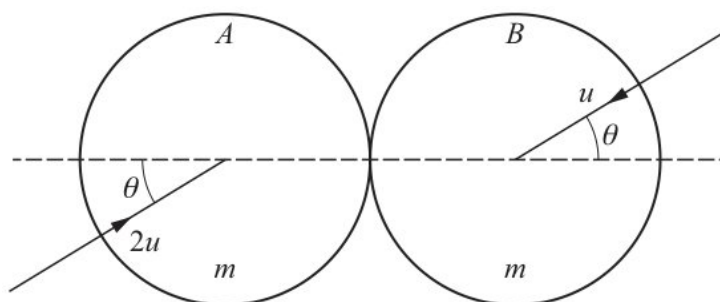
- (b) (i) the probability generating function of Z to find $E(Z)$.

vertical forces that the ground exerts on a stationary van are shown.

.....

[3]

- (iv) the iterative formula in part (c) to calculate a correct to 4 decimal places. Give the result of each iteration to 6 decimal places.



.....

[10]

- (ii) Find the rank of \mathbf{A} and a basis for the null space of \mathbf{T} .

Hence explain why the roots of the equation $16x^4 - 20x^2 + 5 = 0$ are $x = \pm \sin \frac{1}{5}\pi$ and $x = \pm \sin \frac{2}{5}\pi$.

expression gives the electrical resistance of the metal cube between X and Y ?

.....

[10]

24 (ii)

Interval	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$
Expected frequency	1	7	a	b	c	91

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 $ax + by + cz = d$.

.....

[4]

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

(c) point D is such that $ABCD$ is a parallelogram.

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

filter is rotated about the normal axis through an angle θ .

.....

[4]

(a) Show that $a = \frac{1}{3} \ln(251 - a - a^2)$.

.....

[3]

(b) with a reason, whether it was necessary to use the Central Limit Theorem in your answer to part (b).

.....

[8]

- (i) Find the tension in the string.

variable Y is related to X by $Y = 2^X$.

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

- (c) lengths, in millimetres, of rods produced by a machine are normally distributed with mean μ and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm .

.....

around = ry [6]

- (a) car is accelerated by a constant resultant force of 300 N for 5.0 s .
 that the forces are in equilibrium, find the values of θ and X .

.....

[6]

- (b) diagram shows the force-extension graph produced.

.....

[6]

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

- 14 diagram best represents the electric field surrounding the charges?

lamina is freely suspended at A and hangs in equilibrium.

any assumption that you make, test at the 10% significance level whether the greengrocer's claim is supported by this evidence.

.....

[3]

solid cubes, A and B, are measured to determine the density of their materials.

28 specific latent heat.

Express $\frac{dy}{dx}$ in terms of t .

.....

where Find = qn [10]

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

11 the equations of the asymptotes of C .

Obtain another equation relating u^2, v^2, a and g , and hence find u in terms of a and g .

aircraft, initially stationary on a runway, takes off with a speed of 85 km h^{-1} in a distance of no more than 1.20 km .

