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

if there are no restrictions,

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

[**4**]

14 (f) the exact value of $\int_{\frac{1}{5}\pi}^{\frac{1}{4}\pi} 3\cos^2 5x \; \mathrm{d}x$

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

Density is mass per cubic metre.

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

[**15**]

Show that the possible values of α are 3 and 5 .

(ii) that, at the point of C furthest from the initial line,

[**3**]

(c) weight of the parachutist is 850 N .

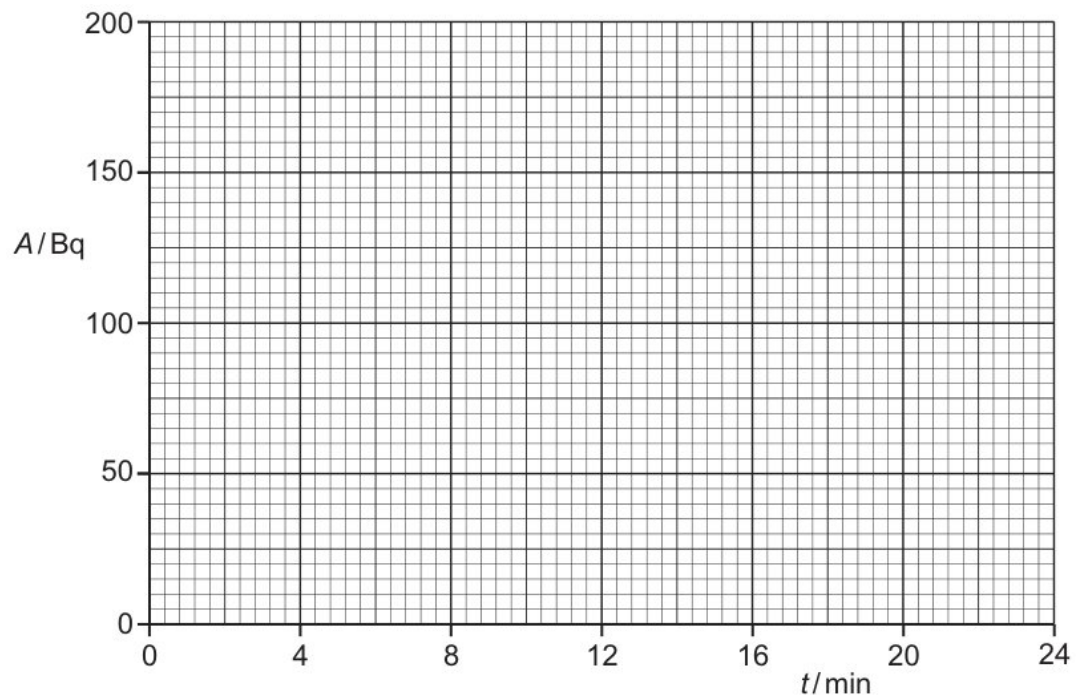(iv) tension in the string when the particle is at Q is twice the tension in the string when the particle is at P.

value = ... zp [**12**]

what is meant by the de Broglie wavelength.
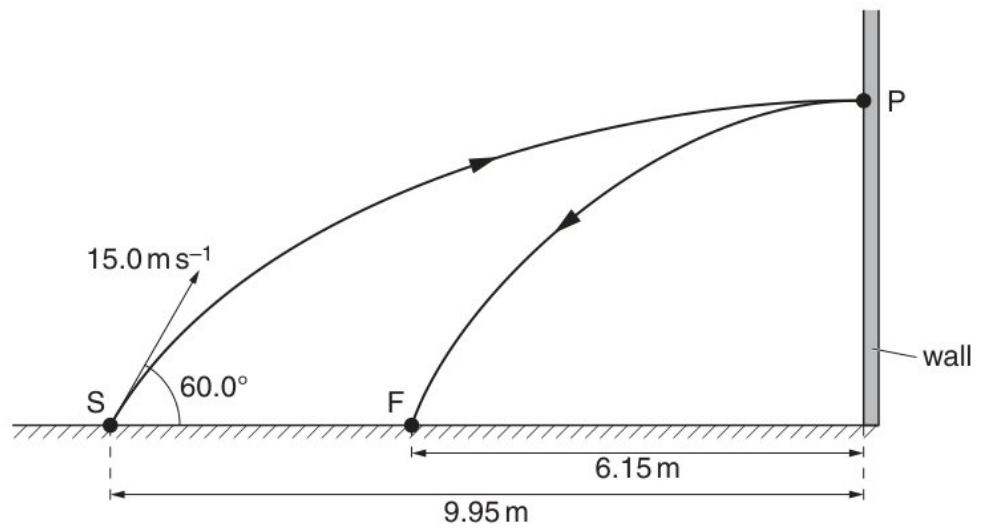
(ii) the moment of a force about a point.

[**6**]

(a) weight of the parachutist is 850 N .

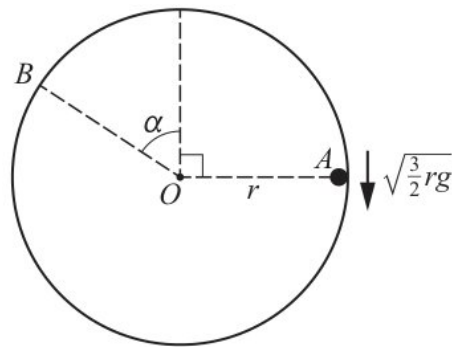

the particular solution of the differential equation

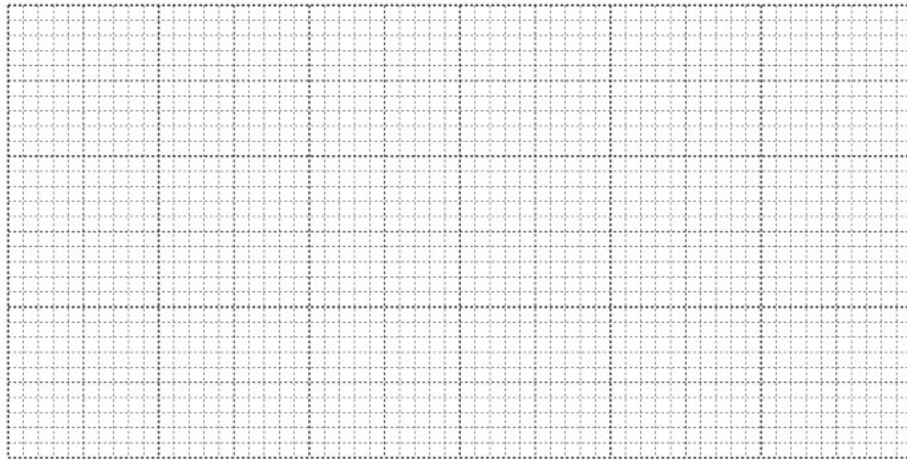(iv) is the force on an electron when it is in the uniform electric field between the plates?

[5]

force = mass × acceleration

(ii) State what happens to the electron and to the positron.

[5]

12

gas is then cooled at constant volume so that its temperature decreases to $2T$.

[4]

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

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

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

Find the value of k for which the set of linear equations

State the name of this type of reaction.

