UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES   **D568/31**
ADMISSIONS ASSESSMENT

November 2020   **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 69 printed pages and 7 blank pages.

                            PV1

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Paper content

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PART A Mathematics

1 The admission charge to a cinema is different for adults and children.

Admission for 2 adults and 3 children costs £20.

Admission for 4 adults and 4 children costs £34.

What does admission cost for 6 adults and 2 children?

A £27

B £29

C £33

D £39

E £44

F £48

G £72

2 The nth term of a sequence is $2n - 5$.

Which row in the table is correct for this sequence?

	term-to-term rule	term which has a value of 17
A	subtract 5	11th
B	subtract 5	29th
C	subtract 2	11th
D	subtract 2	29th
E	add 5	11th
F	add 5	29th
G	add 2	11th
H	add 2	29th

PART A Mathematics

**3** A fair spinner has eight equal sections.

Each section has one number written on it, as shown.
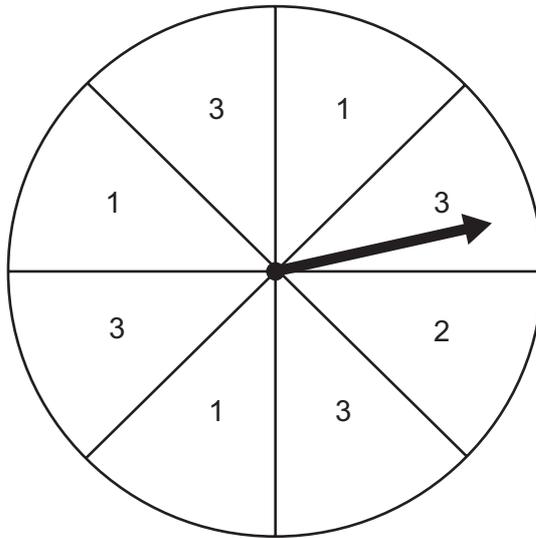
The spinner is spun twice, and the two numbers scored are added.

What is the probability that the sum of the two numbers is 5?

A $\dfrac{1}{8}$

B $\dfrac{5}{8}$

C $\dfrac{1}{16}$

D $\dfrac{3}{16}$

E $\dfrac{25}{64}$

F $\dfrac{55}{64}$

4
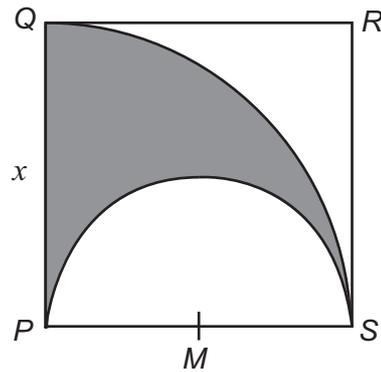
PQRS is a square with side length x.

M is the midpoint of side *PS*.

A circular arc, with centre *M*, is drawn inside the square from *S* to *P*.

Another circular arc, with centre *P*, is drawn inside the square from *S* to *Q*.

What is the area of the shaded region in terms of x?

A $\dfrac{1}{8}\pi x^2$

B $\dfrac{3}{16}\pi x^2$

C $\dfrac{1}{4}\pi x^2$

D $\dfrac{5}{16}\pi x^2$

E $\dfrac{3}{8}\pi x^2$

F $\dfrac{7}{16}\pi x^2$

G $\dfrac{1}{2}\pi x^2$

5   A balloon contains $5000\,cm^3$ of gas.

The gas in the balloon gradually escapes so that the volume of the balloon decreases.

60% of the volume of the balloon is lost each week.

What is the volume of the balloon, in cm^3, after 3 weeks?

A   0

B   128

C   320

D   800

E   1080

6   Consider the four lines with the following equations.

   1 $2x + 6y = 3$

   2 $9y = 3x - 4$

   3 $2y = 6x + 3$

   4 $4x + 6y - 9 = 0$

Which two lines are perpendicular?

A   1 and 2

B   1 and 3

C   1 and 4

D   2 and 3

E   2 and 4

F   3 and 4

7 The equilateral triangle *PQR* has sides of length 8 cm.

A circle, centre *O*, passes through each of the vertices of the triangle.

Find an expression for the circumference of the circle, in cm.

A $\quad \dfrac{\sin 60°}{8\pi}$

B $\quad \dfrac{8\pi}{\sin 60°}$

C $\quad \dfrac{\cos 60°}{8\pi}$

D $\quad \dfrac{8\pi}{\cos 60°}$

E $\quad \dfrac{\tan 60°}{8\pi}$

F $\quad \dfrac{8\pi}{\tan 60°}$

8 Find the sum of the solutions of

$$2\left(\frac{x}{4}+3\right)^2 - \left(\frac{x}{4}+3\right) - 36 = 0$$

A $\quad$ 2

B $\quad \dfrac{3}{2}$

C $\quad \dfrac{1}{2}$

D $\quad$ −4

E $\quad$ −13

F $\quad$ −22

G $\quad$ −26

H $\quad$ −34

9 When the expression

$$(2x + 3)^2 - (x - 3)^2$$

is written in the form $p(x + q)^2 + r$, where p, q and r are constants, what is the value of r?

A -27

B -9

C 0

D 3

E 15

10 Which one of the following expressions is equivalent to

$$\frac{a}{b/c} - \frac{a/b}{c}$$

A 0

B $\dfrac{a(b^2 - 1)}{bc}$

C $\dfrac{a(b^2 - c^2)}{bc}$

D $\dfrac{a^2 b^2 - c^2}{abc}$

E $\dfrac{a(c^2 - 1)}{bc}$

F $\dfrac{a^2 c^2 - b^2}{abc}$

G $\dfrac{b^2 - a^2}{abc}$

11 The table shows statistics relating to the test marks of two groups of students.

	number of students	mean	range
group X	10	36	16
group Y	20	48	21

The results for the two groups of students are combined.

What can be deduced about the mean and range of the combined results?

A mean $= 40$, range ≤ 16

B mean $= 40$, $16 <$ range < 21

C mean $= 40$, range ≥ 21

D mean $= 44$, range ≤ 16

E mean $= 44$, $16 <$ range < 21

F mean $= 44$, range ≥ 21

12 The number of pairs of winter boots sold on a day is inversely proportional to the cube of the outside temperature on that day, measured in °C.