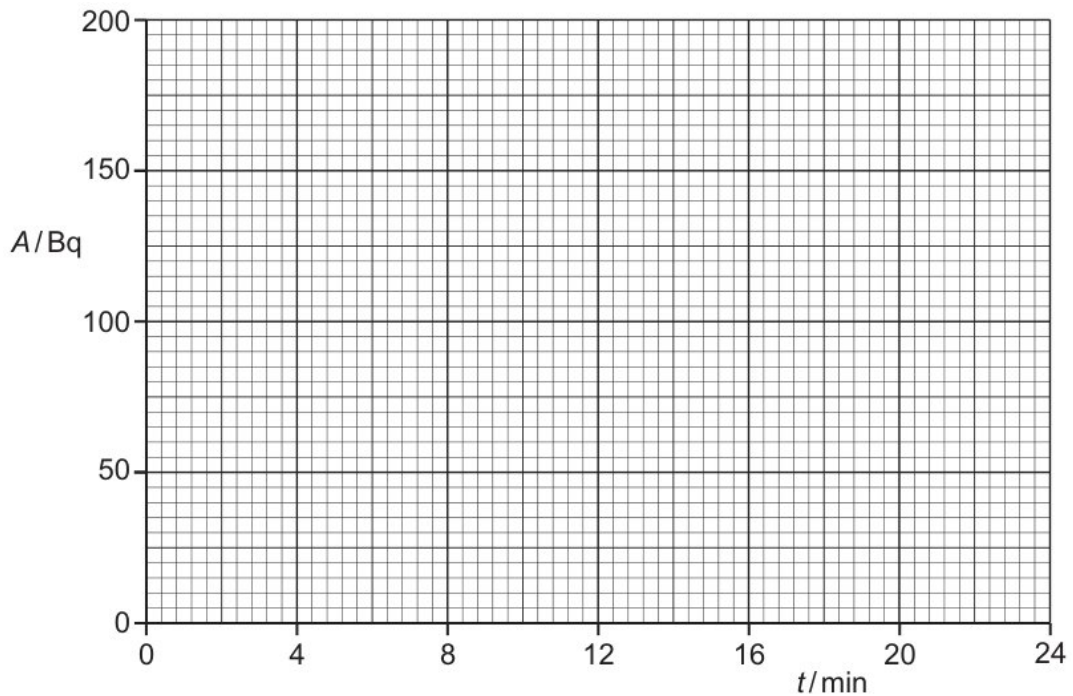
body of mass m , moving at velocity v , collides with a stationary body of the same mass and sticks to it.

.....

[12]

- falling freely with the parachute closed,

13



Find the period of the motion.

.....

[6]

6 the exact area of one loop of the curve.

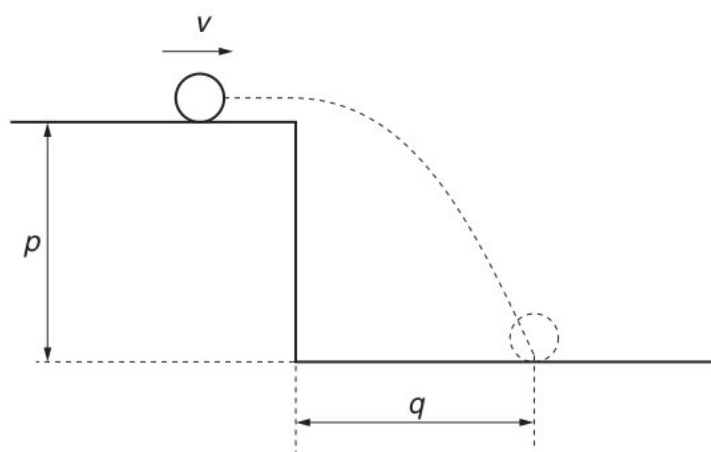
A ductile material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension x of the stretching force F .

$$6 \frac{d^2x}{dt^2} + 3 \frac{dx}{dt} + 6x = e^{-t}$$

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.

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

(b) (iv)

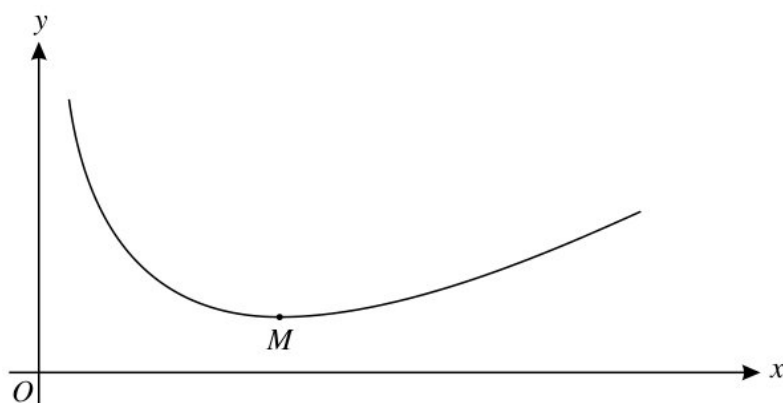


this Saturday's event, 60% of the competitors had times less than 36.0 minutes.

.....

[2]

(ii) is the percentage uncertainty in the calculated density of the liquid?



.....

[5]

- (a) forces, of magnitudes F N, $3F$ N, G N and 50 N , act at a point P , as shown in the diagram.

.....

.....

.....

.....

[4]

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

- 23 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.

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

Find the area of the sector of C between $\theta = 0$ and $\theta = \frac{1}{3}\pi$.

.....