[2]

(h) a 90% confidence interval for the difference in mean crop mass associated with each type of fertiliser.
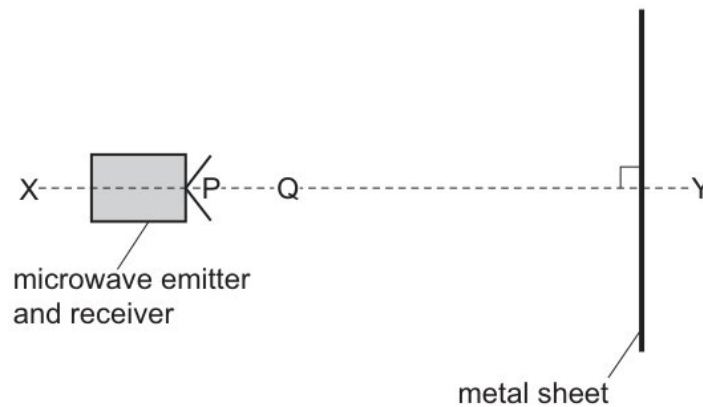
[3]

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

[3]

(c) (i) point D is the reflection of A in l.

the exact volume of the solid generated

[5]

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.

microwave emitter
and receiver

metal sheet

(v) Calculate the acceleration of P when it is at instantaneous rest and $x > 0$.

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

[4]

27   Find the probability that a randomly chosen letter weighs more than 13 g .

Find the weight exceeded by the heaviest 5% of pineapples.

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

women $= \ldots \ldots\ ku$ [6]

16   a tree diagram to represent this information, giving the probability on each branch.

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.
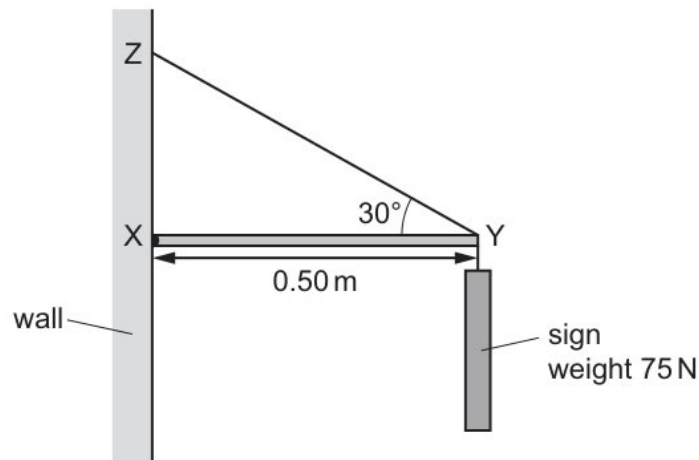

diagram shows two waves R and S.

[**8**]

16   the values of t such that the shortest distance between the lines AB and CD is $\sqrt{2}$.

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

will = ... wy [**6**]

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

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

students = ... mg [**4**]

why Kieran is incorrect.

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

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 m s^{-1} and the extension of the string is x m.

[**8**]

(b) that u_{2n} is divisible by u_n for $n \geqslant 1$.

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.

[**10**]

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

values = ... qf [**3**]

(d) (iii) a, b and c are integers to be determined.

diagram shows a water wave in a shallow tank. The wave is diffracted through a gap in a barrier and spreads. The wavelength of the wave is much smaller than the width of the gap.

[**4**]

diagram illustrates successive wavefronts.

an unbiased estimate of $\mathrm{E}(T)$, and show that an unbiased estimate of $\mathrm{Var}(T)$ is 14.44.
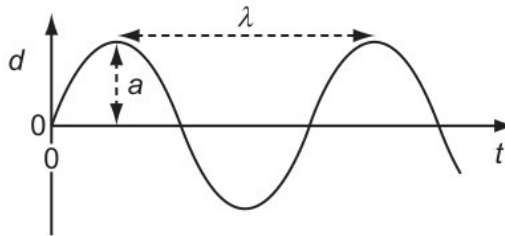
(iv) the type of each transformation and make clear the order in which they are applied

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

[10]

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

$$f(x) = \begin{cases} kx^2 & 0 \leqslant x < 6 \\ 0 & \text{otherwise} \end{cases}$$

(c)

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

that $= \text{.......} \ kv$ **[5]**

(a) (ii) sheets between a light source and the front of the photocell.

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.

[10]

the number of different arrangements of the 7 men and 4 women in a line in which all the men stand together and all the women stand together.

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

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

[**3**]

18 particle moves in a straight line. The velocity v ms^{-1} of the particle t s after leaving a fixed point O is given by $v = k\left(20 + pt - 6t^2\right)$, 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 .

(e) (ii) the acute angle between the directions of l_1 and l_2.

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

variation with time t of the velocity v of the car is shown.

[**4**]

is meant by elastic deformation?

(i) tension in the string of the pendulum is T. The weight of the pendulum bob is W. The string is held at an angle of 30° to the vertical.

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

acting = ... fo [**3**]

(a) (i) the ductile material,

Calculate the length AG.

screen = ... xq [**5**]

Use the information in (d)(iv) to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.
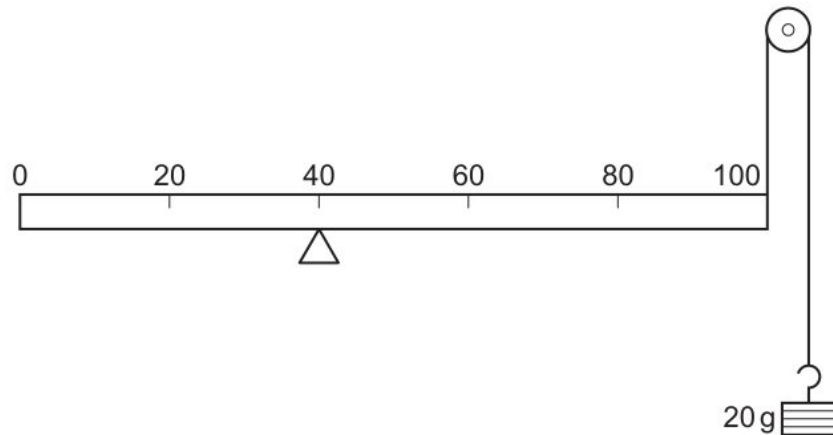
(iv) State the number of roots of the equation $p\left(2^y\right) = 0$, justifying your answer.

pressure, $=$ .... xk [8]

the exact area of one loop of the curve.

(iii)

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

many different colour arrangements are there of the 10 books with exactly 4 books between the 2 yellow books?

radians. $= \dots$ yo **[4]**

(c) (iii) Table 4.1 to show, in terms of some or all of W, T and U, the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

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

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 $AC = a$.

projected $= \dots\dots\dots\dots$ ux **[3]**

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 $\frac{3k+1}{3(1-k)}$.
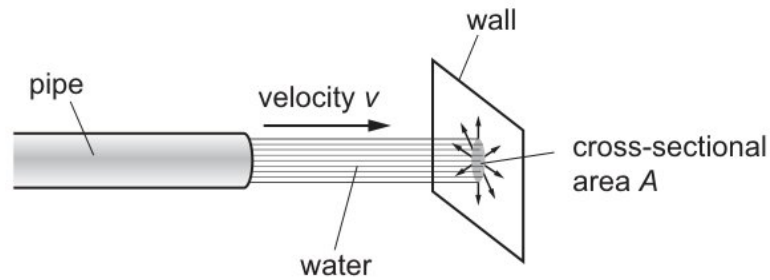
(i) Its speed decreases to zero, then increases to a value less than 20 ms^{-1}.

$$E_{\mathrm{K}} = \frac{1}{2}mv^2.$$

[6]

analysis of the data,

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

continuous random variable X has probability density function f given by

[12]

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

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

that the eigenvalues of **A** are $-1, 1$ and 5.