On a day when the outside temperature is $8\,°C$, 250 pairs of boots are sold.

The next day, when the outside temperature is $x\,°C$, the number of pairs of boots sold is 700% more than on the previous day.

What is the value of x?

A 2

B 4

C $\dfrac{8}{\sqrt[3]{7}}$

D $8\sqrt[3]{7}$

E 16

12

13 In a sale, all prices are reduced by 25%.

A customer calculates the pre-sale price of a bicycle incorrectly by increasing the marked sale price by 25%.

The customer's calculated pre-sale price is incorrect by £15.

What is the correct pre-sale price of the bicycle?

A £180

B £195

C £210

D £225

E £240

14 A paint colour is a mixture of red paint, blue paint and yellow paint.

The ratio of red paint to blue paint in the mixture is $18:5$

The ratio of blue paint to yellow paint in the mixture is $p:3$

The ratio of red paint to yellow paint in the mixture is $12:5$

What is the value of p?

A 2

B 4.5

C 5

D 7.5

E 12

15
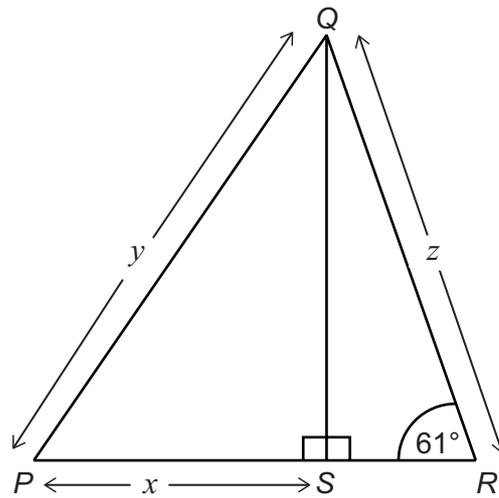
[diagram not to scale]

In the diagram, *QS* is perpendicular to *PR*.

PS = *x* cm
PQ = *y* cm
QR = *z* cm

angle *QRS* = 61°

PSR is a straight line.

Which one of the following is an expression for the length *z*, in cm?

A $\sqrt{y^2 + x^2}\,\sin 61°$

B $\sqrt{y^2 - x^2}\,\sin 61°$

C $\sqrt{y^2 + x^2}\,\cos 61°$

D $\sqrt{y^2 - x^2}\,\cos 61°$

E $\dfrac{\sqrt{y^2 + x^2}}{\sin 61°}$

F $\dfrac{\sqrt{y^2 - x^2}}{\sin 61°}$

G $\dfrac{\sqrt{y^2 + x^2}}{\cos 61°}$

H $\dfrac{\sqrt{y^2 - x^2}}{\cos 61°}$

16 Two identical fair six-sided dice each have their faces numbered from 1 to 6, with one number on each face.

Both dice are thrown, and the number on each of the dice is recorded.

They are then both thrown again, and the number on each of the dice is recorded.

What is the probability that at least one of the four recorded numbers is even?

A $\dfrac{1}{4}$

B $\dfrac{1}{2}$

C $\dfrac{9}{16}$

D $\dfrac{3}{4}$

E $\dfrac{15}{16}$

17 The quadratic equation $2x^2 - px - 4 = 0$, where p is a positive constant, has two solutions that differ by 6.

What is the value of p?

A   2

B $4\sqrt{7}$

C   12

D $4\sqrt{11}$

E $4\sqrt{34}$

F $6\sqrt{30}$

18 Two vertices of a square are at $(1, 1)$ and $(3, 5)$.

Whatis the difference between the perimeters of the largest and smallest possible squares that can be drawn with these points as two of their vertices?

A 0

B $4\sqrt{3}\left(2 - \sqrt{2}\right)$

C $4\sqrt{3}\left(\sqrt{2} - 1\right)$

D $4\sqrt{5}\left(2 - \sqrt{2}\right)$

E $4\sqrt{5}\left(\sqrt{2} - 1\right)$

F $4\sqrt{13}\left(2 - \sqrt{2}\right)$

G $4\sqrt{13}\left(\sqrt{2} - 1\right)$

H $4\sqrt{3}\sqrt{5}\left(2 - \sqrt{2}\right)$

19 The point *M* is (2, 5) and the point *N* is (−3, −1).

The line segment *MN* is transformed to the line segment *TU* by two transformations:

MN is rotated 90° clockwise about the origin to give the line segment *RS*.

RS is then translated by the vector $\begin{pmatrix} p \\ q \end{pmatrix}$ to give the line segment *TU*.

The coordinates of the midpoint of *TU* are (7, −2.5).

Find the vector $\begin{pmatrix} p \\ q \end{pmatrix}$

A $\begin{pmatrix} 2 \\ 0.5 \end{pmatrix}$

B $\begin{pmatrix} 0.5 \\ 2 \end{pmatrix}$

C $\begin{pmatrix} 5 \\ -3 \end{pmatrix}$

D $\begin{pmatrix} -3 \\ 5 \end{pmatrix}$

E $\begin{pmatrix} 9 \\ -2 \end{pmatrix}$

F $\begin{pmatrix} -2 \\ 9 \end{pmatrix}$

20 A solid cone has a base radius x cm.

The ratio of the perpendicular height of the cone to the radius of the cone is $5:2$

A solid hemisphere of radius $\dfrac{y}{2}$ cm is made from the same material as the cone.

Which one of the following is a correct expression for

$$\dfrac{\text{volume of the cone}}{\text{volume of the hemisphere}}$$

(Volume of a cone $= \frac{1}{3}\pi r^2 h$ where r is the radius and h is the perpendicular height.)

(Volume of a sphere $= \frac{4}{3}\pi r^3$ where r is the radius.)

A $\dfrac{5x^3}{y^3}$

B $\dfrac{5x^3}{4y^3}$

C $\dfrac{8x^3}{5y^3}$

D $\dfrac{10x^3}{y^3}$

E $\dfrac{14x^3}{y^3}$

PART B Physics

21 The diagram represents the structure of a charged atom (ion) of one isotope of an element.

nucleus

electrons
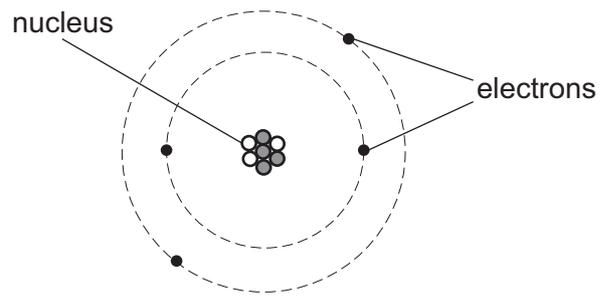
Which diagram represents the structure of an oppositely charged ion of a different isotope of the same element?

