

27 the value of n .

$$\text{plane} = \dots \dots \dots rx \quad [5]$$

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

the median and the interquartile range of the times of the runners from the Gulls.
speeds of the particles.

[3]

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

[10]

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

$$\text{Show that } v^2 = u^2 + \frac{14}{5}ag.$$

$$f(x) = \begin{cases} kx & 0 \leq x < 1 \\ k(8-x) & 1 \leq x \leq 8 \\ 0 & \text{otherwise} \end{cases}$$

[5]

(b) a and b are constants. It is given that $(x+2)$ is a factor of $p(x)$ and that, when $p(x)$ is divided by $(x+1)$, the remainder is 24 .

[5]

6 student wishes to investigate projectile motion.

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

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.

Calculate the speed of the star relative to the Earth.

[2]

26 is given that $\sum x^2 = 1823.0$.

[10]

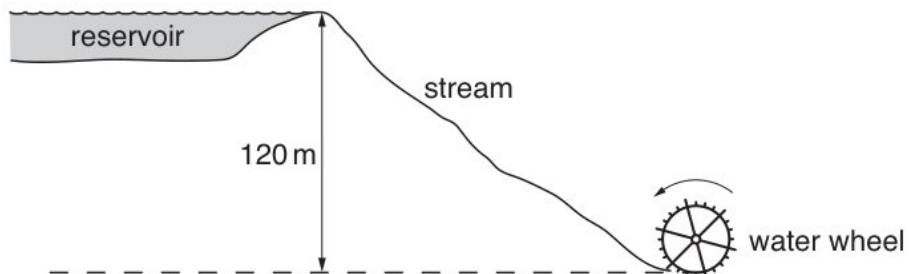
22

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

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

[10]

- 12 the principle of moments.
the term interference.



[1]

- 13 force is caused only by a pressure difference?
row describes the horizontal and vertical components of its motion as it travels between the plates?

[4]

- 22 an iterative formula based on the equation in part (a) to determine a correct to 2 decimal places. Give the result of each iteration to 4 decimal places.

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

[4]

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

[4]

- 25 $\frac{\text{wavelength of M}}{\text{wavelength of N}} = 10^5$.

is now given that the true value of p is 0.05 .

[15]

- 14 Find the equations of the asymptotes of C .

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.

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

- (e) analysis of the data,

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

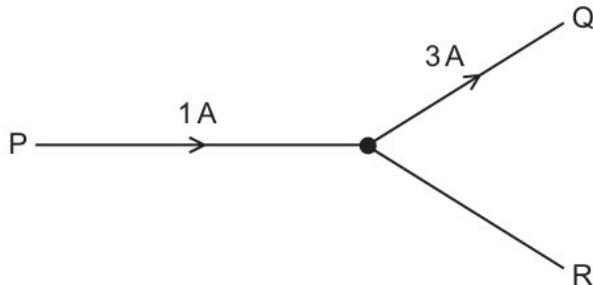
[4]

(a)

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

curve C has equation $y = \frac{1}{2}(e^x + e^{-x})$ for $0 \leq x \leq \ln 5$. Find

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



[5]

(b) curve C has parametric equations

[12]

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

[5]

28 statements about what person P and person Q hear during the motion of the car are correct?

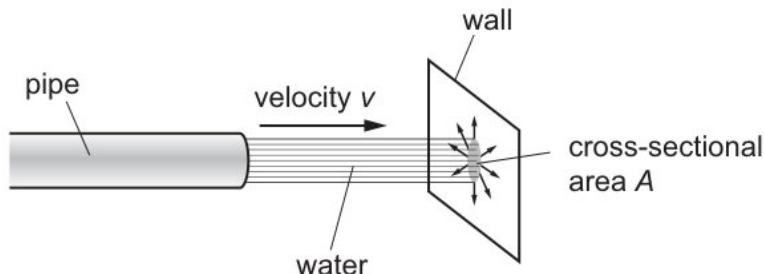
[5]

33 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 .

was the by-product of this reaction?

(i) 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 ductile material,



[6]

(vi) Draw box-and-whisker plots in a single diagram on graph paper to illustrate the marks for History and Physics.

[4]

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

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

Find the values of p and q such that

[6]

- 7 bolt is subjected to a tensile force, as shown.

[6]

- 11 projectile is thrown at an angle to the ground.

$$y = 0.46x + 1.62 \quad \text{and} \quad x = 0.93y + 8.24$$

[6]

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

[8]

- 16 the acute angle between the directions of l_1 and l_2 .

[8]

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

[12]

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

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

- (a) the experimental observations that show radioactive decay is

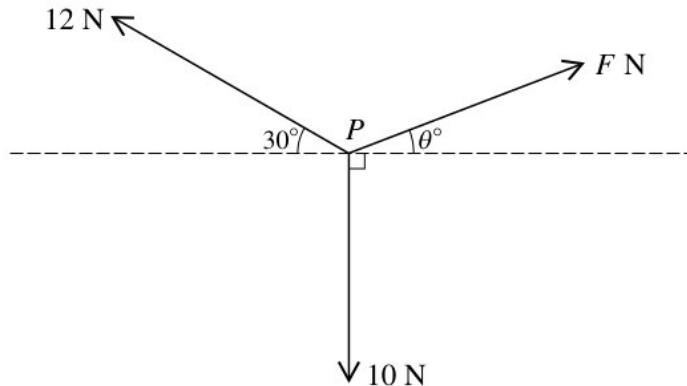
[4]

- (b) the number of different arrangements of the 7 men in a line in which Ali and Ben do not stand next to each other.

the value of α .

[12]

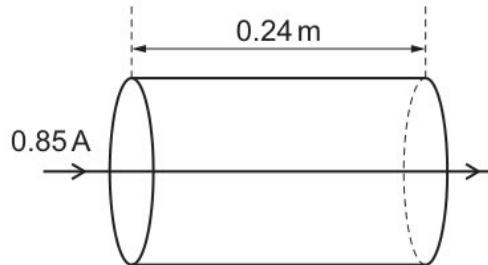
- (c) paving slab has a mass of 68 kg and dimensions $50 \text{ mm} \times 600 \text{ mm} \times 900 \text{ mm}$.



[4]

- 17 the solution of the differential equation

weight of the parachutist is 850 N .



[5]

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

- (c) Amplitude is inversely proportional to velocity.

[10]

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

[4]

(b)

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

point $P(2, 1)$ lies on the curve with equation

Show that, at the points (other than the pole) at which a tangent to C is parallel to the initial line,

[6]

- (e) the probability that the sum of three independent values of X is between 3 and 5 inclusive. [3]

[6]

- 9 Find the rate of working of the tension at this instant.
[6]
- 18 matrix \mathbf{M} represents a sequence of two geometrical transformations in the $x - y$ plane.
is the ratio $\frac{\text{tension in wire } X}{\text{tension in wire } Y}$?
[10]
- 23 For this value of k , find the set of possible solutions, giving your answer in the form
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?
 (a) projectile is launched at 45° to the horizontal with initial kinetic energy E .
 end of a light elastic string of natural length 0.4 m and modulus of elasticity 8 N is
 attached to a fixed point O on a smooth horizontal plane. The other end of the string
 is attached to a particle P of mass 0.2 kg which moves on the plane in a circular path
 with centre O . The speed of P is $v \text{ m s}^{-1}$ and the extension of the string is $x \text{ m}$.
[3]
- (b) there are no restrictions,
[4]
- (d) time T , particle P is moving at an angle of 60° below the horizontal.
[10]
- (c) The wavelength of maximum intensity of emission is used to determine a value for the
surface temperature of the star.
[5]
- 13 region enclosed between the x axis and the curve is rotated through 2π radians about the
 x axis
- $$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \mathbf{a} + t\mathbf{b}$$
- the general solution of the differential equation
- $$\begin{aligned} x + 3y + kz &= 4 \\ 4x - 2y - 10z &= -5 \\ x + y + 2z &= 1 \end{aligned}$$
- (b) what is meant by a fundamental particle.
[10]
- (a) which mark on the rule must a 50 g mass be suspended so that the rule balances?
Hence find the value of $\frac{d^2y}{dx^2}$ at the point $(1, \frac{1}{4}\pi)$ on C .
[15]
- (f) plane Π_2 contains the lines
[6]

- 10 the probability generating functions, $G_X(t)$ of X and $G_Y(t)$ of Y .

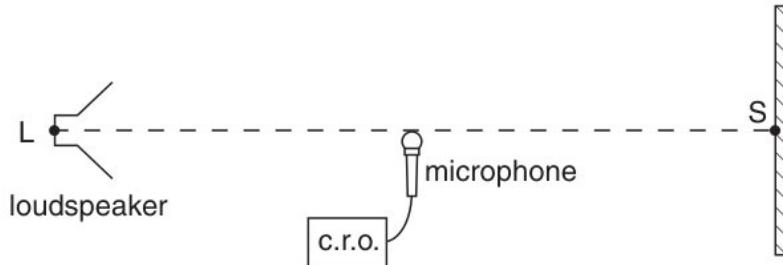
The waves must be polarised.

- (c) are the amplitude and the period of wave S ?

[15]

- (b) graph is correctly labelled?

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



[10]

- (e) the position vector of the foot of the perpendicular from the point with position vector $\mathbf{i} + 10\mathbf{j} + 3\mathbf{k}$ to Π .

p and q are given real numbers, then

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

[2]

- 18 the value of θ .

$$I_n = \int_0^{\frac{1}{2}\pi} \cos^n x \, dx$$

- (a) 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 $t = 2$.

[5]

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

[10]

- (d) graph shows the relationship between force acting on a compression spring and change in length of the spring.

[4]

- (b) there are no restrictions,

[10]

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

- (a)



is meant by elastic deformation?

[12]

- (c) Show that $\frac{dy}{dx} = \frac{1}{\sin \theta \cos^3 \theta}$.
a cubic equation whose roots are $\alpha^3 - 1, \beta^3 - 1, \gamma^3 - 1$

$$\text{..... } X \rightarrow \text{..... } Z + \text{..... } \cdot \cdot \cdot$$

[20]

- 18 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.

[5]

- 14 number of cars sold per day at another showroom has the independent distribution $\text{Po}(0.6)$. Assume that the distribution for the first showroom is still $\text{Po}(0.7)$.

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

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

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

the median value of X .

[12]

- 17 Explain why the observed wavelength and the emitted wavelength have different values.
how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

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

when = le [3]

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

[6]

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

[12]

22 the team contains more boys than girls.

[15]

18 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.

an expression for $\tan \theta$ in terms of e .

the distribution function of X .

the matrix \mathbf{A} ,

- (b) the data to carry out a goodness of fit test at the 5% significance level to test the scientist's claim.

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

[8]

- (a) the lowest note produced by a horn, a node is formed at the mouthpiece and the antinode is formed at the bell. The frequency of this note is 75 Hz .

[1]

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

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

[8]

18 State what happens to the electron and to the positron.

wave pattern produced in (b) is shown in Fig. 7.1.

[4]

13 van is 2.50 m long with the wheels at a distance of 0.600 m from the front of the van and 0.400 m from the rear of the van.

Find the cartesian equation of Π_1 .

[5]

31 shop sign weighing 75 N hangs from a frame attached to a vertical wall.

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

[8]

17 with a reason, whether f has an inverse.

[10]

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

[8]

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

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

[6]

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

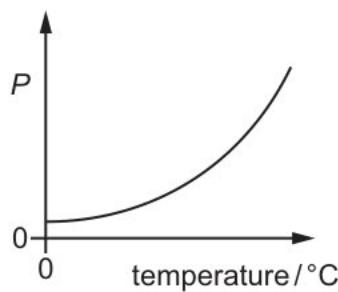
[4]

- (d) the solution of the differential equation

Draw up the probability distribution table for X .

[4]

(a)



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

[4]

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

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

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

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

[15]

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

[5]

- 7 what is meant by work done.

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

[6]

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

- (c) diagram shows a trace of a wave on a cathode-ray oscilloscope.
- 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.
- aeroplane is flying horizontally. The aeroplane's engines are producing a constant power of 5500 kW , and the aeroplane experiences a constant horizontal resistance force of 25 kN .
- The 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 $\lambda\mu$.

[12]

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

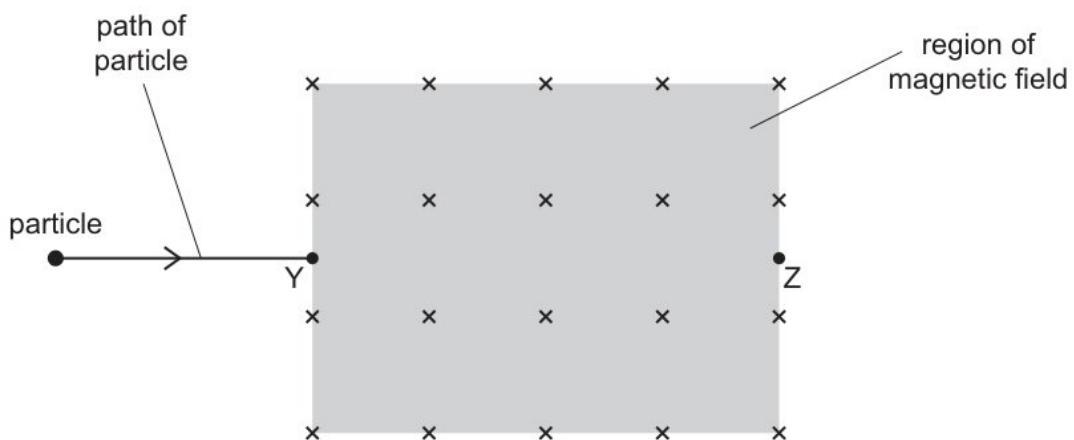
[6]

- (d) Q hears a sound of decreasing frequency.

[4]

- 24 Find the value of a for which $\arg(u^*) = \frac{3}{4}\pi$, where u^* denotes the complex conjugate of u .

- (a)



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

point $P(2, 1)$ lies on the curve with equation

[5]

- (f) continuous random variable X has probability density function f given by

[12]

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

[5]

- 10 momentum = mass \times velocity

[4]

- 15 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.



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.

student wishes to investigate projectile motion.

[10]

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

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

[8]

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

[8]

- 17 the total time for which she is in motion from the instant that she passes O .

[8]

- 13 Find the interquartile range of X .

are selected from these 20 to perform at a concert.

(a) magnetic flux density.

[12]

(g) is the average velocity of the toy car for the journey shown by the graph?

variables x and y satisfy the differential equation

[5]

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

[3]

- 25 State the work W done by F .

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

Deduce that the cartesian equation of C is

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

[10]

- 26 the grid below, draw a box-and-whisker plot to summarise the information in the cumulative frequency graph.

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

t is the thickness of one sheet, α is the absorption coefficient of glass and V_0 is the

[6]

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

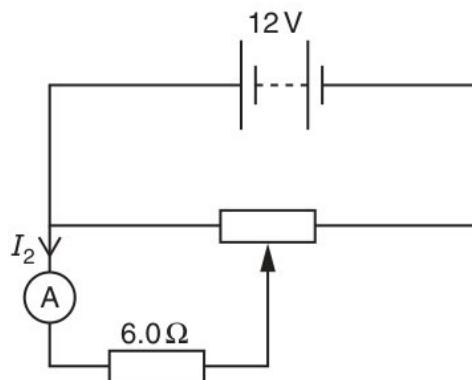
the probability that more than 7 study Art or Music.

It results in the measured value being different from the correct value.

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} .

[6]

(v)



turbine at a hydroelectric power station is situated at a vertical distance of 30 m below the level of the surface of a large lake. The water passes through the turbine at a rate of 340 m^3 per minute.

[3]

- (ix) Show that the total distance fallen is 1048 m .

[4]

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

[6]

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

[5]

14 Hence show that the differential equation

[4]

16 $I_n = \int_0^1 x^n (1-x)^{\frac{1}{2}} dx$, for $n \geq 0$. Show that, for $n \geq 1$,

[6]

19 up the probability distribution table for X .

[3]

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

[6]

25 momentum = mass \times velocity

$$f(x) = \begin{cases} kx & 0 \leq x < 1 \\ k(8-x) & 1 \leq x \leq 8 \\ 0 & \text{otherwise} \end{cases}$$

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

[8]

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

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

that \mathbf{e} is an eigenvector of \mathbf{A}^3 with corresponding eigenvalue λ^3 .

[5]

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

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

$$\mathbf{A}^n = \begin{pmatrix} 2^n & 3(2^n - 1) \\ 0 & 1 \end{pmatrix}$$

(d) P hears a sound of increasing frequency.

[2]

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

[8]

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

[5]

16 Find the value of x .

[4]

11 an experiment to demonstrate two-source interference of light, a beam of light is split into two beams using two slits 0.50 mm apart. These two beams are incident on a laboratory wall at a distance of 4.0 m .

(c) the term isotope.

[12]

(d) 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.

[4]

31 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.