[**8**]

25 should pay particular attention to

diagram shows the curve $y = x - 2\ln x$ and its minimum point M.

(d) mass of cherries sold per day in a supermarket is normally distributed with mean 72.4 kg and standard deviation σkg. It is known that on 10% of days less than 59.1 kg of cherries are sold.

There will always be 9.0 V across the battery terminals.

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

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.

[**4**]

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

$$f(x) = \begin{cases} kx^2 & 0 \leqslant x < 6 \\ 0 & \text{otherwise} \end{cases}$$

diffraction = ... yr [**4**]

(a) (iii) particle oscillates in simple harmonic motion with centre O. When its distance from O is 3 m its speed is 16 m s^{-1}, and when its distance from O is 4 m its speed is 12 m s^{-1}. Find the period and amplitude of the motion.

do each of the symbols represent for an electric current in a metal wire?

[**10**]

the probability density function of Y,

(iv) Find the rank of **M**.

In the case where $k = 2$,

motion = ... bt [**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.

(v) time-base setting on the oscilloscope should be used?

control of variables,

move = ... fo [**6**]

7 Amplitude is inversely proportional to velocity.

rows = ... eq [**4**]

19 The orbit has a period of 25 hours.

is the percentage uncertainty in the calculated density of the liquid?

(b) standard results from the list of formulae (MF19) to show that

Find the median of X.

[**5**]

(f) (v) time taken by P to travel directly from L to M is 2 s .

cubic polynomial p(x) is defined by

[6]

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

(ii) Find the values of a and b.

that the forces are in equilibrium, find the values of θ and X.

[3]

P and Q form an isolated system.

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

524   526   520   523   530

[6]

11 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.

(a) that $(z_1 z_2)^* = z_1^* z_2^*$.

curve C has polar equation $r = 3 + 2\cos\theta$, for $-\pi < \theta \leqslant \pi$. The straight line l has polar equation $r\cos\theta = 2$. Sketch both C and l on a single diagram.

[6]

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

[2]

18

(d) (i)

	transverse wave	longitudinal wave	can travel in free space	key 5* ✓ = property of an electromagnetic wave $\boldsymbol{x}$ = not a property of an electromagnetic wave
A	✓	χ	✓	
B	✓	χ	×	
C	×	✓	✓	
D	×	✓	×	

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

force applies = ... aj **[6]**

only one of the following two alternatives.

(v) 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 m s^{-1}. Find the value of V.

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

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

[10]

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

(iii) the values of t such that the shortest distance between the lines AB and CD is $\sqrt{2}$.

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

slope ends = ... xt **[20]**

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.

(iv) Show that $\frac{dy}{dx} = 2t^{\frac{1}{2}} \frac{dy}{dt}$ and $\frac{d^2y}{dx^2} = 2\frac{dy}{dt} + 4t\frac{d^2y}{dt^2}$.

Find the cartesian equation of Π_1.

Sound waves can travel in a vacuum but light waves cannot travel in a vacuum.

[8]

(c) diagram shows part of the curve

drug = ... ur **[1]**

21 $\frac{\text{force}}{\text{length} \times \text{speed}}$

the distribution function of X.

roots of the cubic equation $x^3 + 2x^2 - 3 = 0$ are α, β and γ.

(c) (i) beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

s friend says,"This survey is about sports facilities, so you should choose a sample of students from the school sports teams."

[2]

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

(ii) linear transformation $\text{T} : \mathbb{R}^4 \to \mathbb{R}^4$ is represented by the matrix $\mathbf{M} =$
$$\begin{pmatrix} 1 & 3 & -2 & 4 \\ 5 & 15 & -9 & 19 \\ -2 & -6 & 3 & -7 \\ 3 & 9 & -5 & 11 \end{pmatrix}.$$
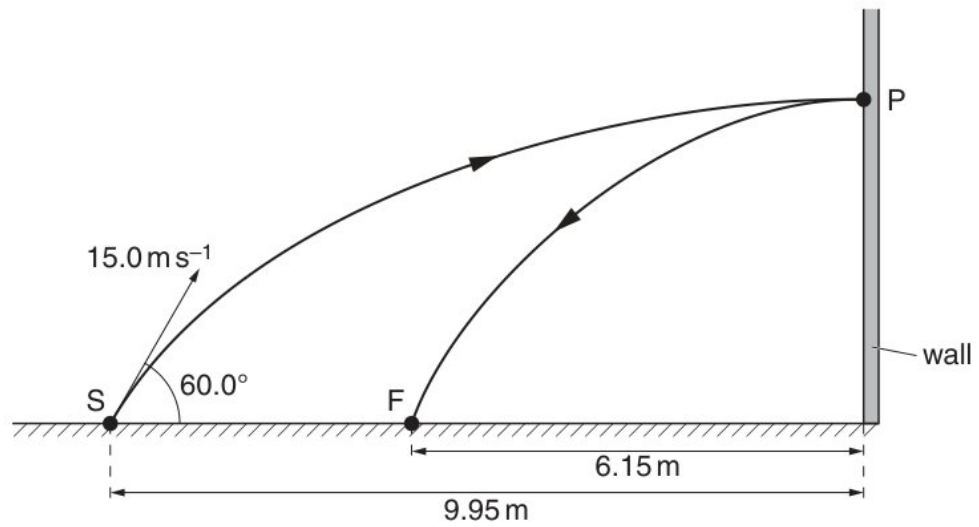
Show that the mass of Mars is 6.4×10^{23} kg.

Show that the tension in the string is 10 N .

[5]

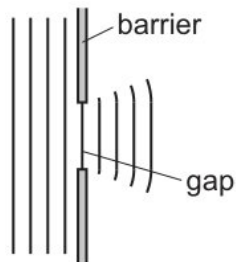photocell. This may be carried out in the laboratory by varying the number of identical thin

(v)

Find the modulus of elasticity of the string in terms of W.

Calculate the speed of the star relative to the Earth.

[**8**]

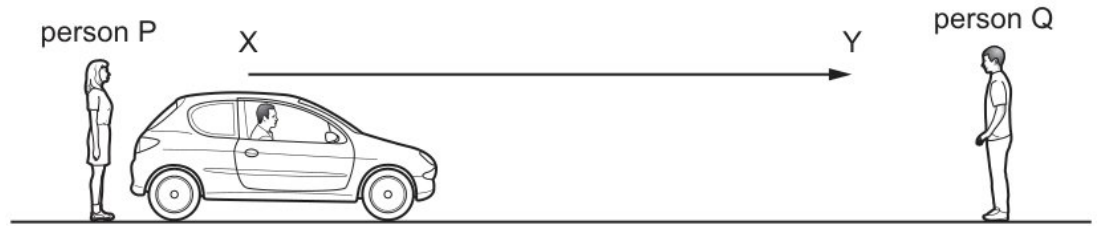(b) (i) Find the equation of the tangent to the curve at the point where $x = 0$.

