**NATURAL SCIENCES
ADMISSIONS ASSESSMENT**

D568/11

2022

60 minutes

SECTION 1

INSTRUCTIONS TO CANDIDATES

Please read these instructions carefully, but do not open this question paper until you are told that you may do so. This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 60 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **four** parts: **A**, **B**, **C** and **D**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **one** further part chosen from:

Part B   Physics
Part C   Chemistry
Part D   Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **two** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Please wait to be told you may begin before turning this page.

This question paper consists of 65 printed pages and 3 blank pages.

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Paper content

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PART A Mathematics

1 Which one of the following is a simplification of

$$y\left(\frac{3x^{\frac{1}{2}}z}{y^3}\right)^2$$

A $\dfrac{3xz^2}{y^4}$

B $\dfrac{3xz^2}{y^5}$

C $\dfrac{9x^{\frac{1}{2}}z^2}{y^5}$

D $\dfrac{9xz^2}{y^4}$

E $\dfrac{9xz^2}{y^5}$

F $\dfrac{9x^{\frac{5}{2}}z^2}{y^5}$

2 Triangle PQR has a right angle at Q.

The point T lies on QR such that $QT = \dfrac{1}{4}QR$

$PT = 6\,\text{cm}$

$PR = 12\,\text{cm}$

What is the length of QT, in cm?

A 2

B $2\sqrt{3}$

C $\dfrac{3}{2}\sqrt{2}$

D $\dfrac{6}{5}\sqrt{5}$

E $\dfrac{2}{7}\sqrt{21}$

3   Find the complete set of values of x that satisfy the inequality

$$\frac{3}{4}(5-x) - \frac{1}{2}(6-x) - x < 0$$

A $x < \dfrac{1}{3}$

B $x > \dfrac{1}{3}$

C $x < \dfrac{3}{5}$

D $x > \dfrac{3}{5}$

E $x < \dfrac{3}{4}$

F $x > \dfrac{3}{4}$

G $x < \dfrac{3}{2}$

H $x > \dfrac{3}{2}$

4   I have two fair dice, X and Y, each of which has six sides.

The faces on X are labelled 1, 1, 2, 3, 4, 5.

The faces on Y are labelled 2, 3, 4, 5, 6, 6.

I roll the dice together and calculate my total score by adding the number rolled on X to the number rolled on Y.

What is the probability that my total score is greater than 9?

A $\dfrac{1}{4}$

B $\dfrac{1}{6}$

C $\dfrac{1}{9}$

D $\dfrac{5}{12}$

E $\dfrac{5}{36}$

5 Rob keeps a record of what he earns each day.

On Monday, he earned 50% less than he earned on Sunday.
On Tuesday, he earned 20% more than he earned on Monday.
On Wednesday, he earned 30% less than he earned on Tuesday.

On Wednesday, he earned £84.

How much did Rob earn on Sunday?

A £15.12

B £35.28

C £117.60

D £200

E £210

F £300

G £1200

6 The nth term of a sequence T is $(n-3)^2$, where n is a positive integer.

The nth term of another sequence V is $3n + p$, where p is a constant and n is a positive integer.

The 10th term in T is equal to twice the 5th term in V.

What is the 4th term in V?

A -16

B 4

C 16.5

D 21.5

E 31

F 46

G 95

7 Which one of the following is a simplification of

$$\frac{5x^2 - 17x - 12}{25x^2 - 9} \div \frac{x^2 + x - 12}{x^2 - x - 6}$$

A $\dfrac{(x-4)(x+2)}{(x-3)(x+4)}$

B $\dfrac{(x-3)(x+2)}{(5x-3)(x+3)}$

C $\dfrac{(x-4)(x+2)}{(5x-3)(x+4)}$

D $\dfrac{(x-4)(x-3)}{(5x-3)(x-6)}$

E $\dfrac{(x+2)}{(5x+3)}$

F $\dfrac{(x+4)(x-6)}{(5x+3)(x+2)}$

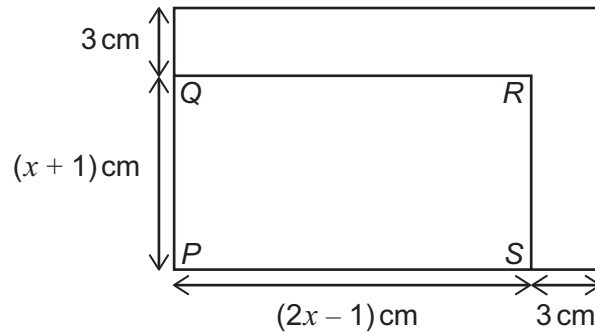**G** $\dfrac{(x-3)(x+2)}{(5x+3)(x+3)}$

8 S is a list of six numbers:

$$1, 2, x, x+1, x+1, 15 \qquad \text{where } 2 \le x \le 14$$

The mean of S is one more than the median of S.

What is the value of x?

A $2\frac{2}{3}$

B $3\frac{2}{3}$

C $4\frac{2}{3}$

D $5\frac{2}{3}$

E $6\frac{2}{3}$

9 A rectangle *PQRS* has length $(2x - 1)$ cm and width $(x + 1)$ cm as shown on the diagram.

A larger rectangle is made by adding 3 cm to both the length and the width of *PQRS*, as shown.

The larger rectangle has an area of 360 cm².

[diagram not to scale]

What is the ratio of *PQ* to *PS*?

A 1:2

B 4:7

C 5:8

D 7:11

E 10:17

F 17:31

10 t is inversely proportional to the square of w.

t and w are positive numbers.

$t = 36$ when $w = 2 \times 10^{-2}$

What is the value of w when $t = 100$?

A 1.2×10^{-4}

B 1.2×10^{-2}
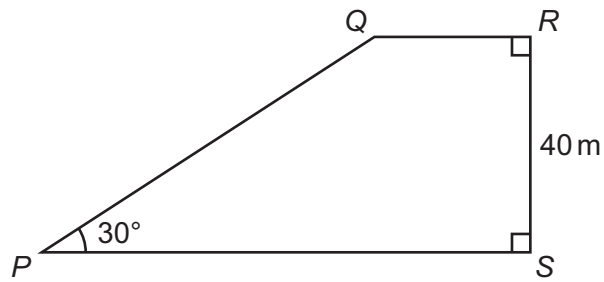
C 1.44×10^{-6}

D 1.44×10^{-3}

E $\dfrac{10}{3} \times 10^{-4}$

F $\dfrac{10}{3} \times 10^{-2}$

G 7.2×10^{-6}

H 7.2×10^{-3}

11   *PQRS* is a trapezium as shown.

[diagram not to scale]

$\tan RSQ = \dfrac{5}{8}$

What is the length of *PS*, in metres?

A   45

B   65

C   80

D   120

E $25 + \dfrac{40\sqrt{3}}{3}$

F $40 + \dfrac{64\sqrt{3}}{3}$

G $25 + 40\sqrt{3}$

H $64 + 40\sqrt{3}$

12 A cyclist rides along a track to the top of a hill then immediately turns around and descends along the same track to her starting point.

She takes 40 minutes at an average speed of $12\,\text{km}\,\text{h}^{-1}$ to reach the top.

Her average speed for the whole journey is $15\,\text{km}\,\text{h}^{-1}$.

What is the average speed of her descent?

A $16\,\text{km}\,\text{h}^{-1}$

B $18\,\text{km}\,\text{h}^{-1}$

C $20\,\text{km}\,\text{h}^{-1}$

D $24\,\text{km}\,\text{h}^{-1}$

E $30\,\text{km}\,\text{h}^{-1}$

13 A solid cylinder has radius r cm and height h cm.

A cube has side length $3r$ cm.

The total surface area of the cylinder is equal to four times the total surface area of the cube.

Which of the following is an expression for h in terms of r?

A $\left(\dfrac{18}{\pi} - 2\right)r$

B $\left(\dfrac{18}{\pi} - 1\right)r$

C $\dfrac{27r}{\pi}$

D $\left(\dfrac{27}{\pi} - 1\right)r$

E $\left(\dfrac{27}{4\pi} - 1\right)r$

F $\dfrac{108r}{\pi}$

G $\left(\dfrac{108}{\pi} - 1\right)r$

H $\left(\dfrac{108}{\pi} - \dfrac{1}{2}\right)r$

14 Consider the equation $2x^2 + 4x + c = 0$, where c is a constant.

The positive difference between the roots of this equation is $\sqrt{10}$.

What is the value of c?

A -5

B -4.5

C -3

D -0.5

E 0.75

F 8

15 The variables x and y are related by the equation:

$$x = 5 - \frac{2y^3 + 1}{1 - 2y^3}$$

Which of the following is a rearrangement to make y the subject?

A $y = \sqrt[3]{\dfrac{x-4}{8x-48}}$

B $y = \sqrt[3]{\dfrac{x-6}{8x-32}}$

C $y = \sqrt[3]{\dfrac{x-2}{x-6}}$

D $y = \sqrt[3]{\dfrac{x-3}{x-4}}$

E $y = \sqrt[3]{\dfrac{x-4}{2x-12}}$

F $y = \sqrt[3]{\dfrac{x-6}{2x-8}}$

16 *PQR* is a triangle as shown.

S and *T* are points on the sides *PQ* and *PR*.

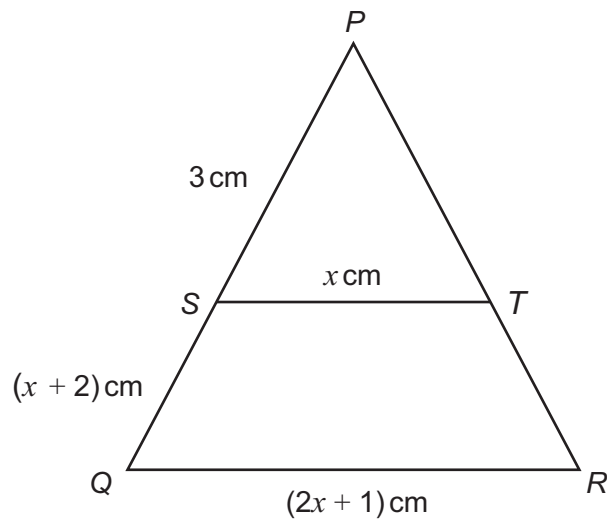*ST* is parallel to *QR*.

$PS = 3\,\text{cm}$
$ST = x\,\text{cm}$
$QS = (x + 2)\,\text{cm}$
$QR = (2x + 1)\,\text{cm}$

[diagram not to scale]

What is the length, in cm, of *QR*?

A $2 + \sqrt{5}$

B $2 + \sqrt{13}$

C $5 + 2\sqrt{7}$

D $5 + 2\sqrt{11}$

E 7

F 9

17 Three different numbers are chosen at random from $\sqrt{1}$, $\sqrt{2}$, $\sqrt{3}$, $\sqrt{4}$, $\sqrt{5}$.

What is the probability that the three numbers form the three sides of a right-angled triangle?

A $\dfrac{1}{15}$

B $\dfrac{1}{10}$

C $\dfrac{3}{10}$

D $\dfrac{1}{3}$

E $\dfrac{2}{5}$

F $\dfrac{2}{3}$

G $\dfrac{4}{5}$

18 P, Q and R are regular polygons.

Q has three times as many sides as P.

An interior angle of Q is 10° larger than an interior angle of P.

R has twice as many sides as Q.

How much larger is an interior angle of R than an interior angle of Q, in degrees?

A $2\dfrac{1}{2}$

B 5

C $6\dfrac{2}{3}$

D $7\dfrac{1}{2}$

E 10

F 15

G $16\dfrac{2}{3}$

19 The point $(-1, 5)$ is translated to the point $(3, 2)$ by two successive translations.

The first translation is by the vector $\begin{pmatrix} 3p \\ -4p \end{pmatrix}$

The second translation is by the vector $\begin{pmatrix} q \\ -2q \end{pmatrix}$

What is the value of $p + q$?

A −14

B −7

C −5

D −1

E 1

F 5

G 7

H 14

20 Consider the graphs of the form

$$y = x^2 + 2ax + a$$

What is the complete range of values of a for which the minimum point of the graph lies above the x-axis?

A There are no values of a

B $a < 0$

C $0 < a < 1$

D $-1 < a < 1$

E $a < -1$ or $a > 1$

F $a < 0$ or $a > 1$

G a can take any value

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PART B Physics

21 There is a constant current in a conducting wire. A charge of 20 C passes through the wire in 1.5 minutes.

An 18 cm straight section of this wire lies in a uniform magnetic field. This section of wire is perpendicular to the direction of the field. The magnetic field strength is 0.15 T.

What is the magnitude of the magnetic force on this section of wire?

A 0.0060 N

B 0.36 N

C 0.60 N

D 0.81 N

E 36 N

F 49 N

G 81 N

H 4900 N

22 A rider on a rollercoaster moves very quickly towards a solid wall. While moving, the rider shouts, and hears an echo of the shout from the wall. The echo is quieter than the original shout.

How do the amplitude and frequency of the echo heard by the rider compare to the amplitude and frequency of the original shout?

	amplitude	frequency
A	lower	lower
B	lower	unchanged
C	lower	higher
D	unchanged	lower
E	unchanged	higher
F	higher	lower
G	higher	unchanged
H	higher	higher

23 The diagram shows a system consisting of two large copper tanks of water connected to each other by a solid cylindrical copper bar.
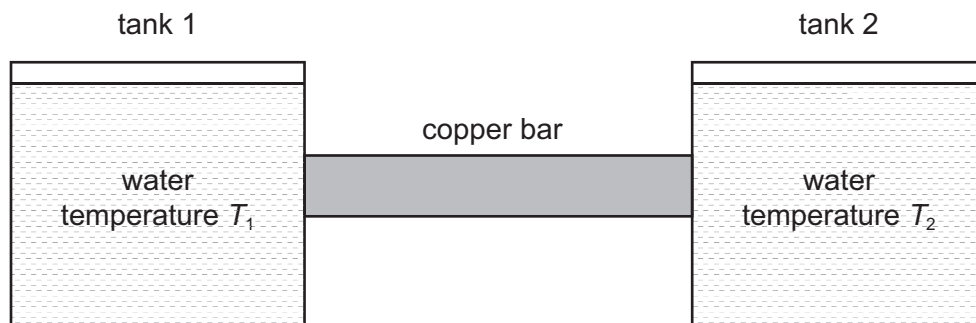
The temperature of the water in tank 1 is T_1. The water in tank 2 is at a higher temperature T_2.

The following four statements list changes that can be made, independently, to the system. At all times $T_1 < T_2$.

    1   increase temperature T_1

    2   increase temperature T_2

    3   increase the length of the copper bar

    4   increase the diameter of the copper bar

Which two changes each independently result in an increase in the rate of conduction of thermal energy along the copper bar?

A   1 and 2

B   1 and 3

C   1 and 4

D   2 and 3

E   2 and 4

F   3 and 4

24 Two identical resistors are connected in parallel to a 6.0 V battery. The two resistors dissipate a total power of 0.15 W.

One of these resistors is removed from the circuit and connected to a 12 V battery.

How much charge passes through this resistor in 6.0 minutes?

A   0.025 C

B   0.050 C

C   0.15 C

D   0.30 C

E   0.75 C

F   1.5 C

G   9.0 C

H   18 C

25 A small piece of space debris of mass 0.10 g strikes the International Space Station at a relative speed of $15000 \, \text{m s}^{-1}$.

The piece of debris comes to rest relative to the space station in a time of 0.010 s.

What is the average force exerted on the space station by the piece of debris during this time?

A   0.0010 N

B   1.0 N

C   1.5 N

D   100 N

E   150 N

F   1500 N

26 A block of mass 6.0 kg is pushed along a rough horizontal surface by a constant force of 8.0 N. The block accelerates uniformly from rest. After 4.0 s its velocity is 2.0 m s^{-1}.

How much work is done against resistive forces during this 4.0 s?

A 12 J

B 20 J

C 24 J

D 32 J

E 40 J

F 64 J

27 Ultrasound is used to find a crack inside a cuboid block of metal. An ultrasound probe is held in contact with the top surface of the metal block and perpendicular to the surface. A short pulse of ultrasound is sent into the metal block at time $t = 0$ ms and reflects from both the crack and the bottom surface of the metal block.
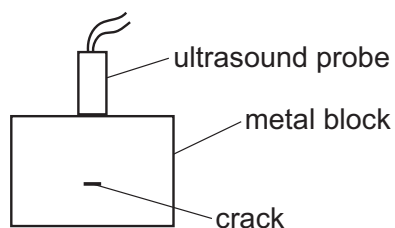
The times between the emission of the ultrasound pulse and the return of the reflections to the probe, and the strengths of the reflected pulses, are measured. The results are shown on the graph.
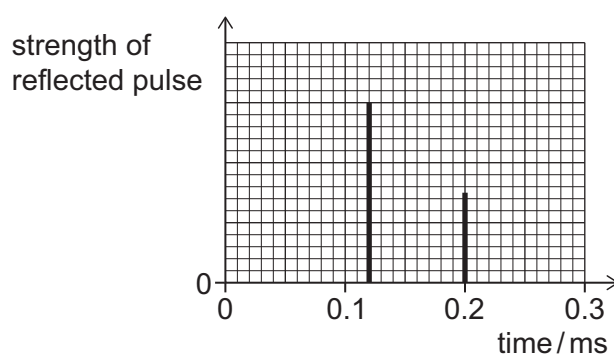
The speed of ultrasound in the metal is $5000\ \mathrm{m\,s^{-1}}$.

What is the distance between the **bottom surface** of the metal block and the crack?

A 0.2 m

B 0.3 m

C 0.4 m

D 0.5 m

E 0.6 m

F 1.0 m

28 Power is supplied to an electric motor at 0.800 kW.

The motor has an efficiency of 60% and is switched on for half an hour.

How much energy is **wasted** during this time?

A 0.160 J

B 0.240 J

C 160 J

D 240 J

E 576 J

F 864 J

G 576 000 J

H 864 000 J

29 The diagram shows a circuit that includes two ammeters and a resistor R.

The readings on the ammeters are shown.
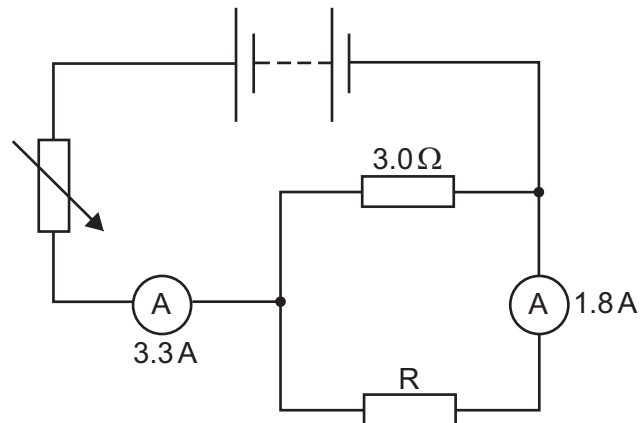
What is the resistance of resistor R?

A 0.40 Ω

B 2.5 Ω

C 3.0 Ω

D 3.6 Ω

E 5.5 Ω

F 8.5 Ω

30 The graph shows potential difference plotted against current for a filament lamp and a resistor.
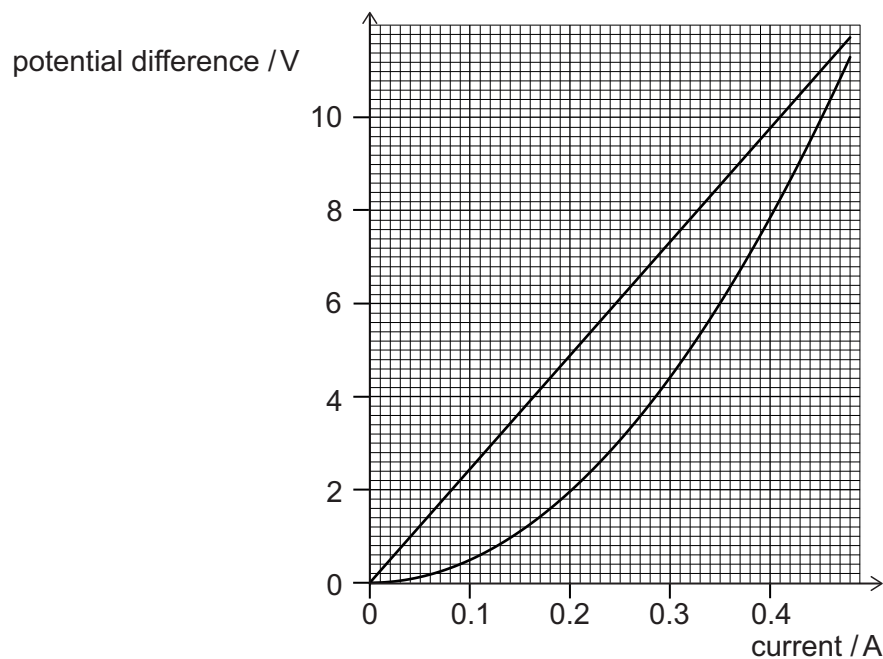
The lamp and the resistor are connected in parallel with each other to a 6.0 V power supply and the current in the lamp, I, is recorded.

In a second circuit, the lamp and the resistor are now connected in series with each other to the same power supply, and the current in the resistor is 0.18 A. The potential difference across the lamp, V, is recorded.

What are the values of I in the first circuit and V in the second circuit?

	I / A	V / V
A	0.25	1.6
B	0.25	3.0
C	0.25	4.4
D	0.35	1.6
E	0.35	3.0
F	0.35	4.4

31 A child is bouncing a ball of mass 0.16 kg vertically up and down on a bat. Each time the ball hits the bat the duration of the contact is 0.20 s. The speed of the ball immediately before hitting the bat and immediately after it loses contact with the bat is 4.0 m s^{-1}.

What is the average contact force between the bat and the ball during each collision?

(gravitational field strength = 10 N kg^{-1})

A 1.6 N

B 3.2 N

C 4.8 N

D 6.4 N

E 8.0 N

32 A transverse wave on a string has a speed of 500 m s^{-1}.

The horizontal distance between two points P and Q on the wave is 4.0 m, as shown in the diagram.
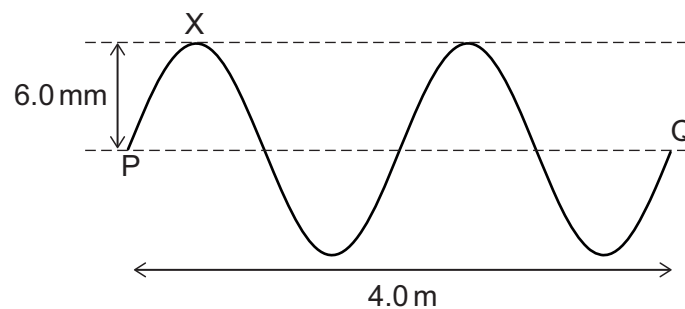
At time $t = 0$ ms, point X on the string is at its maximum displacement of 6.0 mm above equilibrium.