[5]

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

In the case where $k = 1$,

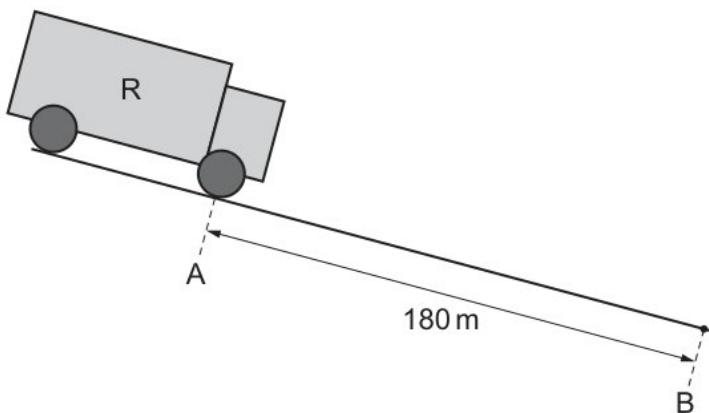
[6]

10 Use de Moivre's theorem to show that

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

[6]

14



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

[6]

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

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

[2]

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

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

[4]

- (e) Show that the substitution $u = 1 + \sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$. Hence evaluate s .

[12]

- (c) 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.

[12]

- (f) Show that x satisfies the equation

Calculate the acute angle between the planes p and q .

[2]

- 27 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.

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

[5]

- (a) a vector equation for l .

[8]

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

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

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

the values of p and q

[5]

- 18 the probability density function of Y

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

[5]

- (c) is given that $z_1 = 3e^{\frac{1}{4}\pi i}$, $z_2 = \frac{3}{2}e^{\frac{1}{6}\pi i}$ and $\omega = 2e^{\frac{1}{2}\pi i}$

a cubic equation with roots α, β and γ , given that

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

[5]

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

[5]

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

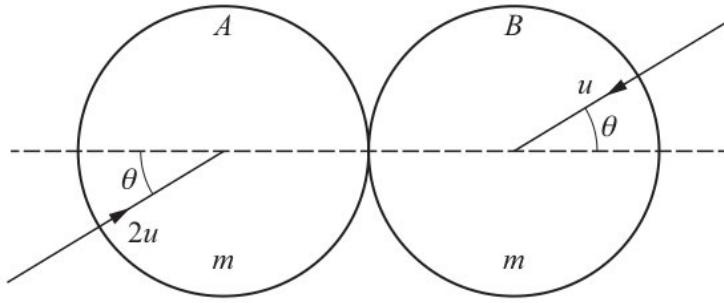
[6]

- (d) Show that the kinetic energy of the electron before the collision is 1.1×10^{-15} J.

State the equation of the other asymptote.

[6]

- 8 is the total displacement of the ball from its original position after 1.5s ?



of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of 4.91×10^{-7} m.

considering the sum of the areas of these rectangles, show that

$$\text{straight} = \dots \dots \dots \quad vf \quad [4]$$

- 18 Show that the substitution $u = 1 + \sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$. Hence evaluate s .

curve C has polar equation $r = \theta e^{\frac{1}{8}\theta}$, for $0 \leq \theta \leq 2\pi$.

sample of a radioactive substance emits particles that are positively charged and have a continuous range of kinetic energies.

specific latent heat.

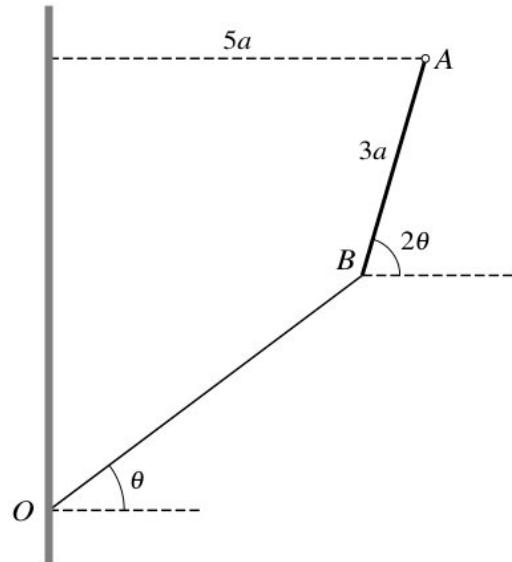
- (iv) uniform rod AB of length $3a$ and weight W is freely hinged to a fixed point at the end A . The end B is below the level of A and is attached to one end of a light elastic string of natural length $4a$. The other end of the string is attached to a point O on a vertical wall. The horizontal distance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

[6]

- (vii) 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.

[6]

(iii)



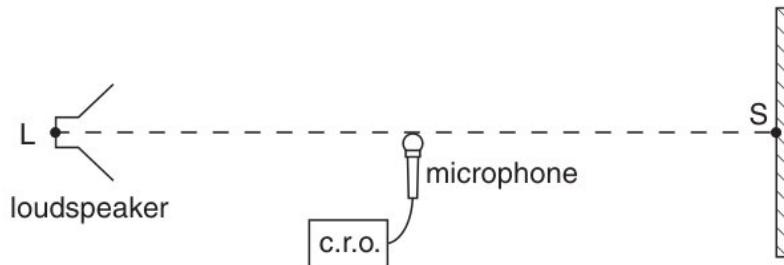
Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

the torque of a couple.

Show that the substitution $u = 1 + \sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$.
Hence evaluate s .

[20]

- (i) with a reason, whether you agree with Nikki's friend.



[5]

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

[8]

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

- (d) expression calculates the fractional uncertainty in the value of this speed?
that, at the point of C furthest from the initial line,

[4]

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

[15]

- (c) Find the cartesian equation of Π_2 .

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

[8]

- (a) curve C has equation $\tan y = x$, for $x > 0$.

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

[6]

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

[3]

- 23 cyclist is travelling along a straight horizontal road at a speed of 4 ms^{-1} when she passes a point O . She accelerates at a constant rate for a distance of 42 m , reaching a speed of $V \text{ m s}^{-1}$. She maintains the speed of $V \text{ m s}^{-1}$ for 50 m and then decelerates at 2 m s^{-2} before coming to rest. The distance travelled while decelerating is 16 m .

[5]

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

[12]

- 24 the value of α .

- (a) particle P is projected from a point O on horizontal ground. 0.4 s after the instant of projection, P is 5 m above the ground and a horizontal distance of 12 m from O .

[5]

- (b) that if a sequence of values given by the iterative formula

[8]

- 11 Find a set of corresponding eigenvectors.

- (b) $f(x)$ is divided by $(x + 2a)$ the remainder is $-22a^3$ When $f(x)$ is divided by $(3x - a)$ the remainder is $-a^3$

[6]

- (a) Over 50 198 212 217 229 235 242

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.

[12]

- 24 flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

	momentum	kinetic energy
A	mv	$\frac{1}{4}mv^2$
B	mv	$\frac{1}{8}mv^2$
C	$2mv$	$\frac{1}{2}mv^2$
D	$2mv$	mv^2

[20]

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

[4]

- 22 spherical object falls through water at constant speed. Three forces act on the object.
Find the interquartile range of X .

[6]

- 15 Find the position vector of D .

[6]

- 15 Find the values of p and q such that

[5]

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

sequence x_1, x_2, x_3, \dots defined by

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

[4]

- (a) what is meant by the de Broglie wavelength.

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

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

[12]

- (d) 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.

[8]

- (c) any assumption that you make, test at the 10% significance level whether the green-grocer's claim is supported by this evidence.

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 $ax + by + cz = d$.

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

[6]

- 14 speeds of the particles.

[12]

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

Wavelength is proportional to amplitude.

- (d) Calculate the gravitational potential ϕ at the surface of Mars. Give a unit with your answer.

[15]

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

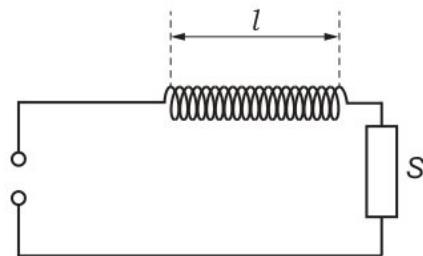
between gravitational potential energy and electric potential energy.

[6]

- (a) 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 .

[4]

(c)



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

[5]

- 17 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.

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

[2]

- (i) particle starts from a point O and moves in a straight line. The velocity of the particle at time t s after leaving O is v m s $^{-1}$, where

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

[4]

- (iii) 400 nm to 700 nm

[4]

- (ii) shop sign weighing 75 N hangs from a frame attached to a vertical wall.

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 .

[2]

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

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

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

- (c) Potential difference is energy per unit current.

[6]

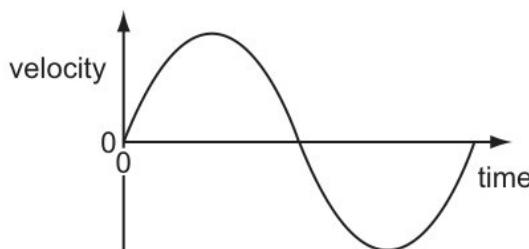
- (h) number of cars sold per day at another showroom has the independent distribution Po(0.6). Assume that the distribution for the first showroom is still Po(0.7).

[6]

- (b) variable Y is related to X by $Y = 2^X$.

[8]

- 30 find the position vectors of P and Q .



is the efficiency of the process?

[5]

- 20 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.

- (a) show that $PQ = 13$,

[6]

- (b) 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.

[2]

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

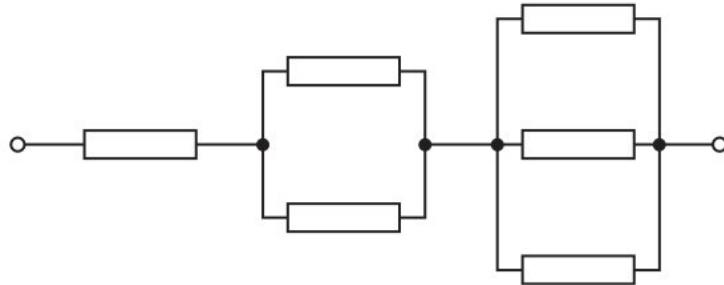
time T , the particle strikes a smooth horizontal plane at a point which is a horizontal distance D from O and a vertical distance H below O .

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

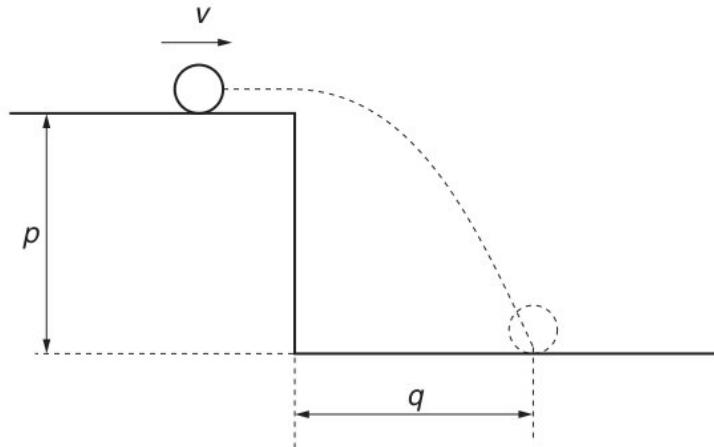
- (d) stationary nucleus has nucleon number A .

[8]

(c)



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



[10]

- (b) throws three coins at the same time.

$$\text{Find} = \dots \dots \dots \quad qm \quad [6]$$

- (f) Find the period of the motion.

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

[8]

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

[3]

16 lamina is freely suspended at A and hangs in equilibrium.
is the efficiency of the process?

[12]

15 a time 8.4 minutes later, the activity is 120 Bq .
is given that $f(n) = 3^{3n} + 6^{n-1}$.

[6]

10 be written as a quadratic equation in x .

[6]

9 the type of each transformation and make clear the order in which they are applied

[10]

16 A contains 4 balls numbered 2, 4, 5, 8. Bag B contains 5 balls numbered 1, 3, 6, 8, 8. Bag C contains 7 balls numbered 2, 7, 8, 8, 8, 8, 9. One ball is selected at random from each bag.
the probability generating function of Z , expressing your answer as a polynomial in t .

[8]

9 only one of the following two alternatives.

person's eye colour may be categorised as "brown", "blue" or "other". A scientist claims that these eye colours are uniformly distributed and hence are equally likely to occur in the population. A survey of 120 people from this population found that 38 people had brown eyes, 52 people had blue eyes and 30 people had eyes which were neither brown nor blue.

[6]

8 diagram shows two waves R and S .

[8]

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

[5]

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

[3]

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

[4]

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

[10]

- 10 the past, the population mean time was 62.4 seconds.
- parallel plates, a distance 25 mm apart, have a potential difference between them of 12 kV
- .
- a similar method to find a lower bound for $\sum_{r=1}^n \frac{n}{n^2+r^2}$. Give your answer in terms of n and π .
- (c) is the energy transferred in the resistor and the time taken for the charge to pass through the resistor?
- [10]
- (d) 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.

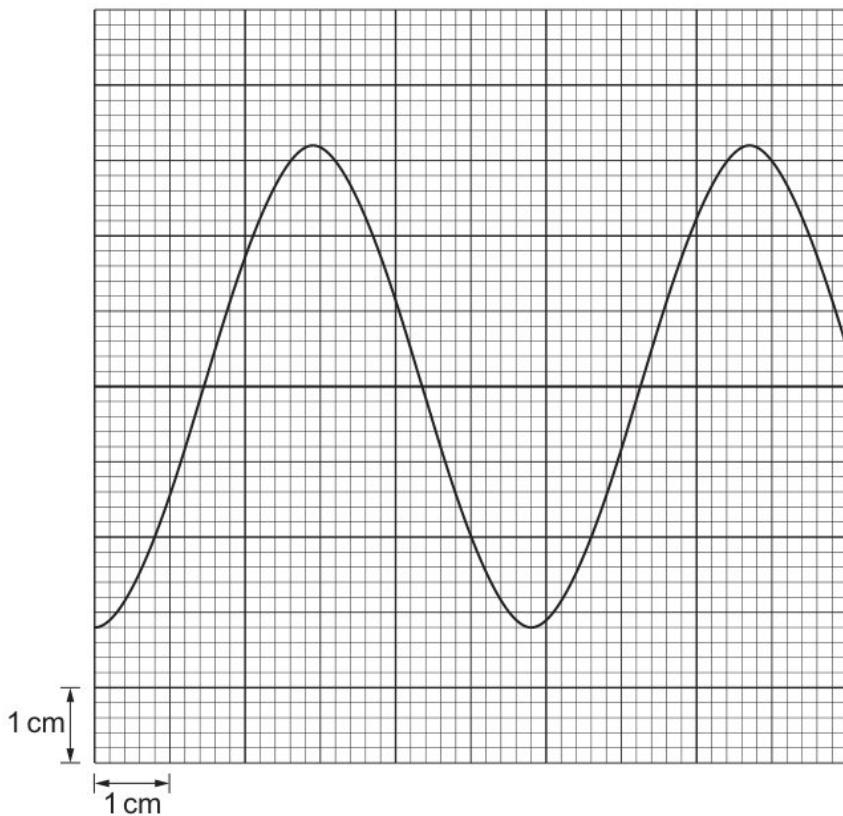
[8]

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

$$\frac{d^n}{dx^n} (e^x \sin x) = 2^{\frac{1}{2}n} e^x \sin \left(x + \frac{1}{4}n\pi \right)$$

[5]

- 15 the apparatus used to produce two sources of coherent waves that have circular wavefronts,



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

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

[5]

- 15 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.

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

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

produced = ia [12]

- (b) 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?

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

[4]

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

Find the values of a and b .

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

[6]

- 22 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.

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

[6]

- 11 the coordinates of any stationary points on C .

[6]

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

is the value of R ?

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

is the change to the quark composition of a nucleus that takes place during β^+ decay?

[6]

- 9 Different isotopic nuclei have different proton numbers.

- (c) (amplitude)² $\propto \sqrt{\text{intensity}}$

source of sound of constant power P is situated in an open space. The intensity I of sound at distance r from this source is given by

[5]

- (d) analysis of the data,

[12]

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

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

Find the coordinates of the turning points of C .

[5]

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

[6]

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

[3]

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

[4]

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

point D is such that ABCD is a parallelogram.

[8]

- 10 The waves must have equal amplitudes.

- (a) Find $\frac{dy}{dx}$ and deduce that if C has two stationary points then $-\frac{3}{2} < \lambda < 1$.
by induction that $u_n = 6^n - 1$ for all positive integers n .

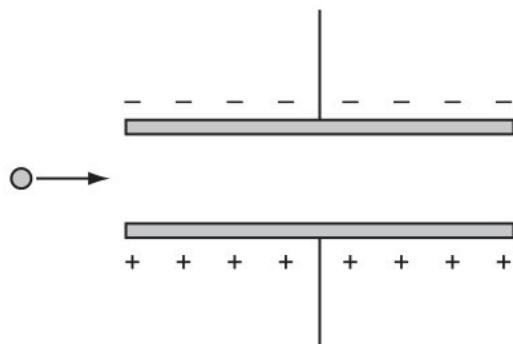
[3]

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

$$\text{above} = \dots \dots \dots hq \quad [4]$$

- (e) is the speed of the block after falling this distance?

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



[3]

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

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

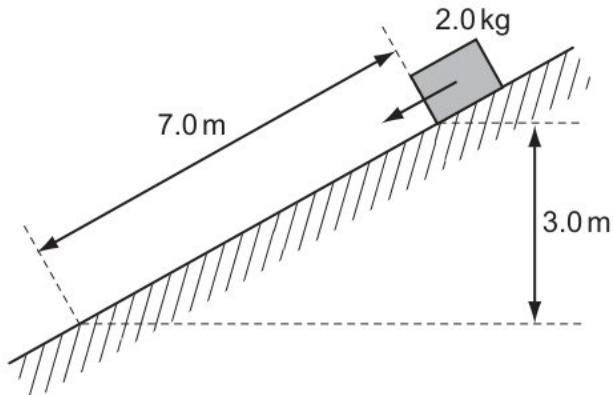
that $y = 0$ when $x = 3$ Give your answer in an exact form

[6]

- 11 (a) The waves must have equal amplitudes.