A

B

C

D

E

F

G
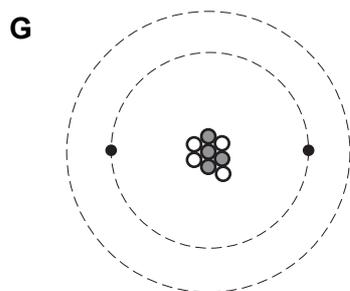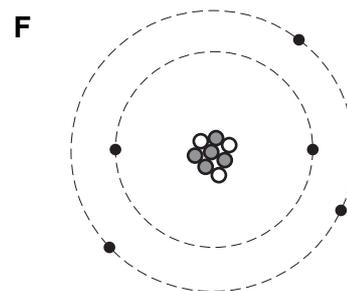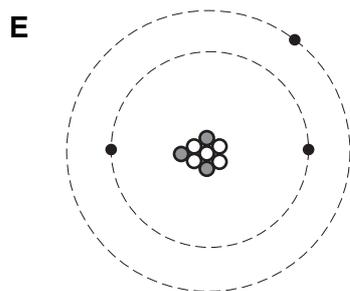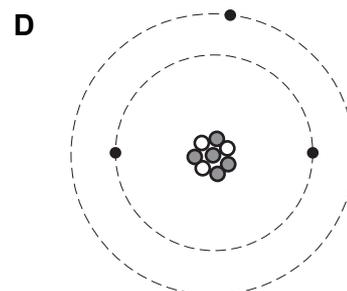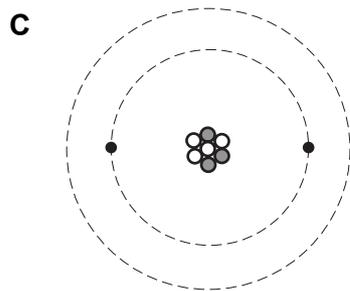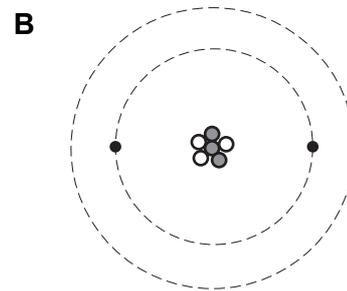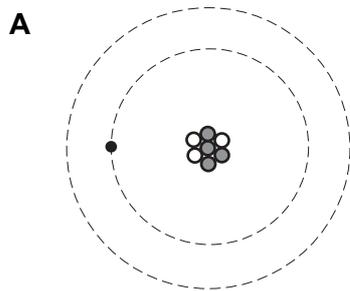
22   A soldering iron has a copper tip of mass 2.0 g.

The tip is heated with 30 W of thermal power. In 50 s, the temperature of the tip increases by 200 °C.

How much energy is transferred from the tip to the surroundings in this time?

(specific heat capacity of copper $= 400\,\text{J}\,\text{kg}^{-1}\,^\circ\text{C}^{-1}$)

A   160 J

B   500 J

C   1340 J

D   1500 J

E   1660 J

F   1840 J

G   2500 J

23 A water wave is travelling in a shallow tank of water. The wave passes from region X into region Y where the speed of the wave differs from that in region X. The diagram shows the directions of travel in the two regions and peaks of the wave that are separated by one wavelength.
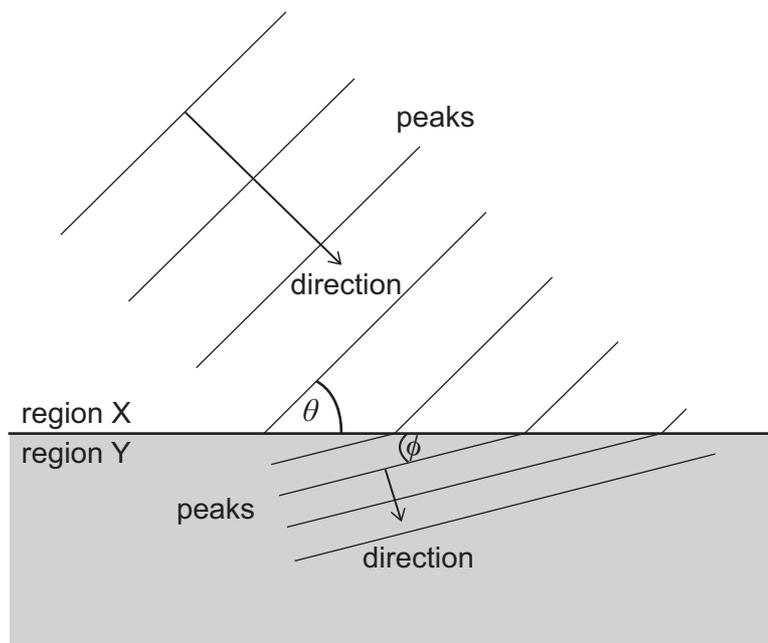

In region X, the angle between the wave peaks and the boundary between the regions is θ.

In region Y, the angle between the wave peaks and the boundary is ϕ.