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

[**5**]

Find the perpendicular distance of the point A from the line BC.

(ii) X and Y are connected in series to a cell.

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

summarised $= $ .... es **[5]**

15 the ratio $H : D$.

(iv) satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

Find the values of a and b.

[8]

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

$\mathbf{a} \times \mathbf{b}$ and deduce the area of the triangle OAB.

[6]

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

(e) Find the values of a and b.

constant a is such that $\int_1^a 6x\ln x \, dx = 4$

$$x = \ln(\tan t), \quad y = \sin^2 t,$$

[2]

15 diffraction grating with 500 lines per mm is used to observe diffraction of monochromatic light of wavelength 600 nm .

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

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

Express $5\cos\theta - 3\sin\theta$ in the form $R\cos(\theta + \alpha)$, where $R > 0$ and $0° < \alpha < 90°$, giving the exact value of R and the value of α correct to 2 decimal places.

[**5**]

$n \geqslant 0$. Use the fact that $\tan^2 x = \sec^2 x - 1$ to show that, for $n \geqslant 2$,

(iii) The force F is removed from the materials in (d) just before the breaking point is reached. Describe the subsequent change in the extension for

particle P is moving in simple harmonic motion with centre O. When P is 5 m from O its speed is V m s^{-1}, and when it is 9 m from O its speed is $\frac{3}{5}V$ m s^{-1}. Show that the amplitude of the motion is $\frac{15}{2}\sqrt{2}$ m.

[**4**]

(a)

	Area 1	Area 2	Area 3
Local bus service	73	36	30
Road surfaces	47	44	20

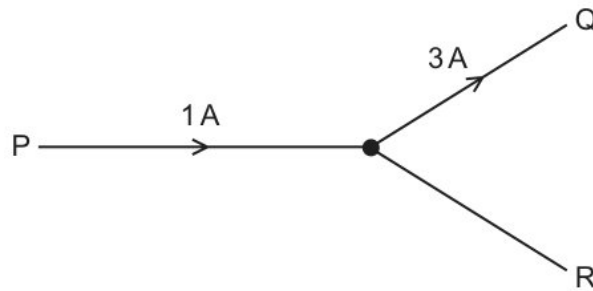The extension of the wire is proportional to the tensile force.

all necessary working, solve the equation $2\log_2 x = 3 + \log_2(x+1)$, giving your answer correct to 3 significant figures.

[**10**]

(d) curve C has parametric equations $x = e^t \cos t, y = e^t \sin t$, for $0 \leqslant t \leqslant \pi$. Find the arc length of C.

[**8**]

7

variables x and y satisfy the differential equation

[5]

14   student is investigating how a volume of nitrogen gas is affected by the pressure exerted

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

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

[12]

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

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

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

with = ... np **[5]**

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

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

[6]

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

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

could M and N be?

$$\text{purple} = \text{................} \quad bh \qquad \textbf{[6]}$$
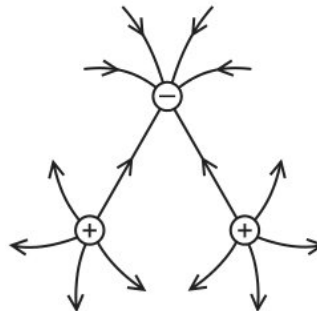
14 diagram shows two waves R and S.

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

(b) the exact value of I_2

The power to X will decrease and the powers to Y and Z will increase.

$$\textbf{[6]}$$

(a) (iv)

the equations of the asymptotes of C.

that u_{2n} is divisible by u_n for $n \geqslant 1$.

$$\text{collides collides} = \text{..................} \quad kb \qquad \textbf{[5]}$$

Show that the tension in the string is 10 N .

(ii) Write down the least value of $15\cos\theta - 9\sin\theta$ as θ varies.

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 $X \sim \mathrm{N}\left(3.2, 0.4^2\right)$ and $Y \sim \mathrm{N}\left(4.3, 0.6^2\right)$. The income generated by the oil from the two fields is \$90 per barrel for A and \$95 per barrel for B.
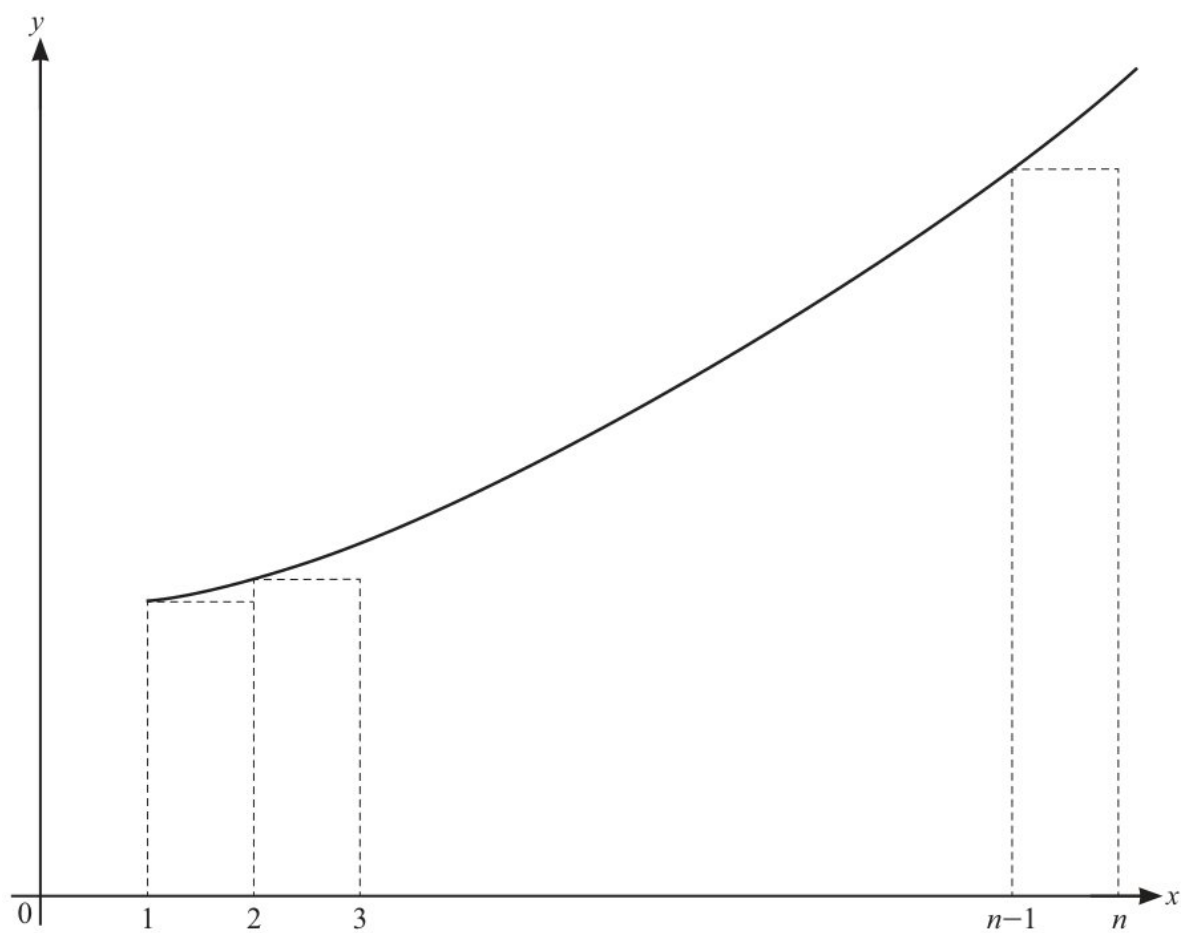
[**8**]

21   selects 4 books from her 10 different books from the series Squares and Circles.