[6]

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



[8]

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

[1]

- 15 the kinetic energy of the car at time $t = 5.8$ s.

is a general description of a baryon?

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

an electron and an antineutrino

[10]

- (b) is the effect of a systematic error on the measurement of a physical quantity?

[3]

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

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

$$E_K = \frac{1}{2}mv^2.$$

[5]

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

Find the values of a and b .

[6]

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

[5]

- 12 expression has the same SI base units as pressure?

is the value of R ?

masses of small bags of pasta sold by the company are normally distributed with mean μ kg and standard deviation σ kg. Tests show that 77% of these bags have masses greater than 1.26 kg and 44% have masses less than 1.35 kg

[5]

- 15 continuous random variable, X , has probability density function given by

[6]

- 10 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 .

[2]

- 16 the lowest note produced by a horn, a node is formed at the mouthpiece and the antinode is formed at the bell. The frequency of this note is 75 Hz .

$$a^2 \left(\frac{1}{6}\pi - \frac{1}{8}\sqrt{3} \right)$$

matrix matrix represented = ek [6]

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

second coin is biased so that the probability of obtaining a head when it is thrown is $\frac{1}{4}$.
only one of the following two alternatives.

[12]

- 10 the probability that a 3 is obtained for the second time before the 6th throw.

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

[4]

(d) from the definitions of \tanh and sech in terms of exponentials, prove that

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).

[3]

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

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

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.

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

[12]

- (f) Show that x satisfies the equation

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

[4]

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

[4]

- 25 an electron and an antineutrino

[4]

- 16 diagram shows part of the curve

[15]

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

- (d) is the grand-daughter product?

the solution of the differential equation

Express v in terms of x .

[2]

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

[6]

- (c) the length of C .

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

[8]

- 21 student investigates the cooling of a liquid in a beaker.

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

[8]

(d) is a necessary condition for observable interference fringes to be produced?

[6]

11 Nucleus X undergoes β^- decay to form nucleus Z .

[4]

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

[20]

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

[8]

17 Find the probability that a box is rejected.

[10]

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

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

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

the speed of the combined particle after this collision.

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

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

Calculate the speed of projection of P .

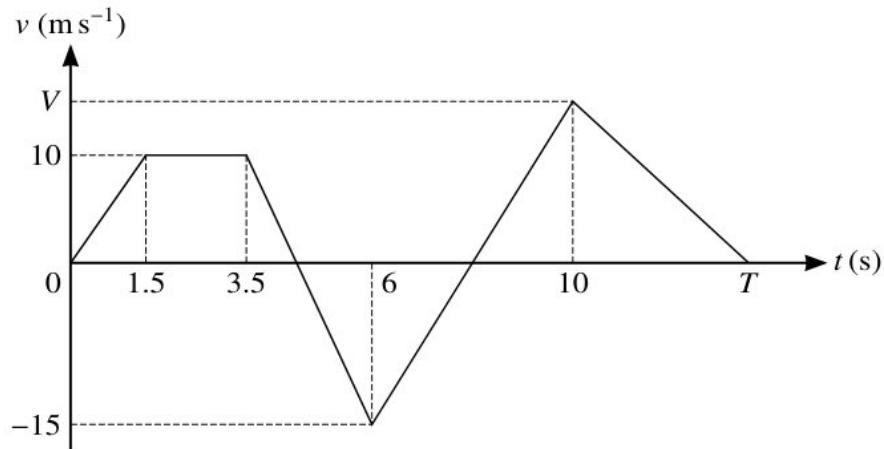
a cubic equation whose roots are $\alpha^3 - 1, \beta^3 - 1, \gamma^3 - 1$

[12]

(c) variables x and y satisfy the differential equation

[6]

- (b) is the density of the mixture with volume 2.0 m^3 ?



[8]

- 18 (c) up to antidown

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

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 .

[15]

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

line L_1 passes through the points $A(2, 5)$ and $B(10, 9)$. The line L_2 is parallel to L_1 and passes through the origin. The point C lies on L_2 such that AC is perpendicular to L_2 . Find

[5]

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

- (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 .

[4]

- (b) of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of $4.91 \times 10^{-7} \text{ m}$.

[20]

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

[2]

- 21 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.

[5]

- 26 diagram shows part of a current-carrying circuit. The ammeter has negligible internal resistance.

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

- (d) as a result of the collision, A moves in a direction which is perpendicular to the line of centres.

Given that on a particular flight Julian does not get a good night's sleep, find the probability that he is flying economy class.

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

[6]

- (a) that e is an eigenvector of A^3 with corresponding eigenvalue λ^3 .

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

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.

[5]

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

[10]

- (c) A contains 6 red marbles, 5 blue marbles and 1 green marble.

[6]

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

Find the value of a for which $\arg(u^*) = \frac{3}{4}\pi$, where u^* denotes the complex conjugate of u .

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

[5]

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

- 1 Which quantity is a scalar quantity?

find corresponding eigenvectors.

[6]

- 24 Use de Moivre's theorem to prove that

[6]

- 19 Find the probability that a box is rejected.

- (a) Find, in the form $ax^3 + bx^2 + c = 0$, an equation of which α is a root.
transmitted light has intensity $0.75I$.

with = nm [1]

- (c) by calculation that a lies between 2 and 2.1.

[4]

- (b) Show that $m = 0.9$.

an electron and a neutrino

only one of the following two alternatives.

[5]

- (d) progressive water waves X and Y travel along a straight line from point A to point B .
The variation of displacement of the waves with distance from A at an instant in time
is shown in Fig. 3.1.

[6]

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

[5]

- 12 progressive wave is incident normally on a flat reflector. The reflected wave overlaps with the incident wave and a stationary wave is formed.

[5]

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

[5]

- 16 waves are emitted from two sources.

[3]

- 13 191.5 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} .

$n \geq 0$. Show that, for all $n \geq 2$,

the probability generating function of Z , expressing your answer as a polynomial in t .

(c) $\frac{\text{force}}{\text{length} \times \text{time}}$

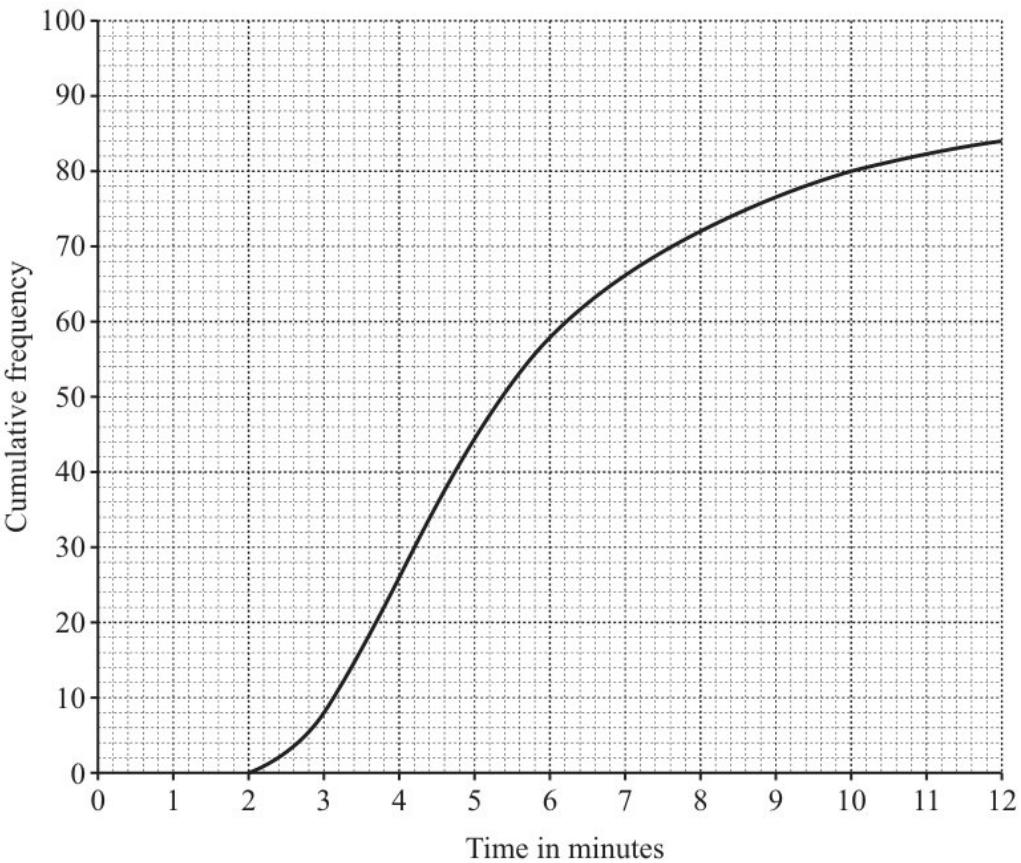
the torque of a couple.

[15]

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

[4]

11



polynomial $p(x)$ is defined by

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

[12]

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

[4]

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

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

(b) are the amplitude and period of the wave?

[5]

- (c) the speed of the body is increased to 40 ms^{-1} , what is its new kinetic energy?

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

[5]

- (d) the value of V .

[3]

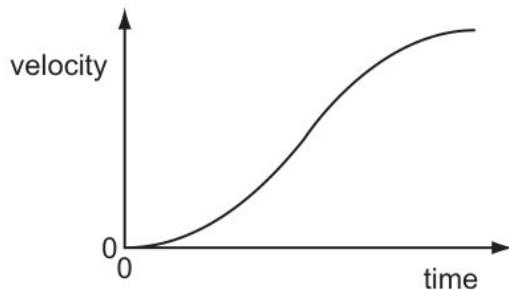
- 29 On Fig. 3.2, sketch the variation with x of F for a brittle material up to its breaking point.

[6]

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

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

- (b) the set of values of x for which the expansion in part (b) is valid.



the probability that all three cars are the same colour.

[3]

- (d) the speed of the body is increased to 40 ms^{-1} , what is its new kinetic energy?

[4]

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

[10]

- (a) this compression, work W is done on the gas.

the value of σ .

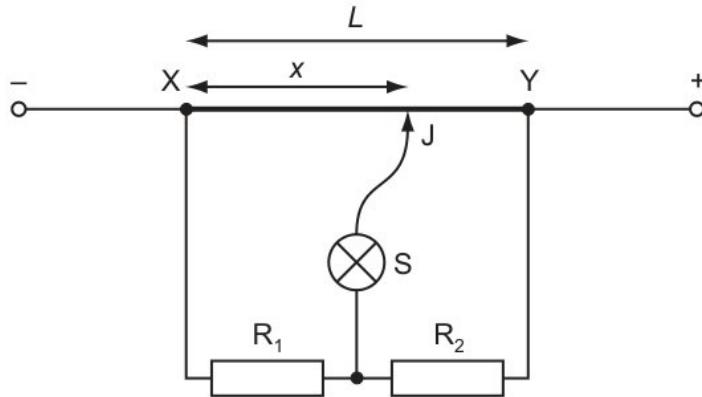
[6]

- 25 Find a 99% confidence interval for μ , giving your answer correct to 2 decimal places.

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

[5]

23



Use implicit differentiation to show that
what is meant by the de Broglie wavelength.

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 $\lambda\mu$.

[8]

- 18 considering the sum of the areas of these rectangles, show that

[12]

- 8 Find the equation of the tangent to the curve at P .

[12]

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

- (b) 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).

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

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

[6]

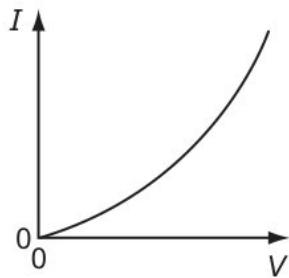
- (c) Find the perpendicular distance of the point A from the line BC .

[6]

- (d) the value of α .

[4]

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

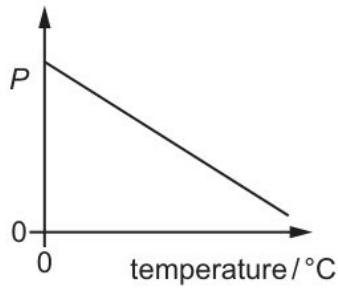


[12]

- 13 Show that $u^3 + 8 = 0$.

[6]

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



[4]

- 26 (c) 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.

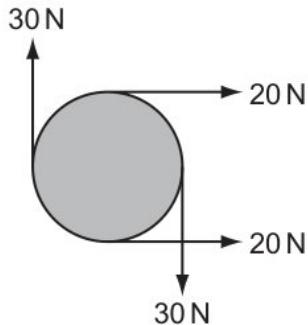
[4]

- (a) 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

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} .

[10]

- (d) is given that a is a positive constant such that



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.

[6]

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

- (v) In the case where $k = 2$,

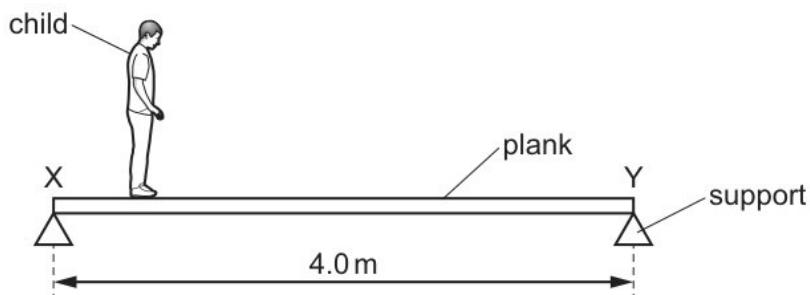
[6]

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

curve C has parametric equations

[15]

- (iii)



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

Show that the substitution $u = 1+\sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$.

Hence evaluate s .

[8]

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

[3]

- 9 the probability that both marbles chosen are the same colour.
 $\sum_{r=1}^n (4r - 3)(4r + 1)$, giving your answer in its simplest form.

[6]

- 23 particle is projected with speed 15 m s^{-1} at an angle of 40° above the horizontal from a point on horizontal ground. Calculate the time taken for the particle to hit the ground.

[4]

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

[12]

- 24 density of the water is ρ . The water does not rebound from the wall.

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

[5]

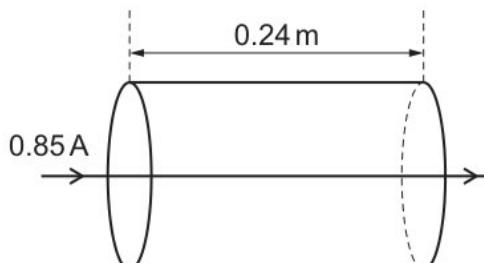
- (iv) are two marks on the tube. The top mark is positioned at $115 \pm 1 \text{ mm}$ on the adjacent rule and the lower mark at $385 \pm 1 \text{ mm}$. The ball passes the top mark at $1.50 \pm 0.02 \text{ s}$ and passes the lower mark at $3.50 \pm 0.02 \text{ s}$.

the probability density function of Y ,

between time $t = 0$ and time $t = 5.8 \text{ s}$ the work done against resistive forces is $4.7 \times 10^4 \text{ J}$

[2]

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



[6]

- 18 that l_1 and l_2 do not intersect.

as shown in Fig. 2.1.

$$\begin{array}{c} {}^{14}X \rightarrow \cdots Z + \dots \cdots \\ \cdots \cdots \end{array}$$

obtain the roots of the equation

[6]

- 28 marble is now chosen at random from bag B .

[20]

- 11 parametric equations of a curve are

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

[3]

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

[20]

- 21 stationary nucleus has nucleon number A .

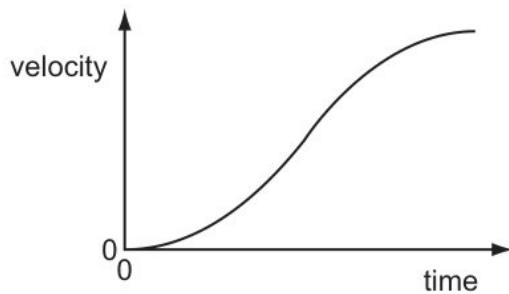
- (c) satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

[6]

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

[5]

- (b) charge of 4.0 C passes through the resistor.



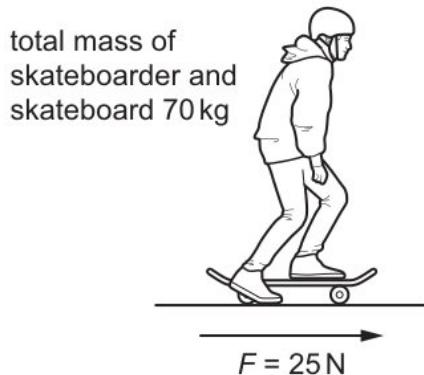
[5]

- 9 Find the tension in the string.

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

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

- (c)



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

[10]

- (b) is suggested that the strength B of the magnetic field at the centre of a flat circular coil is inversely proportional to the radius r of the coil.

[4]

- (d) 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° .

$$\Sigma b = 92.0 \quad \Sigma b^2 = 216.5 \quad \Sigma g = 129.8 \quad \Sigma g^2 = 288.8$$

[6]

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

[3]

- 31 $\sum_{r=1}^n (4r - 3)(4r + 1)$, giving your answer in its simplest form.