What is the displacement of point X at time $t = 7.0$ ms?

A 6.0 mm above equilibrium

B between 0 mm and 6.0 mm above equilibrium

C 0 mm

D between 0 mm and 6.0 mm below equilibrium

E 6.0 mm below equilibrium

33 A neutral atom Q of a particular element contains a total of 20 particles (protons, neutrons and electrons).

The table shows information about the number of particles and relative charges of four atoms or ions W, X, Y and Z.

atom or ion	number of particles	relative charge of atom or ion
W	21	0
X	21	−1
Y	20	+1
Z	22	0

Which of these atoms or ions could be of a different isotope to Q but of the same element as Q?

A W only

B X only

C Z only

D X and Z only

E W and Y only

F W, X and Y only

G W, Y and Z only

H X, Y and Z only

34 Radioactive isotope X undergoes a single beta (β^-) decay to form the stable isotope Y.

A sample consists only of X and Y. The graph shows how the mass of Y present in the sample varies with time. After a long time, the mass of Y in the sample becomes a constant 50 g.
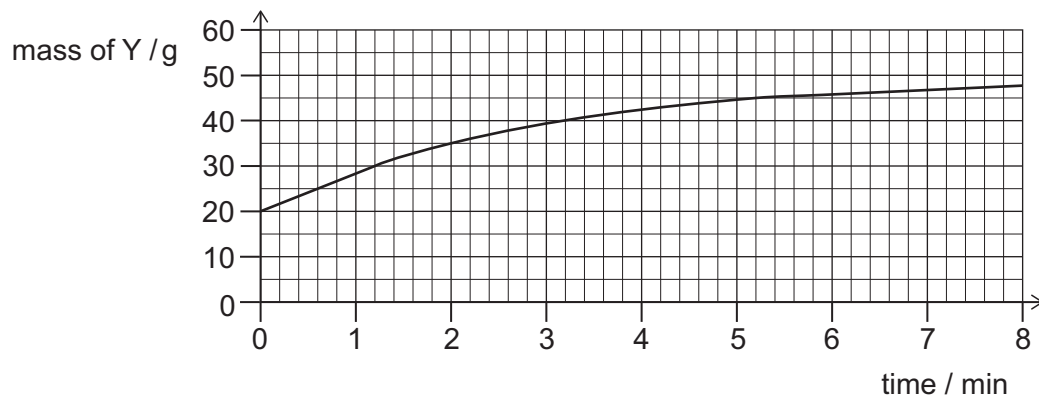
What is the half-life of X?

A 0.6 minutes

B 1.2 minutes

C 2.0 minutes

D 3.2 minutes

E 4.0 minutes

F 5.2 minutes

35 A piece of metal of mass 50 g is at thermal equilibrium in a hot liquid at temperature T.

The metal is removed from the liquid and immediately placed in 100 g of water that is at 20 °C.

The water is stirred and reaches a final temperature of 26 °C.

material	specific heat capacity / $J\,kg^{-1}\,°C^{-1}$
hot liquid	2000
metal	350
water	4200

What is the temperature T of the hot liquid?

(Assume that heat transfers to or from the surroundings are negligible.)

A 38 °C

B 51 °C

C 150 °C

D 170 °C

E 480 °C

36 A bar magnet is placed at position X close to one end of a coil and on the axis of the coil as shown.

The graph shows how the velocity of the magnet varies as it is then moved rapidly to position Y and back to position X.
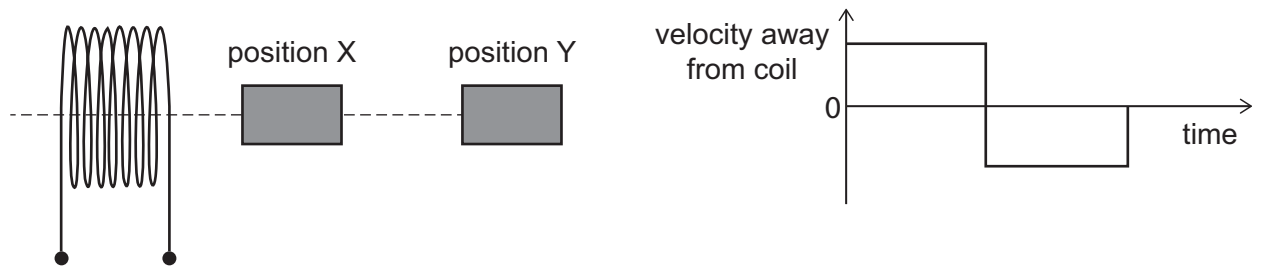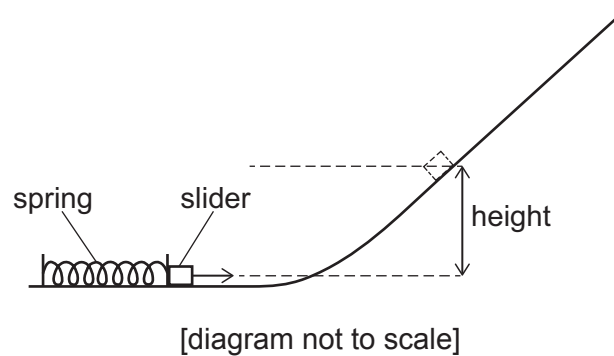

The magnetic field of the bar magnet still affects the coil when the magnet is at position Y.

Which graph represents how the induced voltage in the coil changes as the magnet moves?
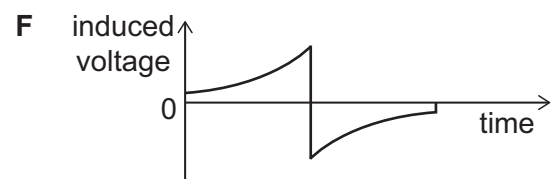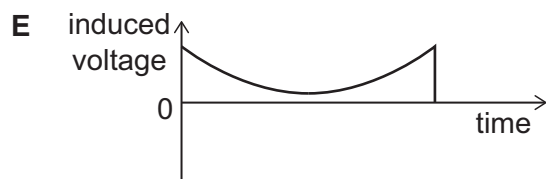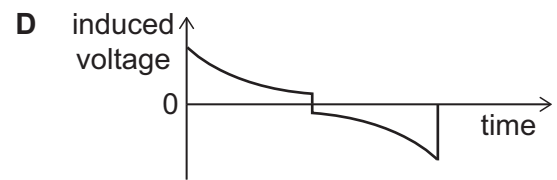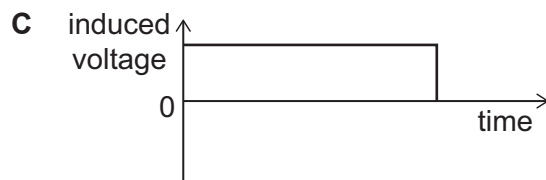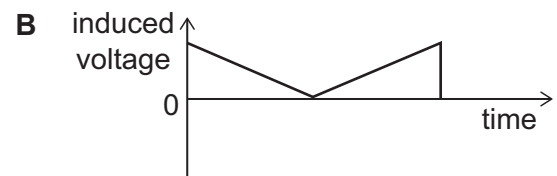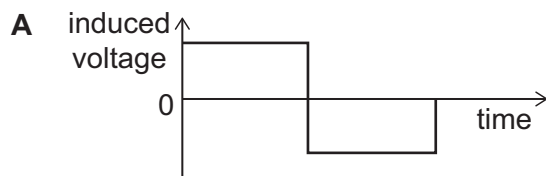
37 A small slider of mass 30 g is at rest near the bottom of a frictionless slope and in contact with a light uncompressed spring as shown.

[diagram not to scale]

The spring is compressed by 5.0 cm and the slider remains in contact with it.

The spring is released and causes the slider to rise up the slope to a maximum vertical height of 20 cm.

The slider is replaced with one of mass 20 g.

The spring is now compressed by 15 cm, and the new slider remains in contact with it.

To what maximum vertical height does this new slider rise after it is released?

(the spring obeys Hooke's law; assume that air resistance is negligible)

A 40 cm

B 60 cm

C 90 cm

D 120 cm

E 180 cm

F 270 cm

38 A tall, smooth cylinder contains air at atmospheric pressure of 1.00×10^5 Pa. The density of the air in the cylinder is $1.20\,\mathrm{kg\,m^{-3}}$.

A heavy piston is now placed in the top of the cylinder and allowed to fall slowly downwards, compressing the air until the piston rests in equilibrium.

The mass of the piston is $50.0\,\mathrm{kg}$ and its cross-sectional area is $0.0200\,\mathrm{m^2}$.

What is the density of the air in the cylinder when the piston rests in equilibrium?

(gravitational field strength $= 10\,\mathrm{N\,kg^{-1}}$; assume that the air behaves as an ideal gas and that the temperature remains constant)

A $0.960\,\mathrm{kg\,m^{-3}}$

B $1.20\,\mathrm{kg\,m^{-3}}$

C $1.25\,\mathrm{kg\,m^{-3}}$

D $1.28\,\mathrm{kg\,m^{-3}}$

E $1.50\,\mathrm{kg\,m^{-3}}$

F $4.80\,\mathrm{kg\,m^{-3}}$

39 There are two types of earthquake waves, called P-waves and S-waves.

When an earthquake occurs, both types of wave are produced at the same time and follow the same path.

The P-waves travel outwards from the source at $5.0\,\mathrm{km\,s^{-1}}$ and the S-waves travel out at $3.0\,\mathrm{km\,s^{-1}}$.

A seismic monitoring station detects the P-waves $30\,\mathrm{s}$ before the S-waves.

How far have the waves travelled from the source of the earthquake to reach the seismic monitoring station?

A $60\,\mathrm{km}$

B $90\,\mathrm{km}$

C $135\,\mathrm{km}$

D $150\,\mathrm{km}$

E $225\,\mathrm{km}$

40 A solid cuboid has a mass of 32 kg and a density of 4.0 g cm^{-3}.

Faces 1, 2 and 3 of the cuboid have different areas.

When the cuboid rests on one of these faces on a flat horizontal surface, the pressure on the surface due to the cuboid is 1.6 N cm^{-2}.

When it rests on another of these faces, the pressure on the surface due to the cuboid is 0.80 N cm^{-2}.

What is the pressure on the surface due to the cuboid when it rests on the third of these faces?

(gravitational field strength = 10 N kg^{-1})

A 0.40 N cm^{-2}

B 1.2 N cm^{-2}

**C** 3.2 N cm^{-2}

D 6.4 N cm^{-2}

E 8.0 N cm^{-2}

PART C Chemistry

41 The following pairs of $0.1\,mol\,dm^{-3}$ solutions are mixed separately in test tubes.

    1 $AgNO_3$(aq) with NaI(aq)

    2 Cl_2(aq) with NaI(aq)

    3 HCl(aq) with NaOH(aq)

    4 $MgCl_2$(aq) with NaBr(aq)

Which pair(s) of solutions, when mixed, would produce a visible chemical change?

A 1 only

B 2 only

C 3 only

D 4 only

E 1 and 2 only

F 1 and 3 only

G 2 and 4 only

H 3 and 4 only

42 Some reactions of metal M and its compounds are shown in the following diagram.
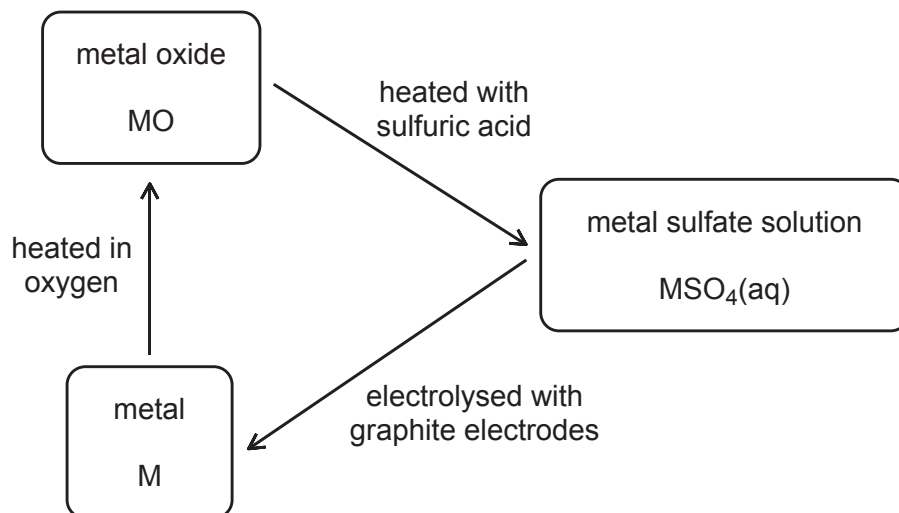
Which one of the following could be the identity of metal M?

A aluminium

B copper

C magnesium

D potassium

E silver

43 Consider the following properties of compound X:

melting point	−114 °C
boiling point	−85 °C
conductivity as a solid	poor
conductivity as a liquid	poor
conductivity in aqueous solution	good

Which one of the following could be the identity of compound X?

A ammonium chloride, NH_4Cl

B barium chloride, $BaCl_2$

C hydrogen chloride, HCl

D potassium chloride, KCl

E tetrachloromethane, CCl_4

44   Which of the following statements about losing electrons is/are correct?

    1   During the electrolysis of a molten binary compound the ions attracted to the cathode (negative electrode) lose electrons at that electrode.

    2   Descending Group 1 of the Periodic Table from lithium to caesium, the atoms of the elements lose electrons more easily.

    3   When a substance is acting as a reducing agent it loses electrons.

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   1 and 3 only

G   2 and 3 only

H   1, 2 and 3

**45**   Which of the following chemical reactions is/are redox reactions?

    1 $Ba^{2+}(aq) + SO_4{}^{2-}(aq) \rightarrow BaSO_4(s)$

    2 $PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(aq)$

    3 $KrF_2(s) \rightarrow Kr(g) + F_2(g)$

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   1 and 3 only

G   2 and 3 only

H   1, 2 and 3

46 Three samples of calcium of different masses were added separately to excess dilute hydrochloric acid and the volume of gas released, measured at room temperature and pressure, was monitored.

One sample was powdered calcium, one was granules of calcium, and one was a solid piece of calcium.

The results are shown on the graph.
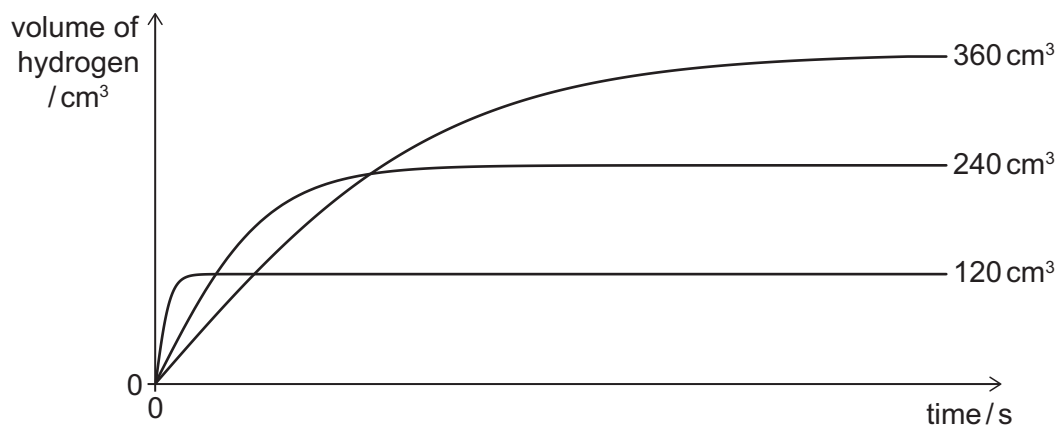
What is the mass of powdered calcium used in this experiment?

(A_r value: Ca = 40. Assume that one mole of gas occupies a volume of $24\,dm^3$ at room temperature and pressure.)

A 0.200 g

B 0.400 g

C 0.600 g

D 1.20 g

E 8.00 g

F 16.0 g

G 24.0 g

47 Concentrated aqueous solutions of three compounds are electrolysed with inert electrodes.

The constituent elements of which of the following compounds may be collected using this process?

    1   copper(II) bromide

    2   hydrogen chloride

    3   potassium chloride

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

48 $50 \, cm^3$ of $0.100 \, mol \, dm^{-3}$ hydrochloric acid has a pH of 1.0.

What is the pH of the mixture formed when $450 \, cm^3$ of $0.010 \, mol \, dm^{-3}$ calcium hydroxide solution is added?

A pH = 1.0

B 1.0 < pH < 2.0

C pH = 2.0

D 2.0 < pH < 7.0

E pH = 7.0

F pH > 7.0

49 Carboxylic acid X reacts with propanol in the presence of an acid catalyst to form compound Y.

Compound Y has a relative molar mass of 116.

What is the relative molar mass (M_r) of X?

(A_r values: C = 12; H = 1; O = 16)

A 45

B 46

C 55

D 56

E 59

F 60

G 73

H 74

**50** Element Z is in Group 1 of the Periodic Table.

A pure sample of element Z consists of two isotopes with mass numbers 85 and 87, and has a relative atomic mass of 85.5.

Which of the following statements is/are correct about element Z in this sample?

    1 Element Z reacts with bromine to form an ionic compound with formula ZBr_2.

    2 Element Z forms a basic oxide.

    3 More than 70% of the atoms of element Z have mass number 85.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

51 Three mixtures (P, Q and R) of amino acids were separated using paper chromatography.
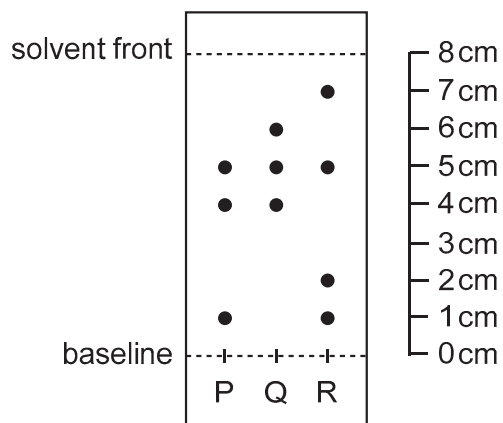
The test was repeated with the same mixtures, paper and solvent but this time the distance travelled by the common component of the mixtures was 7.5 cm.

How far did the most mobile component of mixture Q travel in the second test?

A 6.0 cm

B 8.5 cm

C 9.0 cm

D 9.6 cm

E 10.5 cm

F 12.0 cm

52 A typical sample of dry air is at room temperature and pressure. There is a total of 25.0 mol of gas in this sample.

One of the gases in the sample, X, contributes 1.50×10^{23} separate particles to the mixture.

A second gas in the sample, Y, would, if alone, occupy a volume of 468 dm^3 at room temperature and pressure.

What are the identities of gases X and Y, and what would be the total amount of all of the remaining gases in the sample?

(Take Avogadro's number as 6.00×10^{23}. Assume that one mole of any gas occupies a volume of 24.0 dm^3 at room temperature and pressure.)

	identity of gas X	identity of gas Y	total amount of all of the remaining gases in the sample in moles
A	Ar	N_2	5.250 mol
B	O_2	N_2	5.250 mol
C	O_2	Ar	5.250 mol
D	Ar	O_2	5.375 mol
E	Ar	N_2	5.375 mol
F	O_2	N_2	5.375 mol

53 The atomic number of fluorine is 9.

An element X forms a fluoride with the formula XF_3. Each molecule of XF_3 has 32 electrons in total.

Element X has two isotopes. One isotope has the same number of neutrons as protons and the other isotope has a number of neutrons one greater than the number of protons.

The relative abundance of the heavier isotope is 0.80 (80%).

What is the relative atomic mass of element X?

A   5.2

B   5.8

C   10.2

D   10.8

E   14.2

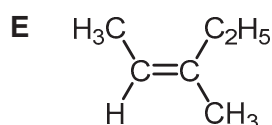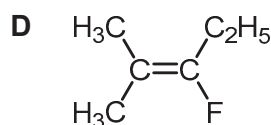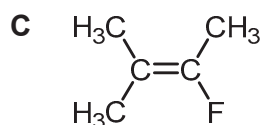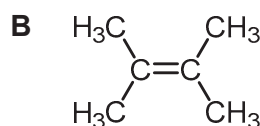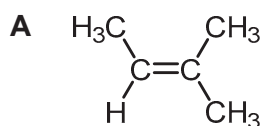**F**   14.8

G   16.2

H   16.8

54 1 mol of compound X undergoes complete combustion to produce $144\ dm^3$ of carbon dioxide (measured at room temperature and pressure).

1 mol of X can also undergo an addition reaction with 1 mol of hydrogen to form a saturated compound that has one branch.

X undergoes addition polymerisation. A section of the addition polymer containing three repeating units has an M_r value greater than 200 but less than 300.

Which one of the following structural formulae could be that of compound X?

(A_r values: C = 12; H = 1; F = 19. Assume that one mole of any gas occupies a volume of $24\ dm^3$ at room temperature and pressure.)

A
```
H3C        CH3
    \      /
     C = C
    /      \
   H        CH3
```

B
```
H3C        CH3
    \      /
     C = C
    /      \
  H3C       CH3
```

C
```
H3C        CH3
    \      /
     C = C
    /      \
  H3C       F
```

D
```
H3C        C2H5
    \      /
     C = C
    /      \
  H3C       F
```

E
```
H3C        C2H5
    \      /
     C = C
    /      \
   H        CH3
```

55 The equation shows the complete combustion of an alkane.

$$\text{alkane} + aO_2 \rightarrow bCO_2 + cH_2O$$
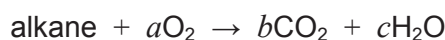
$100\ cm^3$ of a gaseous alkane requires $650\ cm^3$ of oxygen for complete combustion. The volumes of both gases were measured at the same temperature and pressure.

What is the value of $a + b + c$?

A 10.5

B 12

C 14

D 15.5

E 17.5

F 19

56 A sample of magnesium carbonate, $MgCO_3$, was reacted completely with $50\,cm^3$ of $0.10\,mol\,dm^{-3}$ hydrochloric acid, which is an excess.