(iii) magnetic flux density.

in terms of m and g, the magnitude of the frictional force in this position.
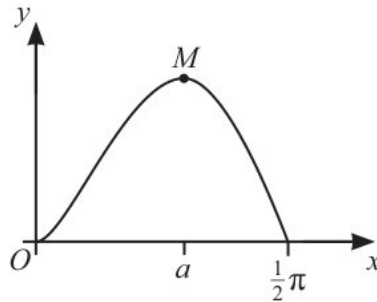
[**5**]

(iv) (e)

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

[3]

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

(b) the value of σ.

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

[4]

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

(a) variables x and y satisfy the differential equation

at the 2.5% significance level whether this evidence supports Mr Lee's assertion.

[3]

(ii) (e) analysis of the data,

the values of t such that the shortest distance between the lines AB and CD is $\sqrt{2}$.

[8]

Show that the total distance fallen is 1048 m .

(a) Find the exact area of the shaded region.

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

[4]

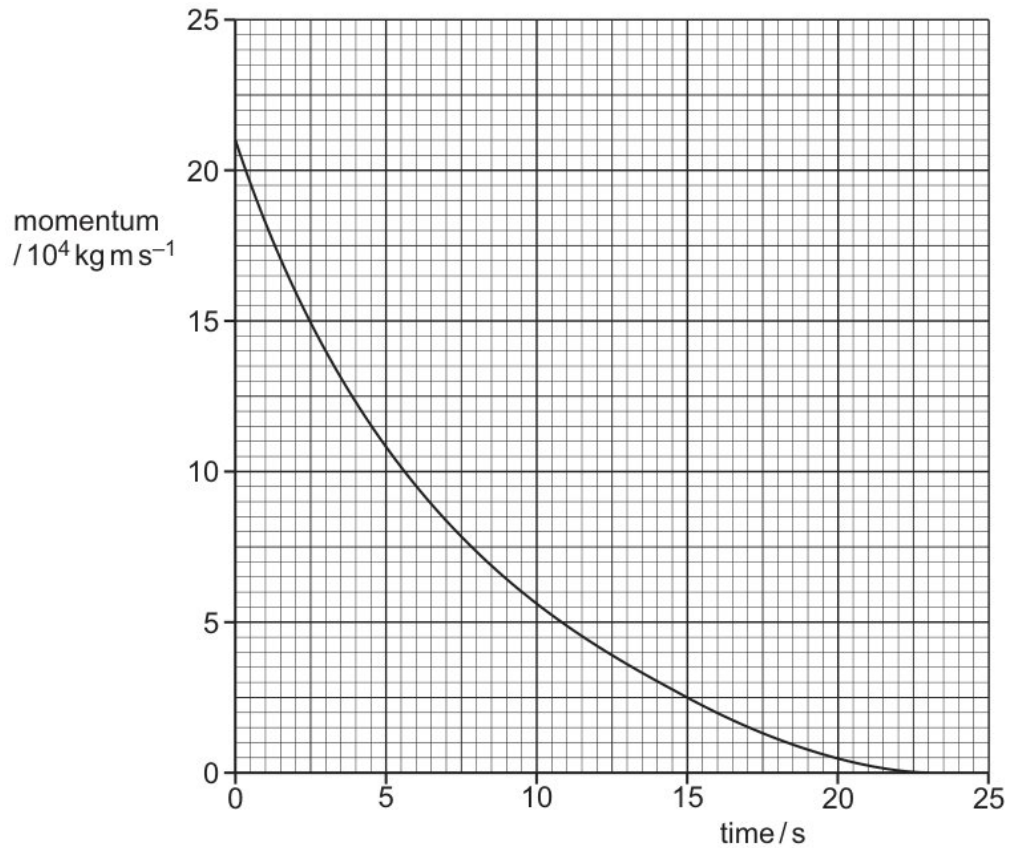(v) (a) Explain why two gamma-ray photons are produced, rather than just one.

On Fig. 3.2, sketch the variation with x of F for a brittle material up to its breaking point.

[8]

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

(b) diagram best represents the electric field surrounding the charges?

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

[**8**]

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

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

move = ... jp [**3**]

17 (c) 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.

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

[8]

Find the angle that this tangent makes with the x-axis.

(i) how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.
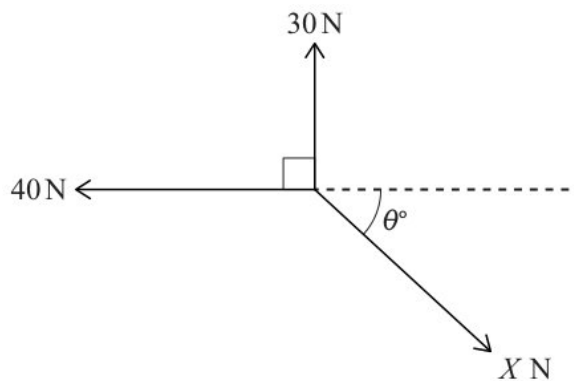
[6]

point P is the foot of the perpendicular from A to l.

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

[**5**]

(e)

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

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

(iv) the equations of the asymptotes of C.

[**5**]

resistors of equal value are connected as shown.

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

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

[**12**]

a, b and c are integers to be determined.

(ii) which direction does the droplet accelerate, and which change needs to be made to the separation of the plates in order to stop this acceleration?
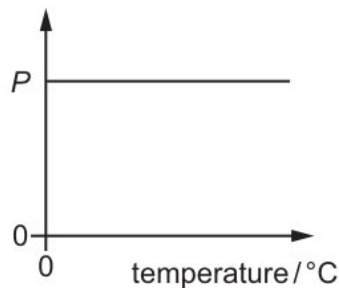
[8]

the value of μ.

(iii) 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.

parametric equations of a curve are

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

[8]

(a) amplitude $\propto$ intensity

(iii) 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.

Find the volume obtained when the shaded region is rotated through $360°$ about the x-axis, giving your answer in terms of π.

[6]

times taken to run 200 metres at the beginning of the year and at the end of the year are recorded for each member of a large athletics club. The time taken, in seconds, at the beginning of the year is denoted by x and the time taken, in seconds, at the end of the year is denoted by y. For a random sample of 8 members, the results are shown in the following table.