.....

.....

.....

opposite = ff [3]

student is investigating a non-inverting operational amplifier (op-amp) circuit.

- 14 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 θ is 90° .

.....

.....

.....

.....

[6]

a certain time, the projectile has a horizontal velocity of 23.0 ms^{-1} and a vertical velocity of -10.1 m s^{-1} .

29 no digit can be repeated,

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

.....

[6]

$\sum_{r=1}^n (4r-3)(4r+1)$, giving your answer in its simplest form.

14 is given that $\int_1^a x^{\frac{1}{2}} \ln x \, dx = 2$, where $a > 1$.

.....

along above above = gi [6]

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

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

.....

contains present different = js [10]

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 .

10 Given that exactly two of the selected balls have the same number, find the probability that they are both numbered 2.

.....

[12]

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

- (g) (vi) aircraft, initially stationary on a runway, takes off with a speed of 85 km h^{-1} in a distance of no more than 1.20 km .

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

Find the proportions of large, small and medium pineapples.

.....

[6]

- (i) a, b and c are integers to be determined.

could M and N be?

a diagram, on page 3, showing the arrangement of your equipment. In your account

.....

[8]

- (ii) the general solution of the differential equation

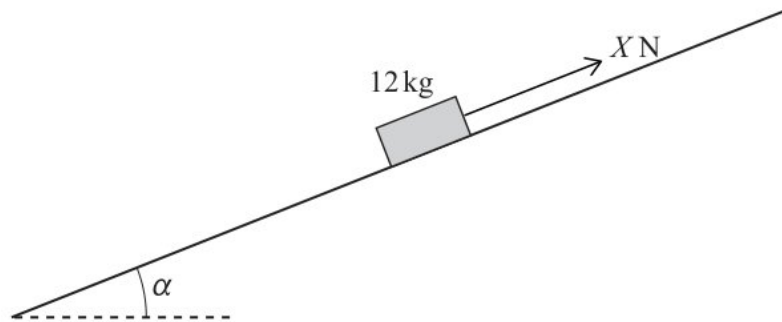
three coplanar forces shown in the diagram act at a point P and are in equilibrium.

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

.....

[5]

- (c) the roots of the equation $z^3 = 27 - 27i$, giving your answers in the form $re^{i\theta}$, where $r > 0$ and $-\pi \leq \theta < \pi$.
only one of the following two alternatives.



.....

.....

.....

.....

[12]

- (b) control of variables,

.....

.....

.....

.....

[6]

- (d) (v)

	resultant force	resultant torque
A	zero	zero
B	zero	non-zero
C	non-zero	zero
D	non-zero	non-zero

down to antiup

.....

.....

.....

.....

[6]

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

The total momentum and the total kinetic energy are always conserved.

The particle comes to rest at B at time T s. Given that the total distance travelled by the particle between $t = 0$ and $t = T$ is 100 m , find the value of T .

.....
.....
.....
.....

[10]

the period of small oscillations,

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

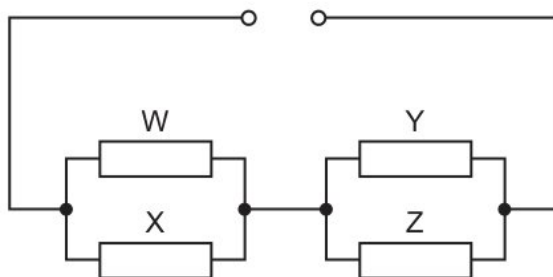
- 12 uniform small smooth spheres A and B have equal radii and each has mass m . Sphere A is moving with speed u on a smooth horizontal surface when it collides directly with sphere B which is at rest. The coefficient of restitution between the spheres is $\frac{2}{3}$. Sphere B is initially at a distance 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 $\frac{1}{3}$.

.....

string = kr [4]

- 16 When the tensile force is removed, the wire returns to its original length.

Without using a calculator, find the exact values of



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

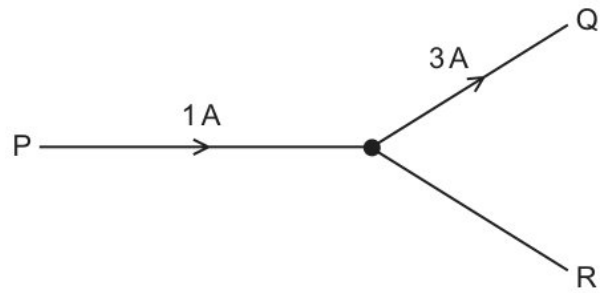
- (c) (iii) Find, showing all necessary working, the equation of the regression line of y on x .