[6]

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

[6]

- 26 plane Π_1 passes through the points $(1, 2, 1)$ and $(5, -2, 9)$ and is parallel to the vector $\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}$.

[6]

- 24 Solve the inequality $|2x - 5| < |x + 3|$.

[4]

- 12 marble is chosen at random from bag A and placed in bag B .

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

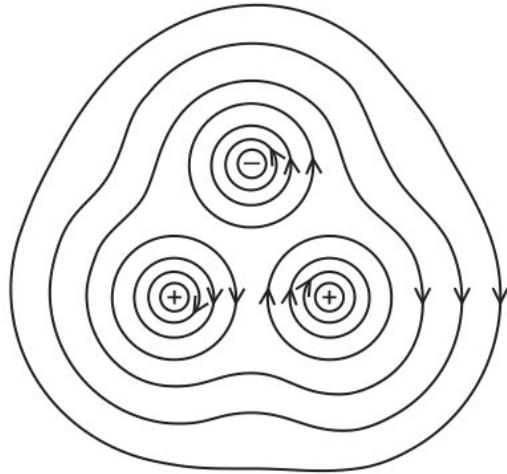
[5]

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

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

[8]

- (c) should pay particular attention to



statement about the weight of the plank is correct?

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.

[12]

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

[4]

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

[8]

- 15 time T , particle P is moving at an angle of 60° below the horizontal.

[5]

- 16 (b) the value of μ .

[15]

- (a) of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of 4.91×10^{-7} m.

[5]

- (d) region enclosed between the x axis and the curve is rotated through 2π radians about the x axis

$$\mathbf{Ax} = p \begin{pmatrix} 1 \\ 3 \\ 5 \\ -2 \end{pmatrix} + q \begin{pmatrix} -1 \\ -1 \\ -8 \\ 3 \end{pmatrix}$$

Amplitude is inversely proportional to velocity.

[2]

- 16 How many possible arrangements are there of seating Mary, Ahmad, Wayne, Elsie and John if Mary and Ahmad sit together in the front row and the other three sit together in one of the other rows?

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

is the work done by F on the skateboarder and skateboard?

Find the power output of the tractor's engine.

[8]

- 28 what is meant by the de Broglie wavelength.

- (b) the position vector of D .

[3]

- (a) 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.

[4]

- 19 the value of θ for which the transformation represented by \mathbf{M} has a line of invariant points.
[7]

$$x = \ln(\cosh t), \quad y = \tan^{-1}(\sinh t), \quad \text{for } 0 \leq t \leq 1.$$

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

[8]

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

$$1 - \tanh^2 u = \operatorname{sech}^2 u.$$

equation gives v in terms of A and u ?

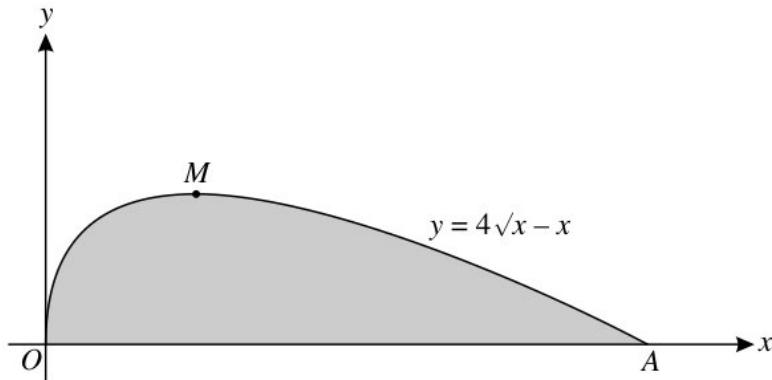
find corresponding eigenvectors.

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

Hence show that the differential equation

[2]

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



[8]

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

[8]

- (c) 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 .

[4]

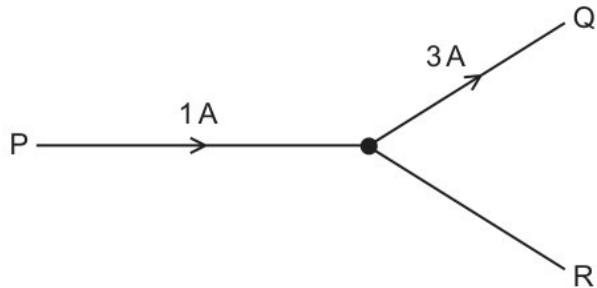
- (a) it is given that $y = 2$ when $x = 1$. Solve the differential equation and obtain an expression for y in terms of x .

[6]

- (b) the probability of a Type I error.

[6]

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



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

- (c) Find the matrix product $\mathbf{A} \begin{pmatrix} -1 \\ 1 \\ -1 \\ 1 \end{pmatrix}$ and hence find the general solution of the equation

$$\mathbf{Ax} = \begin{pmatrix} 3 \\ 21 \\ 24 \\ 27 \end{pmatrix}.$$

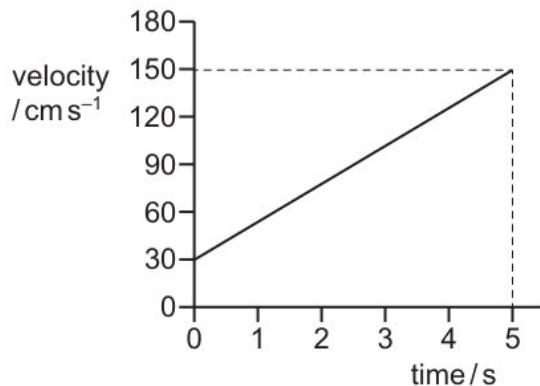
[12]

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

Find the area of the region enclosed by C .

[3]

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



[6]

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

is the speed of the block at the bottom of the slope?

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

[6]

- 16 no unique solution.

the particular solution of the differential equation

- (d) 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.

[8]

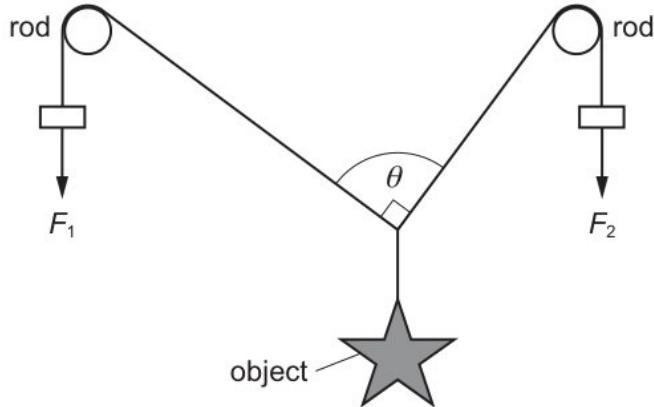
- (c) this compression, work W is done on the gas.

[5]

- (a) variable Y is related to X by $Y = 2^X$.

[4]

- 14 the sum to infinity of the progression.



- (c) 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

[5]

(f)

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

the median and the interquartile range of the times of the runners from the Gulls.

[15]

- (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.

roots of the equation

[6]

- (b) Estimate the probability of throwing a 4.

[12]

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

[4]

- 15 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

[6]

- 24 Hence find the solutions of the equation

Find also the value of $\frac{1}{\alpha^2\beta^2} + \frac{1}{\beta^2\gamma^2} + \frac{1}{\gamma^2\alpha^2}$.

turbine at a hydroelectric power station is situated at a vertical distance of 30 m below the level of the surface of a large lake. The water passes through the turbine at a rate of 340 m^3 per minute.

[6]

- 15 State the work W done by F .

State the name of this type of reaction.

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

[3]

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

[5]

- 11 Find the values of F and θ .

[2]

- 10 plane Π_1 passes through the points $(1, 2, 1)$ and $(5, -2, 9)$ and is parallel to the vector $\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}$.

- (a) 400 nm to 700 nm

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

[6]

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

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.

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

[6]

- (c) from the definitions of \tanh and sech in terms of exponentials, prove that

[10]

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

[2]

- 19 competitors who took part in this Saturday's event are selected at random.

are speed v_1 and speed v_2 ?

- (iv) all the ice has melted, and all the water in the beaker has reached thermal equilibrium,
the final temperature of all the water is 10.3°C .

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

[5]

- (iii) competitors who took part in this Saturday's event are selected at random.

[5]

- (i) equation $x^2 + px + q = 0$, where p and q are constants, has roots -3 and 5 .

525 520 522 524 518 520 519 525 527 516

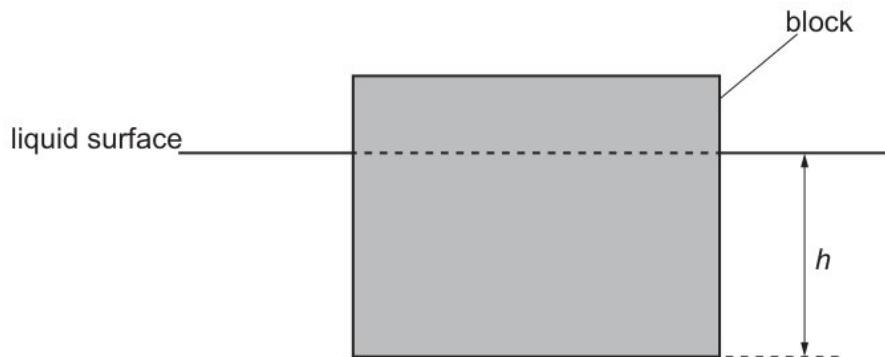
[12]

- (v) Derive an expression for v in terms of B and the electric field strength E .

[8]

- 9 the value of θ for which the transformation represented by \mathbf{M} has a line of invariant points.
[7]

from the definitions of tanh and sech in terms of exponentials, prove that



[12]

- 27 Use an iterative formula based on the equation in part (i) to find the value of a correct to 4 significant figures. Give the result of each iteration to 6 significant figures.

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

[4]

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

[4]

- 17 Show that the speed of B after its collision with the wall is $\frac{5}{18}u$.

diagram shows the curve with equation $y = \frac{1}{x^2+1}$ for $0 \leq x \leq 1$, together with a set of n rectangles of width $\frac{1}{n}$.

the value of $\frac{dy}{dx}$ at P ,

- (c) how the pattern of interfering waves may be observed.

[8]

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

[20]

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

[5]

- (d) an experiment to demonstrate two-source interference of light, a beam of light is split into two beams using two slits 0.50 mm apart. These two beams are incident on a laboratory wall at a distance of 4.0 m .

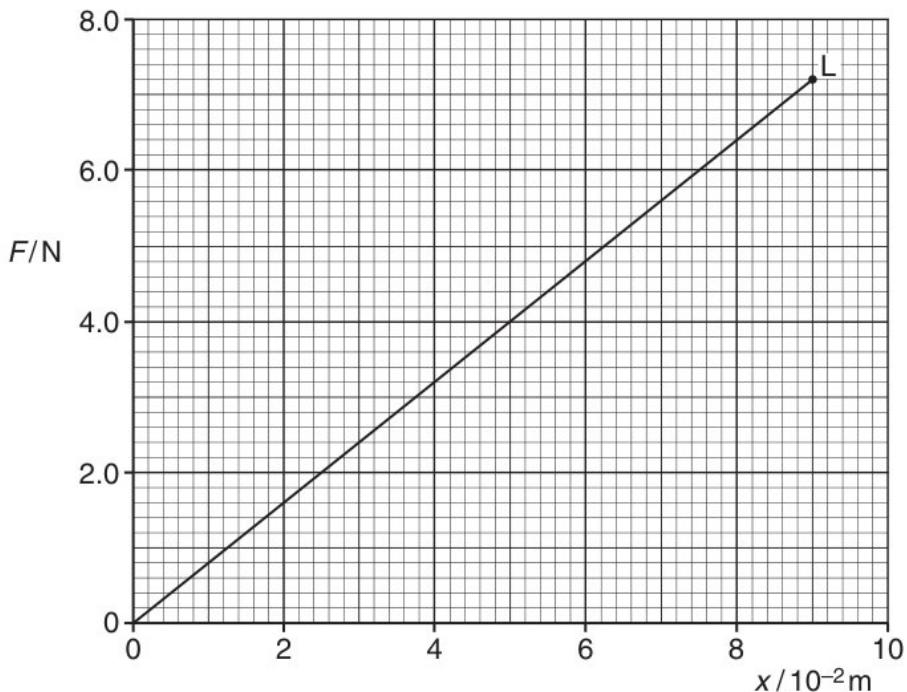
[10]

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

[5]

- 15 obtain the expansion of $f(x)$ in ascending powers of x , up to and including the term in x^2 . that $\tan \theta = \frac{4}{3}$, find ω in terms of a and g .

(c)



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

[6]

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

[8]

- (d) force is caused only by a pressure difference?

$$(x+1) \frac{dy}{dx} = y(x+2)$$

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

springs = gf [5]

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

[4]

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

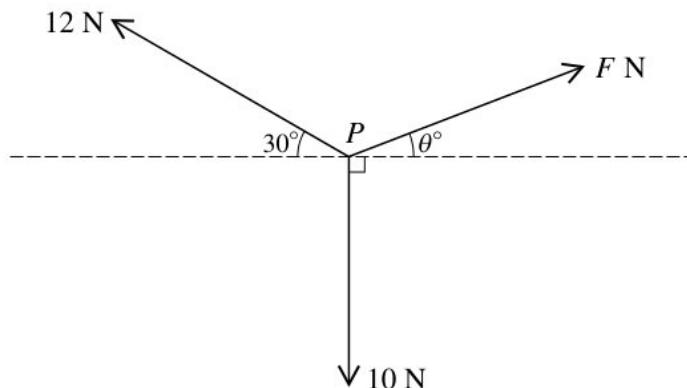
- (c) curve C with equation

$$\text{that } rp^3 = q^3.$$

student wishes to measure a distance of about 10 cm to a precision of 0.01 cm .

[8]

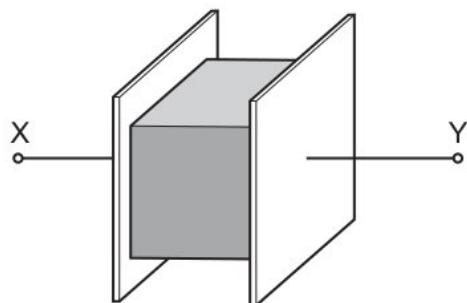
- (b)



only one of the following two alternatives.

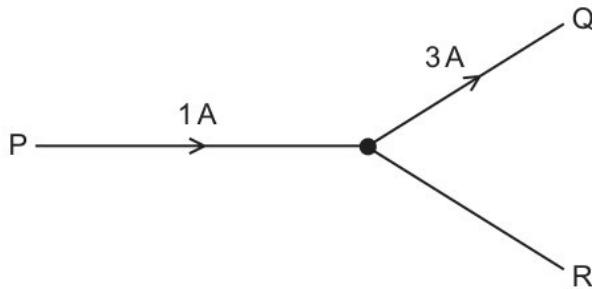
[4]

- 15 sample of nitrogen gas is trapped in a vertical tube of uniform cross-sectional area by a



Use de Moivre's theorem to show that

(b)



an unbiased estimate of $E(T)$, and show that an unbiased estimate of $\text{Var}(T)$ is 14.44.

X and Y are connected in series to a cell.

the value of V .

[2]

(a) is its change in momentum?

[15]

(g) the set of values of x for which the expansion in part (b) is valid.

[8]

(c) Show that, at the points (other than the pole) at which a tangent to C is parallel to the initial line,

[10]

23 the rank of the matrix

a set of 40 values of x , it is found that

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

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

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

[8]

18 the mean value of y with respect to x over the interval $0 \leq x \leq \ln 5$,

(e) waves are emitted from two sources.

[6]

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

the identity $\cot^2 \theta - \tan^2 \theta \equiv 4 \cot 2\theta \operatorname{cosec} 2\theta$.

[4]

(a) of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

[3]

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

[12]

- 26 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.

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

are speed v_1 and speed v_2 ?

[6]

- (b) sample of an ideal gas at thermodynamic temperature T has internal energy U .

[6]

- 18 the mean of the times taken by all 50 runners.

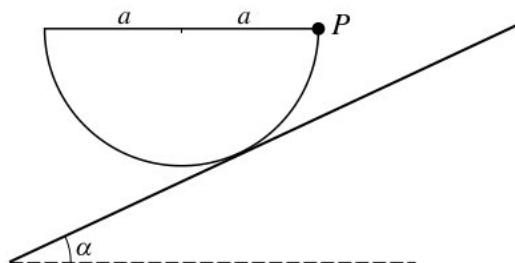
- (f) variation with extension x of the force F for a spring A is shown in Fig. 6.1.

[3]

- (a) of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

[3]

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



[5]

- 17 not have a unique solution.

[20]

- 31 the type of each transformation, and make clear the order in which they are applied.

[5]

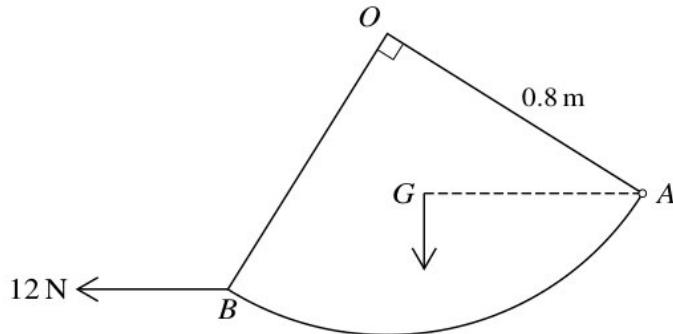
- 20 800 nm to 1000μ m

[4]

- 13 small smooth ring R , of mass 0.6 kg , is threaded on a light inextensible string of length 100 cm . One end of the string is attached to a fixed point A . A small bead B of mass 0.4 kg is attached to the other end of the string, and is threaded on a fixed rough horizontal rod which passes through A . The system is in equilibrium with B at a distance of 80 cm from A (see diagram).