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

[4]

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

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

the exact value of a.

standard results from the list of formulae (MF19) to show that

radius = ... ka [5]

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

Use the information in (d)(iv) to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

(ii) Use a different object that has twice the volume and the same density as the original object.
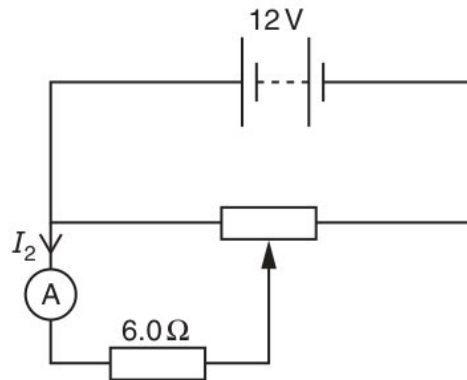
large = ... ob [6]

diagram shows a trace of a wave on a cathode-ray oscilloscope.

(iv) be written as a quadratic equation in x.

past hoped = ... tp [8]

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

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

12 V

I_2

A

6.0 Ω

[5]

19 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 $\frac{1}{3}$.

shows shows ground. = ... ho [20]

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

the eigenvalues and corresponding eigenvectors of the matrix $\mathbf{A} = \begin{pmatrix} 4 & -1 & 1 \\ -1 & 0 & -3 \\ 1 & -3 & 0 \end{pmatrix}$.

(c) polar equation of a curve C is $r = a(1 + \cos\theta)$ for $0 \leqslant \theta < 2\pi$, where a is a positive constant.

[5]

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

[**10**]

(b) (vi) the number of different arrangements of the 7 men and 4 women in a line in which all the men stand together and all the women stand together.

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

For the case where $\theta = 15$ and the plane on which B rests is smooth, find the acceleration of B.

[**4**]

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

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

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

[**10**]

15 $\mathbf{A}^{2n}$, where n is a positive integer.

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

the gradients of the tangents to the curve when $x = 0$.

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

.

[**15**]

(c) (iii) 1.1 shows the measurements for cube A.

Find the tension in the string in terms of W.

random variable Y is defined by $Y = \sqrt[3]{X}$

[**4**]

Find the exact value of the arc length of C.

(i) is given instead that $\mu \neq 0.15$ and that when $X = 10$, the block is on the point of moving down the plane.

Find the probability that a randomly chosen letter weighs more than 13 g .

[**6**]

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

(ii)

	amplitude /cm	period /ms
A	2	10
B	2	90
C	4	10
D	4	90

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.

that $y = 0$ when $x = 0$. Give your answer in an exact form.

[6]

(e) 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.

[5]

(b) the inequality $|x| < |5 + 2x|$.

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

particular plane suitable $=$ .... ik **[10]**

9   By using the substitution $y = \frac{1}{x^2}$, find the cubic equation with roots $\frac{1}{\alpha^2}, \frac{1}{\beta^2}$ and $\frac{1}{\gamma^2}$.

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

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

[12]

the particular solution of the differential equation

(i) the value of V.

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

[**6**]

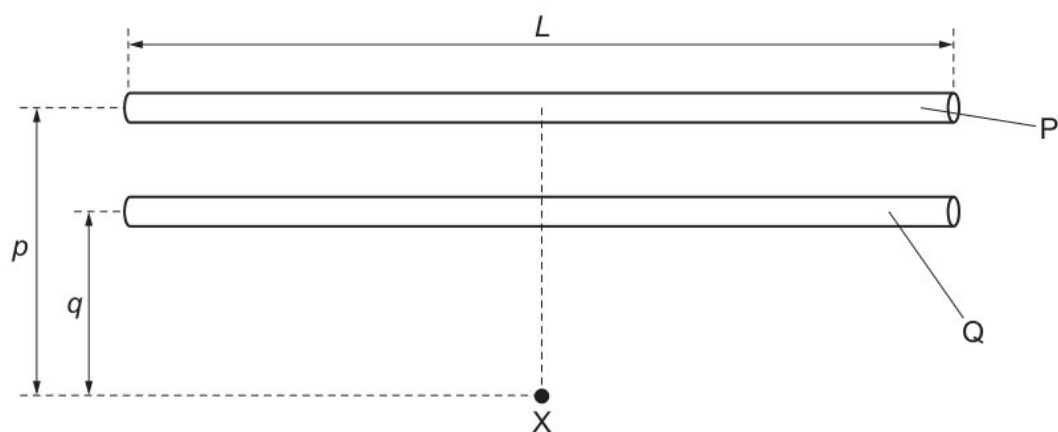(a) (iii) is the angle between the second-order maximum and the third-order maximum?

particle of mass m is attached to the mid-point of a light elastic string. The string is stretched between two points A and B on a smooth horizontal surface, where $AB = 2a$. The string has modulus of elasticity λ and natural length $2l$, where $l < a$. The particle is in motion on the surface along a line passing through the mid-point of AB and perpendicular to AB. When the displacement of the particle from AB is x, the tension in the string is T. Given that x is small enough for x^2 to be neglected, show that

as shown in Fig. 2.1.

books, books, book $= \ldots\ldots\ldots tl$ [**10**]

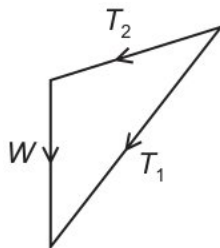Sound waves can travel in a vacuum but light waves cannot travel in a vacuum.

(iv)

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

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

[**10**]

region enclosed between the x axis and the curve is rotated through 2π radians about the x axis

(i) Find the coordinates of the point A on C at which $\frac{dy}{dx} = 0$ and $x \neq 0$.

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

[15]

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

angle radius inner = ... fy **[1]**

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

(iv) (a) a butternut squash seed is sown the probability that it will germinate is 0.86 , independently of any other seeds. A market gardener sows 250 of these seeds. Use a suitable approximation to find the probability that more than 210 germinate.
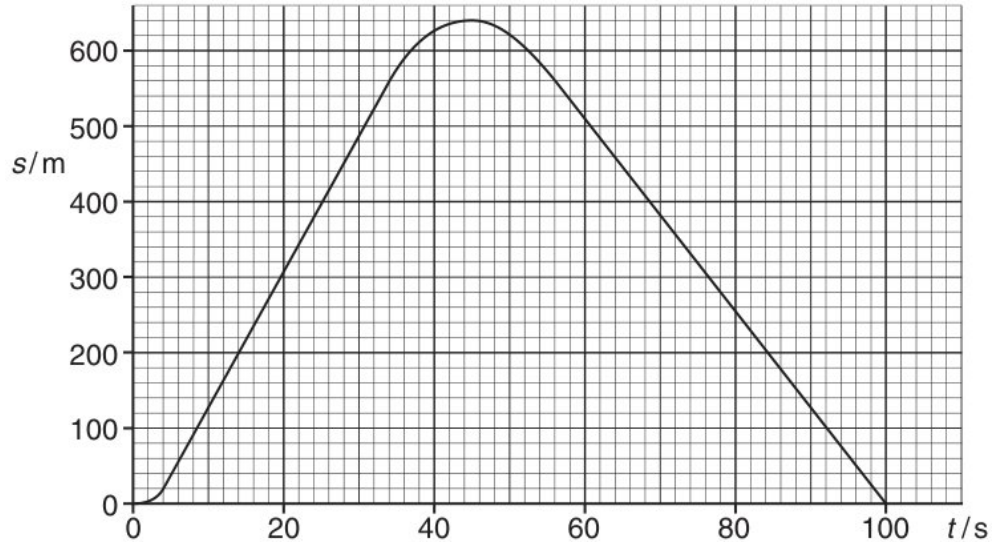
that $y = 0$ when $x = 3$ Give your answer in an exact form

leptons are emitted from the sodium-21 nucleus during the decay?

skateboard, = ... hn **[12]**

diagram shows an experiment to measure the speed of a small ball falling at constant speed through a clear liquid in a glass tube.