The remaining hydrochloric acid was titrated with $0.20\,mol\,dm^{-3}$ sodium hydroxide solution. $5.0\,cm^3$ of sodium hydroxide was required for complete neutralisation.

What was the original mass of magnesium carbonate used, in mg?

(M_r value: $MgCO_3 = 84$)

A 42 mg

B 84 mg

C 168 mg

D 210 mg

E 336 mg

F 420 mg

57 A student mixed together $30.0\,cm^3$ of $3.0\,mol\,dm^{-3}$ hydrochloric acid and $20.0\,cm^3$ of $4.0\,mol\,dm^{-3}$ aqueous ammonia in an insulated container.

The initial temperatures of both solutions were $20.0\,°C$.

The maximum temperature observed was $40.0\,°C$.

Assume that the specific heat capacity of any aqueous solution is $4.0\,J\,g^{-1}\,°C^{-1}$ and that the density of the reaction mixture is $1.0\,g\,cm^{-3}$.

Using this information, what is the molar enthalpy change, in $kJ\,mol^{-1}$, for the reaction of hydrochloric acid and aqueous ammonia?

A $-4\,kJ\,mol^{-1}$

B $-20\,kJ\,mol^{-1}$

C $-25\,kJ\,mol^{-1}$

D $-30\,kJ\,mol^{-1}$

E $-44\,kJ\,mol^{-1}$

F $-50\,kJ\,mol^{-1}$

G $-75\,kJ\,mol^{-1}$

H $-100\,kJ\,mol^{-1}$

58 An oxide of nitrogen can be prepared by the reaction of copper with hot nitric acid.

The other products of the reaction are copper(II) nitrate and water.

0.060 mol of copper reacted exactly with 40.0 cm^3 of 4.00 mol dm^{-3} nitric acid.

What is the empirical formula of the oxide of nitrogen produced in the reaction?

A NO

B NO$_2$

C NO$_3$

D N$_2$O

E N$_2$O$_3$

F N$_2$O$_5$

59 One mole of an unsaturated hydrocarbon reacts with exactly one mole of bromine to form a compound that contains $\dfrac{6}{15}$ carbon, $\dfrac{1}{15}$ hydrogen and $\dfrac{8}{15}$ bromine by mass.
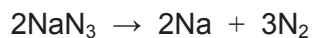
What is the relative molar mass (M_r) of this product?

(A_r values: C = 12; H = 1; Br = 80)

A 150

B 210

C 220

D 290

E 300

F 420

G 440

H 713

60 Airbags in cars contain sodium azide (NaN_3) as a primary reagent, and potassium nitrate (KNO_3) as a secondary reagent.

The sodium azide decomposes according to the following equation to form nitrogen gas, which rapidly fills the airbag:

$$2NaN_3 \rightarrow 2Na + 3N_2$$

The sodium by-product of this first reaction then reacts with excess potassium nitrate according to this second equation:

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

Assume that both reactions go to completion.

An airbag contains 130 g of sodium azide.

What is the total volume of nitrogen gas formed in this airbag, measured at room temperature and pressure?

(A_r values: N = 14.0; Na = 23.0. Assume that one mole of gas occupies 24.0 dm^3 at room temperature and pressure.)

A   72.0 dm^3

B   76.8 dm^3

C   84.0 dm^3

D   89.6 dm^3

E   96.0 dm^3

F   112 dm^3

G   120 dm^3

H   140 dm^3

PART D Biology

61   Which of the following is/are correct when a healthy human **breathes in**?

    1   The ribcage moves up and out because air enters the lungs.

    2   The volume of the thorax decreases and the thoracic pressure increases.

    3   Energy is required to contract the intercostal muscles but not the diaphragm.

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   1 and 3 only

G   2 and 3 only

H   1, 2 and 3

62   Which of the following statements about the cardiovascular system in a healthy individual is/are correct?

    1   When blood flow in the capillaries is restricted, the rate of oxygen exchanged with the tissues is reduced.

    2   Oxygen exchange from the blood in the arteries into the tissues is fast due to the high pressure of blood.

    3   Capillary walls contain a small amount of smooth muscle to constrict the vessels.

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   1 and 3 only

G   2 and 3 only

H   1, 2 and 3

63 The arrow in the diagram shows the net movement of molecule X out of a healthy mammalian cell.
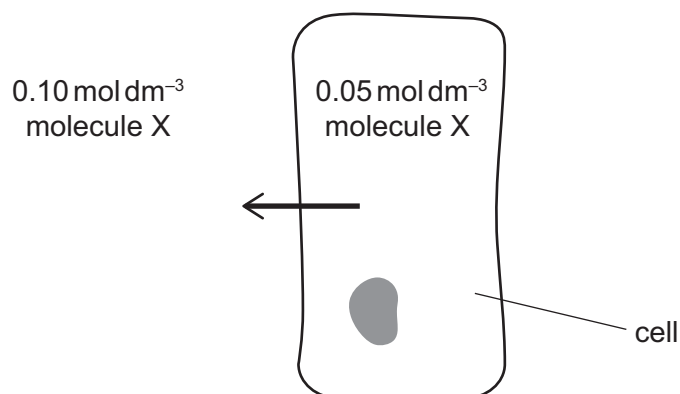
The maximum cell width is 10 µm. The cell membrane accounts for 0.2% of this width.

What is the width of a single cell membrane, in nm, and which process is represented by the arrow in the diagram?

	width of a single cell membrane / nm	*process represented by the arrow in the diagram*
A	0.01	diffusion
B	0.01	active transport
C	0.02	diffusion
D	0.02	active transport
E	10	diffusion
F	10	active transport
G	20	diffusion
H	20	active transport

64 Which one of the following comparisons is correct?

			comparison
A	alveoli	bronchi	both are tissues that are specialised for gas exchange
B	pancreas	ovary	both are organs that function as endocrine glands
C	phloem	xylem	both are organs that transport liquids from leaves to roots in plants
D	sensory neurone	motor neurone	both are tissues that are stimulated by a relay neurone
E	small intestine	trachea	both are organs that have tissues with cilia

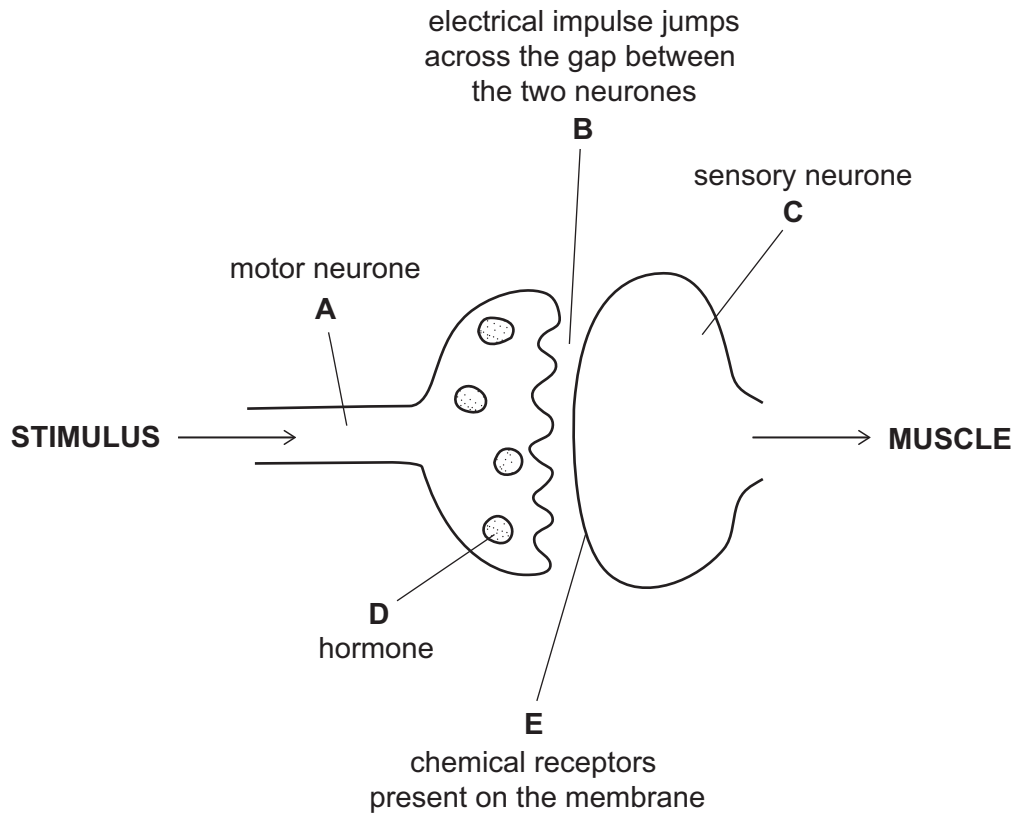**65** The graph shows the cumulative frequency for the heights of a group of 15-year-old students.
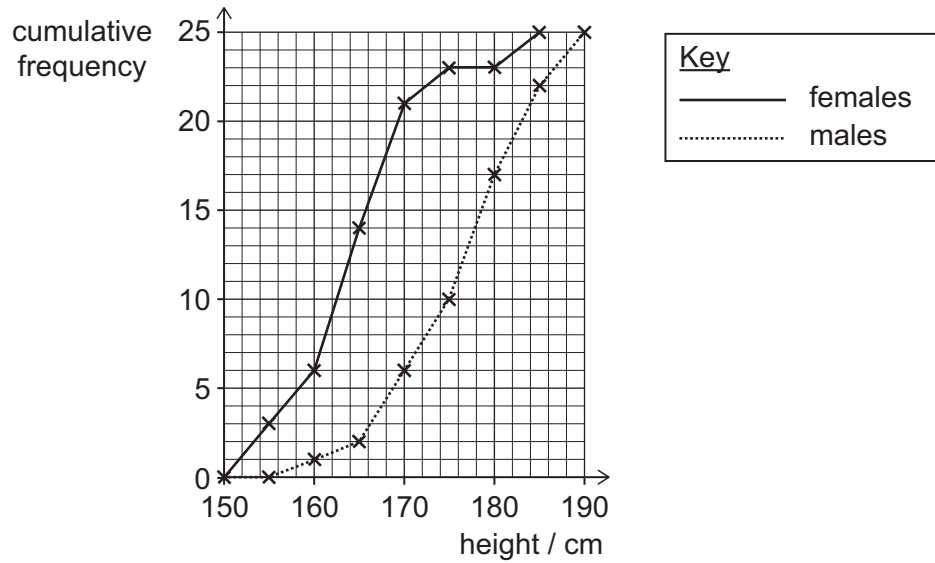
Which of the following statements is/are correct?

1 The difference between the mean heights of male and female students can be found by reading the difference in heights at a cumulative frequency of 12.5.

2 The difference in height between different males is explained by environmental factors alone.

3 The difference in the cumulative frequency graphs for males and females could be explained by a gene on the Y chromosome.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

66 When a person touches a hot object, they rapidly pull their hand away as a result of a reflex arc.

The diagram shows a student's drawing of part of this reflex arc.

Which label (**A**-**E**) is correct?

electrical impulse jumps
across the gap between
the two neurones
B

sensory neurone
C

motor neurone
A

STIMULUS ⟶

MUSCLE ⟶

D
hormone

E
chemical receptors
present on the membrane

67 A cell from a healthy animal was removed. This cell contained four times the mass of DNA when compared to a single gamete from the same animal.
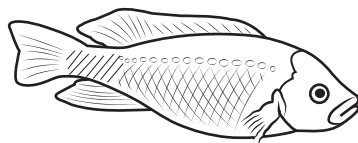
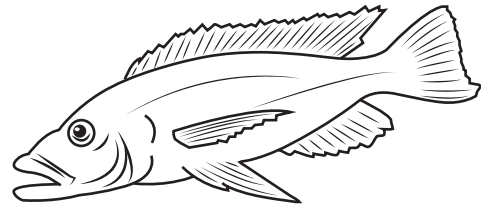Which of the following statements could be correct?

1 The cell was just about to start meiosis.

2 The cell was just about to start mitosis.

3 The cell had just started meiosis.

4 The cell had just started mitosis.

A 1 only

B 2 only

C 1 and 2 only

D 1 and 3 only

E 2 and 3 only

F 2 and 4 only

G 1, 2, 3 and 4

68 Many different species of cichlid fish have evolved from a common ancestor. The drawing shows some of the species that have evolved in Lake Victoria in Africa.
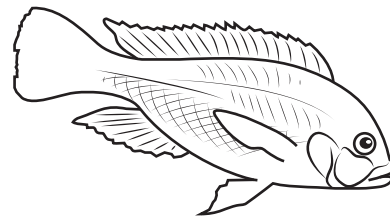
Haplochromis chilotes
(feeds on insects)
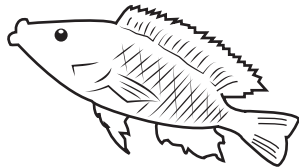
Haplochromis macrognathus
(feeds on other fish)

Astatotilapia elegans
(generalised bottom feeder)

Macropleurodus bicolor
(feeds on snails and other molluscs)

Which of the following statements about evolution of the cichlid fish is/are correct?

1 Different food types being available caused mutations in the DNA of the ancestral population of fish.

2 Natural selection was possible because there were multiple alleles of the genes affecting the traits shown in the diagram.

3 Natural selection of individuals with phenotypes best suited to different parts of the environment took place.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

69 The graph shows the number of live bacteria growing in a nutrient broth at 30 °C over 60 hours.
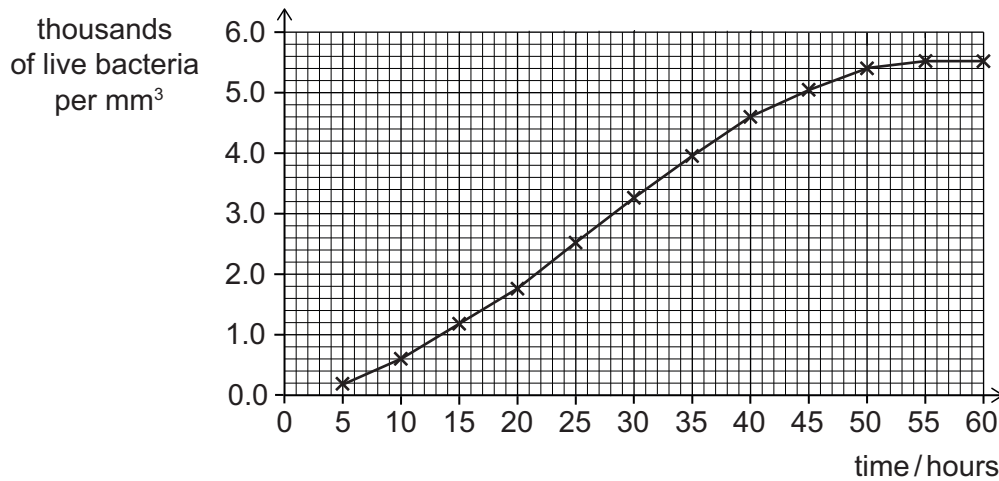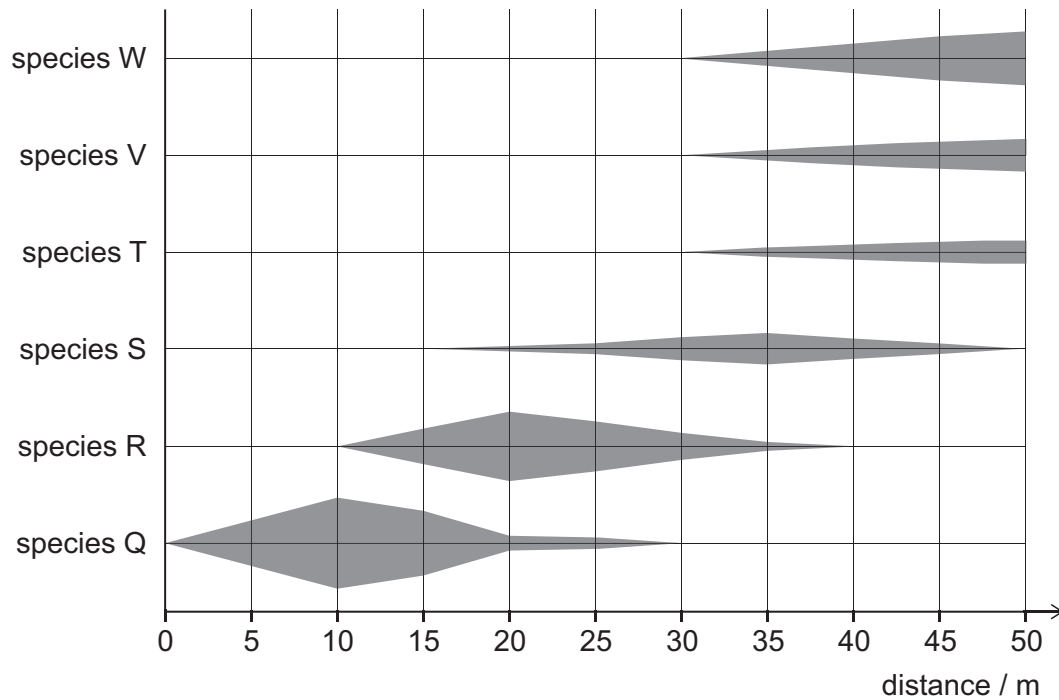

Which statement is correct?

A If there were no limiting factors, the number of live bacteria in the population would be directly proportional to time.

B At 40 hours, there are on average 4.6 live bacteria per mm^3.

C At 60 hours, the number of bacteria dying is greater than the number being produced.

D Some of the live bacteria in the population at 60 hours could be genetically different to the bacteria in the population at 5 hours.

E There is no limiting factor affecting the population of live bacteria over the 60 hour period.

70 Some students collected data using a belt transect on a beach and recorded the results in a kite diagram.

The shading represents the number of individuals present at each point along the belt transect. The wider the shading in the vertical direction, the larger the number of individuals present. The vertical scale is the same for all species. The six species shown were the only ones present.

Data was recorded every 5 m along the belt transect.

Which of the following statements is/are correct?

1 The sampling site with the highest number of different species is at 35 m.

2 The abundance of species T, V and W is the same.

3 At a distance of 5 m, species Q is the only species present.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

71 The effect of pH on the breakdown of starch by pancreatic amylase was investigated.

Starch and pancreatic amylase solution were mixed in test tubes, each at a different pH. The percentage of starch remaining after 5 minutes was recorded on the graph.

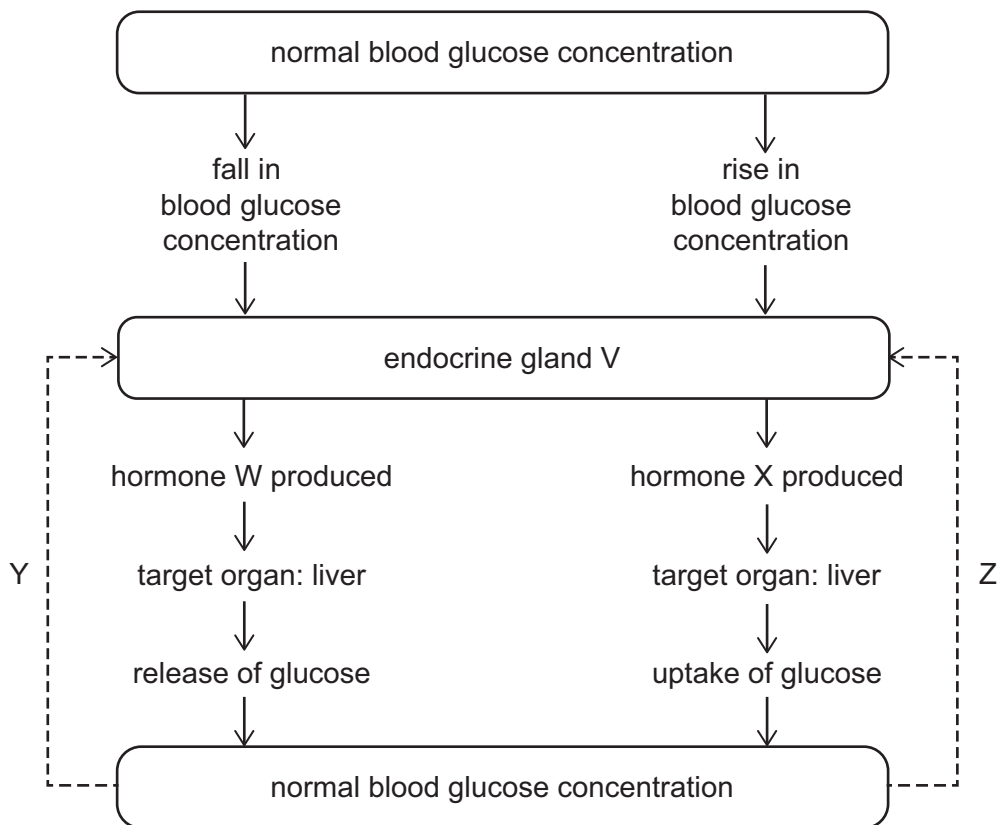All other variables were kept constant.
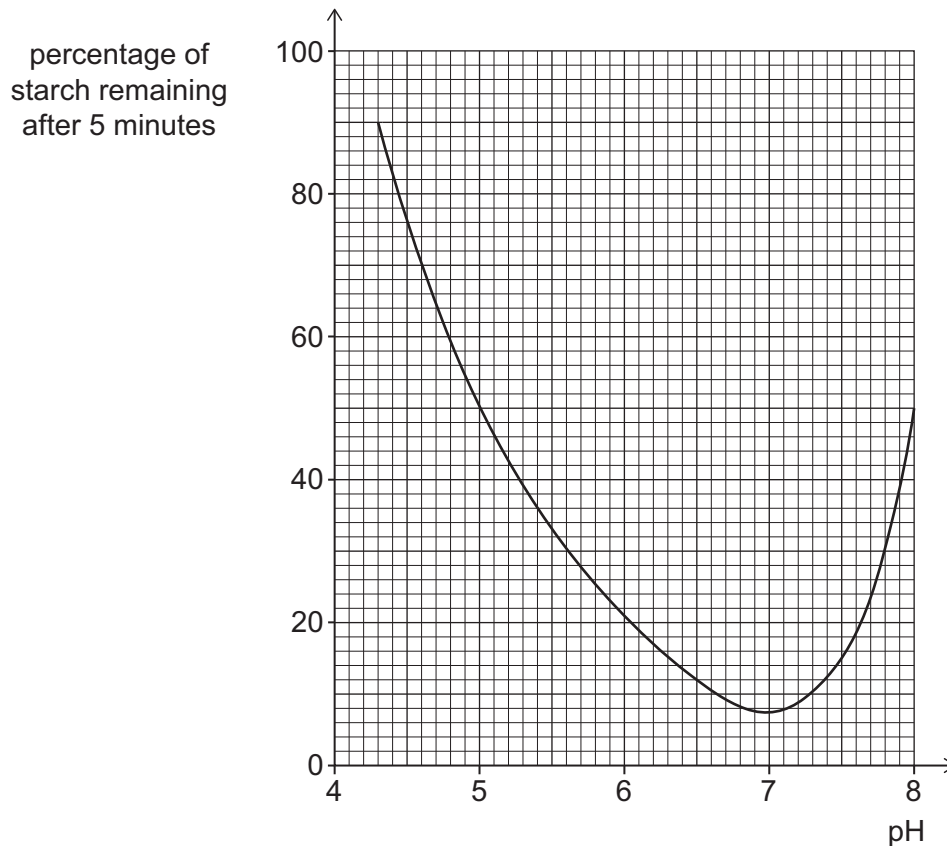
Using these results, which of the following conclusions could be correct?