What are the angle of incidence and the angle of refraction, and in which region is the speed of the wave greater?

	angle of incidence	angle of refraction	speed greater in region
A	θ	ϕ	X
B	θ	ϕ	Y
C	θ	$90° - \phi$	X
D	θ	$90° - \phi$	Y
E	$90° - \theta$	ϕ	X
F	$90° - \theta$	ϕ	Y
G	$90° - \theta$	$90° - \phi$	X
H	$90° - \theta$	$90° - \phi$	Y

24 A sample of an ideal gas is sealed in a cylindrical container by a piston as shown in the diagram.

cylindrical container

gas
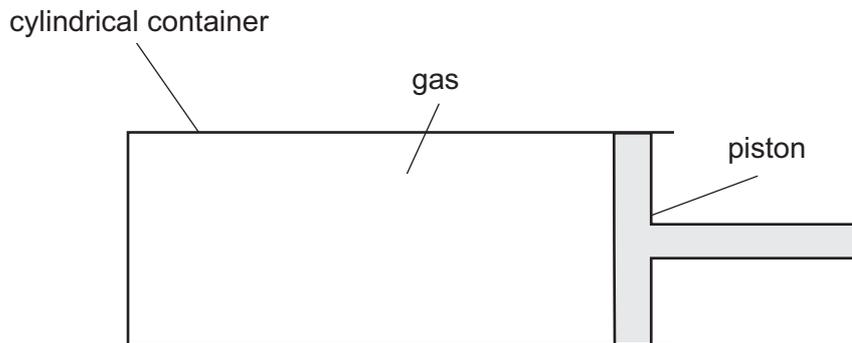
piston

The particles of the gas are moving with an average speed v, and collide with the surface of the piston with a frequency f.

The piston is now slowly pushed into the cylinder until the gas occupies half of its original volume, but the gas remains at the same temperature.

What is the new average speed of the particles of the gas, and at what frequency do they now collide with the surface of the piston?

	average speed	*frequency*
A	$2v$	$\frac{1}{2}f$
B	$2v$	f
C	$2v$	$2f$
D	v	$\frac{1}{2}f$
E	v	f
F	v	$2f$

25 In a laboratory, liquid nitrogen is stored at a very low temperature in the vessel shown in the diagram.
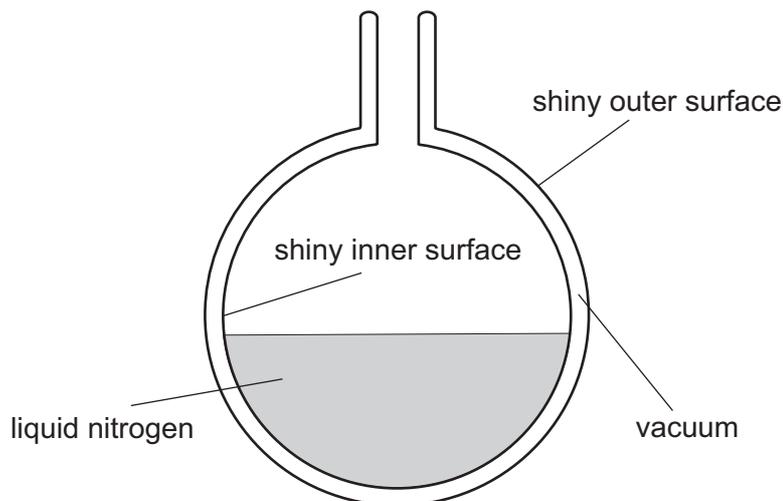
The vessel has a double wall made from a poor thermal conductor. There is a vacuum in the gap between the two walls.

The inner surface of the inner wall is shiny. The outer surface of the outer wall is shiny.

These features insulate the liquid nitrogen by reducing the rate at which thermal energy is transferred to the liquid nitrogen.

Which of the following statements explain(s) why these features help to insulate the liquid nitrogen?

1 The shiny inner surface of the inner wall is a good emitter of thermal radiation.

2 Thermal radiation cannot travel in a vacuum.

3 The shiny outer surface of the outer wall is a poor absorber of radiation.

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

26 Uranium-238 $\left(^{238}_{92}U\right)$ decays by a series of alpha and beta (β^-) emissions to become the stable isotope lead-206 $\left(^{206}_{82}Pb\right)$.

How many beta (β^-) particles are emitted in the decay of one uranium-238 nucleus to lead-206?

A 6

B 8

C 10

D 12

E 14

F 16

27 A dc electricity transmission system uses an undersea cable to send electricity from one country to another. On a particular day, the first country supplies electricity at a voltage of 400 kV and 2000 A to the transmission system. The second country receives electricity from the transmission system at 160 kV and 4000 A.

What is the percentage efficiency of the system and how much energy is wasted every minute?

	efficiency %	energy wasted every minute / J
A	20	9.6×10^9
B	20	3.84×10^{10}
C	20	4.8×10^{10}
D	80	9.6×10^9
E	80	3.84×10^{10}
F	80	4.8×10^{10}

28 The primary coil of an ideal, 100% efficient transformer is connected to a 240 V mains supply.

A lamp L that is connected to the secondary coil has a voltage of 12 V across it. An identical lamp and a switch S are also connected to the transformer as shown in the diagram.
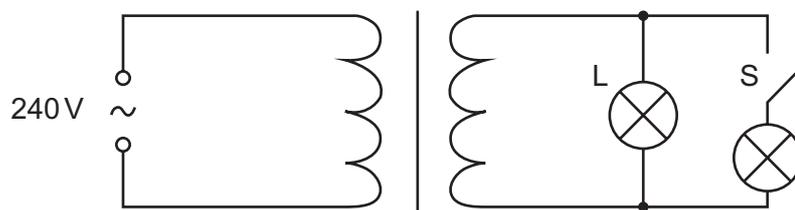
With the switch open, the current in the primary coil is 0.10 A.

The switch is now closed.

What is the current in the primary coil now and what is the current in lamp L?

	current in primary coil / A	current in lamp L / A
A	0.10	1.0
B	0.10	2.0
C	0.10	4.0
D	0.20	1.0
E	0.20	2.0
F	0.20	4.0

29 Two fixed horizontal metal rails are side by side and 12 cm apart. The rails are connected to a dc power supply by a switch that is initially open.

A freely moveable metal rod of length 20 cm is placed on the rails as shown in the diagram. The diagram shows the arrangement seen from above.

The angle between the rod and the rails is 90°.

moveable rod

12 cm 20 cm

fixed rails
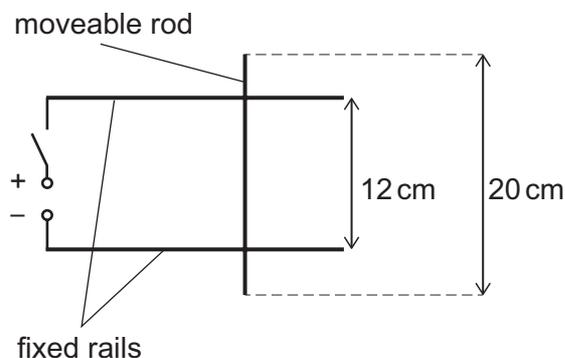
The whole arrangement is placed in a uniform magnetic field of magnitude 0.50 T that is directed perpendicularly into the page.