(c) that the distance travelled by the ball when it is moving upwards is $x = \frac{1}{2k} \ln\left(\frac{g+kU^2}{g+kv^2}\right)$.

[**8**]

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

(b) 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.

the characteristic equation of **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.

eigenvalue that $= \dots rf$ [**4**]

The total momentum of each object in the system is the product of its mass and velocity.

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

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

speed = ... qi **[12]**

(i) (b) 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.

magnetic flux density.

$$\mathbf{A} = \begin{pmatrix} 1 & -1 & -2 & 3 \\ 5 & -3 & -4 & 25 \\ 6 & -4 & -6 & 28 \\ 7 & -5 & -8 & 31 \end{pmatrix}$$

copper = ... am **[3]**

expressing the equation $\tan(\theta + 60°) + \tan(\theta - 60°) = \cot\theta$ in terms of $\tan\theta$ only, solve the equation for $0° < \theta < 90°$.

(a) Show that $r = -2a\sin 2\theta$ and sketch C.

V decreases because there is a p.d. across r.

frequency of the signal is 50 kHz .

[5]

16   is the speed of the block after falling this distance?

(a) (i) is given that $\sum x^2 = 1823.0$.

V decreases because there is a p.d. across r.

[3]

ball is released from rest at time zero. After 1.0 s it bounces inelastically from a horizontal surface and rebounds, reaching the top of its first bounce after 1.5 s .

(iii)

many different colour arrangements are there of the 10 books?

[**12**]

(d) (i) (amplitude $)^2 \propto \sqrt{\text{intensity}}$

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

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

[**6**]

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

(iii) line l passes through B and C.

a basis for the null space of T .

from = ... tc **[5]**

1 Which quantity is a scalar quantity?

(ii) is the angle θ ?

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

[3]

17 specific heat capacity of water is 4.18 J g^{-1}°C^{-1}.

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

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

times = ... nl **[5]**

18 Find the values of p and q.

[10]

14 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.

[5]

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

Find the proportions of large, small and medium pineapples.

[10]

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

[2]

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

nucleus = ... tk **[1]**

24 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 $AC = a$.

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

beginning = ... gx **[5]**

(c) (iv) the sum to infinity of the progression.

Wavelength is proportional to amplitude.

[5]

the significance level of the test.

(ii)

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

[**8**]

Each coulomb of charge from the battery supplies 9.0 J of electrical energy to the whole circuit.

(i) satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

$$a = \ldots\ldots\ldots\ldots\ldots..$$
$$b = \ldots\ldots\ldots\ldots\ldots..$$
$$x = \ldots\ldots\ldots\ldots\ldots..$$
$$y = \ldots\ldots\ldots\ldots\ldots..$$
[3]

where α is a positive integer. It is given that the shortest distance between the line AB and the line CD is equal to $2\sqrt{2}$.

[**12**]

diagram correctly represents the forces acting at point P ?

(iii) down to up

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

[**1**]

(a) (i) what is meant by work done.
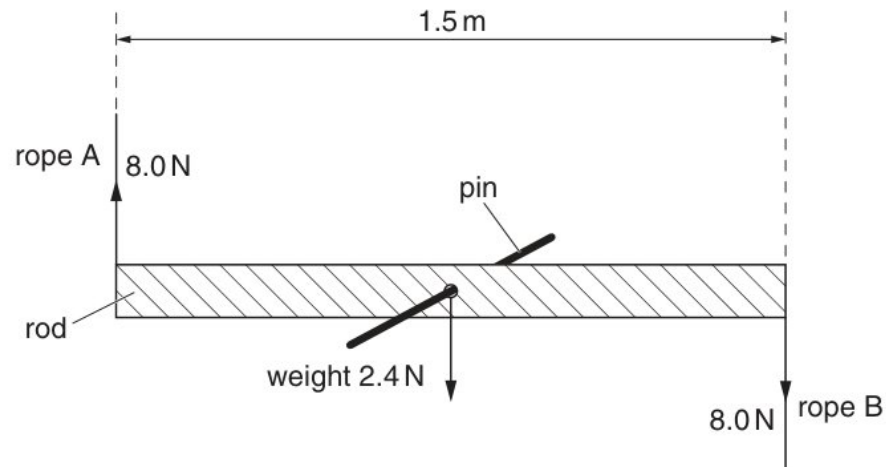
resistors of equal value are connected as shown.

P and Q collide and stick together.

[**8**]

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

(ii) time T, particle P is moving at an angle of 60° below the horizontal.

three quantities that are conserved during the decay.

lines = ... te **[2]**

(f) cube has volume V and is made of a material with resistivity ρ. The connections to the cube have negligible resistance.

[10]

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

are no resistive forces acting on the block.

Find the coordinates of the turning points of C.

[3]

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

circuit is set up as shown in Fig. 2.1.

[8]

9   and explain whether the nuclei in the sample are undergoing α-decay, β^+decay or β^-decay.

the values of p and q

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

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.

[**5**]

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

(a) 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.

smallest smallest $= \ldots.. \; bk$ [**6**]

(f) (ii) parametric equations of a curve are

diagram shows a sketch of the curve $y = \frac{3}{\sqrt{(9-x^3)}}$ for values of x from -1.2 to 1.2 .

all solutions in the interval $0° \leqslant \theta \leqslant 360°$.

[**6**]

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

transmitted light has intensity $0.75I$.

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

t time $t = 5.8$ s the speed of the car becomes constant

[**8**]

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

with $=$ .... sx [**8**]

20 Prove by mathematical induction that, for all positive integers n,

[**4**]

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

the ratio $H : D$.

balls $=$ .... hf [**3**]

18 Show that the mass of P is 0.8 kg .

[**5**]

13 variation with extension x of the force F for a spring A is shown in Fig. 6.1.

[**8**]

21   is the reading on the ammeter?

$$\text{that} = \text{.............} \ fc \quad \textbf{[5]}$$

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

[8]

7   that u_{2n} is divisible by u_n for $n \geqslant 1$.

   (e) (iii)   The individual ages in years of people in the first Art class are denoted by x and
              those in the second Art class by y. By first finding $\sum x^2$ and $\sum y^2$, find the
              standard deviation of the ages of all 19 people.

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

[3]

      overall efficiency of the turbine and generator system is 90%. The density of water is
      $1000 \ \text{kg m}^{-3}$.