1 During the 5 minutes, there are more enzyme–product complexes formed at pH 4.5 than at pH 6.

2 The shape of the enzyme is different at pH 5 compared to the shape at pH 7.

3 The optimum pH for this enzyme is approximately pH 7 under the conditions of this experiment.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

72 The diagram summarises the homeostatic control of blood glucose concentration.

normal blood glucose concentration

fall in
blood glucose
concentration

rise in
blood glucose
concentration

endocrine gland V

hormone W produced

hormone X produced

Y

target organ: liver

target organ: liver

Z

release of glucose

uptake of glucose

normal blood glucose concentration

Which row is correct?

	gland V	hormone W	hormone X	process Y	process Z
A	pancreas	adrenaline	insulin	nervous response	nervous response
B	pancreas	glucagon	insulin	negative feedback	negative feedback
C	pancreas	insulin	glucagon	negative feedback	negative feedback
D	pancreas	insulin	glucagon	nervous response	negative feedback
E	pituitary	adrenaline	ADH	negative feedback	nervous response
F	pituitary	ADH	glucagon	nervous response	negative feedback
G	pituitary	ADH	insulin	nervous response	nervous response
H	pituitary	glucagon	insulin	negative feedback	nervous response

73 The graph shows the rate of transpiration at different temperatures for a plant in its natural environment.
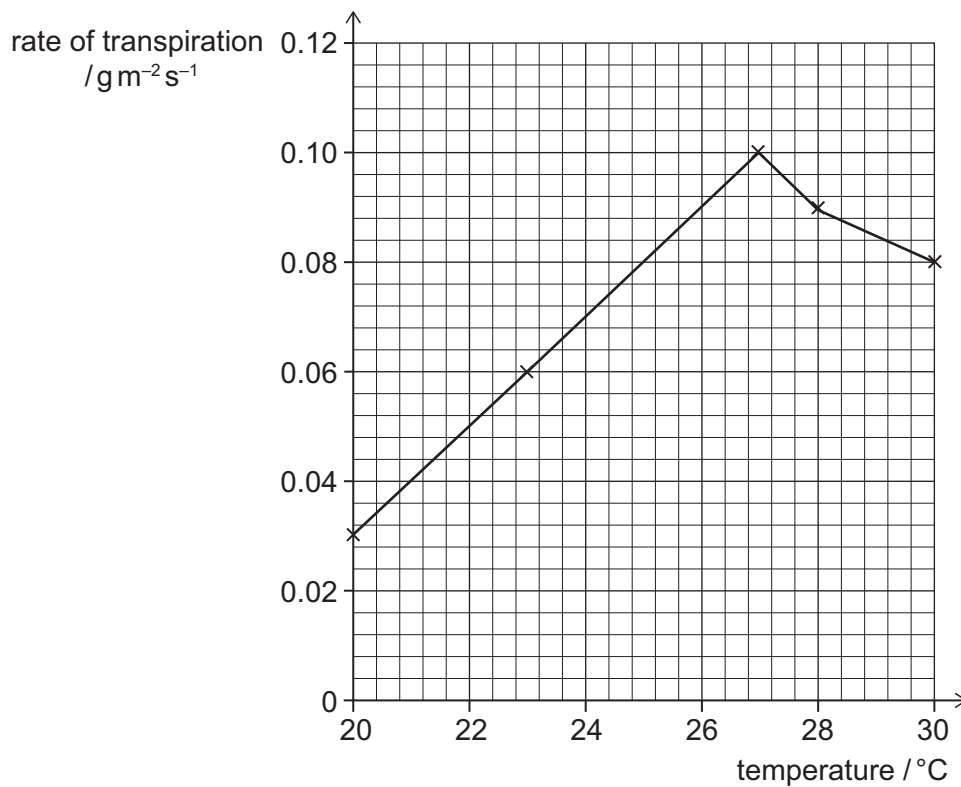
Which of the following statements is/are correct?

1 Stomata open when the guard cells lose water and become flaccid.

2 Between 20 °C and 27 °C, the humidity around the leaves must have decreased.

3 The air speed around the leaves could be higher at 23 °C than at 30 °C.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

74 An investigation was carried out to study the effect of protease concentration on the rate of breakdown of a protein into amino acids.

A protease solution of known concentration was diluted and used in each experiment, and all other variables were kept constant. The table shows the results.

| percentage concentration of protease	10	20	30	40	50	60	70
rate of reaction / arbitrary units	1.8	3.5	5.3	6.0	6.3	6.3	6.3

Which of the following statements is/are correct about this investigation?

1 Between concentrations of 10% and 40%, the rate of reaction has increased as more active sites are available.

2 Between concentrations of 50% and 70%, the enzyme concentration is the limiting factor.

3 At a protease concentration of 60%, the rate of reaction will be faster if substrate concentration is increased.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

75 Different samples of the same pond plant were kept underwater and exposed to five different colours of light at the same light intensity.

All other variables were kept constant.

The time taken for the plant to release 20 bubbles was recorded. The results are shown in the chart.

time taken in seconds for the release of 20 bubbles
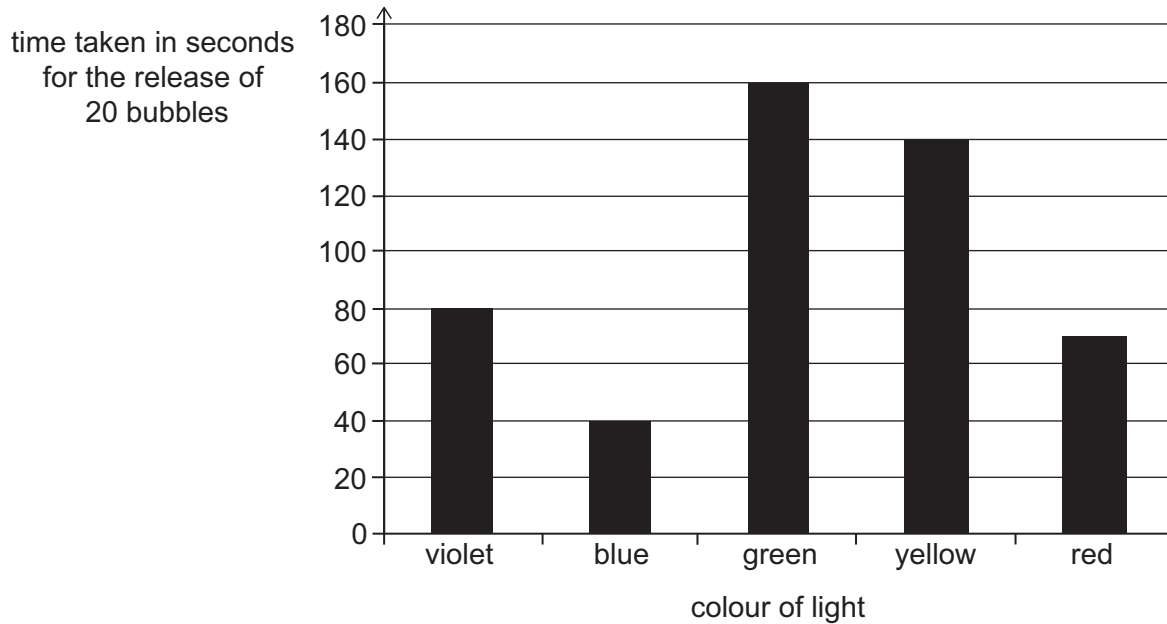
colour of light

Which of the following conclusions is/are correct?

1 This pond plant photosynthesises fastest when exposed to green light.

2 When exposed to any of these colours of light, this pond plant would release only oxygen.

3 When exposed to blue light, this pond plant produces 30 bubbles per minute.

A 1 only

B 2 only

C 3 only

D 1 and 2 only

E 1 and 3 only

F 2 and 3 only

G 1, 2 and 3

76 The diagram shows two sets of apparatus, P and Q, at the beginning of an investigation.
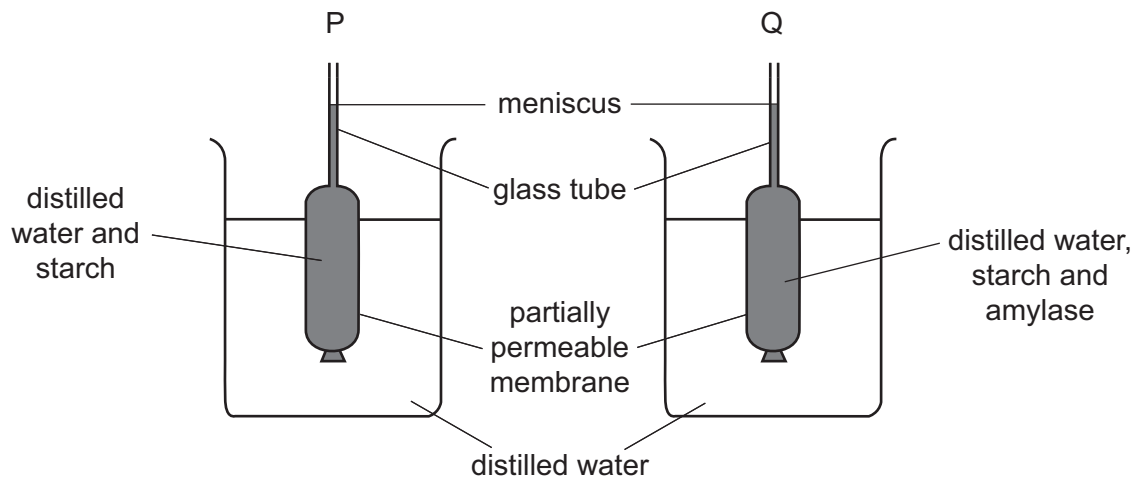
The only difference between P and Q was the contents of the partially permeable membrane.

The membrane is not permeable to starch or amylase but is permeable to smaller molecules.

After 10 minutes:

- the position of the meniscus in P had moved up the tube,
- the position of the meniscus in Q had moved down the tube.

Which of the following statements correctly explain(s) these observations?

1 Water moved by osmosis in P and Q.

2 Amylase was a substrate for starch.

3 Maltose was diffusing across the partially permeable membrane in Q, but not in P.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

77 Two flies, which were both heterozygous for a trait, mated and all their eggs were collected. The resulting offspring grew into young adult flies.

The trait is controlled by a single gene with one dominant allele and one recessive allele.

Which of the following statements, taken independently, could be correct for the young adult fly population?

1 If the presence of two dominant alleles for this trait stops eggs with this genotype from hatching, the genotypic ratio within the young adult fly population would be 1 : 1.

2 If the presence of two recessive alleles for this trait produces sterile individuals, all of the young adult fly population will have the same phenotype.

3 If the population of young adult flies is small, the phenotypic ratio would be 1 : 2 : 1.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

78 The diagram shows part of the process of sperm production in a healthy human male. Only one pair of the 23 pairs of homologous chromosomes is shown.
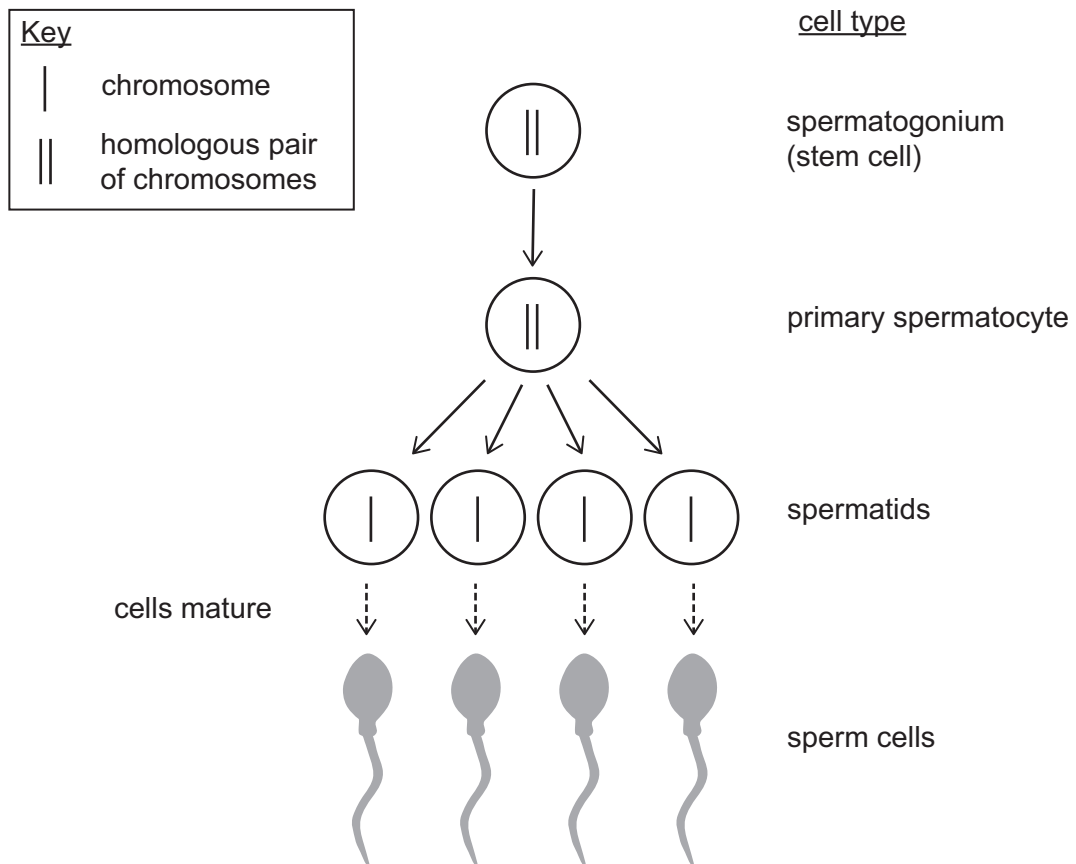
Which of the following statements is/are correct?

1 Gametes are produced from haploid stem cells.

2 Upon fertilisation, it is the male gamete that would determine the sex of the offspring.

3 DNA in the primary spermatocyte is copied before the spermatids are made.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

79 The graph shows the effect of increasing light intensity on the net rate at which a plant releases oxygen into the atmosphere.
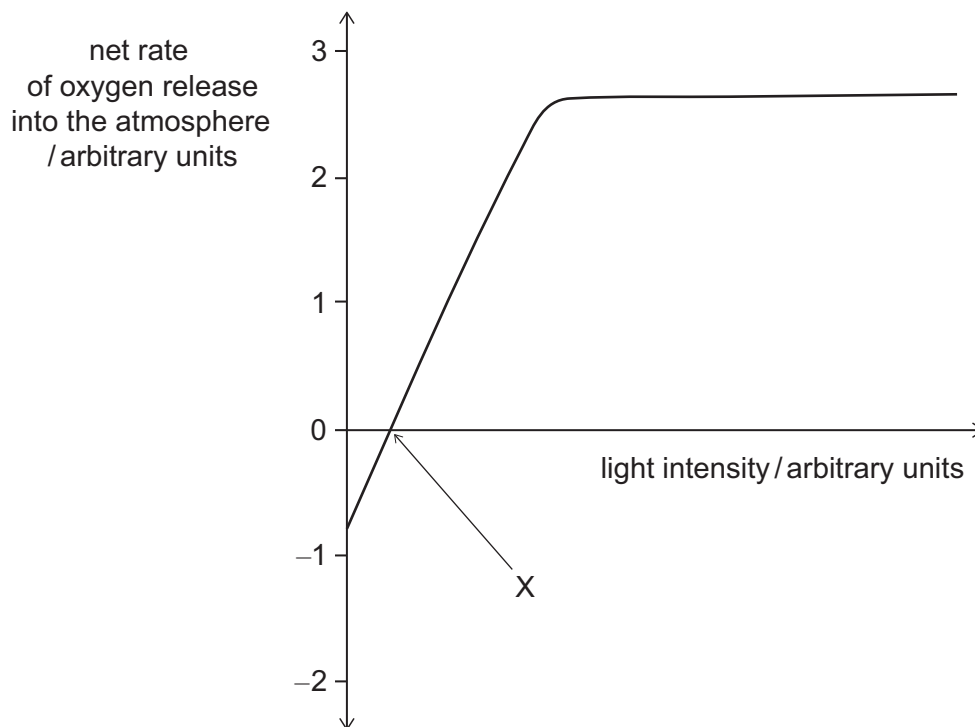
Which of the following could explain why the net rate of oxygen release at point X is zero?

1 The light intensity is too low to produce oxygen through photosynthesis.

2 All of the stomata will be closed at this light intensity, preventing the release of oxygen.

3 The rate of oxygen release from photosynthesis is equal to the rate of oxygen use in respiration.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

80 Two parents are heterozygous for a recessive condition that is controlled by a single autosomal gene with one dominant and one recessive allele. They have a daughter who does not display the condition.

This daughter has a child with a heterozygous man.

What is the probability that this child displays the condition?

(Assume no mutations.)

A $\dfrac{1}{12}$

B $\dfrac{1}{8}$

C $\dfrac{1}{6}$

D $\dfrac{3}{4}$

E $\dfrac{11}{12}$

UNIVERSITY OF CAMBRIDGE

Candidate number

N

Centre number

Date of birth (DD MM YYYY)

First Name(s)

Surname / Family name

Fill in the appropriate circle for your chosen answer e.g.

A B C D E
○ ● ○ ○ ○

Use a soft pencil. If you make a mistake, erase thoroughly and try again.

ALL candidates must complete Part A and attempt ONE of parts B, C, and D.

Part A: Mathematics

1	A B C D E F	11	A B C D E F G H
2	A B C D E	12	A B C D E
3	A B C D E F G H	13	A B C D E F G H
4	A B C D E	14	A B C D E F
5	A B C D E F G	15	A B C D E F
6	A B C D E F G	16	A B C D E F
7	A B C D E F G	17	A B C D E F G
8	A B C D E	18	A B C D E F G
9	A B C D E F	19	A B C D E F G H
10	A B C D E F G H	20	A B C D E F G

21772

Candidate number

N ☐ ☐ ☐ ☐ ☐

N

Attempt any ONE of parts B, C, and D.

Part B: Physics

21	A B C D E F G H	26	A B C D E F	31	A B C D E	36	A B C D E F
22	A B C D E F G H	27	A B C D E F	32	A B C D E	37	A B C D E F
23	A B C D E F	28	A B C D E F G H	33	A B C D E F G H	38	A B C D E F
24	A B C D E F G H	29	A B C D E F	34	A B C D E F	39	A B C D E
25	A B C D E F	30	A B C D E F	35	A B C D E	40	A B C D E

Part C: Chemistry

41	A B C D E F G H	46	A B C D E F G	51	A B C D E F	56	A B C D E F
42	A B C D E	47	A B C D E F G H	52	A B C D E F	57	A B C D E F G H
43	A B C D E	48	A B C D E F	53	A B C D E F G H	58	A B C D E F
44	A B C D E F G H	49	A B C D E F G H	54	A B C D E	59	A B C D E F G H
45	A B C D E F G H	50	A B C D E F G H	55	A B C D E F	60	A B C D E F G H

Part D: Biology

61	A B C D E F G H	66	A B C D E	71	A B C D E F G H	76	A B C D E F G H
62	A B C D E F G H	67	A B C D E F G	72	A B C D E F G H	77	A B C D E F G H
63	A B C D E F G H	68	A B C D E F G H	73	A B C D E F G H	78	A B C D E F G H
64	A B C D E	69	A B C D E	74	A B C D E F G H	79	A B C D E F G H
65	A B C D E F G H	70	A B C D E F G H	75	A B C D E F G	80	A B C D E

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UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES **D568/12**
ADMISSIONS ASSESSMENT

2022 **60 minutes**

SECTION 2

INSTRUCTIONS TO CANDIDATES

Please read these instructions carefully, but do not open this question paper until you are told that you may do so. This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains **three** parts: **X**, **Y** and **Z**.

All candidates should complete only **one** part chosen from:

Part X Physics
Part Y Chemistry
Part Z Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions in your chosen part. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

A Periodic Table is included.

Dictionaries and calculators are NOT permitted.

Please wait to be told you may begin before turning this page.

This question paper consists of 69 printed pages and 7 blank pages.

PV2

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Paper content

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Periodic Table

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1																		He 2
Li 3	Be 4												B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12												Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20		Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38		Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56		Lanthanoids 57-71	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88		Actinoids 89-103	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118

symbol
atomic number

Lanthanoids	La 57	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Actinoids	Ac 89	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

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PART X Physics

1   The diagram shows an object of mass 2.4 kg on a smooth horizontal surface.
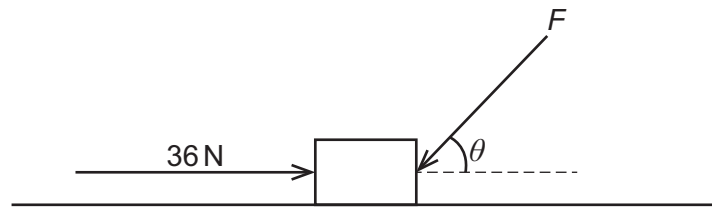
A force F acts on the object at an acute angle θ to the horizontal, where $\tan\theta = \dfrac{4}{3}$.

A force of 36 N acts on the object towards the right.