The moveable rod has a weight of 0.40 N.

The switch is now closed. As a result, there is a current of 2.4 A in the circuit and the rod moves.

What is the initial magnitude of the acceleration of the rod and what is its direction?

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

	acceleration / $\text{m}\,\text{s}^{-2}$	direction
A	0.36	to the left
B	0.36	to the right
C	0.60	to the left
D	0.60	to the right
E	3.6	to the left
F	3.6	to the right
G	6.0	to the left
H	6.0	to the right

30 A circuit contains a 12 V battery, a thermistor and a fixed resistor connected in series. The graph shows how the resistance of the thermistor varies with temperature.
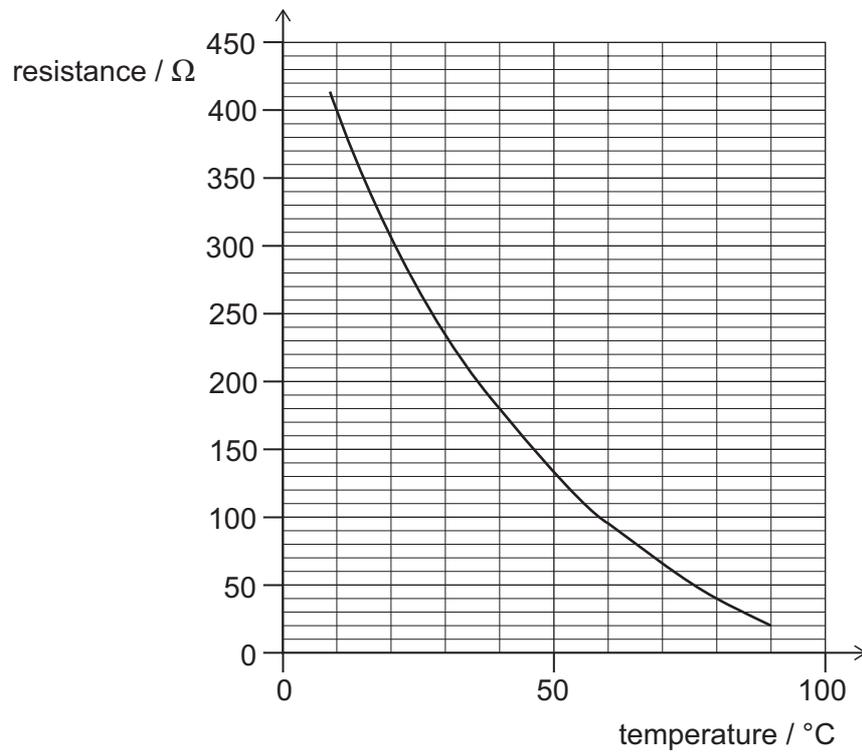
When the temperature of the thermistor is 10 °C the current in the circuit is 25 mA.

What is the current when the temperature of the thermistor is 80 °C?

A 30 mA

B 80 mA

C 100 mA

D 120 mA

E 150 mA

F 300 mA

G 480 mA

31 Two trolleys are moving towards each other along a straight horizontal track.

One trolley has mass 8.0 kg and is travelling to the right at $4.0\,\mathrm{m\,s^{-1}}$.

The other trolley has mass 2.0 kg and is travelling to the left at $1.0\,\mathrm{m\,s^{-1}}$.

When the trolleys collide they stick together.

How much kinetic energy is transferred to other forms of energy in the collision?

A   2.0 J

B   18 J

C   20 J

D   28 J

E   35 J

F   40 J

G   45 J

H   65 J

32 Visible light waves are electromagnetic waves that travel through a vacuum at $300\,000\,\mathrm{km\,s^{-1}}$ with wavelengths that range from 400 nm to 750 nm.

The electromagnetic waves emitted by a source are all at frequencies between $6.0 \times 10^{12}\,\mathrm{Hz}$ and $6.0 \times 10^{14}\,\mathrm{Hz}$.

Which statement about the waves emitted by the source is correct?

A   Infrared waves are emitted, but not ultraviolet or visible light waves.

B   Infrared and visible light waves are emitted, but not ultraviolet waves.

C   Infrared, ultraviolet and visible light waves are all emitted.

D   Ultraviolet waves are emitted, but not infrared or visible light waves.

E   Ultraviolet and visible light waves are emitted, but not infrared waves.

33 Cubes of side 2.0 cm are tightly packed into a rectangular box with internal dimensions 12.0 cm × 10.0 cm × 6.0 cm.

Each cube is either solid concrete or solid steel. There are twice as many steel cubes as concrete cubes.

What is the total mass of the cubes in the box?

(density of concrete = 2.0 g cm^{-3}; density of steel = 8.0 g cm^{-3})

A 2880 g

B 3240 g

C 3600 g

D 3840 g

E 4320 g

F 4800 g

34 A car of mass 800 kg travels in a straight line along a horizontal road.

The car accelerates **non-uniformly** from rest for 5.0 seconds and then moves at constant speed, as shown in the distance–time graph:
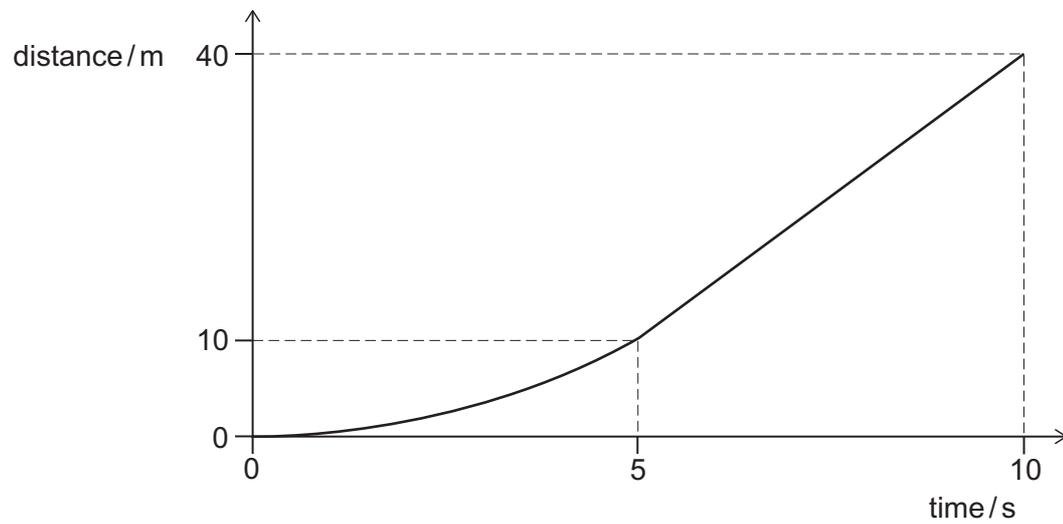
What is the average resultant force acting on the car over the time for which it is accelerating?