[4]

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



- (b) Hence show that there are only two points on the curve at which the tangent is parallel to the x -axis and find the coordinates of these points.

[3]

- (a) lines l_1 and l_2 have equations

[5]

- (d) the value of θ .

[10]

- 24 show that $PQ = 13$,

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

[4]

- 8 Show that the deceleration of the car with the brakes applied is 4.1 m s^{-2} .

[8]

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

[8]

- 13 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.

- (d) points A, B, C have position vectors

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?

is a general description of a baryon?

by mathematical induction, that $\sum_{r=1}^n r \ln\left(\frac{r+1}{r}\right) = \ln\left(\frac{(n+1)^n}{n!}\right)$ for all positive integers n .

[4]

- (f) sequence u_1, u_2, u_3, \dots is such that $u_1 = 5$ and $u_{n+1} = 6u_n + 5$ for $n \geq 1$.

that, at the point $A(-1, 1)$ on C , $\frac{dy}{dx} = -4$.

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

with a reason, whether f has an inverse.

[10]

- (a) statement describes the speed of the object after it is fired until immediately before it reaches the ground again?

de Moivre's theorem to prove that

[12]

- 7 (i) 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.

[6]

- (iv) The mass of the car is 920 kg . At time $t = 0$, the car is at rest. At time $t = 5.8$ s, its velocity is 17 ms^{-1} .

[3]

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

CDs are packed in boxes of 30 . The probability that a blank CD is faulty is 0.04 . A box is rejected if more than 2 of the blank CDs are faulty.

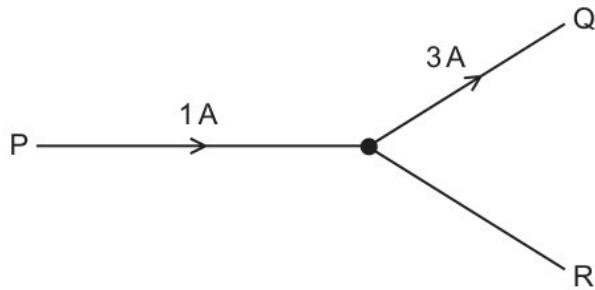
polar equation of a curve C is $r = a(1 + \cos \theta)$ for $0 \leq \theta < 2\pi$, where a is a positive constant.

[6]

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

[10]

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



the solution of the differential equation

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

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

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

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

[12]

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

[8]

- (c) linear transformation $T : \mathbb{R}^4 \rightarrow \mathbb{R}^4$ is represented by the matrix $\mathbf{M} =$

$$\begin{pmatrix} 1 & 3 & -2 & 4 \\ 5 & 15 & -9 & 19 \\ -2 & -6 & 3 & -7 \\ 3 & 9 & -5 & 11 \end{pmatrix}.$$

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

[8]

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

For this value of k , find the set of possible solutions, giving your answer in the form

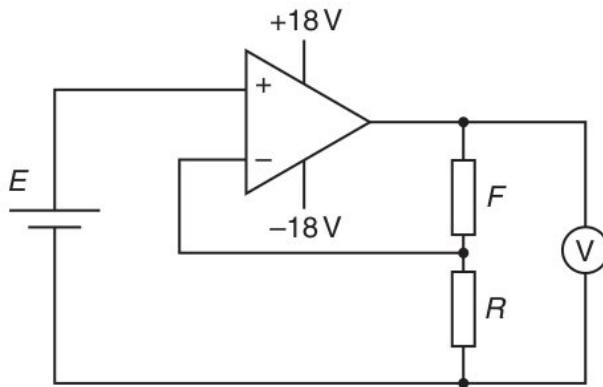
- (a) diagram shows a sketch of the curve $y = \frac{3}{\sqrt{9-x^3}}$ for values of x from -1.2 to 1.2 .

[6]

- (e) line l passes through B and C .

[6]

16



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

[6]

- 10 Find the total distance travelled by the particle in the first 10 seconds of motion.
 linear transformation $T : \mathbb{R}^4 \rightarrow \mathbb{R}^4$ is represented by the matrix \mathbf{A} , where
 flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

[10]

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

- (c) the gradient of the curve

group = wq [12]

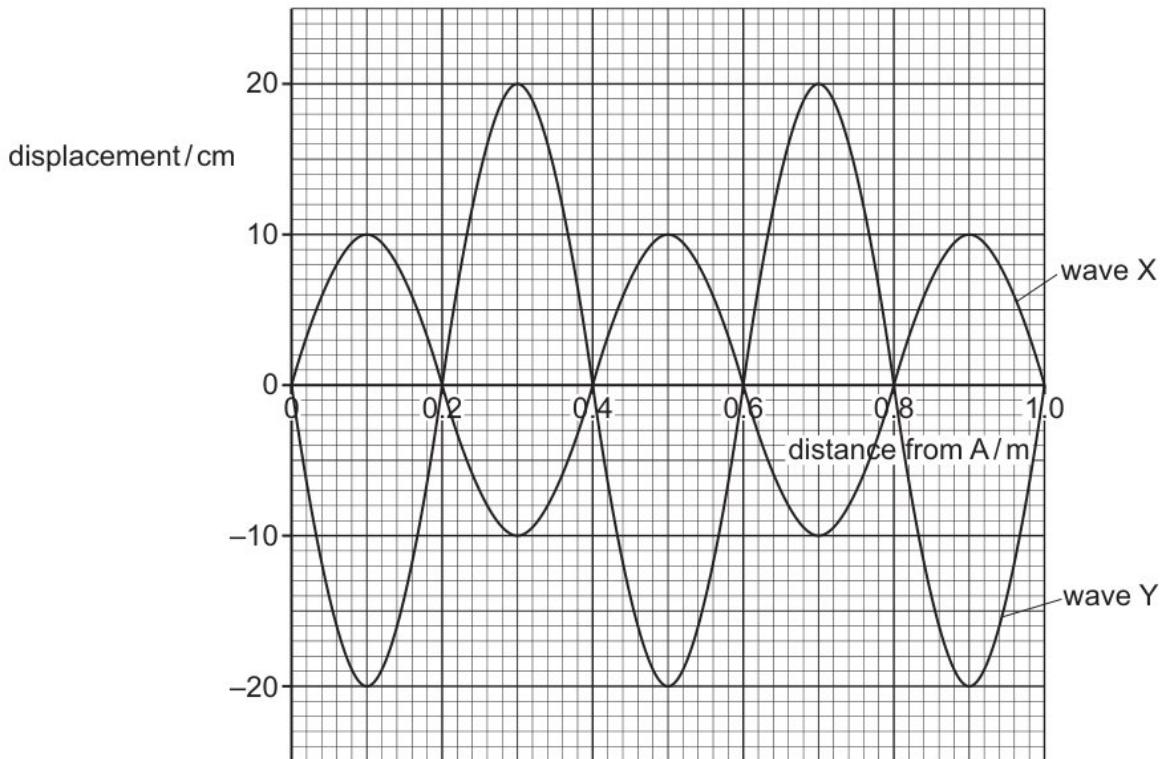
- (b) a different investigation, Nikki uses another large random sample to calculate a 99% confidence interval and an $x\%$ confidence interval.

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

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

[5]

(a)



By setting up and solving a differential equation, show that the equation of the curve is $y = 2e^{x^2-1}$.

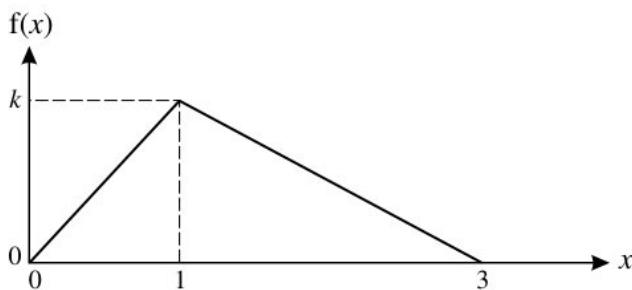
[6]

9 8 Let $I_n = \int_0^{\frac{1}{4}\pi} \sec^n x \, dx$ for $n > 0$.

the median value of X .

is the diameter of the wire?

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



[15]

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

diagram shows a charged particle as it approaches a pair of charged parallel plates in a vacuum.

[1]

- 11 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.

- (d) 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.

[6]

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

[8]

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

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

by calculation that $0.9 < a < 0.95$.

[8]

- (b) the grid below, draw a box-and-whisker plot to summarise the information in the cumulative frequency graph.

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

[2]

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

The 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 $\lambda\mu$.

[8]

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

the value of n .

[5]

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

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

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

activity of a radioactive sample.

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

[10]

- 15 4 astronauts are chosen to go on a mission. Each of these astronauts can take 3 personal possessions with him. How many different ways can these 12 possessions be arranged in a row if each astronaut's possessions are kept together?

$$\mathbf{A}^n = \begin{pmatrix} 2^n & 3(2^n - 1) \\ 0 & 1 \end{pmatrix}$$

[8]

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

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

- (c) plank rests on fixed supports at its ends X and Y .

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 $\frac{1}{3}$.

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

[10]

- (d) in terms of a , the distance that P moves down the plane before coming to rest.

[3]

- 8 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. Find the distance OM .

[6]

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

[20]

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

curve C has polar equation $r = \theta e^{\frac{1}{8}\theta}$, for $0 \leq \theta \leq 2\pi$.

- (c) Find the probability that the number the die lands on is the same as the number of times the coin shows heads.

[3]

- (a) Find also the value of $\frac{1}{\alpha^2\beta^2} + \frac{1}{\beta^2\gamma^2} + \frac{1}{\gamma^2\alpha^2}$.

[4]

- (e) Explain why the observed wavelength and the emitted wavelength have different values.

[5]

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

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

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

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

$$\Sigma(x - 25) = 133, \quad \Sigma(x - 25)^2 = 3762.$$

[8]

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

[5]

- (d) with a reason, whether f has an inverse.

a diagram, on page 3, showing the arrangement of your equipment. In your account
horizontal. magnitude plane = ft [6]

- 10 the probability that, in a randomly chosen week, the first day on which less than 59.1 kg of cherries are sold is the fifth day of the week.

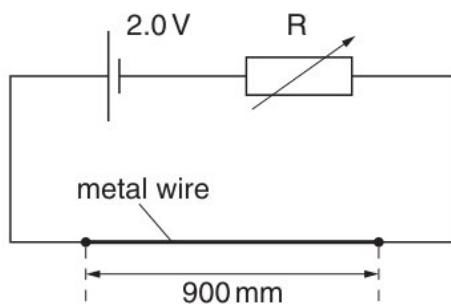
the sum to infinity of the progression.

[20]

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

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

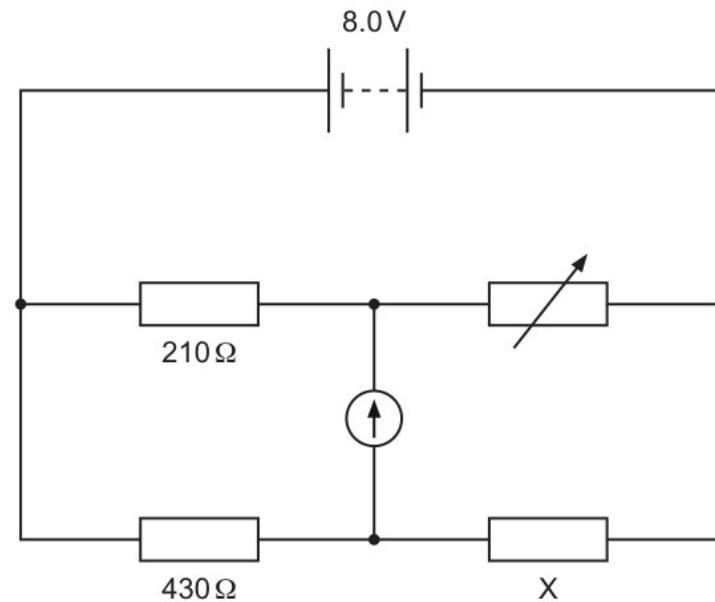
satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.



[5]

- 16 the time taken for the ball to reach its maximum height

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.



[6]

- 20 planes have equations $x + 2y - 2z = 7$ and $2x + y + 3z = 5$.

Show that $a = 19$ and find the values of b and c .

- (iii) are two marks on the tube. The top mark is positioned at 115 ± 1 mm on the adjacent rule and the lower mark at 385 ± 1 mm. The ball passes the top mark at 1.50 ± 0.02 s and passes the lower mark at 3.50 ± 0.02 s.

[6]

- (v) solve the equation $\cot^2 x - \tan^2 x = 5 \sec 2x$ for $0^\circ < x < 90^\circ$.

object weighs 6.0 N on Earth.

vertical. sphere = xz [4]

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

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

[2]

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

[15]

- 22 (f) 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.

[6]

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

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

variables x and y satisfy the differential equation

[5]

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

[5]

- (b) how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

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

[8]

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

[10]

- 23 what is meant by the de Broglie wavelength.

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

[8]

- (c) complex number $1 - (\sqrt{3})i$ is denoted by u .

[10]

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

[8]

- 12 the general solution of the differential equation

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

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

the identity $\cot^2\theta - \tan^2\theta \equiv 4 \cot 2\theta \operatorname{cosec} 2\theta$.

is the speed of the block after falling this distance?

[12]

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

[8]

- (b) transmitted light has intensity I .

[20]

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

- (c) shop sign weighing 75 N hangs from a frame attached to a vertical wall.

[10]

- (d) the Maclaurin s series for $e^{\left(\frac{1}{x+2}\right)}$ up to and including the term in x^2

from the definitions of tanh and sech in terms of exponentials, prove that

[2]

- 21 row describes the relative ionizing power and the relative penetration power per unit length in air of α -particles and γ -rays?

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

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.

[10]

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

[12]

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

a, b and c are integers to be determined.

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

[5]

- 16 show that $PQ = 13$,

[3]

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

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

- (a) believes that 20% of the students at his college are left-handed. His friend believes that the true proportion, p , is less than 20%. Amir plans to use the binomial distribution to test the null hypothesis, $H_0 : p = 0.2$, against the alternative hypothesis, $H_1 : p < 0.2$. not have a unique solution.

[6]

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

[5]

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

[10]

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

[10]

- 16 Find the value of a .

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

sample of a radioactive substance emits particles that are positively charged and have a continuous range of kinetic energies.

the equations of the asymptotes of C

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

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

$$\tan 3\theta = \frac{3 \tan \theta - \tan^3 \theta}{1 - 3 \tan^2 \theta}.$$

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

[6]

- (b)

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 probability that the marble chosen from bag A is blue, given that the marble chosen from bag B is blue.

[8]

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

[6]

- 20 (a) wave pattern produced in (b) is shown in Fig. 7.1.

[2]

- (c) Find the rate of working of the tension at this instant.

[5]

- (d) bag contains 10 marbles, of which 4 are red and 6 are blue. Four marbles are selected from the bag at random, without replacement. The random variable X denotes the number of blue marbles selected.

[12]

- (e) an estimate for the mean length of these 250 leaves.

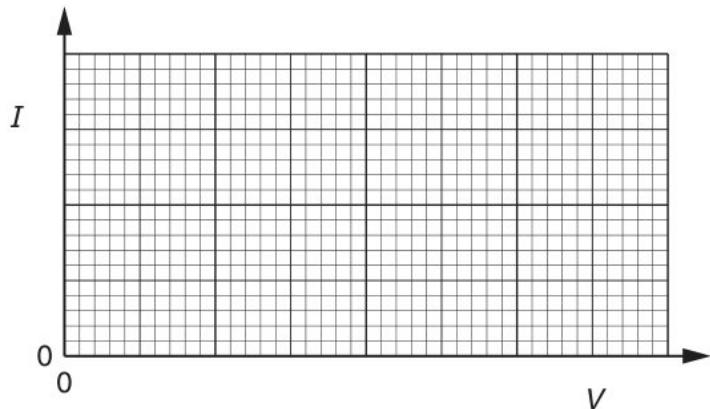
[8]

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

[10]

- 33 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 $t = 2$.

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



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

[8]

- (a) no digit can be repeated,

the number of different arrangements of the 7 men in a line in which Ali and Ben do not stand next to each other.

Hence show that there are only two points on the curve at which the tangent is parallel to the x -axis and find the coordinates of these points.

[3]

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

[5]

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

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



[8]

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

[8]

- 25 400 nm to 700 nm

[6]

- 23 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.

grams = ir [5]

- 20 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 $ax + by + cz = d$.

[10]

- 30 if there are no restrictions,

[12]

- 27 van is 2.50 m long with the wheels at a distance of 0.600 m from the front of the van and 0.400 m from the rear of the van.

[8]

- 15 Show that $a = 19$ and find the values of b and c .