The object is in equilibrium.
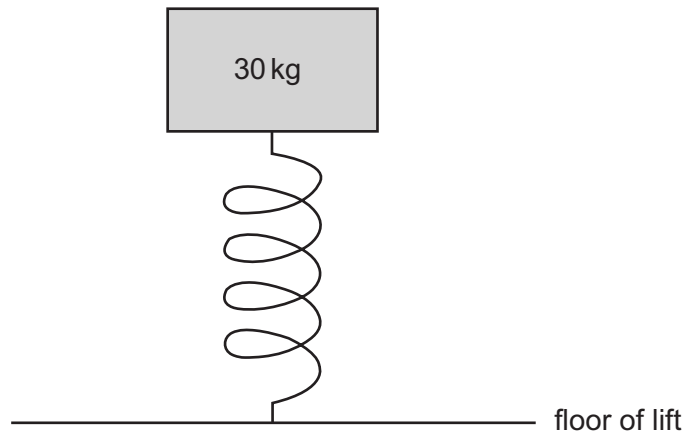
What is the magnitude of the normal contact force exerted on the object by the surface?

(gravitational field strength $= 10\,\text{N}\,\text{kg}^{-1}$)

A   24 N

B   27 N

C   48 N

D   51 N

E   72 N

F   75 N

2 The length of a spring when no force acts on it is L. The spring constant of the spring is $3.0 \times 10^3\,\text{N}\,\text{m}^{-1}$.

The spring is on the floor of an accelerating lift (elevator), and the spring supports a 30 kg mass.

The lift is accelerating downwards at $2.0\,\text{m}\,\text{s}^{-2}$.

What is the difference between L and the length of the spring when the lift is accelerating downwards?

(gravitational field strength $= 10\,\text{N}\,\text{kg}^{-1}$; the spring obeys Hooke's law)

A 0 cm

B 2.0 cm

C 8.0 cm

D 10 cm

E 12 cm

3 Electrical energy is transmitted at high voltage to a remote farm using an overhead power cable. Each of the two wires in the cable has a resistance of $2.5\,\Omega$. The step-down transformer in the farm has a voltage ratio of 5.0. The transformer is ideal and 100% efficient. It supplies a power of 40 kW to a resistive load at the farm at a voltage of 250 V.

What is the rate at which electrical energy is transferred to thermal energy in the overhead cable?

A   1.28 kW

B   2.56 kW

C   5.12 kW

D   32 kW

E   64 kW

F   128 kW

4 A wave is passing through a medium.

A particle of the medium has zero displacement from its equilibrium position at 0.12 s intervals, and at no other times.

The wavelength of the wave is greater than 10.0 m.

Two points are 5.0 m apart along the direction of travel of the wave.

The phase difference between the particles at the two points at the same instant is $\dfrac{\pi}{3}$ radians.

What is the speed of the wave?

A $1.8\,\text{m}\,\text{s}^{-1}$

B $3.6\,\text{m}\,\text{s}^{-1}$

C $7.2\,\text{m}\,\text{s}^{-1}$

D $62.5\,\text{m}\,\text{s}^{-1}$

E $125\,\text{m}\,\text{s}^{-1}$

F $250\,\text{m}\,\text{s}^{-1}$
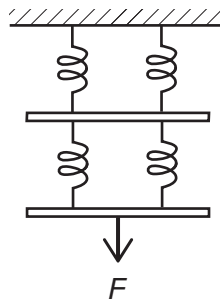
5 Three light springs, P, Q and R, are identical.

Springs P and Q are connected in series as shown. A downwards force T is applied to the lower end.
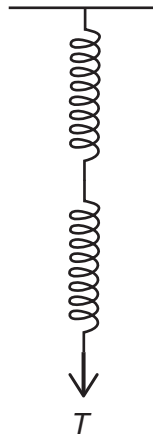
Spring R is cut into four equal lengths, and the four pieces arranged symmetrically as shown. The two connecting bars have negligible mass. A downwards force F is applied to the centre of the lower bar.

The total extensions of the two systems are equal. The springs obey Hooke's law.
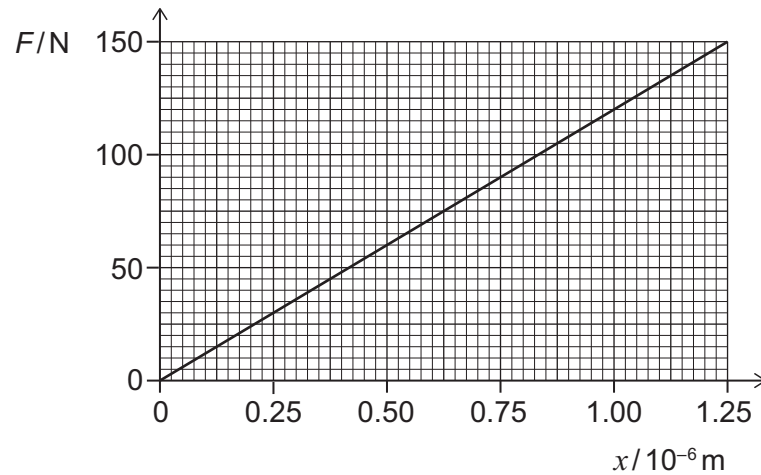
Which expression gives T in terms of F?

A $\dfrac{F}{16}$

B $\dfrac{F}{8}$

C $\dfrac{F}{4}$

D $\dfrac{F}{2}$

E $2F$

F $4F$

G $8F$

H $16F$

6 A nylon cube resting on a horizontal surface has a volume of $64\,\text{cm}^3$.

A force F is applied vertically downwards on the top face of the cube so that it compresses the height by x.

The graph shows the variation of F with x.

What is the Young modulus of the nylon?

(Assume that changes in horizontal cross-sectional area are negligible.)

A $7.7 \times 10^3\,\text{Pa}$

B $4.8 \times 10^6\,\text{Pa}$

C $9.6 \times 10^6\,\text{Pa}$

D $1.2 \times 10^8\,\text{Pa}$

E $1.5 \times 10^9\,\text{Pa}$

F $3.0 \times 10^9\,\text{Pa}$

G $1.9 \times 10^{12}\,\text{Pa}$

7 Five lampposts alongside a straight road are positioned at uniform intervals of 60 m.

A motorbike travelling at a constant velocity passes the first lamppost at time $t = 0$ s. It passes the fifth lamppost at $t = 20$ s.

A car travelling in the same direction as the motorbike is accelerating at $6.0\,\mathrm{m\,s^{-2}}$. At time $t = 0$ s the car passes the first lamppost at a velocity of $3.0\,\mathrm{m\,s^{-1}}$.

At what time t does the car overtake the motorbike?

A 1.5 s

B 2.0 s

C 2.5 s

D 3.0 s

E 3.5 s

F 4.0 s

G 5.0 s

8 An electrical appliance has an input power P which is a function of time t during the first 10 seconds after it is switched on.

This function is

$$P = 3t^2 + 4t$$

where P is in watts and t is in seconds.

The appliance is switched on at time $t = 0$.

The appliance has a constant efficiency of 90%.

What is the energy **wasted** by the appliance during the period $t = 2.0\,\text{s}$ to $t = 3.0\,\text{s}$ after it is switched on?

A 0.60 J

B 0.70 J

C 1.9 J

D 2.9 J

E 4.5 J

F 17 J

G 26 J

H 41 J

9 A solid cylinder is made of transparent glass of refractive index $\dfrac{2}{\sqrt{3}}$. It is surrounded by air.

A ray of light travelling in air hits the cylinder at the centre of one circular face at a non-zero angle θ to the normal, and refracts as it enters the cylinder.

The ray then strikes the curved surface of the cylinder at an angle of incidence equal to the critical angle.

What is the value of θ?

A $\sin^{-1}\dfrac{\sqrt{3}}{4}$

B $\sin^{-1}\dfrac{1}{\sqrt{3}}$

C $\sin^{-1}\dfrac{2}{\sqrt{6}}$

D $\sin^{-1}\dfrac{\sqrt{3}}{2}$

E $\sin^{-1}1$

10 An object of mass 20 kg is acted on by a force that varies in magnitude during the time interval $t = 0$ s to $t = 1.0$ s.

The force causes the object's displacement x to change with time t according to the relationship

$$x = -t^3 - 3t^2 + 4$$

where x is in metres and t is in seconds.

What is the magnitude of the impulse on the object over this time interval?

A 2.8 kgms^{-1}

B 9.0 kgms^{-1}

C 55 kgms^{-1}

D 80 kgms^{-1}

E 100 kgms^{-1}

F 180 kgms^{-1}

11 Two small hard spheres of mass m and $2m$ are suspended side by side from light vertical strings of length l. The more massive sphere is raised so that its string is horizontal, and then released. It swings through 90° and strikes the smaller sphere. The two spheres stick together, and rise to a maximum height h as shown in the diagram.
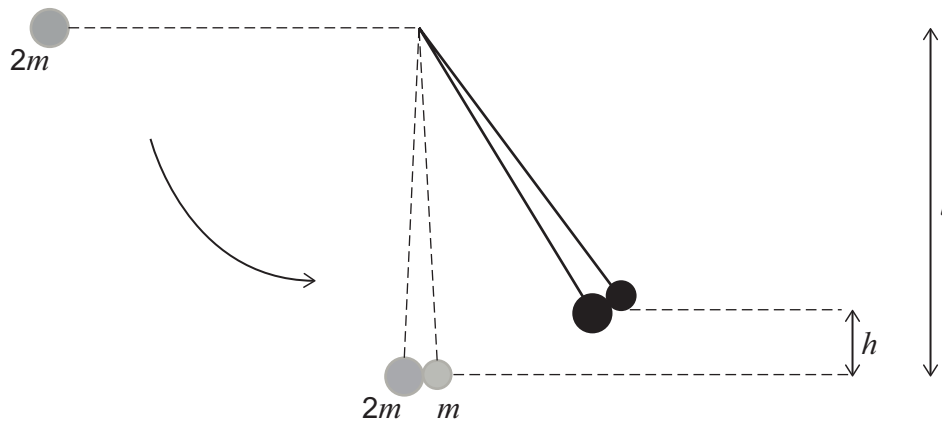
[diagram not to scale]

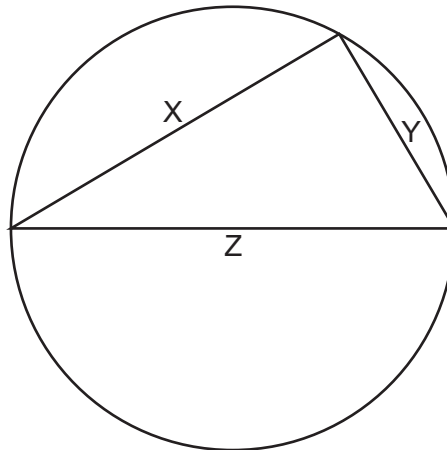Which expression gives the height h in terms of l?

(Assume that air resistance is negligible.)

A $\dfrac{4l}{27}$

B $\dfrac{8l}{27}$

C $\dfrac{4l}{9}$

D $\dfrac{2l}{3}$

E $\dfrac{8l}{9}$

F l

G $2l$

12 Three resistance wires X, Y and Z, made from the same metal, are connected to each other and to a circular plastic ring as shown.

[diagram not to scale]

Wires X and Y each have twice the diameter of wire Z.

Wire X is 12 cm long. Wire Z is 15 cm long and is connected across a diameter of the ring.

A power supply is connected to the two corners of the triangle that lie on the diameter.

What is the value of the ratio

$$\frac{\text{current in X}}{\text{current in Z}} \,?$$

A $\dfrac{1}{5}$

B $\dfrac{7}{20}$

C $\dfrac{7}{10}$

D $\dfrac{5}{7}$

E $\dfrac{7}{5}$

F $\dfrac{10}{7}$

G $\dfrac{20}{7}$

H 5

13 A light rope has cross-sectional area $6.0 \times 10^{-8}\,\text{m}^2$ and unstretched length $0.24\,\text{m}$.

The rope is fixed horizontally between two supports that are $0.24\,\text{m}$ apart.

When a $1.0\,\text{kg}$ mass is suspended from the middle of the rope, the vertical displacement of the middle of the rope from its original position is $0.050\,\text{m}$.

The rope obeys Hooke's law. Assume that changes in cross-sectional area are negligible.

What is the Young modulus of the material from which the rope is made?

(gravitational field strength $= 10\,\text{N}\,\text{kg}^{-1}$)

A $5.2 \times 10^8\,\text{N}\,\text{m}^{-2}$

B $8.0 \times 10^8\,\text{N}\,\text{m}^{-2}$

C $1.0 \times 10^9\,\text{N}\,\text{m}^{-2}$

D $1.3 \times 10^9\,\text{N}\,\text{m}^{-2}$

E $2.0 \times 10^9\,\text{N}\,\text{m}^{-2}$

F $2.6 \times 10^9\,\text{N}\,\text{m}^{-2}$

G $5.2 \times 10^9\,\text{N}\,\text{m}^{-2}$

14 The three graphs show the displacement, velocity and acceleration against time for an object moving in a straight line.

The time axis is shown to the same scale on all three graphs.
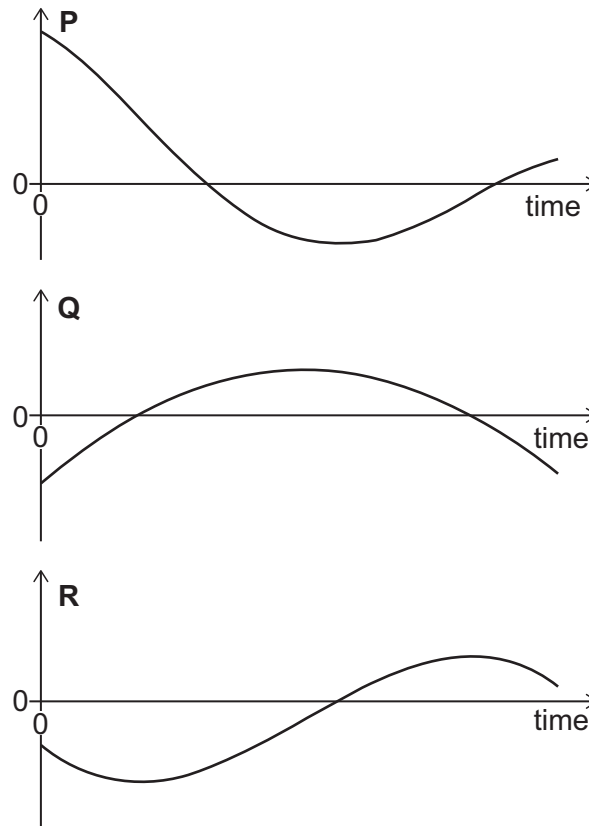
Which graph represents which quantity?

	graph P	graph Q	graph R
A	acceleration	displacement	velocity
B	acceleration	velocity	displacement
C	displacement	acceleration	velocity
D	displacement	velocity	acceleration
E	velocity	acceleration	displacement
F	velocity	displacement	acceleration

15 A system of light springs that does not obey Hooke's law has an unstretched length of 2.0 m.

The extension x of the system is related to the force F applied to it by

$$F = px^2$$

where p is a constant.

A force of 2400 N increases the length of the system to 2.2 m.

How much work is done in increasing the length of the system from 3.0 m to 4.0 m?

A 1.2 kJ

B 60 kJ

C 70 kJ

D 120 kJ

E 140 kJ

F 740 kJ

16 The diagram shows a circuit that includes two batteries, each with negligible internal resistance.
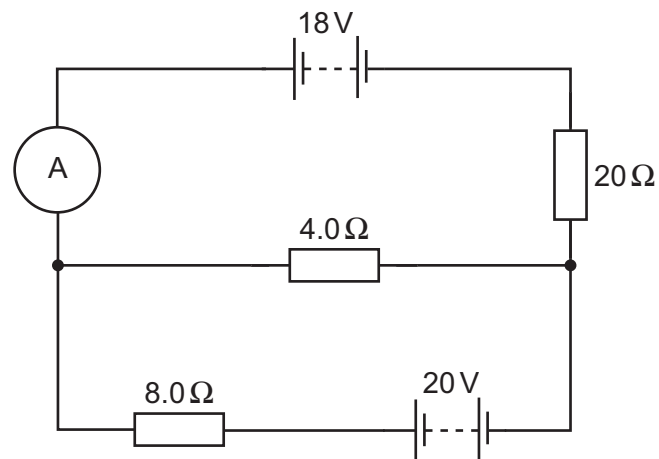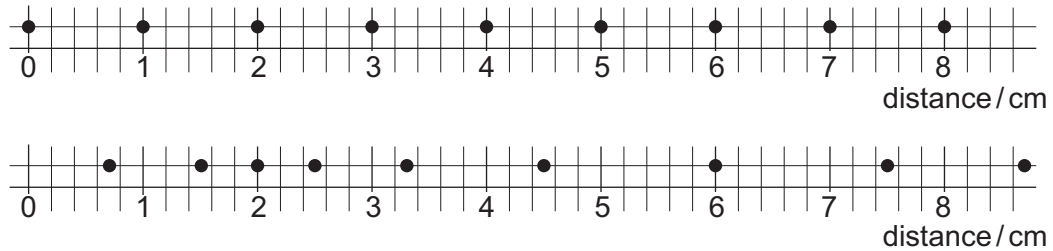

What is the reading on the ammeter?

A   0.0029 A

B   0.0071 A

C   0.063 A

D   0.083 A

E   0.50 A

F   0.65 A

G   1.2 A

H   2.0 A

17 The upper diagram shows the equilibrium positions of nine equally spaced particles in a medium.

The lower diagram shows the positions of the same nine particles when a longitudinal wave is travelling through the medium. The wave is shown at time $t = 0$, travelling to the right.

The frequency of the wave is 0.5 Hz.

Which graph represents the displacements of the particles at a later time $t = 0.5$ s?

(On the graphs, positive displacement values represent particle displacements to the right.)
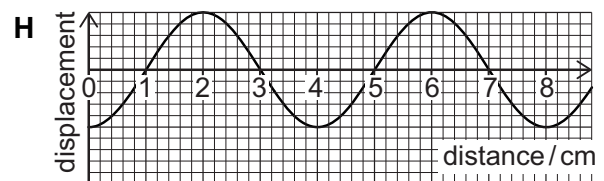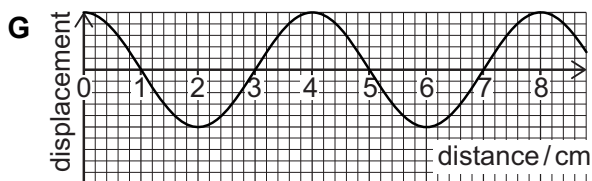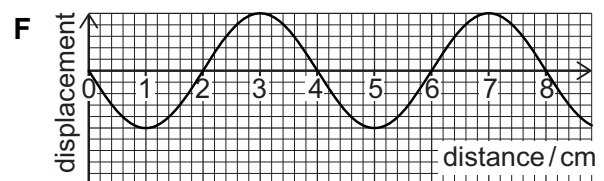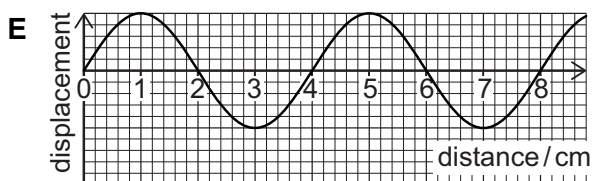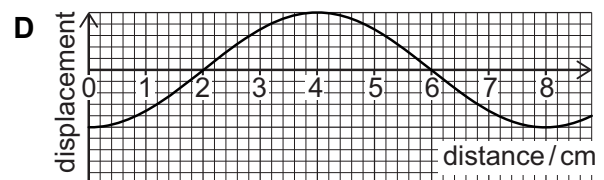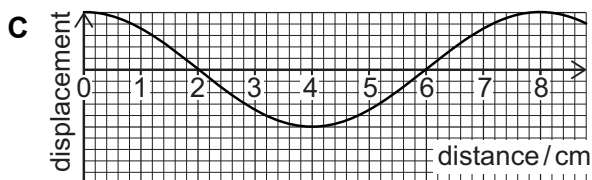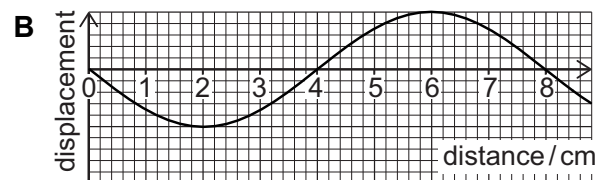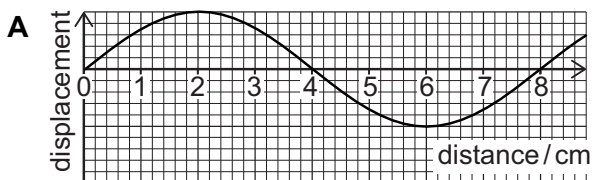
18 A power supply with constant emf and internal resistance r is connected to an external resistor.

The efficiency of the system is defined as

$$\text{efficiency} = \frac{\text{power dissipated by external resistor}}{\text{total power supplied by cell}}$$

Which graph shows how the efficiency varies with the resistance of the external resistor?