A 320 N

B 480 N

C 640 N

D 960 N

E 1600 N

F 3200 N

G 4800 N

35 A sample contains only one radioactive isotope. This isotope decays in a single step with a half-life of 120 minutes to a stable isotope.

The sample is placed near to a radiation detector which measures the count rate. The count rate reading is 910 counts per minute (cpm).

After 240 minutes the measurement is repeated. The count rate reading is now 238 cpm.

After a further 360 minutes have elapsed, a third measurement of the count rate is made.

What is the count rate due to background radiation and what is the expected reading in the third measurement?

	background count rate / cpm	third measurement / cpm
A	224	148
B	224	226
C	142	28
D	142	148
E	142	154
F	14	14
G	14	28
H	14	42

36 P and Q are two fixed points on the surface of the ocean which are 6.0 m apart.

An ocean wave travels in the direction P to Q.

The wave has a frequency of 0.50 Hz and travels at a constant speed.

A wave peak passes Q at time $t = 0$ s.

The next wave peak travelling towards Q passes P at time $t = 0.80$ s.

What is the speed of the wave?

A $2.1\,\text{ms}^{-1}$

B $3.4\,\text{ms}^{-1}$

C $5.0\,\text{ms}^{-1}$

D $7.5\,\text{ms}^{-1}$

E $20\,\text{ms}^{-1}$

37 A parachutist of mass 80.0 kg drops from a plane travelling at 40.0 m s⁻¹, 2000 m above the Earth's surface.

The parachutist hits the ground at a speed of 5.00 m s⁻¹.

How much work is done by the parachutist against drag forces during the fall?

(Take the Earth's gravitational field strength to be 10.0 N kg⁻¹.)

A 1 535 000 J

B 1 624 000 J

C 1 649 000 J

D 1 663 000 J

E 1 726 000 J

38 A solid uniform sphere is made of metal of density ρ_S and has radius r and volume V. It falls vertically through a viscous liquid of density ρ_L.

Three forces act on it: its weight, a drag force D and an upthrust U. The magnitude of the upthrust force is equal to the weight of the liquid displaced by the sphere.

The magnitude of the drag force is given by:

$$D = krv$$

where v is the speed of the metal sphere and k is a constant.

What is the terminal speed of the metal sphere as it falls through this liquid?

(gravitational field strength $= g$)

A $\dfrac{\rho_L g}{Vrk}$

B $\dfrac{\rho_S g}{Vrk}$

C $\dfrac{g(\rho_s - \rho_L)}{Vrk}$

D $\dfrac{g(\rho_s + \rho_L)}{Vrk}$

E $\dfrac{V\rho_L g}{rk}$

F $\dfrac{V\rho_S g}{rk}$

G $\dfrac{Vg(\rho_s - \rho_L)}{rk}$

H $\dfrac{Vg(\rho_s + \rho_L)}{rk}$

PART B Physics

39 A rocket travelling in space is burning its fuel at a constant rate. By expelling the burnt fuel through a nozzle, the engine is applying a constant force to the rocket.

What is happening to the magnitude of the acceleration of the rocket?

A It is increasing at an increasing rate.

B It is increasing at a constant rate.

C It is increasing at a decreasing rate.

D It is not changing.

E It is decreasing at an increasing rate.

F It is decreasing at a constant rate.

G It is decreasing at a decreasing rate.

40 A light spring of unstretched length 0.10 m has a spring constant of $20\,\mathrm{N\,m^{-1}}$. The spring is suspended so that it is vertical and a load of mass 0.050 kg is attached to the end of the spring.

The load is pulled vertically downwards until the length of the spring is 0.30 m. The load is then released.

What is the speed of the load at the instant that the spring returns to its unstretched length?

(gravitational field strength $= 10\,\mathrm{N\,kg^{-1}}$; assume that resistive forces are negligible)

A $0\,\mathrm{m\,s^{-1}}$

B $4.0\,\mathrm{m\,s^{-1}}$

C $6.0\,\mathrm{m\,s^{-1}}$

D $12\,\mathrm{m\,s^{-1}}$

E $16\,\mathrm{m\,s^{-1}}$

F $\sqrt{6}\,\mathrm{m\,s^{-1}}$

G $\sqrt{12}\,\mathrm{m\,s^{-1}}$

H $\sqrt{30}\,\mathrm{m\,s^{-1}}$

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PART C Chemistry

41 Use the following data table to answer the question.

gas	melting point / °C	boiling point / °C
hydrogen	−259	−253
nitrogen	−210	−196
oxygen	−219	−183
neon	−249	−246
argon	−189	−186

Water and carbon dioxide were removed from a sample of air and the remaining mixture was cooled to −260 °C.

The three most abundant remaining elements are to be separated by fractional distillation.

In which order would these three elements be collected?

A hydrogen, neon, nitrogen

B hydrogen, neon, oxygen

C neon, nitrogen, argon

D neon, nitrogen, oxygen

E nitrogen, argon, oxygen

F nitrogen, oxygen, argon

G oxygen, nitrogen, argon

H oxygen, argon, nitrogen

42 Consider **only** the first three metals in Group 1 (Li, Na, K) and **only** the first three elements in Group 17 (F, Cl, Br).

Which of the following statements is/are correct for the compound lithium bromide?

> **1** It is formed from the least reactive of the three Group 17 elements.
>
> **2** It is formed from the least reactive of the three Group 1 elements and the Group 17 element (of the three) with the lowest boiling point.
>
> **3** It is formed from the Group 1 element (of the three) with the highest melting point.