	M	N
A	microwaves	visible light
B	microwaves	γ -rays
C	γ -rays	microwaves
D	visible light	microwaves

nucleus of sodium- $21, {}_{11}^{21}\text{Na}$, decays to form a new nucleus containing 10 protons and 11 neutrons.

the number of different 3-digit numbers greater than 300 that can be made from the digits 1, 2, 3, 4, 6, 8 if

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

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

Find the coordinates of the turning points of C .

[15]

- (d) amplitude $\propto \sqrt{\text{intensity}}$

[5]

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

[3]

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

Find the proportions of large, small and medium pineapples.

[4]

- 23 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.
gravitational potential at a point.

[10]

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

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

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

origin line vectors = om [1]

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

[4]

- 28 point D is the reflection of A in l .

[4]

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

Amplitude is inversely proportional to velocity.

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

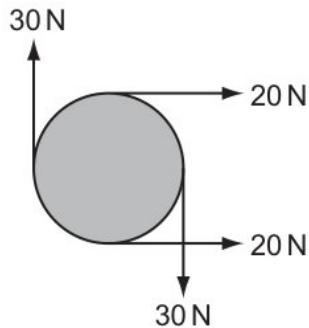
sample contains a single radioactive isotope that decays to form a stable isotope.

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

[8]

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

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.



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

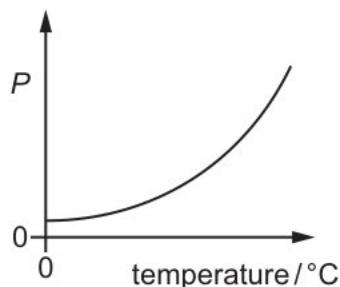
places silver. white, = *lf* [4]

- (b) 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]

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

$$E_K = \frac{1}{2}mv^2.$$

- (b) students are selected at random from the students who study Science.



[5]

- (e) 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° .

The waves must be coherent.

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

[8]

- 13 up the probability distribution table for X .

[2]

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

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

- (d) the particular solution of the differential equation

[10]

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

[8]

- 14 the mean of the times taken by all 50 runners.

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

[6]

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

Show that $u^3 + 8 = 0$.

[5]

- (d) It results in the measured value being different from the correct value.

[3]

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

[6]

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

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

[6]

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

[8]

- (a) shop sign weighing 75 N hangs from a frame attached to a vertical wall.

[5]

- (f) the principle of superposition.

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

[5]

- 21 Find the deceleration of the tractor at the instant it begins to climb the hill.

[1]

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

[5]

- 8 projectile is launched at 45° to the horizontal with initial kinetic energy E .

Find the set of values of k for which the line $y = k$ does not intersect C .

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

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

- (ii) Find the perpendicular distance of the point A from the line BC .

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

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

[3]

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

Q has mass 2.0 kg and is moving at a speed of 4.2 m s^{-1} at an angle of 35° to the path of P .

[4]

- (i) 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.

[6]

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

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

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

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 $AC = a$.

[6]

(b) 1,2 and 3

[5]

- (a) year, an online store sold a large number of computers. 55% of the computers were made by company F , 30% were made by company G and 15% were made by company H .

[6]

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

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

- (h) 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 .

[6]

- (b) the probability that Ali, Ben and Charlie are all in the same group.

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

[5]

- 13 car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.
the value of $(\alpha^3 - 1)^2 + (\beta^3 - 1)^2 + (\gamma^3 - 1)^2$
 $\omega^4 - \omega^3 + \omega^2 - \omega = -1$

[6]

- 14 the acute angle between the planes ABC and ABD .

[8]

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

- (h) Find the probability that a box is rejected.

[3]

- (f) the de Broglie wavelength of an electron moving at a speed of 4.9×10^7 m s⁻¹.

[6]

- 10 battery is marked 9.0 V .

- (f) Potential difference is energy per unit current.

[6]

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

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

[5]

- (b) 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 .

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

525 520 522 524 518 520 519 525 527 516

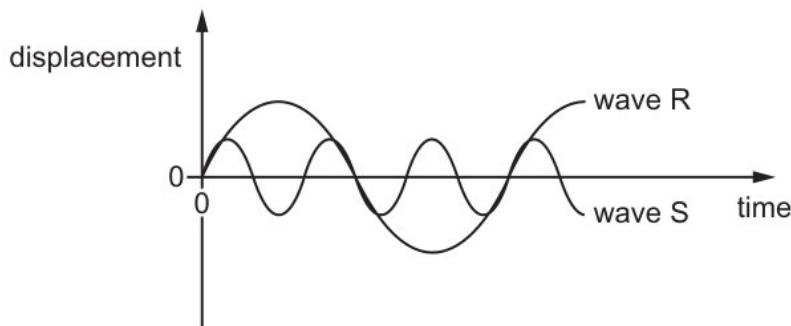
[8]

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

[6]

- 32 diagram shows part of the curve

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



[2]

- 22 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.

[6]

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

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

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.

$$\Sigma x = 4, \quad \Sigma x^2 = 10, \quad \Sigma y = 8, \quad \Sigma y^2 = 102$$

[8]

- 17 diagram shows a charged particle as it approaches a pair of charged parallel plates in a vacuum.

[12]

- 18 the past the number of cars sold per day at a showroom has been modelled by a random variable with distribution $\text{Po}(0.7)$. Following an advertising campaign, it is hoped that the mean number of sales per day will increase. In order to test at the 10% significance level whether this is the case, the total number of sales during the first 5 days after the campaign is noted. You should assume that a Poisson model is still appropriate.

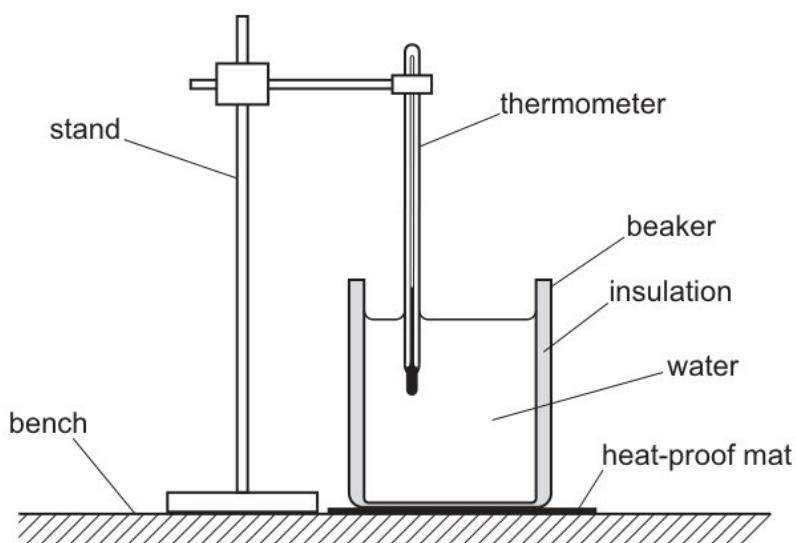
[8]

- 11 statement is correct when S is changed from open to closed?

[3]

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

- (c) certain curve is such that its gradient at a point (x, y) is proportional to xy . At the point $(1, 2)$ the gradient is 4 .



X and Y are connected in series to a cell.

[6]

- (a) for $0^\circ \leq \theta \leq 180^\circ$ the equation $\sin^2 2\theta (\operatorname{cosec}^2 \theta - \operatorname{sec}^2 \theta) = 3$,

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

[5]

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

[6]

- (f) a similar method to find, in terms of n , a lower bound for $\sum_{r=1}^n \frac{1}{\sqrt{r}} e^{\sqrt{r}}$.
 not have a unique solution.
 not have a unique solution.
 wires X and Y are made of different metals. The Young modulus of wire X is twice that of wire Y . The diameter of wire X is half that of wire Y .

[3]

- 22 is a statement of the principle of conservation of momentum for a system?

Find the deceleration of the tractor at the instant it begins to climb the hill.

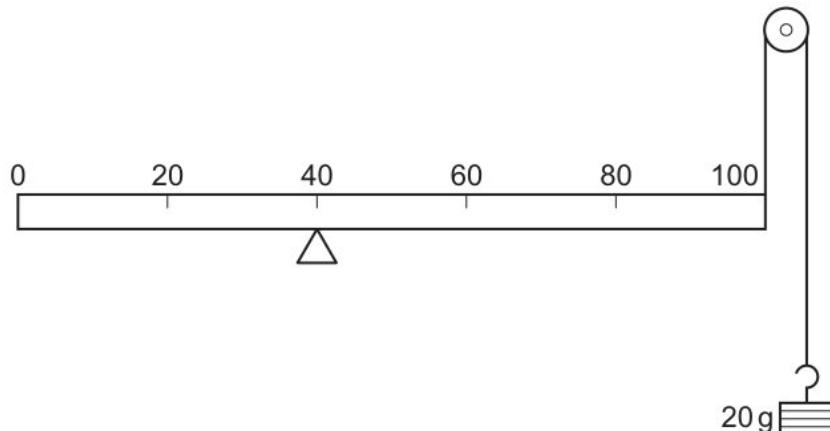
- (d) safety precautions to be taken.
 curve C has equation $\tan y = x$, for $x > 0$.

[5]

- (b) 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 $G_X(t) \times G_Y(t)$.

[4]

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



[2]

- (a) 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.

[8]

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

[3]

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

(d) plane Π_2 contains the lines

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

[2]

(a) It results in the measured value being different from the correct value.

[2]

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

[3]

(b) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

statement about nuclei is correct?

matrix \mathbf{A} , given by

[3]

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

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

(c) constant speed of the ball is calculated by $\frac{385-115}{3.50-1.50} = \frac{270}{2.00} = 135 \text{ mm s}^{-1}$.

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

of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of $4.91 \times 10^{-7} \text{ m}$.

exactly at point S

[2]

- (b) 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.

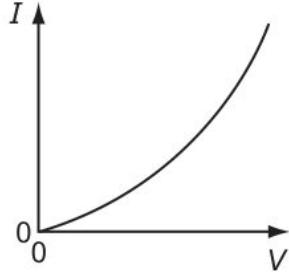
It is given that the determinant of \mathbf{A} is equal to the product of the eigenvalues of \mathbf{A} . Use this result to find the third eigenvalue of \mathbf{A} , and find also a corresponding eigenvector.

[3]

- (e) continuous random variable X has probability density function f given by
 student is investigating an electrical signal using a cathode-ray oscilloscope (c.r.o).

[8]

19



this compression, work W is done on the gas.

is given that $z_1 = 3e^{\frac{1}{4}\pi i}$, $z_2 = \frac{3}{2}e^{\frac{1}{6}\pi i}$ and $\omega = 2e^{\frac{1}{2}\pi i}$

analysis of the data,

[2]

- 6 variation with time t of the displacement s for a car is shown in Fig. 1.1.

[3]

- 9 Find the position vector of D .

[4]

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

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

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

[5]

- 24 the solution of the differential equation

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

[8]

- (b) 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.

[6]

- (d) the probability density function of Y ,

[10]

- 13 lines l_1 and l_2 have equations

Find the modulus and argument of u .

line l passes through B and C .

[6]

- 6 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.

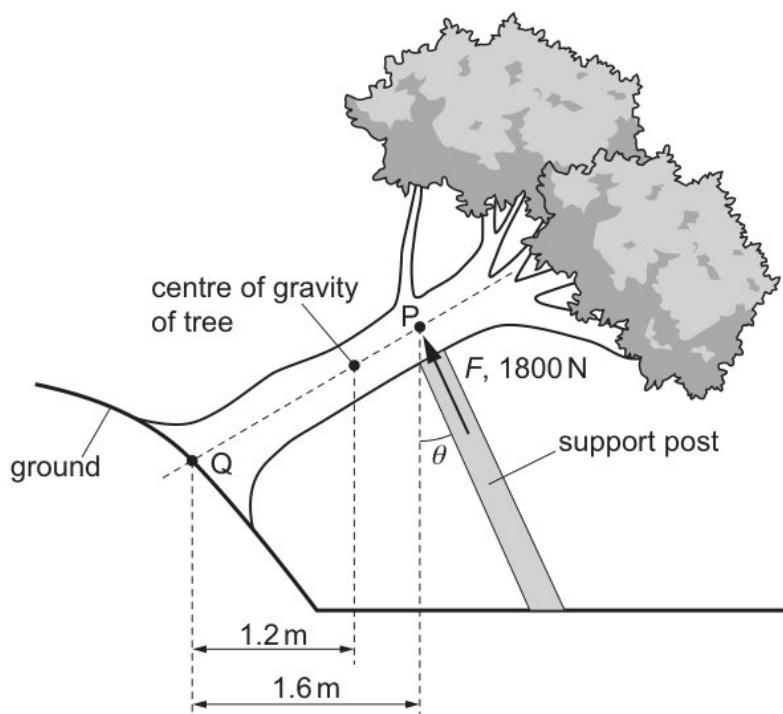
(b) not have a unique solution.

[5]

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

[5]

15



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

[6]

- 21 the distribution function of X .

[4]

- 15 quantities would be measured in order to determine E ?

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

(c) curve C has polar equation $r = \theta e^{\frac{1}{8}\theta}$, for $0 \leq \theta \leq 2\pi$.

[10]

- (a) the particular solution of the differential equation
current-carrying coil produces a magnetic field.

[5]

- (b) researcher records the time, T seconds, taken by adults to complete a questionnaire.

[4]

- 22 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.

- (c) a result of the collision, A moves in a direction which is perpendicular to the line of centres.

[12]

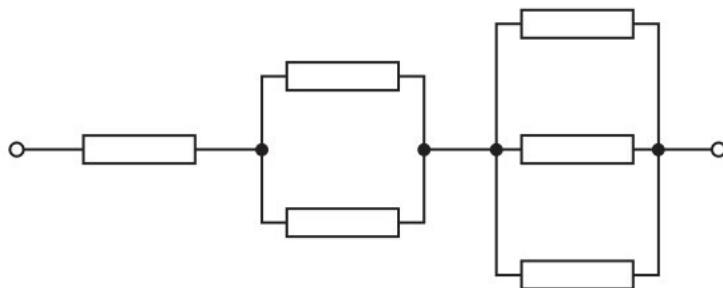
- (a) a positron and a neutrino

light is incident on the front of a photocell, an e.m.f. is generated in the photocell.
student investigates an electrical circuit.

[8]

- 10 m.f. for $n = 0$.

(d)



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

the probability generating functions, $G_X(t)$ of X and $G_Y(t)$ of Y .

[4]

- (c) State what happens to the electron and to the positron.

[3]

- 10 Q hears a sound of decreasing frequency.

- (e) Use the equation of a suitable regression line to estimate the number of hours of sunshine on a day when the mid-day temperature is 2°C .

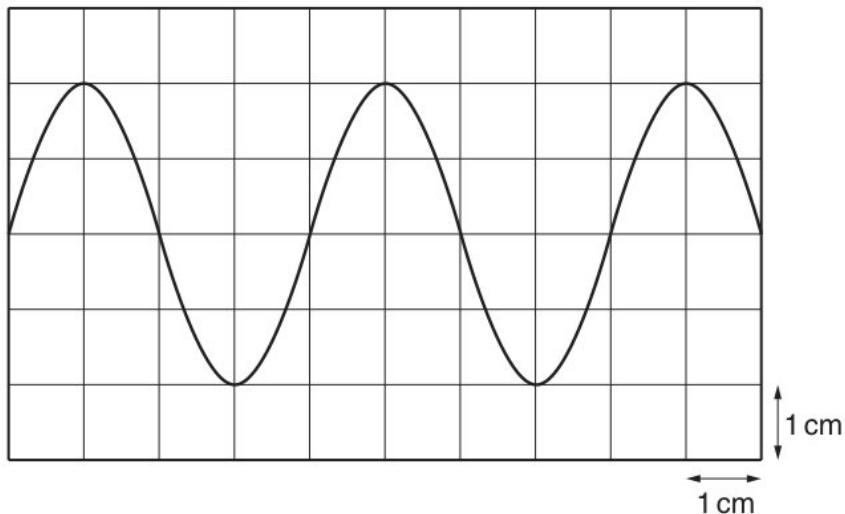
[15]

- (a) as shown in Fig. 2.1.

the value of V .

[5]

- 7 The 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 $\lambda\mu$.



[8]

- 22 Find the values of p and q such that

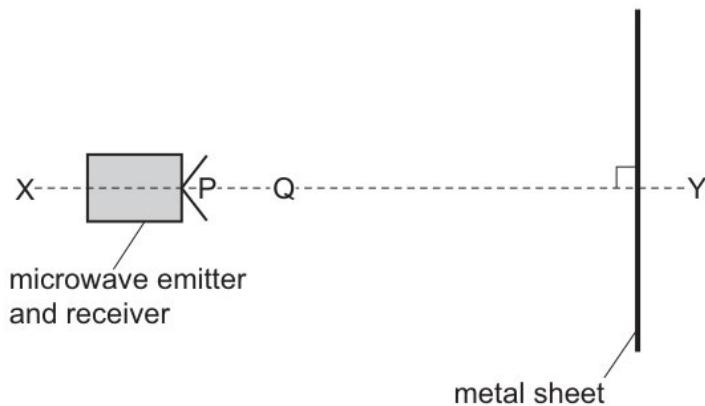
$$x^2 + y^2 = a \left(x + \sqrt{(x^2 + y^2)} \right).$$

[6]

- 17 When the tensile force is removed, the wire does not return to its original length.
statement describes the speed of the object after it is fired until immediately before it reaches the ground again?