A

B

C

D

E

F
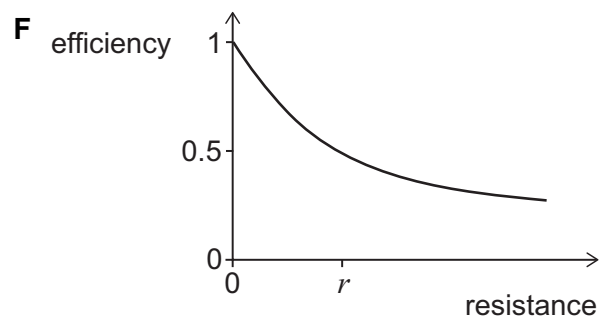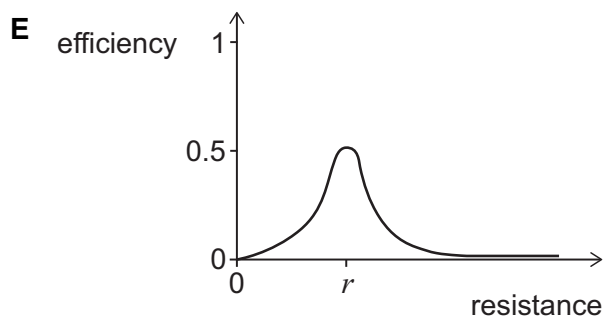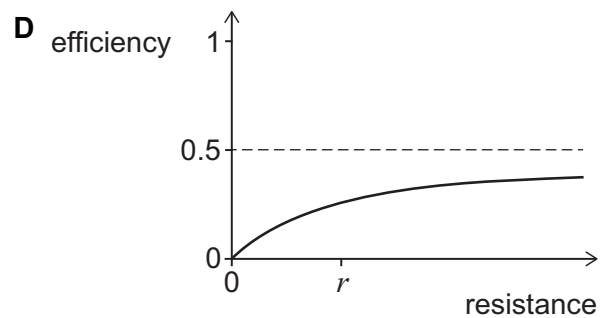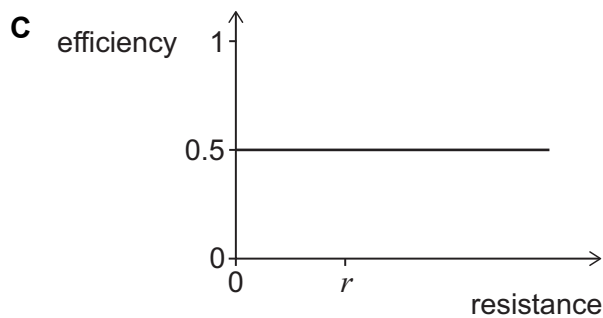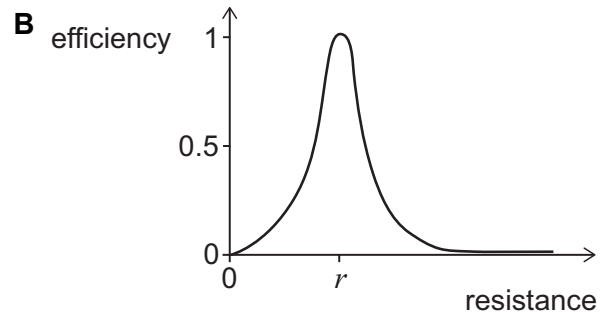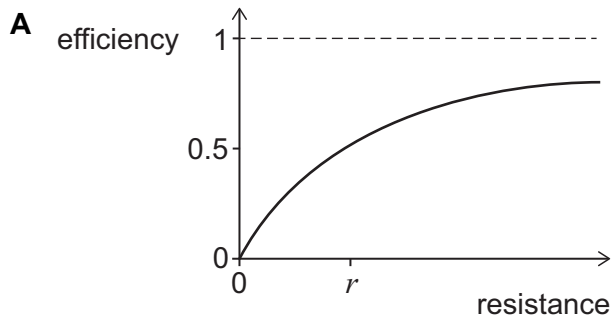
19 A 10 kg projectile is launched from ground level at an angle of 60° above the horizontal, with an initial speed of $12\,\text{m s}^{-1}$. The horizontal component of its velocity is to the right.

At the point during its flight when the vertical component of its velocity is zero, the projectile splits into two pieces, P and Q, each of mass 5 kg.

Immediately after the projectile splits, piece P has velocity $14\,\text{m s}^{-1}$ to the right.

What is the speed of piece Q immediately before it hits the ground?

(Assume that air resistance is negligible, and that the ground is horizontal.)

A $2\,\text{m s}^{-1}$

B $\sqrt{31}\,\text{m s}^{-1}$

C $6\sqrt{3}\,\text{m s}^{-1}$

D $4\sqrt{7}\,\text{m s}^{-1}$

E $2\sqrt{43}\,\text{m s}^{-1}$

F $4\sqrt{13}\,\text{m s}^{-1}$

G $4\sqrt{19}\,\text{m s}^{-1}$

H $2\sqrt{127}\,\text{m s}^{-1}$

20 The density ρ of a sphere varies from its centre to its surface according to the equation

$$\rho = \rho_0\left(1 - \frac{x}{2R}\right)$$

where x is the distance from its centre, R is its radius and ρ_0 is the density at its centre.

What is the mass of the sphere?

(the surface area of a sphere of radius x is equal to $4\pi x^2$)

A $\dfrac{2\pi R^3 \rho_0}{3}$

B $\dfrac{5\pi R^3 \rho_0}{6}$

C $\dfrac{8\pi R^3 \rho_0}{9}$

D $\pi R^3 \rho_0$

E $\dfrac{29\pi R^3 \rho_0}{24}$

F $\dfrac{19\pi R^3 \rho_0}{15}$

G $\dfrac{4\pi R^3 \rho_0}{3}$

H $2\pi R^3 \rho_0$

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PART Y Chemistry

21 In this question, consider only the elements potassium, rubidium, calcium, strontium, bromine and iodine. Assume that there are similar trends in physical properties in Periods 4 and 5 as there are in Periods 2 and 3.

Consider the enthalpy change for the process:

$$X(g) + e^- \rightarrow X^-(g)$$
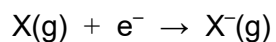
The element for which this process is most exothermic reacts with the metal with the highest first ionisation energy.

What is the relative molar mass (M_r) of the product from this reaction?

(A_r values: K = 39; Rb = 86; Ca = 40; Sr = 88; Br = 80; I = 127)

A 119

B 120

C 166

D 200

E 213

F 248

G 294

H 342

PART Y CHEMISTRY

22 The following diagram gives the mass spectra of samples of the elements gallium (Ga) and chlorine (Cl).
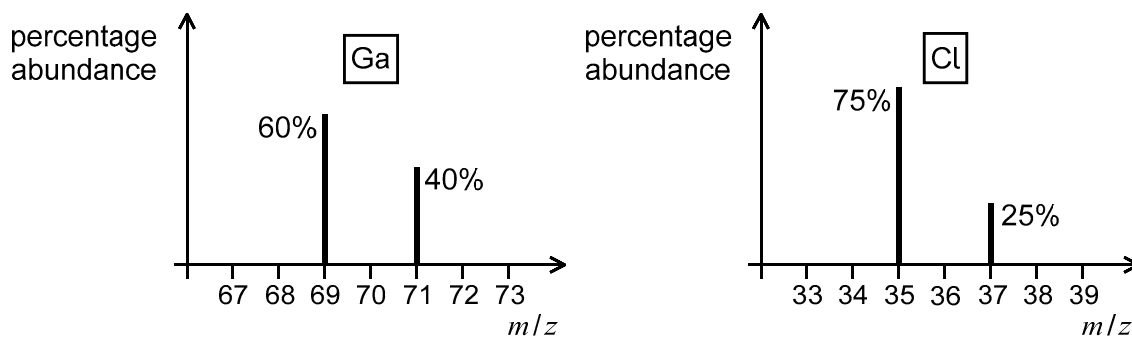
Gaseous gallium chloride has a formula of $GaCl_3$.

The mass spectrum of gallium chloride shows peaks at different mass-to-charge ratio (m/z value).

What is the abundance ratio of the molecular ion $GaCl_3^+$ with the largest m/z value to the smallest m/z value?

A $2:9$

B $2:16$

C $2:36$

D $2:54$

E $2:81$

23 4.00 g of bromine reacts with excess fluorine at temperatures over 150 °C to form 8.75 g of compound X only. The molecular formula of X is the same as the empirical formula.

Using the VSEPR model, what is the smallest bond angle in compound X?

(A_r values: Br = 80; F = 19)

A 120°

B in the range 114°-119°

C 109.5°

D in the range 104°-109°

E 90°

F in the range 84°-89°

24 An aqueous solution of NaCl is added to an aqueous solution containing the complex ion $Fe(H_2O)_6^{3+}$ and an equilibrium is established:

$$Fe(H_2O)_6^{3+}(aq) + 4Cl^-(aq) \rightleftharpoons FeCl_4^-(aq) + 6H_2O(l)$$
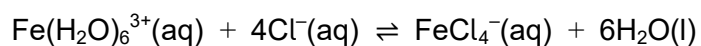
The concentration of Cl^- in the equilibrium mixture is $2.0\,mol\,dm^{-3}$.

The numerical value of the equilibrium constant, K_c, is 0.05.

The expression for K_c does not include the solvent.

What is the ratio of the concentrations $[FeCl_4^-] : [Fe(H_2O)_6^{3+}]$ in the equilibrium mixture?

(All concentrations are in $mol\,dm^{-3}$.)

A 4:5

B 5:4

C 1:10

D 10:1

E 1:320

F 320:1

25 When organic compounds are treated with an alkaline aqueous solution of iodine, a yellow precipitate is formed by those compounds that contain either of these structural fragments:

$$\underset{H_3C}{\overset{O}{\underset{}{\overset{\|}{C}}}}\!\!\!\diagdown\!\!\!\sim \quad \text{or} \quad \underset{H_3C}{\overset{H\quad OH}{\underset{}{C}}}\!\!\!\diagdown\!\!\!\sim$$
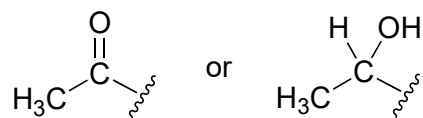
There are 8 structurally isomeric alcohols with the molecular formula $C_5H_{12}O$.

Each of these alcohols was heated under reflux with excess acidified potassium dichromate(VI).

How many of these alcohols gave a product that would form a yellow precipitate with an alkaline aqueous solution of iodine?

A   1

B   2

C   3

D   4

E   5

F   6

G   7

34

26 Calcium cyanamide is a compound containing calcium, carbon and nitrogen only. It contains 50% calcium by mass, and reacts with water to form ammonia and one other product that does not contain nitrogen or hydrogen.

One mole of calcium cyanamide contains one mole of calcium.

What volume of water, in cm^3, is required to react exactly with 8.0 g of calcium cyanamide?

(A_r values: H = 1; C = 12; N = 14; O = 16; Ca = 40. Density of water is $1.0\,g\,cm^{-3}$.)

A $1.8\,cm^3$

B $2.7\,cm^3$

C $3.6\,cm^3$

D $5.4\,cm^3$

E $18\,cm^3$

F $27\,cm^3$

G $36\,cm^3$

H $54\,cm^3$

27 ΔG (Gibbs free energy change), ΔH (enthalpy change) and ΔS (entropy change) are thermodynamic quantities for a reaction linked by the equation

$$\Delta G = \Delta H - T\Delta S$$

where T = temperature measured in kelvin (K).

The graph shows how ΔG, in $kJ\,mol^{-1}$, varies with temperature, in K, for a reaction at constant pressure.
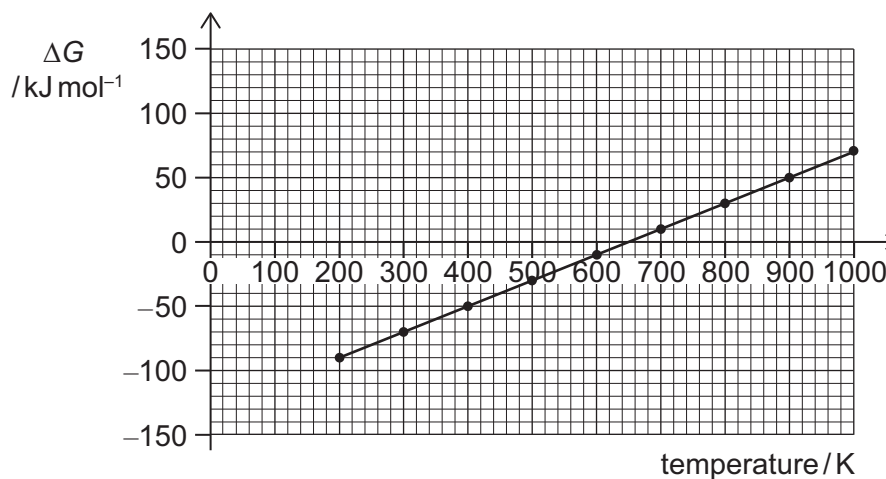
Is the reaction endothermic or exothermic, and what is the value of ΔS, in $J\,mol^{-1}\,K^{-1}$?

(Assume that ΔH and ΔS do not vary with temperature over this range.)

	the reaction is…	$\Delta S\,/\,J\,mol^{-1}\,K^{-1}$
A	endothermic	−0.20
B	endothermic	+0.20
C	endothermic	−200
D	endothermic	+200
E	exothermic	−0.20
F	exothermic	+0.20
G	exothermic	−200
H	exothermic	+200

28 The table gives information relating to the enthalpy change of formation of calcium chloride.

	enthalpy change / kJ mol^{-1}
$Ca(s) \rightarrow Ca(g)$	+190
$Ca(g) \rightarrow Ca^{+}(g) + e^{-}$	+590
$Ca^{+}(g) \rightarrow Ca^{2+}(g) + e^{-}$	+1150
$Cl_2(g) \rightarrow 2Cl(g)$	+240
$Cl(g) + e^{-} \rightarrow Cl^{-}(g)$	−360
$CaCl_2(s) \rightarrow Ca^{2+}(g) + 2Cl^{-}(g)$	+2240

Using the data provided, what is the enthalpy change of formation of calcium chloride?

A $+650 \, kJ \, mol^{-1}$

B $-430 \, kJ \, mol^{-1}$

C $-790 \, kJ \, mol^{-1}$

D $-910 \, kJ \, mol^{-1}$

E $-980 \, kJ \, mol^{-1}$

F $-1270 \, kJ \, mol^{-1}$

G $-1380 \, kJ \, mol^{-1}$

H $-1700 \, kJ \, mol^{-1}$

29 Copper metal reacts with aqueous iron(III) ions to form aqueous iron(II) ions and aqueous copper(II) ions.

Which of the following statements can be deduced about this reaction?

A Copper(II) ions are a stronger reducing agent than iron(II) ions.

B Copper(II) ions are a stronger oxidising agent than iron(III) ions.

C Iron(II) ions are a stronger reducing agent than copper metal.

D Copper metal is a stronger oxidising agent than iron(II) ions.

E Iron(III) ions are a stronger oxidising agent than copper(II) ions.

30 Heat loss is a problem in calorimetry experiments and can lead to inaccurate results. One way to address this problem is to carry out an experiment to find the heat capacity of the calorimeter (for example, 100 g of water in a copper can) using a reaction where the molar enthalpy change is known.

A student burned $m^{(\text{ethanol})}$ grams of ethanol (relative molar mass = $M_r^{(\text{ethanol})}$) in a burner and the temperature of the water in the calorimeter rose by $\Delta T^{(\text{ethanol})}$ in °C. The molar enthalpy of combustion of ethanol is $\Delta H^{(\text{ethanol})}$.

The student then burned $m^{(\text{propanol})}$ grams of propanol (relative molar mass = $M_r^{(\text{propanol})}$) in the burner using the same calorimeter and the temperature of the water rose by $\Delta T^{(\text{propanol})}$ in °C.

Which expression gives the molar enthalpy of combustion of propanol $\Delta H^{(\text{propanol})}$?

(All other conditions for these experiments were identical.)

A $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}$

B $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{propanol})}}$

C $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}$

D $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{propanol})}}$

E $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}$

F $\quad \Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}$

31 In an experiment to investigate diffusion, four separate identical flasks containing one of hydrogen, helium, nitrogen or neon are placed in a large cubic box filled with argon, each in a different corner. All gases, including the argon, are at atmospheric pressure.

The temperature of the box is uniform and remains constant throughout the experiment. Temperature is directly proportional to the average kinetic energy of the particles in a gas.

The stoppers of the flasks are removed simultaneously and the time is recorded when a fixed proportion of each gas reaches a detector at the centre of the box.

A second experiment is carried out under the same conditions but at a higher temperature.

(A_r values: H = 1.0; He = 4.0; N = 14; Ne = 20)

Which statement is correct?

A If hydrogen is detected in t minutes, then helium will be detected in $\sqrt{2}t$ minutes.

B The kinetic energy of every gas particle in the box will be the same at the same room temperature.

C The order in which the gases are detected at both temperatures is hydrogen, then helium, then nitrogen, and lastly neon.

D The average speed at which a helium particle travels is 5 times the speed at which an average neon particle travels.

E When the temperature of the box is increased, the average kinetic energy of the gases will decrease.

32 A high temperature reaction vessel requires a steady supply of an atmosphere free of oxygen, carbon monoxide and NO_x gases.

In order to achieve this, methane was burned in air to give a mixture of carbon dioxide, water vapour and nitrogen only.
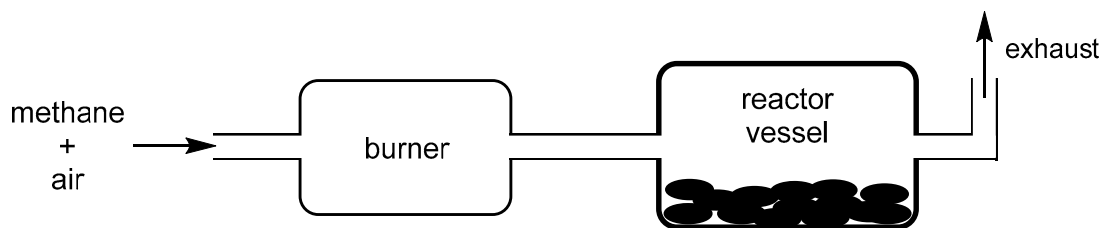
Assume that air is composed of 20% oxygen and 80% nitrogen only by volume.

What **mass** ratio of air to methane should be supplied to the burner?

(A_r values: H = 1; C = 12; N = 14; O = 16. Assume that one mole of any gas occupies the same volume at a given temperature and pressure.)

A 2:1

B 2.5:1

C 4.5:1

D 5:1

E 9:1

F 18:1

G 20:1

33 In preparation for the disposal of $500\,cm^3$ of $4\,mol\,dm^{-3}$ hydrochloric acid with a pH value of -0.6 (minus 0.6) into a drain, the following steps were taken:

step 1 The acid was diluted with $100\,dm^3$ water.

step 2 90 g of calcium carbonate powder was added which completely reacted.

step 3 The resulting solution was diluted with water to give a final volume of $500\,dm^3$.

What is the final pH value of the solution?

(M_r value: $CaCO_3 = 100$. All pH values were measured at the same temperature.)

A 2.9

B 3.4

C 3.6

D 4.4

E 4.6

F 5.4

G 6.0

H 7.0

34 Lutetium (Lu) is a metallic element which forms compounds in which lutetium always has the same oxidation state.

When 3.50 g of lutetium is heated and burned in excess oxygen, 360 cm^3 of oxygen, measured at room temperature and pressure, is needed for complete reaction to form lutetium oxide.

When 3.50 g of lutetium reacts completely with dilute sulfuric acid, hydrogen and aqueous lutetium sulfate are produced. The salt is extracted from solution and allowed to crystallise into a white solid.

The solid is a hydrated salt with a 1 : 1 molar ratio of water to salt.

What is the maximum mass of hydrated salt that could be made from 3.50 g of lutetium?

(A_r values: Lu = 175; S = 32; O = 16; H = 1. Assume that one mole of any gas occupies 24 dm^3 at room temperature and pressure.)

A 5.42 g

B 5.78 g

C 6.38 g

D 6.56 g

E 9.26 g

F 9.62 g

G 12.76 g

H 13.12 g

35 Sodium feredetate trihydrate and iron(II) sulfate can both be used to treat iron deficiency.

The formula for sodium feredetate trihydrate is:
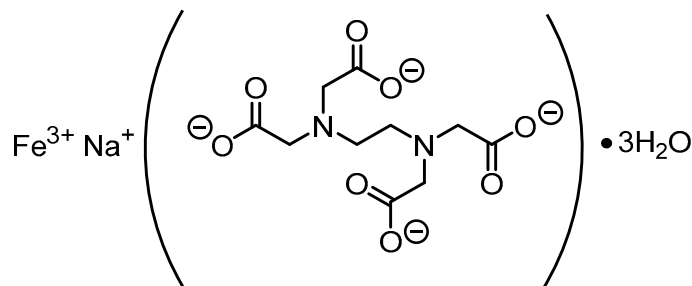
Sodium feredetate trihydrate is used as a solution. $5.00\,cm^3$ of this solution contains $210.5\,mg$ of sodium feredetate trihydrate.

Iron(II) sulfate is used in tablet form. One iron tablet contains $63.0\,mg$ of iron(II) ions.

What volume of sodium feredetate trihydrate solution would give the same mass of iron as one iron(II) sulfate tablet?

(A_r values: H = 1.0; C = 12; N = 14; O = 16; Na = 23; Fe = 56)

A $0.450\,cm^3$

B $2.25\,cm^3$

C $9.81\,cm^3$

D $10.29\,cm^3$

E $10.93\,cm^3$

F $11.25\,cm^3$

36 Three half-equations involved in the oxidation of ethanol to ethanoic acid are:

$$Cr_2O_7{}^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$CH_3CH_2OH \rightarrow CH_3CHO + 2e^- + 2H^+$$

$$CH_3CHO + H_2O \rightarrow CH_3COOH + 2e^- + 2H^+$$
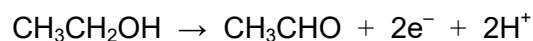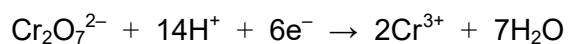
A flask contains 0.345 g of ethanol. An excess of dilute sulfuric acid is added to the flask.

A separate flask contains 0.200 mol dm^{-3} aqueous dichromate ions, $Cr_2O_7{}^{2-}$.

What volume of aqueous dichromate is needed to exactly convert all the ethanol to ethanoic acid?

(M_r value: $CH_3CH_2OH = 46$)

A 6.25 cm^3

B 9.38 cm^3

C 12.50 cm^3

D 25.00 cm^3

E 37.50 cm^3

F 56.25 cm^3

G 112.50 cm^3

37 V is a compound with empirical formula CH_2. It undergoes an addition reaction with hydrogen bromide, producing compound W.

W reacts with potassium cyanide to produce organic compound X which contains approximately $\frac{1}{6}$ by mass of nitrogen.

W also reacts with warm aqueous sodium hydroxide to give organic compound Y.

Y reacts with hot acidified potassium dichromate(VI) to produce organic compound Z.

Z does not react with aqueous sodium carbonate, nor does it react with Tollens' reagent.

Which of the following is a possible identity for W?

(A_r values: H = 1; C = 12; N = 14)

A   1-bromobutane

B   1-bromopentane

C   1-bromopropane

D   2-bromo-2-methylpropane

E   2-bromobutane

F   2-bromo-2-methylbutane

G   2-bromopropane

H   3-bromopentane

38   A student is planning an experiment to determine the percentage of iron in a 3 g sample of the iron ore haematite, which contains Fe_2O_3 as the only iron-containing species and other material which will not react in this experiment. The sample contains approximately 50% iron by mass.

The student's plan is:

step 1   Make a solution of Fe^{3+} ions by reacting iron(III) oxide with concentrated acid.

step 2   Reduce the Fe^{3+} ions to Fe^{2+} ions using a solution of tin(II) chloride.

step 3   Make up the solution containing Fe^{2+} to 250 cm^3 by adding water.

step 4   Titrate 25 cm^3 portions using potassium dichromate(VI) solution, $K_2Cr_2O_7$.