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 Which of the following tests could be used, on its own, to distinguish between all three of the following white solids: potassium carbonate, calcium chloride and sodium sulfate?

1 Add a small amount of each solid separately to a platinum wire and hold in a colourless flame.

2 Dissolve a small amount of each solid separately in deionised water and add a few drops of sodium hydroxide solution.

3 Dissolve a small amount of each solid separately in deionised water and add a few drops of hydrochloric acid, followed by barium chloride solution.

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

44 Molecule J is a straight-chain hydrocarbon containing one carbon-carbon double bond.

The relative atomic mass (A_r) of hydrogen is 1 and carbon is 12.

What is the **minimum** additional information that is needed in order to determine the molecular formula of molecule J?

1 The percentage by mass of carbon in the molecule.

2 The percentage by mass of hydrogen in the molecule.

3 The relative molar mass (M_r) of the molecule.

A 1 only

B 3 only

C 1 and 2 only

D 1 and 3 only

E 1, 2 and 3

45 Iodic acid, HIO_3, can be made from iodine in the following reaction:

$$I_2 \ + \ wH_2O \ + \ xCl_2 \ \rightarrow \ yHIO_3 \ + \ zHCl$$
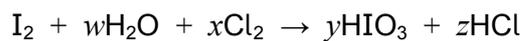
What is the value of x when the equation is balanced?

A 1

B 2

C 3

D 4

E 5

F 6

46 Which one of the following formulae is correct for the compound given?

A aluminium sulfate, $Al(SO_4)_3$

B ammonium carbonate, $(NH_4)_2CO_3$

C calcium hydroxide, $CaOH$

D magnesium nitrate, $MgNO_3$

E potassium bromide, KBr_2

47   Which of the following statements about elements in the Periodic Table is/are correct?

   1   When the element in Period 5, Group 2 reacts with the element that is in
       Period 3, Group 17, a redox reaction occurs.

   2   In each Group, the elements from Period 2 are more reactive than the elements
       from Period 5.

   3   The compound formed between the element in Period 2, Group 14 and the element
       in Period 3, Group 17 will have a simple molecular structure.

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 Some dilute aqueous solutions were electrolysed using graphite electrodes.

Which of the rows in the table show(s) the correct products of electrolysis?

	aqueous electrolyte	*products of electrolysis*	
		at the cathode (negative electrode)	*at the anode (positive electrode)*
1	potassium hydroxide	potassium	oxygen
2	copper(II) chloride	chlorine	copper
3	sodium sulfate	hydrogen	sulfur

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

49 A paper chromatogram is set up with an orange food colouring spotted on the baseline.

Ten minutes after the start, the solvent front has moved 15.0 cm up the paper from the baseline and a yellow spot is 12.0 cm above the baseline.

Five minutes later, the solvent front has moved up a further 10.0 cm.

How far from the baseline will the yellow spot be 15 minutes after the start?

A   8.0 cm

B   12.0 cm

C   15.0 cm

D   20.0 cm

E   22.0 cm

F   25.0 cm

G   31.3 cm

50 Which of the following equations represent(s) a redox reaction?

    1 $K_2Cr_2O_7 + 2KOH \rightarrow 2K_2CrO_4 + H_2O$

    2 $8HNO_3 + 3C_2H_6O + K_2Cr_2O_7 \rightarrow 2KNO_3 + 3C_2H_4O + 7H_2O + 2Cr(NO_3)_3$

    3 $H_2O + SO_2 \rightarrow H_2SO_3$

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 $100 \, cm^3$ of ethane is mixed with $1400 \, cm^3$ of oxygen and the mixture is ignited.

All volumes are measured at atmospheric pressure and a temperature of 150 °C.

What will be the **total** volume of gas after the complete combustion?

(Assume that equal amounts of any gas at the same temperature and pressure occupy the same volume.)

A $500 \, cm^3$

B $1250 \, cm^3$

C $1500 \, cm^3$

D $1550 \, cm^3$

E $1700 \, cm^3$

F $2000 \, cm^3$

52 10 g of a mixture of solid magnesium hydroxide, $Mg(OH)_2$, and solid sodium hydroxide, $NaOH$, is added to an excess of water and stirred.

One of the components of the mixture dissolves. Assume that the other is completely insoluble.

The mixture is filtered to remove the insoluble component of the mixture.

$50 \, cm^3$ of $1.0 \, mol \, dm^{-3}$ sulfuric acid exactly neutralises the remaining solution.

What is the mass of magnesium hydroxide in the original mixture?

(M_r values: $Mg(OH)_2 = 58$; $NaOH = 40$)

A 2.0 g

B 2.9 g

C 4.0 g

D 5.8 g

E 6.0 g

F 8.0 g

53 Calcium carbonate reacts with hydrochloric acid according to the following chemical equation:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Line **P** on the graph shows how the volume of carbon dioxide formed changes with time when 4.0 g of calcium carbonate reacts with 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 20 °C.

A second reaction was carried out under identical conditions with the same mass of calcium carbonate but using 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

Which line (**A**-**F**) best represents how the volume of carbon dioxide formed changes with time in the second reaction?

(M_r value: CaCO$_3$ = 100)
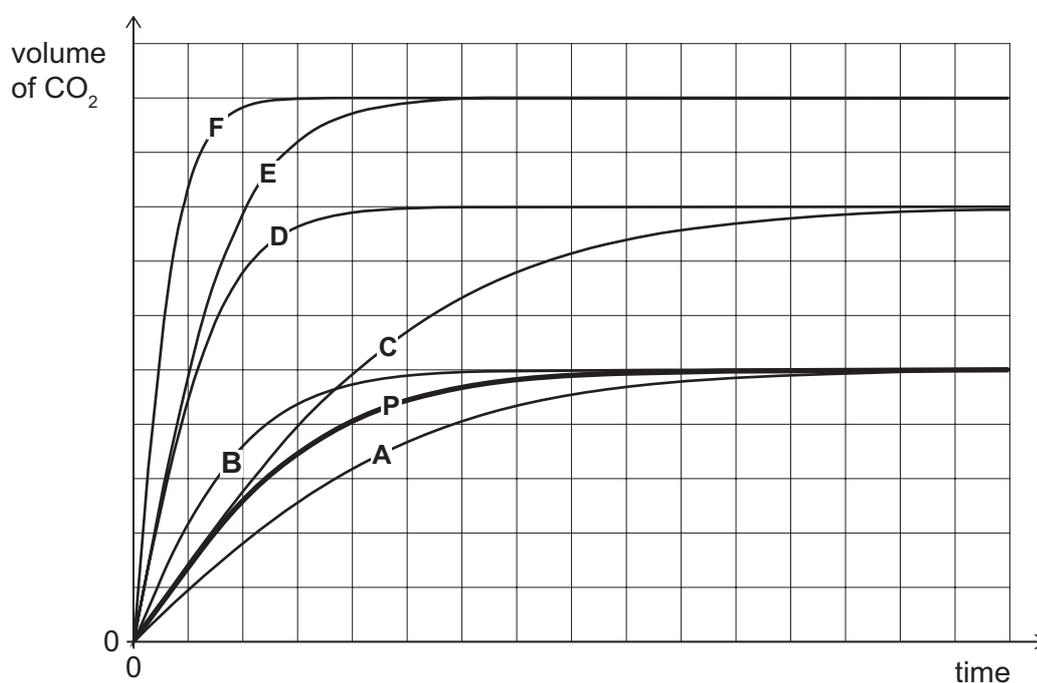
54 Hydrochloric acid, sulfuric acid and phosphoric(V) acid are inorganic acids.