[15]

- 23



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

[3]

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

$$x = 1 + 2 \sin^2 \theta, \quad y = 4 \tan \theta$$

- (b) owns a small hotel and offers accommodation to guests. Over a period of 100 nights, the numbers of rooms, x , that are occupied each night at Roberto's hotel and the corresponding frequencies are shown in the following table.

[6]

- (a) the term elastic limit.

height vertically Fig. = oa [2]

- 12 the period of small oscillations,

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

Show that the substitution $u = 1 + \sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$.

Hence evaluate s .

[8]

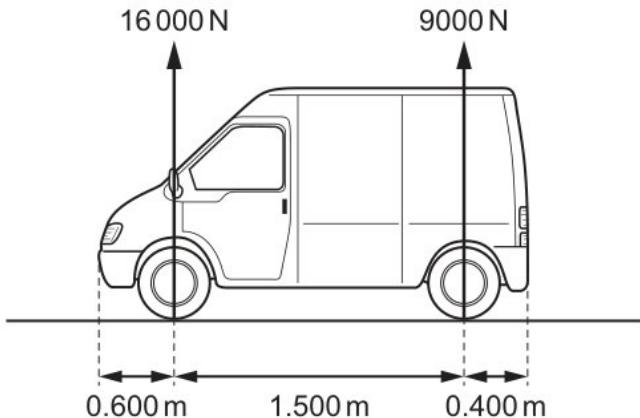
- 15 statement about sound waves in air at constant temperature is correct?

be written as a quadratic equation in x .

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

[6]

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



[6]

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

neutron decays to form a proton.

[5]

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

[6]

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

[6]

- 22 the time taken for the ball to reach its maximum height

[5]

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

$$\begin{pmatrix} 1 & 3 & -2 & 4 \\ 5 & 15 & -9 & 19 \\ -2 & -6 & 3 & -7 \\ 3 & 9 & -5 & 11 \end{pmatrix}.$$

sequence x_1, x_2, x_3, \dots defined by

[4]

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

- (a) internal diameter of the beaker is $0.05 \text{ m} \pm 3\%$.

Show that the deceleration of the car with the brakes applied is 4.1 m s^{-2} .

[4]

- (b) 1 Which quantity is a scalar quantity?

[6]

- (c) water is added to an insulated beaker, as shown in Fig. 2.1.

[10]

- 26 object is fully submerged in a liquid.

[4]

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

[10]

- 12 t is the thickness of one sheet, α is the absorption coefficient of glass and V_0 is the

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

is the current in the load resistor?

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

[6]

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

[6]

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

[12]

- 21 is the horizontal distance of the van's centre of gravity from the front of the van?

- (d) your answer correct to 2 decimal places.

[15]

- (b) a sketch of an Argand diagram, shade the region whose points represent complex numbers z which satisfy both the inequalities $|z| < 2$ and $|z| < |z - 2 - 2i|$.

isotopes of the element uranium are $^{235}_{92}\text{U}$ and $^{238}_{92}\text{U}$.

[6]

- (a) copper wire is 6.4 m long and has a resistance of 0.92Ω .

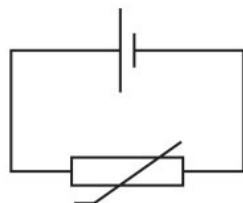
[10]

- (c) The waves must be coherent.

[3]

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

- (c) 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.



[3]

- (e) Find the rate of working of the tension at this instant.

a, b and c are integers to be determined.

[12]

- (b) - decelerating at a constant rate with the parachute open,
eigenvalues 1, -1 and -2 .

[1]

- (a) the speed of Q after the collision.

[5]

- 7 The waves must be polarised.

diagram, showing these three forces to scale, is correct?

[5]

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

the period of small oscillations,

matrix \mathbf{A} is given by

[8]

- 10 1 and 2 only

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

- (a) amplitude \propto intensity

[6]

- (d) relationship is used in the derivation of the equation shown?

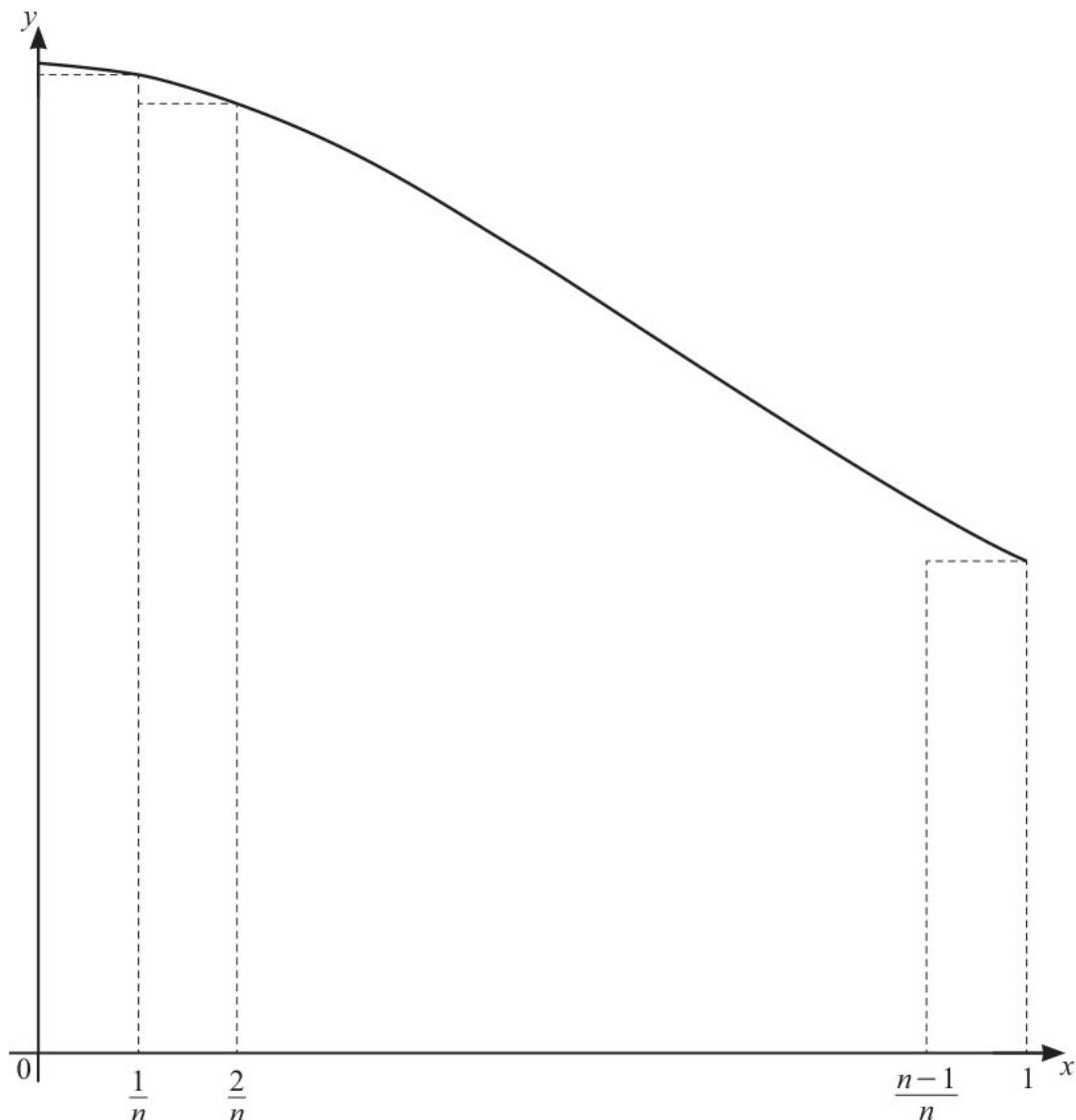
400 nm to 700 nm

[5]

- (c) the surface area generated when C is rotated through 2π radians about the x -axis.

have = iy [5]

25



the general solution of the differential equation

[8]

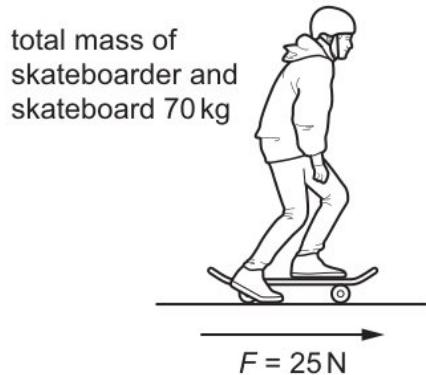
- 16 the number of different ways in which the 6 musicians can be selected if there must be at least 3 guitarists, at most 2 pianists and exactly 1 drummer.

[6]

- 28 the equation for this decay.

Given = ge [6]

19



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

[4]

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

curve C has equation

the geometric effects of multiplying z_1 and z_2 by ω

- (b) object weighs 6.0 N on Earth.

[6]

- (d) control of variables,

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

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

$\mathbf{A} = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$. Prove by mathematical induction that, for every positive integer n ,

[3]

- (g) the probability that a 3 is obtained for the second time before the 6th throw.

[5]

- (e) Show that the deceleration of the car with the brakes applied is 4.1 m s^{-2} .

decimal = dl [5]

- 13 the grid below, draw a cumulative frequency graph to illustrate this information.

- (b) the distribution function of X .

[8]

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

[3]

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

[6]

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

[4]

20 is the total elastic potential energy stored in the four springs?

[10]

13 Find the mean and variance of the daily income, in millions of dollars, generated by field A.

[8]

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

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

Find a 99% confidence interval for μ , giving your answer correct to 2 decimal places.

The waves must not be polarised.

Find the area of one loop of C .

[4]

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

[8]

15 is the relationship between the amplitude of a wave and its intensity?

(b) 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 .

[6]

(a) State one other feature of this orbit.

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

is given that $z_1 = 3e^{\frac{1}{4}\pi i}$, $z_2 = \frac{3}{2}e^{\frac{1}{6}\pi i}$ and $\omega = 2e^{\frac{1}{2}\pi i}$

[8]

(e) There will always be 9.0 V across the battery terminals.

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

[6]

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

[6]

27

Member	A	B	C	D	E	F	G	H
x	24.2	23.8	22.8	25.1	24.5	24.0	23.8	22.8
y	23.9	23.6	22.8	24.5	24.2	23.5	23.6	22.7

curve C has parametric equations

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

[5]

- 15 a sketch of an Argand diagram, shade the region whose points represent complex numbers z which satisfy both the inequalities $|z| < 2$ and $|z| < |z - 2 - 2i|$.

a digit can be repeated and the number made is even.

- (a) are selected from these 20 to perform at a concert.

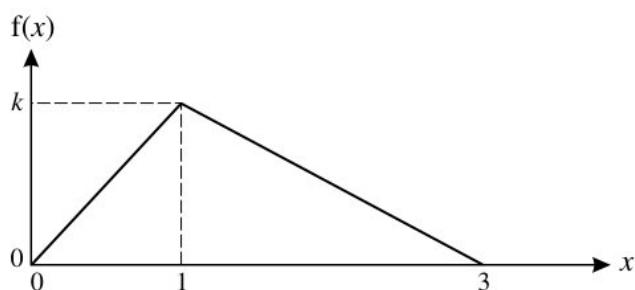
quartile: 28, Median: 39, Upper quartile: 67.

[4]

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

[20]

- 25 Both light waves and sound waves show the Doppler effect.



Explain the features of the graphs in (d) that show the characteristics of ductile and brittle materials.

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

t is the thickness of one sheet, α is the absorption coefficient of glass and V_0 is the seconds, beginning = vr [2]

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

[12]

- 17 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.

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

[6]

- 12 the probability that the 3 customers bought computers all made by different companies. an unbiased estimate of $E(T)$, and show that an unbiased estimate of $\text{Var}(T)$ is 14.44.

- (f) the length of C .

[5]

- (b) 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.

[2]

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

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

$$\text{discs} = \dots \dots \dots ky \quad [6]$$

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

[6]

- 12 the length of C .

[3]

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

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

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

Hence find the value of $\frac{1}{\alpha^2} + \frac{1}{\beta^2} + \frac{1}{\gamma^2}$.

[4]

- 27 Find the mean and variance of the daily income, in millions of dollars, generated by field A .

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

[1]

- 12 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 .

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

[6]

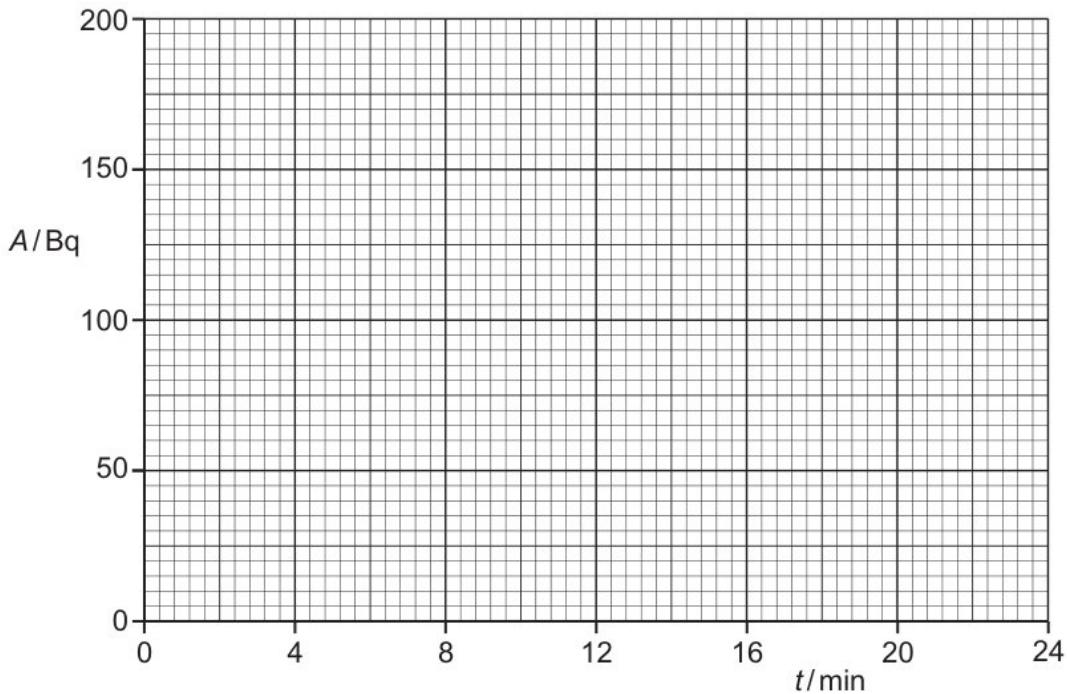
- (b) Density is mass per cubic metre.

[3]

- (c) a diagram, on page 3, showing the arrangement of your equipment. In your account polynomial $ax^3 - 3x^2 - 11x + b$, where a and b are constants, is denoted by $p(x)$. It is given that $(x + 2)$ is a factor of $p(x)$, and that when $p(x)$ is divided by $(x + 1)$ the remainder is 12 .

[12]

12

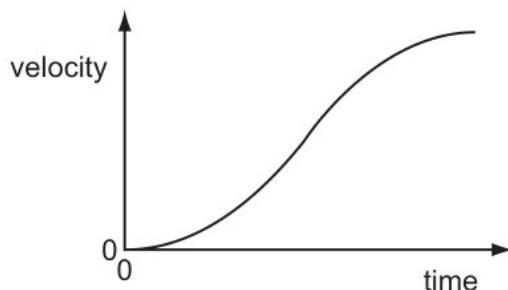


electric current I is given in the list of formulae on page 3 as $I = Anvq$.

Find the cartesian equation of Π_1 .

[8]

24



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

[4]

- 8 C , stating the coordinates of the intersections with the axes.

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

Find the coordinates of A and M .

[5]

- 23 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.

- (c) control of variables,

$$\begin{aligned}\alpha + \beta + \gamma &= -1 \\ \alpha^2 + \beta^2 + \gamma^2 &= 29 \\ \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} &= -1\end{aligned}$$

[6]

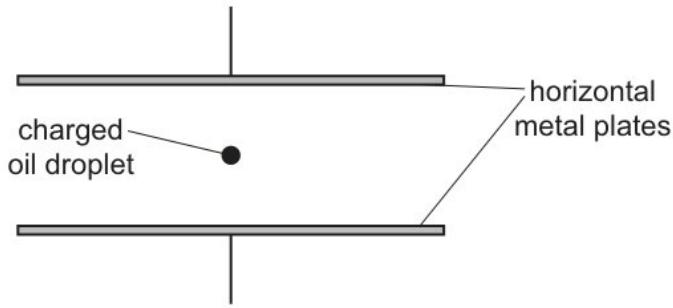
- (b) sample of 216 observations of the continuous random variable X was obtained and the results are summarised in the following table.

$$\tan 3\theta = \frac{3 \tan \theta - \tan^3 \theta}{1 - 3 \tan^2 \theta}.$$

[12]

- 19 only one of the following two alternatives.

- (a)



a and b are constants. It is given that $(x + 2)$ is a factor of $p(x)$ and that, when $p(x)$ is divided by $(x + 1)$, the remainder is 24 .

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

[4]

- (b) diagram shows the curve with equation $y = \frac{1}{x^2+1}$ for $0 \leq x \leq 1$, together with a set of n rectangles of width $\frac{1}{n}$.

[10]

- (e) the principle of moments.

Calculate the initial speed and the angle of projection of P .

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

[3]

- 25 the expected value and variance of Y .