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 θ with the upward vertical.

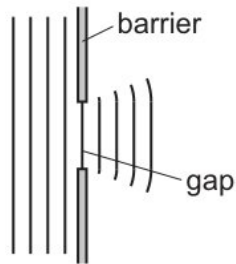
.....

[2]

(iv)



Find the eigenvalues and corresponding eigenvectors of the matrix \mathbf{A} , where



.....

[8]

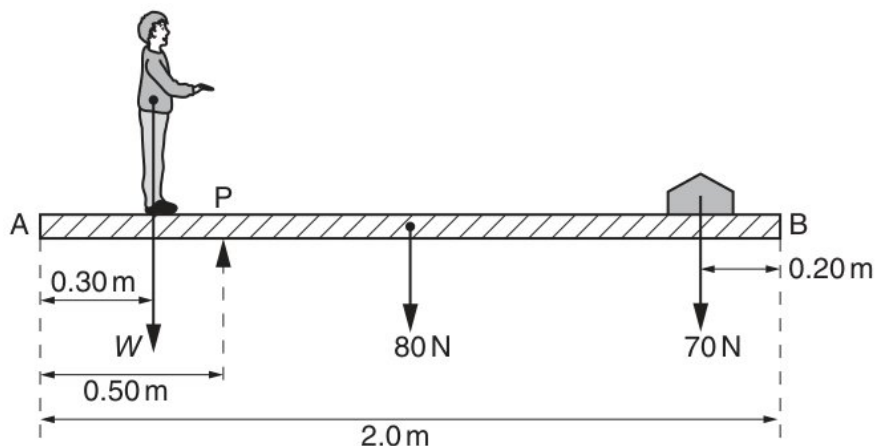
(ii) the value of $\sum_{r=1}^{\infty} \frac{1}{(2-3r)(5-3r)}$.

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

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[4]

- (d) curve C has equation $y = \frac{x^2+px+1}{x-2}$, where p is a constant. Given that C has two asymptotes, find the equation of each asymptote.



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[10]

- 36 body travelling with a speed of 10 ms^{-1} has kinetic energy 1500 J .

uniform disc with centre O , mass m and radius a is free to rotate without resistance in a vertical plane about a horizontal axis through O . One end of a light inextensible string is attached to the rim of the disc and wrapped around the rim. The other end of the string is attached to a block of mass $3m$ (see diagram). The system is released from rest with the block hanging vertically. While the block is in motion, it experiences a constant vertical resisting force of magnitude $0.9mg$. Find the tension in the string in terms of m and g .

- (iii) (b) projectile is thrown at an angle to the ground.

cubic equation $x^3 + 2x + 1 = 0$ has roots α, β, γ .

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many = bq [6]

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

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

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[2]

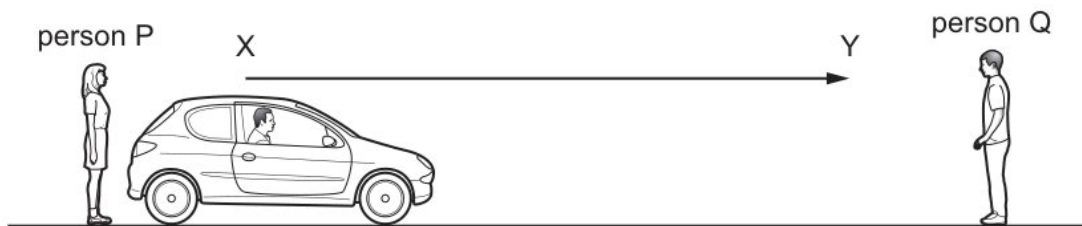
- (vii) When the tensile force is removed, the wire returns to its original length.

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[8]

sample contains a single radioactive isotope that decays to form a stable isotope.

18



Find the area of the region enclosed by C .

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

cable car of weight W hangs in equilibrium from its cable at point P .

your answer in (b)(ii) to determine the distance of the star in (b) from the Earth.

[8]