The equations for the reactions occurring are:

$$Fe_2O_3 \; + \; 6H^+ \; \rightarrow \; 2Fe^{3+} \; + \; 3H_2O$$

$$Sn^{2+} \; + \; 2Fe^{3+} \; \rightarrow \; Sn^{4+} \; + \; 2Fe^{2+}$$

$$Fe^{2+} \; \rightarrow \; Fe^{3+} \; + \; e^-$$

$$Cr_2O_7{}^{2-} \; + \; 14H^+ \; + \; 6e^- \; \rightarrow \; 2Cr^{3+} \; + \; 7H_2O$$
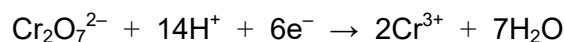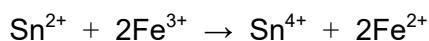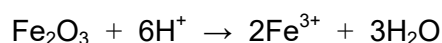
In order to obtain titre values of between 15 cm^3 and 35 cm^3, what concentration of potassium dichromate(VI), in mol dm^{-3}, should the student use?

(A_r value: Fe = 56)

A   0.02 mol dm^{-3}

B   0.04 mol dm^{-3}

C   0.10 mol dm^{-3}

D   0.20 mol dm^{-3}

E   0.50 mol dm^{-3}

F   1.00 mol dm^{-3}

39 0.92 g of gaseous dinitrogen tetroxide, N_2O_4(g), is placed in a syringe with a free moving piston at 25 °C and atmospheric pressure.

At 25 °C, gaseous dinitrogen tetroxide dissociates and forms an equilibrium mixture with gaseous nitrogen dioxide, NO_2(g), only.

At equilibrium, the total volume of gas in the syringe is 288 cm³.

What percentage of the dinitrogen tetroxide has dissociated?

(A_r values: N = 14; O = 16. Assume that, for all of the gases, one mole of gas occupies a volume of 24 dm³ at 25 °C and atmospheric pressure.)

A 10%

B 20%

C 30%

D 40%

E 50%

F 60%

G 70%

H 80%

40 Fluoride ions can be added to drinking water to improve dental health.

The recommended concentration of fluoride ions in drinking water for observable health benefits is between 1.0 and 1.5 ppm by mass.

The concentration of fluoride ions in a full 10 million litre water storage reservoir is 0.5 ppm.

The following three compounds can be used to supply fluoride ions to water:

sodium fluoride (NaF, $M_r = 42$)

hexafluorosilicic acid (H_2SiF_6, $M_r = 144$)

sodium fluorosilicate (Na_2SiF_6, $M_r = 188$)

Assume that all the fluorine present in the compounds ionises in water to form fluoride ions.

Which of the following treatments can be added to increase the fluoride ion concentration to within the recommended range?

(A_r value: F = 19. Density of water is $1\,g\,cm^{-3}$. 1 ppm = 1 part per million = 0.0001%.)

A   6.30 kg of sodium fluoride (NaF)

B   7200 g of hexafluorosilicic acid (H_2SiF_6)

C   14 400 g of hexafluorosilicic acid (H_2SiF_6)

D   18.8 g of sodium fluorosilicate (Na_2SiF_6)

E   37.6 kg of sodium fluorosilicate (Na_2SiF_6)

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PART Z Biology

41 A solution containing sucrose, starch and amylase was incubated at 37 °C. After the reactions had completed, the student divided the solution into three test tubes and carried out the following tests:

- add biuret reagent
- add iodine solution
- add Benedict's solution and heat

Which row shows the final colours after the tests?

	add biuret reagent	add iodine solution	add Benedict's solution and heat
A	purple	yellow-brown	blue
B	purple	blue-black	red
C	purple	yellow-brown	red
D	purple	blue-black	blue
E	blue	yellow-brown	blue
F	blue	blue-black	red
G	blue	yellow-brown	red
H	blue	blue-black	blue

42 A sample of blood was taken from a healthy human.

There were 5×10^9 red blood cells in $1\,cm^3$ of the blood.

The ratio of the volume of red blood cells to other blood components was $2:3$.

Which of the following statements is/are correct?

    1   The genetic material of a mature red blood cell is contained in its nucleus.

    2   The mean volume of a red blood cell is $8 \times 10^{-8}\,mm^3$.

    3   Human red blood cells have a higher surface area to volume ratio compared to a spherical cell of the same volume.

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   1 and 3 only

G   2 and 3 only

H   1, 2 and 3

43 An enzyme called EcoRI is used to cut out a gene from the middle of a human chromosome. This process produces sticky ends as shown in the diagram.
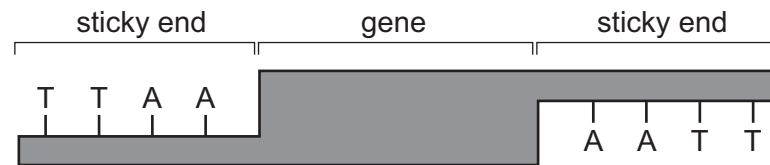
When guanine separates from its complementary base, three hydrogen bonds are broken, whereas two are broken when the other pair of bases separate.

Which row is correct?

	EcoRI is a	*the number of base-pairing hydrogen bonds broken when this gene was cut out using EcoRI*
A	restriction enzyme	16
B	restriction enzyme	20
C	restriction enzyme	24
D	ligase	16
E	ligase	20
F	ligase	24

44 A student studied the effect of different colours of light on photosynthesis by algae. Large numbers of algal cells were trapped inside balls of a clear jelly-like substance. The average diameter of the algal balls was 5 mm.

These balls were then placed in a test tube filled with a solution. The solution contained substances necessary for photosynthesis by the algal cells, and had a pH of 7.8. The whole test tube was then wrapped in a coloured filter and left in bright light for two hours. All other factors were kept constant.

After two hours the pH of each solution was measured. The results are shown in the table.

colour of filter	pH of solution after two hours
blue	8.3
green	7.5
red	8.6
colourless	9.3
black	7.1

The volume of a sphere is $\frac{4}{3}\pi r^3$, where r is the radius.

Which of the following statements is/are correct?

1 The average volume of one of the algal balls is $\frac{1}{6}\pi\,cm^3$.

2 In only the test tubes with red, blue and colourless filters, the increase in pH can be explained by an increase in the amount of carbon dioxide released by the algal balls.

3 Conducting these experiments at a higher temperature could increase the rate of change in pH in all the tubes.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

45 In a test to compare the function of the human respiratory system in different individuals, they were asked to breathe out as hard as possible for as long as possible. The volume exhaled was recorded.

The graph shows the results obtained after carrying out this test on two males with the same height and body mass.
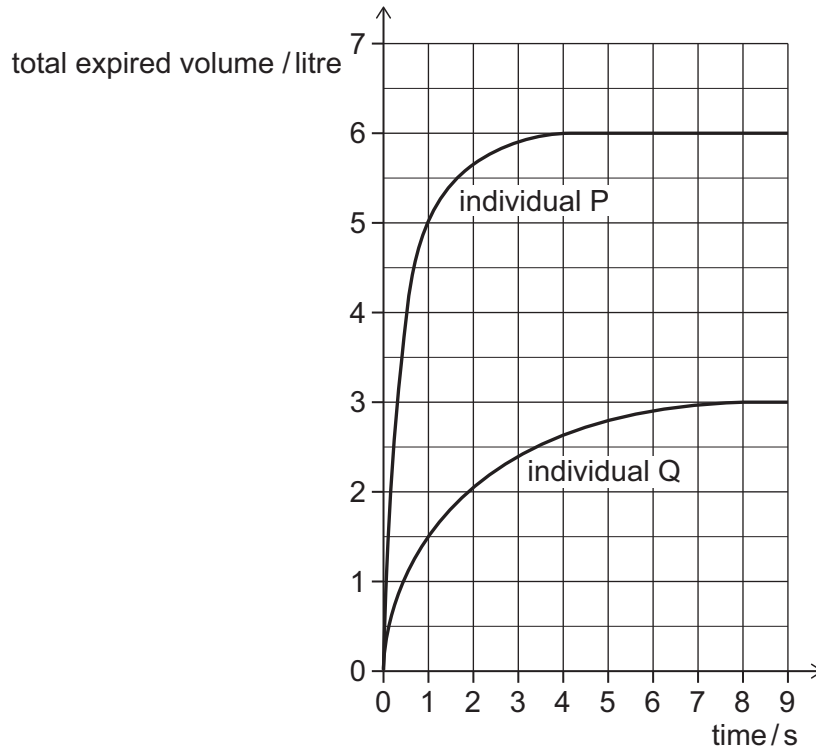
Which of the following statements is/are correct?

1 Individual P exhaled 200% more than individual Q.

2 Individual Q's diaphragm was more domed at 7 seconds than at 2 seconds.

3 The mean rate of air flow in the first second was 233% more in individual P than in individual Q (to the nearest whole percentage).

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

46 The graph shows the mass of antibody produced by antibody-producing cells over a period of 20 hours.

total mass of antibody molecules produced per 10^6 antibody-producing cells / μg

time / hours
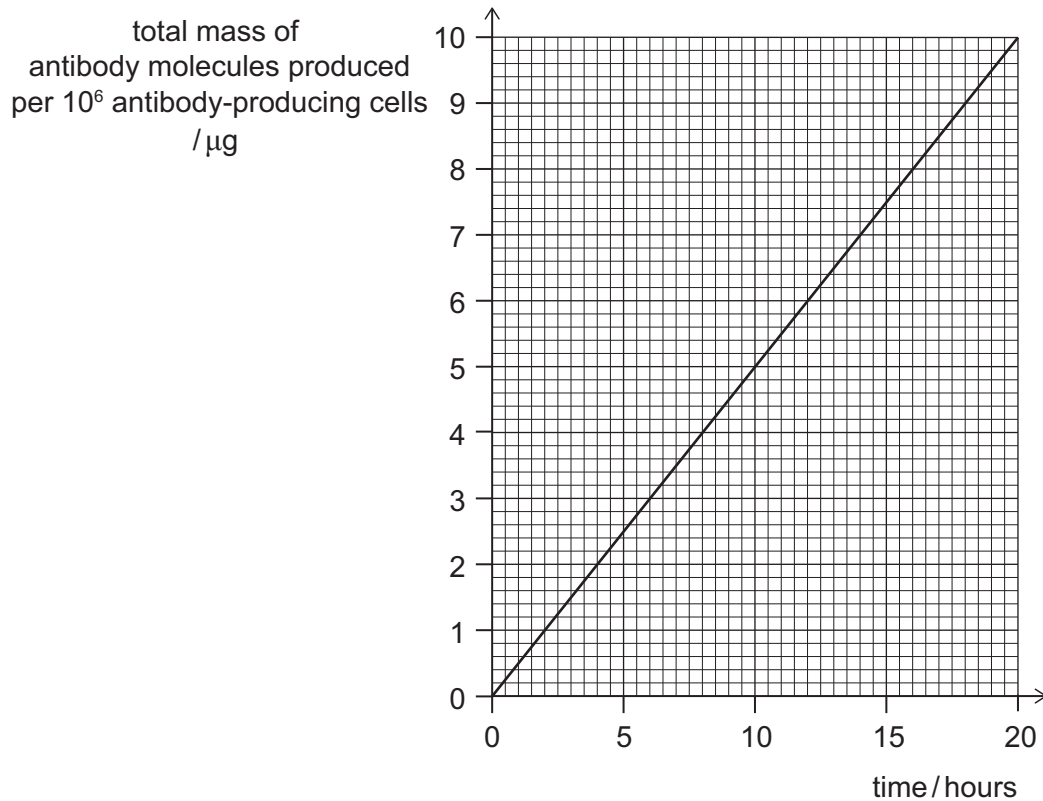
Assume that one antibody molecule has a mass of 2.5×10^{-19} g.

Which of the following statements is/are correct?

1 One antibody-producing cell produces 2×10^6 antibody molecules per hour.

2 Antibodies are produced in response to dead and living pathogens.

3 Phagocytes produce antibodies.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

47 The table identifies various values relating to microscopy.

Which row in the table is correct?

	the maximum useful magnification of a light microscope	the resolution limit of a transmission electron microscope	the actual diameter of an adenovirus pathogen based on a 1×10^6 magnified image with a diameter of 20 mm
A	×150	0.2 nm	20 nm
B	×150	0.2 nm	20 µm
C	×150	200 nm	20 nm
D	×150	200 nm	200 nm
E	×1500	0.2 nm	20 nm
F	×1500	0.2 nm	200 nm
G	×1500	200 nm	20 µm
H	×1500	200 nm	200 nm

48   Complete ribosomes are made from one large subunit and one small subunit joined together. The subunit names are based on their sizes as shown in the table.

size of ribosomal subunit	name of subunit in eukaryotes	name of subunit in prokaryotes
small	40S	30S
large	60S	50S

In a study, scientists found that one organism made and assembled the subunits in its nucleus. The complete ribosome was then transported to the cytoplasm.

Which row is correct?

	name of the large subunit in the complete ribosome studied	components found in the ribosomal subunits
A	50S	amino acids and no nucleotide bases
B	50S	adenine, cytosine, guanine, thymine
C	50S	amino acids, adenine, cytosine, guanine, thymine
D	50S	amino acids, adenine, cytosine, guanine, uracil
E	60S	amino acids and no nucleotide bases
F	60S	adenine, cytosine, guanine, thymine
G	60S	amino acids, adenine, cytosine, guanine, thymine
H	60S	amino acids, adenine, cytosine, guanine, uracil

49 Some varieties of plant crops, like maize, can survive at low temperatures, such as 4 °C.

Scientists identified protein Z that they believe to be involved in the response to low temperatures in maize.

One method of studying how plants survive at low temperatures is to investigate the levels of ion leakage from cells damaged by the low temperatures. Higher levels of ion leakage are associated with lower levels of survival.

The scientists measured the levels of ions leaking from cells of three varieties of maize.

variety of maize	description
P	normal maize plant
Q	contains a single base pair insertion in the DNA near the start of the gene coding for protein Z
R	is genetically modified to produce the highest levels of protein Z

Other than the changes listed in the table, the plants were genetically identical.

Ion leakage from samples of cells of each variety was measured after the plants had been kept at 4 °C for 4 days. All other variables were kept constant.

The results of this investigation are shown in the chart.
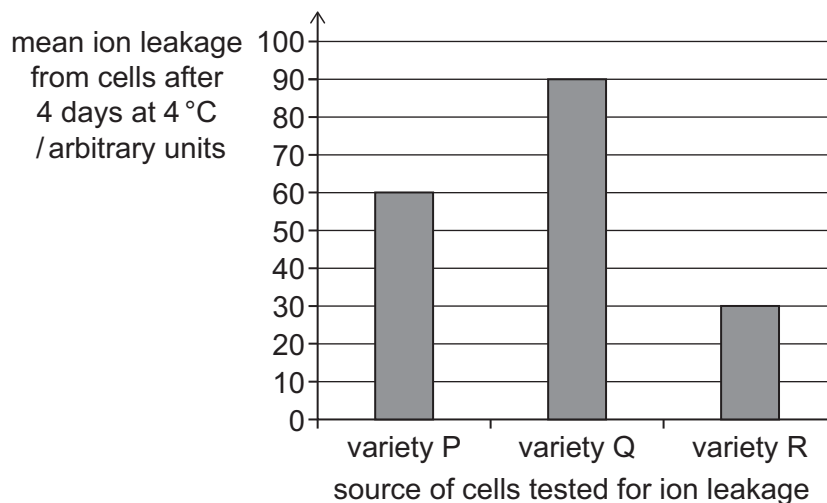
49 Which of the following statements is/are correct?

1 The cell wall in maize cells controls the leakage of ions from the cell at 4 °C.

2 Inserting an extra base pair near the start of the gene for protein Z could change the overall amino acid sequence of the protein.

3 The presence of protein Z in maize cells increases the chance of the maize plant surviving at 4 °C.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

50 Some bacteria become resistant to antibiotics due to the loss of the proteins in their cell surface membranes that the antibiotic uses to enter the cell. To overcome this problem, scientists have developed nanomachines that can make holes in these membranes, allowing the antibiotic to enter and destroy the bacteria.

Scientists studied the effects of these nanomachines in two antibiotic-resistant strains of bacteria, R and S. Each culture started with 2.5×10^6 living cells. They carried out two sets of experiments, one without the nanomachines and one with the nanomachines. The results are shown in the chart.

All other factors were kept the same.
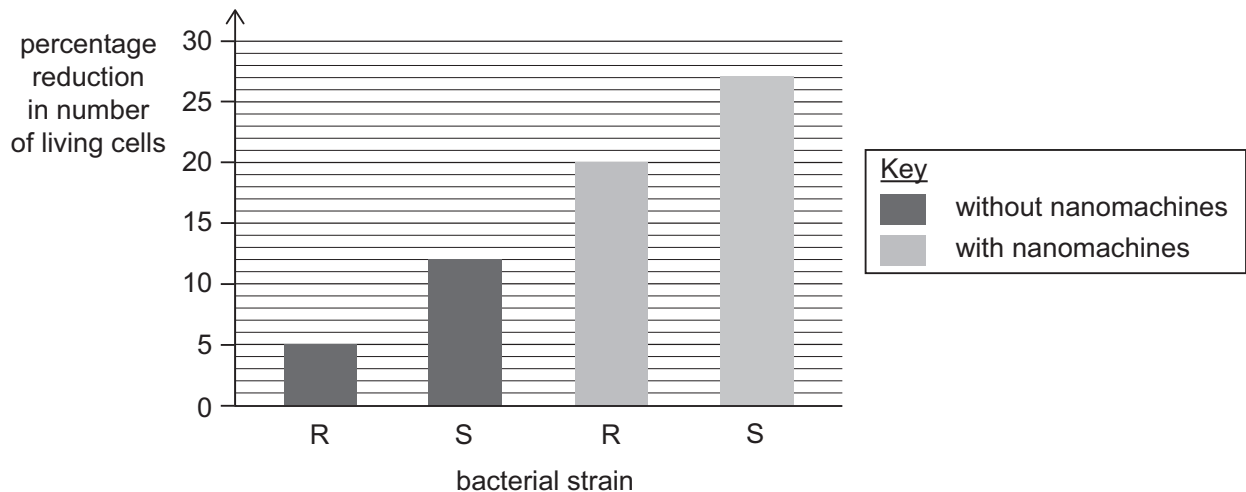
Which of the following statements is/are correct?

1 The number of living cells of strain S in the experiment with the nanomachines is 2.25 times higher than in the experiment without the nanomachines.

2 The cells of strain S may have more proteins in their cell membranes than strain R, which allow the antibiotic to enter their cells.

3 There would be 2×10^6 living cells of strain R at the end of the experiment with the nanomachines.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

51   Some chemotherapy drugs interfere with the mitotic cell cycle.

The following table lists five chemotherapy drugs and their mechanisms of action.

chemotherapy drug	mechanism of action
Dinaciclib	prevents cells progressing beyond prophase
Doxorubicin	prevents DNA repair following incorrect DNA replication
Methotrexate	inhibits enzymes responsible for DNA synthesis
Vinblastine	inhibits spindle fibre assembly
Wiskostatin	inhibits cytokinesis

The following diagram shows a simplified version of the mitotic cell cycle.
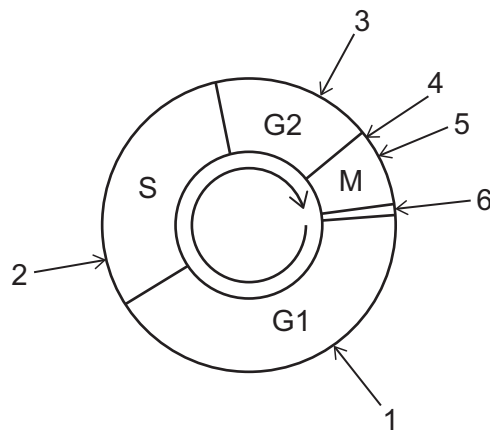
Which row identifies the position on the diagram where each chemotherapy drug is most likely to act?

	Dinaciclib	Doxorubicin	Methotrexate	Vinblastine	Wiskostatin
A	4	3	1	6	5
B	3	2	4	5	6
C	5	2	3	6	4
D	4	3	2	5	6
E	3	4	2	1	5
F	3	2	4	1	5
G	4	5	2	3	6

52 The properties of three biological membranes were investigated. It was found that:

- There is a positive correlation between the fluidity of a membrane and the rate of simple diffusion of substance X across it.

- Cholesterol increases the fluidity of membranes at low temperatures, but decreases their fluidity at high temperatures.

- The cell surface membrane has the highest percentage of cholesterol, and the lysosomal membrane has the second highest percentage of cholesterol.

Which of the following sketch graphs is consistent with this information?

Key
.... Golgi apparatus membrane
– – – – – – – inner mitochondrial membrane
——————— cell surface membrane

A permeability to substance X
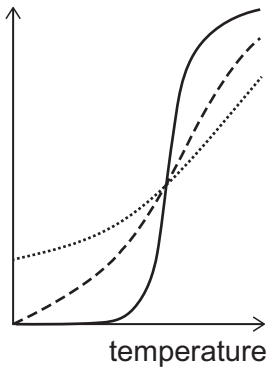
temperature

B permeability to substance X

temperature

C permeability to substance X

temperature

D permeability to substance X

temperature

E permeability to substance X

temperature
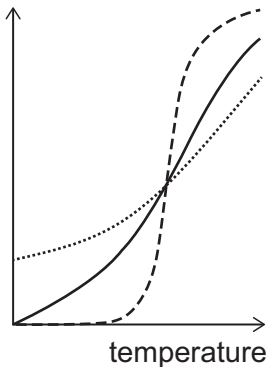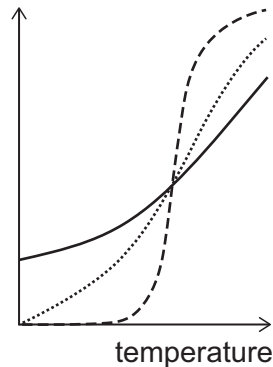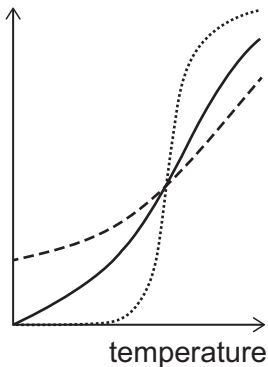
F permeability to substance X

temperature
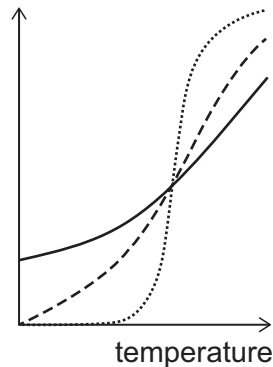
53 A 0.2 cm long section of xylem, with internal diameter 60 μm, was studied.