   (i)   are the weight and the mass of the body when it is on the Moon?

         an electron and an antineutrino

[4]

the equation $2\ln(2x+3) - \ln(2x+5) = \ln(3x)$.

roller-coaster car (including passengers) has a mass of 840 kg . The roller-coaster ride includes a section where the car climbs a straight ramp of length 8 m inclined at $30°$ above the horizontal. The car then immediately descends another ramp of length 10 m inclined at $20°$ below the horizontal. The resistance to motion acting on the car is 640 N throughout the motion.

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

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.

[5]

(c) (iii) Find the product moment correlation coefficient for the data.

narrow groove is cut along a diameter in the surface of a horizontal disc with centre O. Particles P and Q, of masses 0.2 kg and 0.3 kg respectively, lie in the groove, and the coefficient of friction between each of the particles and the groove is μ. The particles are attached to opposite ends of a light inextensible string of length 1 m . The disc rotates with angular velocity ωrads^{-1} about a vertical axis passing through O and the particles move in horizontal circles (see diagram).

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

[2]

Find the value of I_2.

Show that $m = 0.9$.

(v) a, b and c are constants, has two asymptotes. It is given that $y = 2x - 5$ is one of these asymptotes.

Use the trapezium rule, with two intervals, to estimate the value of

runners = ... bp [**15**]

only one of the following two alternatives.

(i) the complex numbers z for which $\frac{z+4}{z+4i}$ is real and $|z| = \sqrt{10}$. Give your answers in the form $z = x + iy$, where x and y are real.

mean = ... wv [4]

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

[4]

14 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}.

attached equilibrium = ... yn [8]

17 (a) Show by calculation that a lies between 2 and 4 .

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

[5]

(d) how the pattern of interfering waves may be observed.
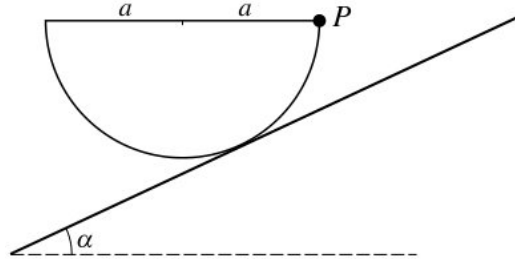
[3]

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

[10]

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

Show that the acceleration of the particle between $t = 3.5$ and $t = 6$ is -10 m s^{-2}.

(d) (ii) Find the probability that a randomly chosen boy aged 16 years in Jimpuri weighs more than 65 kilograms.

[4]

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

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

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

Find the coordinates of the turning points of C.

$$\frac{d^n}{dx^n} \left(x^n \ln x \right) = n! \left(\ln x + 1 + \frac{1}{2} + \ldots + \frac{1}{n} \right).$$

[6]

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}.

(iv) Find the probability that a box is rejected.

Sketch on Fig. 5.4 the $I - V$ characteristic of a filament lamp.

tank. wave $= \ldots yg$ [3]

diagram shows part of the curve

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

(i) nucleus X has 14 nucleons and p protons. The ratio of charge to mass for nucleus X is $4.1 \times 10^7 \text{Ckg}^{-1}$.

$$9y^2 - 3\sinh^{-1}(xy) = 1 - 3\ln 3.$$

[10]

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

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

[2]

9 the coordinates of C,

a positron and an antineutrino

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

[5]

7 down to antiup

[12]

19 process does not require energy to be supplied?

could M and N be?

combined resistance is 66kΩ.

(b) is given that P remains at rest in this new position.

$$n = 60 \quad \sum t = 3678 \quad \sum t^2 = 226313.36$$

follows. appropriate variance = ... iu **[8]**

(e) (ii) In the case where $k = 1$,

Find the values of p and q such that

[6]

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

(i) your answer correct to 2 decimal places.

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 .

[4]

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

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

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

$$524 \quad 526 \quad 520 \quad 523 \quad 530$$

[6]

15 is a statement of the principle of conservation of momentum for a system?

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

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

time moving = ... cj **[1]**

21 that u_{2n} is divisible by u_n for $n \geqslant 1$.

[6]

21 the probability that the 3 customers bought computers all made by different companies.

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

diagram shows a charged particle as it approaches a pair of charged parallel plates in a vacuum.
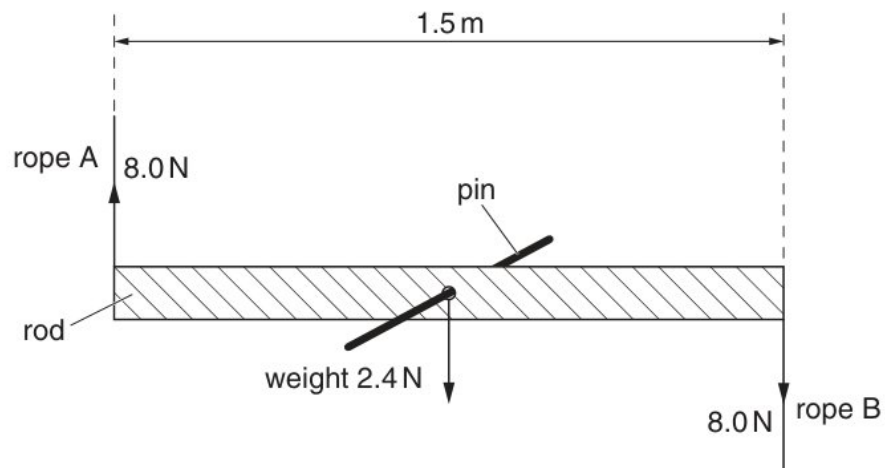
student wishes to investigate the effect of adding various thicknesses of glass in front of

that $\tan 2a = -4a$

[12]

18 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 $0 < \theta < 2\pi$

inner = ... nt **[10]**

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

[8]

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

(b) 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.

[6]

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

Find the values of a and b.

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?

$$\text{average} = \text{................} \; rz \quad [6]$$

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

$[10]$

(c) (iii) Find the value of t when the particle is instantaneously at rest.

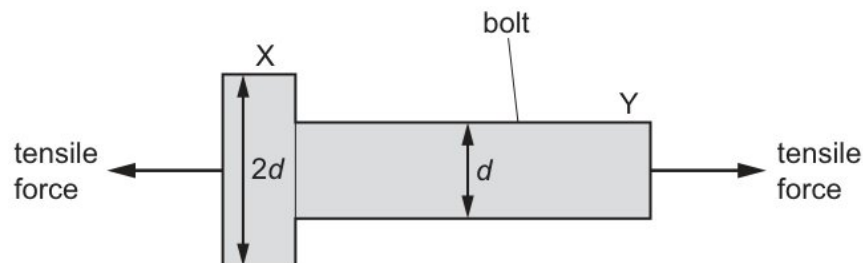row describes the momentum and kinetic energy of the two bodies after the collision?

$[5]$

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

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

(ii) a butternut squash seed is sown the probability that it will germinate is 0.86 , independently of any other seeds. A market gardener sows 250 of these seeds. Use a suitable approximation to find the probability that more than 210 germinate.

Its speed decreases to a value greater than zero, then increases to 20 ms^{-1}.

$[5]$