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

[6]

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

[15]

26 Use the iterative formula

[8]

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

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

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

- (b) the value of θ for which the transformation represented by \mathbf{M} has a line of invariant points. [7]

gravitational potential at a point.

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

[15]

- (e) the range of f ,
activity of a radioactive sample.

[10]

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

[4]

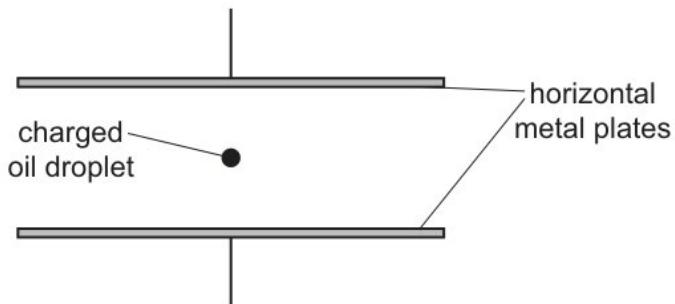
27 (c) Find the rank of \mathbf{A} and show that $\left\{ \begin{pmatrix} 2 \\ 2 \\ -1 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 3 \\ 0 \\ 1 \end{pmatrix} \right\}$ is a basis for the null space of the transformation.

[2]

- (a) Find the direction of motion of the particle 0.4 s after the instant of projection.

[5]

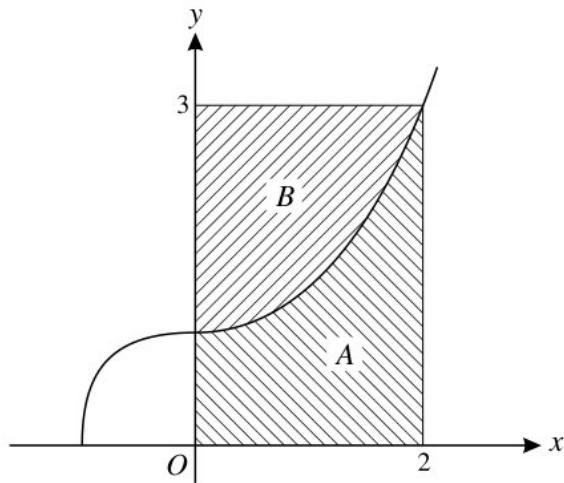
- (d)



why Kieran is incorrect.

[2]

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



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

[8]

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

- (b) not have a unique solution.



[10]

- (c) cell of e.m.f. 2.0 V and negligible internal resistance is connected to a variable resistor R and a metal wire, as shown in Fig. 5.1.

State what is meant by the internal energy of a system.

[3]

- (a) the number of different 3-digit numbers greater than 300 that can be made from the digits 1, 2, 3, 4, 6, 8 if

[6]

- (e) car in (b) is travelling at a constant speed of 25 ms^{-1} . The driver then applies the brakes to stop the car. The constant force resisting the motion of the car is 4600 N .

[3]

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

Show that $m = 0.9$.

The total momentum is conserved only in elastic collisions.

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

[12]

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

Sound waves are transverse waves and light waves are longitudinal waves.

[3]

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

[6]

- (g) eigenvalues 1, -1 and -2 .

[5]

- 10 Calculate the acceleration of P when it is at instantaneous rest and $x > 0$.

[15]

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

[8]

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

Show that the substitution $u = 1 + \sin \theta$ reduces this integral for s to $(\sqrt{2})a \int_0^2 \frac{1}{\sqrt{(2-u)}} du$.

Hence evaluate s .

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

$$I_3 = \frac{3}{1024}\pi + \frac{1}{128}$$

continuous random variable X has probability density function f given by

[8]

- 16 Find the values of F and θ .

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

[6]

- 25 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.

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

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

[4]

- 30 that, at the point $(4, \frac{1}{3})$ on C , $\frac{dy}{dx} = -\frac{1}{2}$.

- (ii) the probability generating functions, $G_X(t)$ of X and $G_Y(t)$ of Y .
analysis of the data,
specific latent heat.

[5]

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

[8]

- (i) diagram correctly represents the forces acting at point P ?

[2]

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

the probability that, in a randomly chosen week, the first day on which less than 59.1 kg of cherries are sold is the fifth day of the week.

[4]

- 12 Find the value of a for which $\arg(u^*) = \frac{3}{4}\pi$, where u^* denotes the complex conjugate of u .

[6]

- 21 the data to carry out a goodness of fit test at the 5% significance level to test the scientist's claim.

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

[6]

- 11 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.

[2]

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

[5]

- 11 in terms of a , the distance that P moves down the plane before coming to rest.

- (c) Explain the features of the graphs in (d) that show the characteristics of ductile and brittle materials.

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.

Nucleus X undergoes β^- decay to form nucleus Z .

[5]

- (e) Find the matrix product $\mathbf{A} \begin{pmatrix} -1 \\ 1 \\ -1 \\ 1 \end{pmatrix}$ and hence find the general solution of the equation

$$\mathbf{Ax} = \begin{pmatrix} 3 \\ 21 \\ 24 \\ 27 \end{pmatrix}.$$

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

[6]

- 12 the position vector of P .

resistance horizontal. = ka [8]

- 17 cyclist is travelling along a straight horizontal road at a speed of 4 ms^{-1} when she passes a point O . She accelerates at a constant rate for a distance of 42 m , reaching a speed of $V \text{ m s}^{-1}$. She maintains the speed of $V \text{ m s}^{-1}$ for 50 m and then decelerates at 2 m s^{-2} before coming to rest. The distance travelled while decelerating is 16 m .

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

[5]

- 15 Find the interquartile range of X .

[6]

- 21 statement about the weight of the plank is correct?

[3]

- 13 cylindrical copper wire P of length 0.24 m is shown in Fig. 6.1.

- (c) resistors, each of resistance R , are connected as shown.

Show that the cartesian equation of C is

[5]

- (b) potential difference across a resistor is 12 V . The current in the resistor is 2.0 A .

[6]

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

[8]

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

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

Use an iterative formula based on the equation in part (i) to find the value of a correct to 4 significant figures. Give the result of each iteration to 6 significant figures.

- (i) is the grand-daughter product?

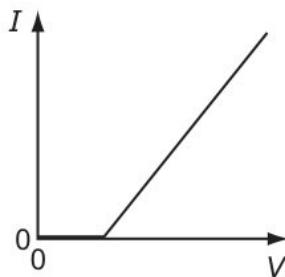
[4]

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

[15]

- 11 is given that $\sum x^2 = 1823.0$.

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.



[5]

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

that $a = \exp\left(\frac{1}{6}\left(\frac{5}{a^2} + 3\right)\right)$ where $\exp(x)$ denotes e^x

OAB is a uniform lamina in the shape of a quadrant of a circle with centre O and radius 0.8 m which has its centre of mass at G . The lamina is smoothly hinged at A to a fixed point and is free to rotate in a vertical plane. A horizontal force of magnitude 12 N acting in the plane of the lamina is applied to the lamina at B . The lamina is in equilibrium with AG horizontal (see diagram).

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

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

your answer correct to 2 decimal places.

[4]

- (d) point $P(2, 1)$ lies on the curve with equation

$$\sqrt{3}x^5 - 10x^4 + 40x^2 - 32 = 0$$

[12]

- 13 are selected from these 20 to perform at a concert.

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

expression has the same SI base units as pressure?

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

particle 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 is moving in complete vertical circles with the string taut. When the particle is at the point P , where OP makes an angle α with the upward vertical through O , its speed is u . When the particle is at the point Q , where angle $QOP = 90^\circ$, its speed is v (see diagram). It is given that $\cos \alpha = \frac{4}{5}$.

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

[5]

- (b) \mathbf{a} and \mathbf{b} are vectors and t is a scalar.

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

[10]

- 14 the speed of the aeroplane.

By setting up and solving a differential equation, show that the equation of the curve is $y = 2e^{x^2-1}$.

the probability that all three cars are the same colour.

[8]

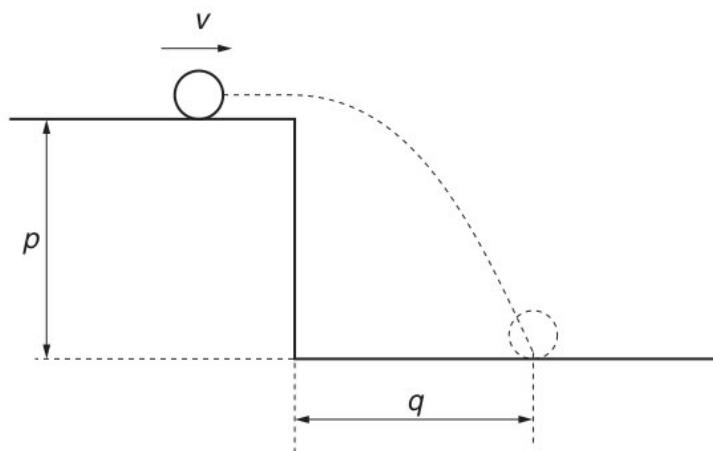
- 6 which mark on the rule must a 50 g mass be suspended so that the rule balances?

[6]

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

[6]

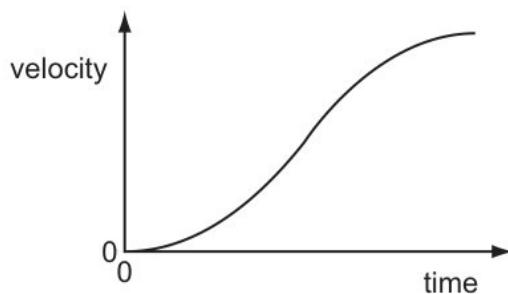
13



Find the proportions of large, small and medium pineapples.

[12]

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



The orbit has a period of 25 hours.

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

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

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 ?

[12]

- (a) Find the value of k for which the set of linear equations

[4]

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

[4]

- 9 student is investigating an electrical signal using a cathode-ray oscilloscope (c.r.o).

- (a) between gravitational potential energy and electric potential energy.

[6]

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

[4]

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

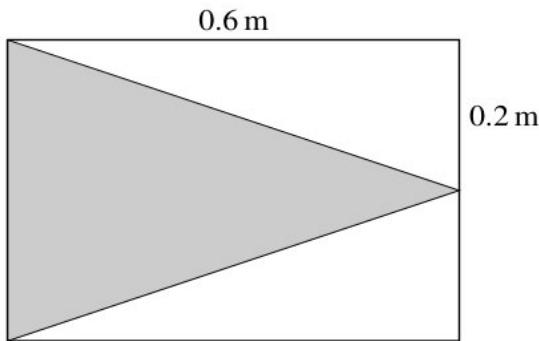
[6]

- (d) Find the equations of the asymptotes of C .

matrix \mathbf{A} is given by

matrix eigenvalue eigenvalue = wq [8]

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



[6]

- 20 that l_1 and l_2 do not intersect.

magnetic flux density.

the particular solution of the differential equation

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

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

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

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

[8]

- (d) Find the value of k for which the set of linear equations

[5]

- 21 light is incident on the front of a photocell, an e.m.f. is generated in the photocell.

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

$\mathbf{A} = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$. Prove by mathematical induction that, for every positive integer n ,

are selected from these 20 to perform at a concert.

- (d) the distance moved by the particle between the time at which its acceleration is zero and the time at which its velocity is zero.

[8]

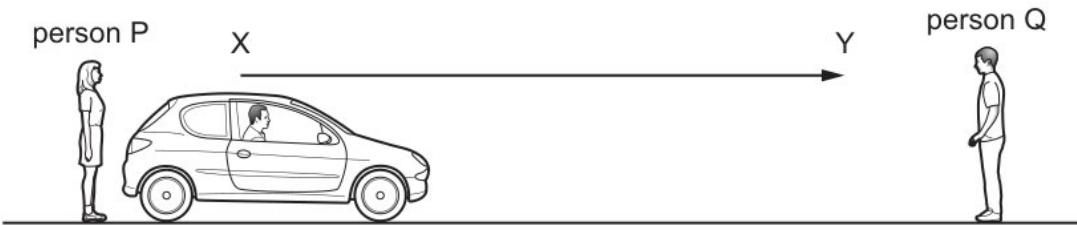
- (c) diagram shows the curve $y = \sqrt{1 + x^3}$. Region A is bounded by the curve and the lines $x = 0$, $x = 2$ and $y = 0$. Region B is bounded by the curve and the lines $x = 0$ and $y = 3$.

A fair tetrahedral die has faces numbered 1, 2, 3, 4. A coin is biased so that the probability of showing a head when thrown is $\frac{1}{3}$. The die is thrown once and the number n that it lands on is noted. The biased coin is then thrown n times. So, for example, if the die lands on 3, the coin is thrown 3 times.

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

[4]

- 9 the polar coordinates of the points of intersection of C and l .



Hence find the value of $\frac{1}{\alpha^2} + \frac{1}{\beta^2} + \frac{1}{\gamma^2}$.

Use a goodness-of-fit test at the 5% significance level to determine whether the Poisson distribution is a suitable model for the number of rooms occupied each night at Roberto's hotel.

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

[4]

- (c) graph is correctly labelled?

[1]

- (b) OAB is a uniform lamina in the shape of a quadrant of a circle with centre O and radius 0.8 m which has its centre of mass at G . The lamina is smoothly hinged at A to a fixed point and is free to rotate in a vertical plane. A horizontal force of magnitude 12 N acting in the plane of the lamina is applied to the lamina at B . The lamina is in equilibrium with AG horizontal (see diagram).

[10]

- (d) many competitors would you expect to have times within 1.2 minutes of the mean time?

[15]

- (e) the surface area generated when C is rotated through 2π radians about the x -axis.

[10]

10 measurements to be taken,

[5]

18 between time $t = 0$ and time $t = 5.8$ s the work done against resistive forces is 4.7×10^4 J
[5]

24 is the speed of the block at the bottom of the slope?

$$I_3 = \frac{3}{1024}\pi + \frac{1}{128}$$

[6]

17 is the grand-daughter product?

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

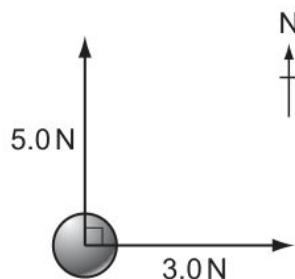
Using a 5% significance level, test whether there is non-zero correlation between the variables.

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.

much energy is stored in the compressed column?

[6]

15



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

[2]

21 considering momentum, calculate the speed of nucleus R after the decay.

Amplitude is inversely proportional to velocity.

[8]

16 the number of different 3-digit numbers greater than 300 that can be made from the digits 1, 2, 3, 4, 6, 8 if

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

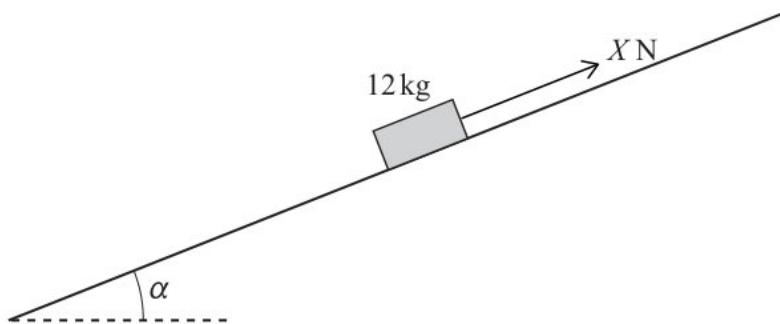
[1]

- (c) 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

Member	A	B	C	D	E	F	G	H
x	24.2	23.8	22.8	25.1	24.5	24.0	23.8	22.8
y	23.9	23.6	22.8	24.5	24.2	23.5	23.6	22.7

[8]

(a)



of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

[4]

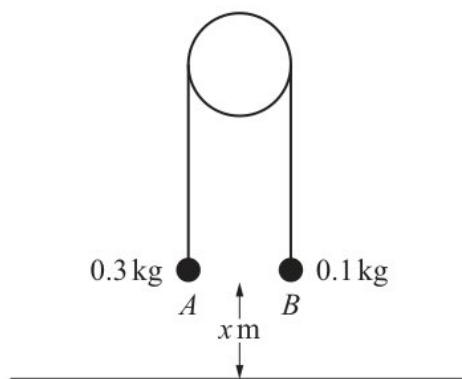
- 13 student wishes to investigate the effect of adding various thicknesses of glass in front of ground = pl [5]

- 14 the expected value and variance of Y .

[6]

- 12 curve C has polar equation $r = \theta e^{\frac{1}{8}\theta}$, for $0 \leq \theta \leq 2\pi$.

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



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

a vector equation for l .

[10]

- 26 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.

[8]

- 14 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.

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

- (d) State the equation of the other asymptote.

[10]

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

[5]

- 16 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.

[4]

- 22 matrix \mathbf{A} is given by

the expected value and variance of Y .

X and Y are connected in series to a cell.

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

[8]

- 20 It results in the measured value being different from the correct value.

[6]

- 14 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.

smooth = xh [3]

- 10 (vi) only one of the following two alternatives.

[8]

(i)

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

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

$$\tan 3\theta = \frac{3 \tan \theta - \tan^3 \theta}{1 - 3 \tan^2 \theta}.$$

[6]

(v) row correctly identifies the properties of all electromagnetic waves?

[15]

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

[15]

10 Find the upward force on the parachutist due to the parachute, during the second stage.

[10]

8 Find the tension in the string.

[4]

17 activity of a radioactive sample.

[4]