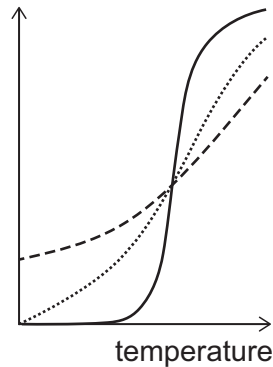The velocity at which substances were transported through the xylem in a plant was found to be 3.6 metres per hour in the morning. Later in the day the velocity was greater.

Which row of the table is correct?

	velocity of substance transport in the morning / μm s⁻¹	internal volume of the xylem section / μm³	environmental factor that could have resulted in change in velocity later in the day
A	0.001	180π	increased sunlight
B	0.001	720π	increased humidity
C	0.001	1 800 000π	increased humidity
D	1000	180π	increased wind speed
E	1000	1 800 000π	increased sunlight
F	1000	7 200 000π	increased humidity
G	3 600 000	720π	increased wind speed
H	3 600 000	7 200 000π	increased sunlight

54 In cold conditions mice maintain their core body temperature by increased heat production.

The graph shows the effect of environmental temperature on oxygen consumption by one strain of mouse.
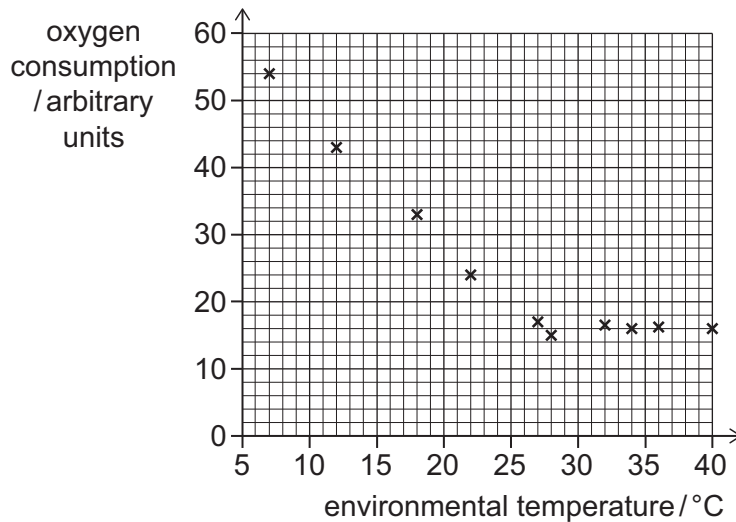
Mice of the same strain have been produced with a mutation that results in a thinner and less insulating layer of fat in their skin.

Which of the following statements is/are correct?

1 The homeostatic control of core body temperature only occurs in environmental temperatures between 28 °C and 40 °C.

2 Between 12 °C and 18 °C, each 1 °C increase in temperature decreases the mean oxygen consumption by $1\frac{2}{3}$ arbitrary units.

3 Between 10 °C and 20 °C, the change in oxygen consumption for the mice with the mutation will decrease more than for the non-mutated mice.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

55 A scientist studied the aorta, a renal artery and a capillary in a healthy human.

The scientist measured the radii of two of the vessels, P and Q, and made a drawing of the third, R.

- P: lumen radius $= 2.5 \times 10^{-3}\,\text{m}$
- Q: lumen radius $= 8000\,\mu\text{m}$
- R: at magnification $\times 5000$, diameter of lumen in drawing $= 4.5\,\text{cm}$

Which row identifies the three blood vessels?

	vessel P	vessel Q	vessel R
A	aorta	capillary	renal artery
B	aorta	renal artery	capillary
C	capillary	aorta	renal artery
D	capillary	renal artery	aorta
E	renal artery	aorta	capillary
F	renal artery	capillary	aorta

56 A student investigated the effect of increasing the size of an agar (a jelly-like substance) cube on its efficiency to absorb and distribute a blue dye.

Two agar cubes were prepared, one with side lengths of 1 cm and the other with side lengths of 3 cm. They were put in a solution of blue dye for 30 minutes.

The cubes were then removed from the dye and cut in half to measure the penetration of the dye into the agar.

In the 3 cm cube the dye had penetrated to a depth of 0.75 cm. The cross section of this cube is shown:

clear region of agar

agar penetrated
by blue dye
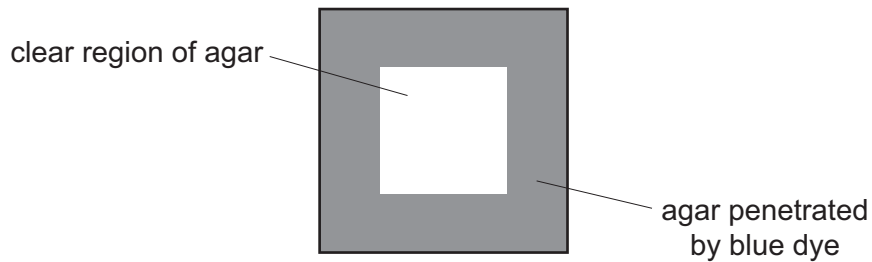
[diagram not to scale]

When the cube with sides of 1 cm was cut in half, all the agar had been penetrated with the dye.

Which row is correct for this investigation?

	percentage of the volume of the 3 cm cube penetrated by the dye	change in surface area : volume ratio as cube size increases	process(es) to describe the movement of the blue dye into the cube
A	12.5	increases	active transport and osmosis
B	75.0	increases	diffusion and osmosis
C	87.5	decreases	diffusion only
D	12.5	decreases	diffusion and osmosis
E	75.0	decreases	diffusion only
F	87.5	increases	diffusion and osmosis
G	75.0	increases	active transport and osmosis
H	87.5	decreases	active transport and osmosis

57 The graph shows the rate of removal of sodium ions from a giant axon in a squid. Between 100 and 230 minutes, a reversible inhibitor of mitochondrial activity was present.
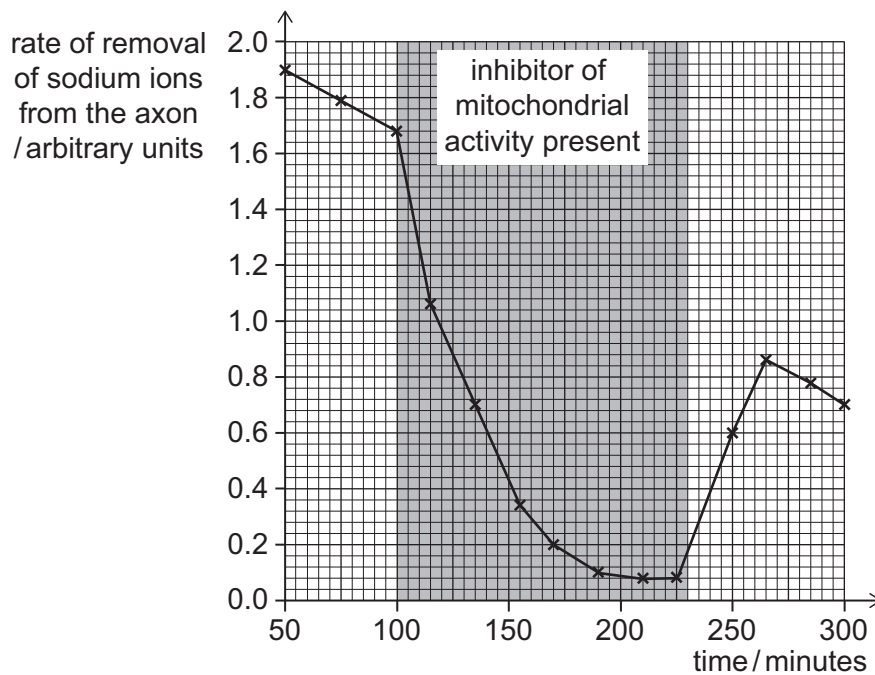
Which of the following statements is/are correct?

1 The removal of sodium ions across the cell surface membrane of the axon is an active process requiring ATP.

2 The concentration of sodium ions in the axon must increase after the inhibitor has been removed.

3 In the 50 minutes before the inhibitor was added, the rate of removal of sodium ions from the axon decreases by 4.4×10^{-3} arbitrary units per minute.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

58 The diagrams show some stages of mitosis and meiosis in a healthy human male.
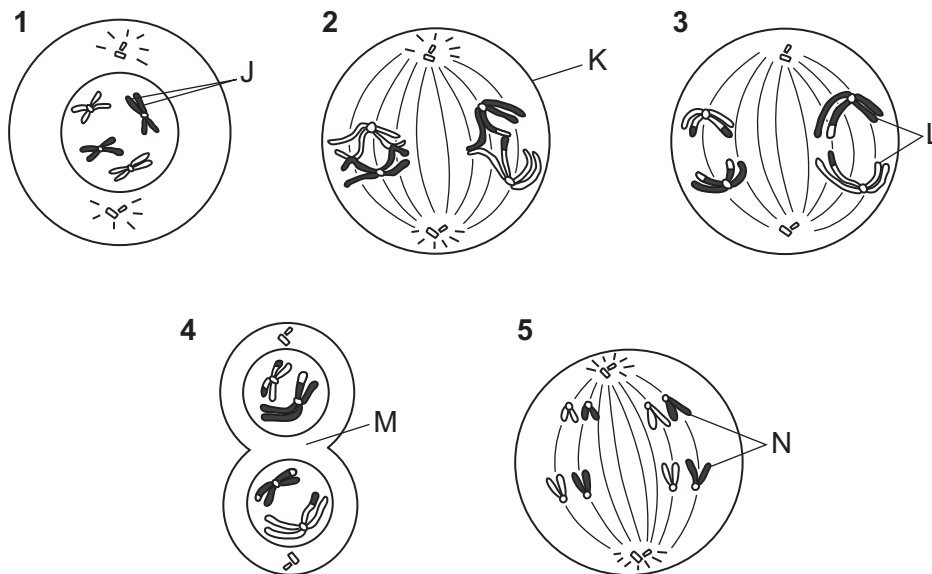
Which row identifies the correct process, the stage of that process, and label?

	diagram number	process	stage	label
A	1	mitosis	prophase	J: paired homologous chromosomes
B	2	meiosis	metaphase 1	K: nuclear membrane of sperm cell
C	3	meiosis	anaphase 2	L: bivalents being separated
D	4	meiosis	telophase 1	M: cleavage of cytoplasm
E	5	mitosis	metaphase	N: sister chromatids

59 The family tree shows inheritance of the alleles for one characteristic in a mammal. The gene for this characteristic was found on a non-sex chromosome in the nucleus.
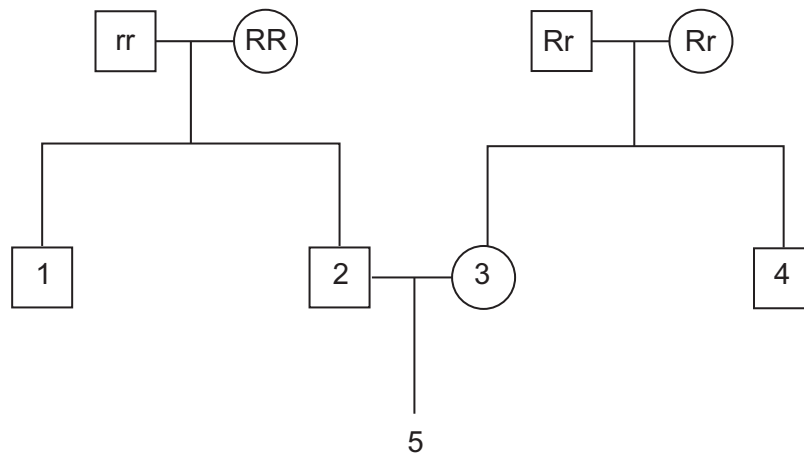
What is the probability that individual 5 is homozygous for the allele R?

A 0

B 0.25

C 0.33

D 0.5

E 0.67

F 0.75

G 1

60 A particular functional protein consists of two smaller chains of amino acids joined together, chain P and chain Q. A group of scientists made this protein using bacterial cells.

They created recombinant plasmid R by inserting the genes for chain P and chain Q into a plasmid. They also inserted a gene for an antibiotic resistance protein into the plasmid so that cells containing the recombinant plasmid could be selected using antibiotics.

A map of the recombinant plasmid is shown:

gene for antibiotic
resistance protein
1800 bases long

plasmid
R

gene for chain P
600 bases long

gene for chain Q
3300 bases long
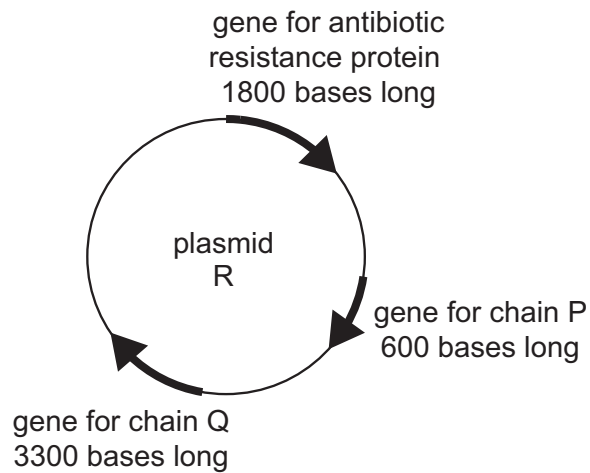
This process is not efficient and must be carried out several times to be certain of creating plasmid R.

Four plasmids were made and individually moved into four bacterial cells, labelled W, X, Y and Z.

The proteins encoded by the genes in the plasmid in the bacterial cells were checked by separating the proteins based on their mass, producing the results as shown in the following diagram.

bacterium

W   X   Y   Z

130 —

110 —

mass / kDa   60 —

20 —
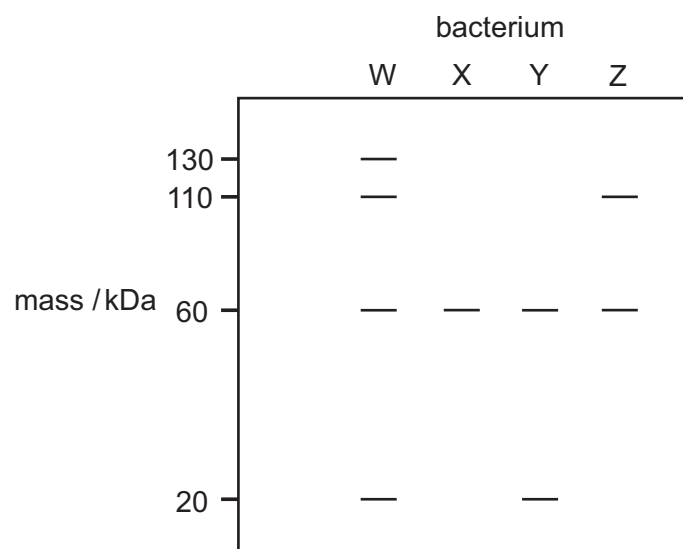
Each band represents a protein or amino acid chain of the given mass.

Assume that one amino acid has a mass of 0.1 kDa.

60 Which of the following statements is/are correct?

1 W is the only bacterium with the fully functional protein.

2 The proteins/amino acid chain(s) in Y and Z are from bacteria that can each only produce one of the parts of the functional protein.

3 The DNA ligase enzymes may not have functioned as intended when creating the plasmid that is in bacterium X.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

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UNIVERSITY OF CAMBRIDGE

Candidate number

N ☐ ☐ ☐ ☐ ☐

Centre number

☐ ☐ ☐ ☐ ☐

Date of birth (DD MM YYYY)

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

First Name(s)

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Surname / Family name

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Fill in the appropriate circle for your chosen answer e.g.

A B C D E
○ ● ○ ○ ○

Use a soft pencil. If you make a mistake, erase thoroughly and try again.

ALL candidates must attempt ONE part only.

Part X: Physics

1 A B C D E F	**6** A B C D E F G	**11** A B C D E F G	**16** A B C D E F G H
2 A B C D E	**7** A B C D E F G	**12** A B C D E F G H	**17** A B C D E F G H
3 A B C D E F	**8** A B C D E F G H	**13** A B C D E F G	**18** A B C D E F
4 A B C D E F	**9** A B C D E	**14** A B C D E F	**19** A B C D E F G H
5 A B C D E F G H	**10** A B C D E F	**15** A B C D E F	**20** A B C D E F G H

N

Candidate number

N					

Part Y: Chemistry

21	A B C D E F G H ○○○○○○○○	**26**	A B C D E F G H ○○○○○○○○	**31**	A B C D E ○○○○○	**36**	A B C D E F G ○○○○○○○
22	A B C D E ○○○○○	**27**	A B C D E F G H ○○○○○○○○	**32**	A B C D E F G ○○○○○○○	**37**	A B C D E F G H ○○○○○○○○
23	A B C D E F ○○○○○○	**28**	A B C D E F G H ○○○○○○○○	**33**	A B C D E F G H ○○○○○○○○	**38**	A B C D E F ○○○○○○
24	A B C D E F ○○○○○○	**29**	A B C D E ○○○○○	**34**	A B C D E F G H ○○○○○○○○	**39**	A B C D E F G H ○○○○○○○○
25	A B C D E F G ○○○○○○○	**30**	A B C D E F ○○○○○○	**35**	A B C D E F ○○○○○○	**40**	A B C D E ○○○○○

Part Z: Biology

41	A B C D E F G H ○○○○○○○○	**46**	A B C D E F G H ○○○○○○○○	**51**	A B C D E F G ○○○○○○○	**56**	A B C D E F G H ○○○○○○○○
42	A B C D E F G H ○○○○○○○○	**47**	A B C D E F G H ○○○○○○○○	**52**	A B C D E F ○○○○○○	**57**	A B C D E F G H ○○○○○○○○
43	A B C D E F ○○○○○○	**48**	A B C D E F G H ○○○○○○○○	**53**	A B C D E F G H ○○○○○○○○	**58**	A B C D E ○○○○○
44	A B C D E F G H ○○○○○○○○	**49**	A B C D E F G H ○○○○○○○○	**54**	A B C D E F G H ○○○○○○○○	**59**	A B C D E F G ○○○○○○○
45	A B C D E F G H ○○○○○○○○	**50**	A B C D E F G H ○○○○○○○○	**55**	A B C D E F ○○○○○○	**60**	A B C D E F G H ○○○○○○○○

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Question	Answer key	Part
Q1	E	MATH
Q2	D	MATH
Q3	D	MATH
Q4	E	MATH
Q5	D	MATH
Q6	D	MATH
Q7	C	MATH
Q8	B	MATH
Q9	B	MATH
Q10	B	MATH
Q11	G	MATH
Q12	C	MATH
Q13	G	MATH
Q14	C	MATH
Q15	E	MATH
Q16	B	MATH
Q17	E	MATH
Q18	A	MATH
Q19	D	MATH
Q20	C	MATH
Q21	A	PHYS
Q22	C	PHYS
Q23	E	PHYS
Q24	G	PHYS
Q25	E	PHYS
Q26	B	PHYS
Q27	A	PHYS
Q28	G	PHYS
Q29	B	PHYS
Q30	D	PHYS
Q31	E	PHYS
Q32	C	PHYS
Q33	G	PHYS
Q34	C	PHYS
Q35	D	PHYS
Q36	D	PHYS
Q37	F	PHYS
Q38	E	PHYS
Q39	E	PHYS
Q40	A	PHYS

Question	Answer key	Part
Q41	E	CHEM
Q42	B	CHEM
Q43	C	CHEM
Q44	G	CHEM
Q45	D	CHEM
Q46	A	CHEM
Q47	E	CHEM
Q48	F	CHEM
Q49	H	CHEM
Q50	G	CHEM
Q51	C	CHEM
Q52	A	CHEM
Q53	D	CHEM
Q54	E	CHEM
Q55	D	CHEM
Q56	C	CHEM
Q57	F	CHEM
Q58	A	CHEM
Q59	E	CHEM
Q60	B	CHEM
Q61	A	BIOL
Q62	B	BIOL
Q63	F	BIOL
Q64	B	BIOL
Q65	D	BIOL
Q66	E	BIOL
Q67	G	BIOL
Q68	G	BIOL
Q69	D	BIOL
Q70	F	BIOL
Q71	G	BIOL
Q72	B	BIOL
Q73	D	BIOL
Q74	F	BIOL
Q75	C	BIOL
Q76	F	BIOL
Q77	A	BIOL
Q78	G	BIOL
Q79	D	BIOL
Q80	C	BIOL

Question	Answer key	Part
Q1	E	PHYS
Q2	C	PHYS
Q3	C	PHYS
Q4	E	PHYS
Q5	B	PHYS
Q6	F	PHYS
Q7	D	PHYS
Q8	D	PHYS
Q9	B	PHYS
Q10	F	PHYS
Q11	C	PHYS
Q12	G	PHYS
Q13	F	PHYS
Q14	C	PHYS
Q15	E	PHYS
Q16	E	PHYS
Q17	A	PHYS
Q18	A	PHYS
Q19	D	PHYS
Q20	B	PHYS
Q21	D	CHEM
Q22	E	CHEM
Q23	F	CHEM
Q24	A	CHEM
Q25	B	CHEM
Q26	D	CHEM
Q27	G	CHEM
Q28	C	CHEM
Q29	E	CHEM
Q30	F	CHEM
Q31	A	CHEM
Q32	F	CHEM
Q33	B	CHEM
Q34	D	CHEM
Q35	F	CHEM
Q36	D	CHEM
Q37	E	CHEM
Q38	A	CHEM
Q39	B	CHEM
Q40	B	CHEM

Question	Answer key	Part
Q41	C	BIOL
Q42	G	BIOL
Q43	A	BIOL
Q44	D	BIOL
Q45	G	BIOL
Q46	E	BIOL
Q47	E	BIOL
Q48	H	BIOL
Q49	G	BIOL
Q50	G	BIOL
Q51	D	BIOL
Q52	D	BIOL
Q53	E	BIOL
Q54	G	BIOL
Q55	E	BIOL
Q56	C	BIOL
Q57	F	BIOL
Q58	D	BIOL
Q59	B	BIOL
Q60	H	BIOL