Phosphoric(V) acid, H_3PO_4, ionises in water in the following series of reactions:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$$

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$$
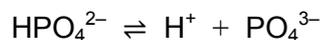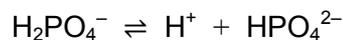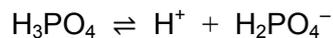
$0.1\,mol\,dm^{-3}$ hydrochloric acid has a pH of 1.0 at room temperature.

Which of the following statements about these acids is/are correct?

1 The pH of $0.1\,mol\,dm^{-3}$ sulfuric acid is greater than 1.0 at room temperature.

2 $H_2PO_4^-$ can act as an acid or as a base.

3 $30\,cm^3$ of calcium hydroxide solution exactly neutralises $20\,cm^3$ phosphoric(V) acid solution when both solutions are the same concentration.

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 Complete combustion of 1 mol of hydrocarbon X requires exactly 8.5 mol of oxygen.

Incomplete combustion of 1 mol of hydrocarbon X, to form carbon monoxide and water only, requires exactly 5.5 mol of oxygen.

How many hydrogen atoms are there in one molecule of hydrocarbon X?

A 6

B 8

C 10

D 12

E 14

56 An element Z forms an ionic compound ZSO_4 which has $M_r = 120.4$

The ion of Z in ZSO_4 has 10 electrons.

Element Z has three isotopes, labelled L, M and N, which contain the following numbers of neutrons.

isotope	L	M	N
number of neutrons	12	13	14

The percentage abundances of isotopes M and N are the same.

What is the percentage abundance of the isotope L in the element Z in ZSO_4?

(M_r value: $SO_4^{2-} = 96.1$)

A 4.10%

B 10.0%

C 13.4%

D 43.3%

E 80.0%

F 91.8%

57 An experiment is carried out using the first three metals in Group 1: lithium, sodium and potassium.

The initial masses of three open beakers each containing 100 g samples of an alcohol are recorded.

In three separate experiments, equal small masses of lithium, sodium and potassium are added to the three beakers, which are on electronic balances.

Each metal reacts in a similar way and after the reaction is complete, the final mass of each beaker and its contents is recorded.

In each case, the final mass of the beaker and its contents is compared to the recorded initial mass before the alkali metal was added.

Which of the following statements is correct?

A   The beaker with lithium added would decrease in mass the most.

B   The beaker with sodium added would decrease in mass the most.

C   The beaker with potassium added would decrease in mass the most.

D   All three beakers would show the same decrease in mass.

E   The beaker with lithium added would increase in mass the most.

F   The beaker with sodium added would increase in mass the most.

G   The beaker with potassium added would increase in mass the most.

H   All three beakers would show the same increase in mass.

58 Four separate experiments were carried out using different quantities of $2\,\text{mol}\,\text{dm}^{-3}$ hydrochloric acid and $2\,\text{mol}\,\text{dm}^{-3}$ sodium hydroxide in insulated polystyrene cups.

After stirring, the maximum temperature was recorded and the results plotted on a graph as shown.

The temperatures of the acid and alkali on their own were also plotted on the graph. Two straight lines were drawn and extrapolated as shown.
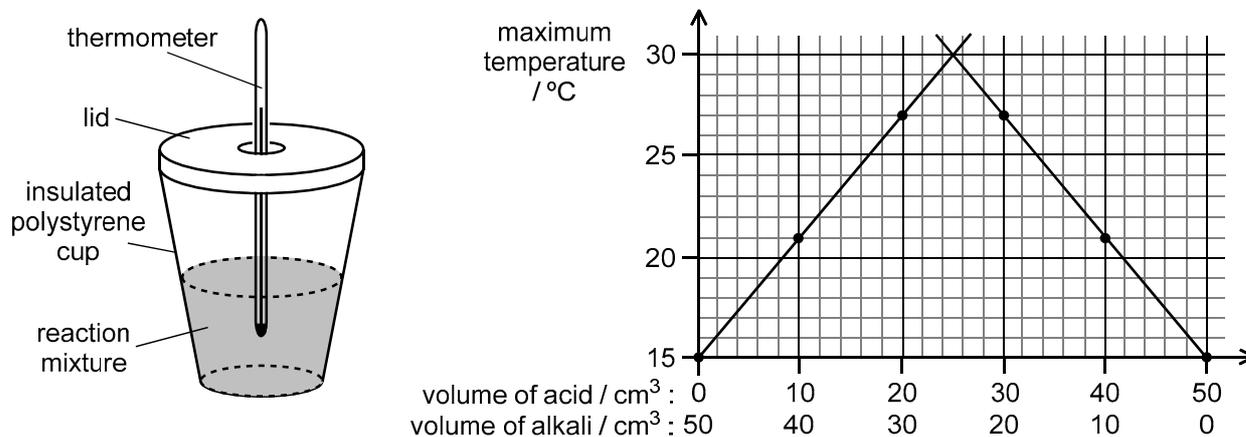
What is the molar enthalpy change for the neutralisation reaction, in $\text{kJ}\,\text{mol}^{-1}$?

(Assume that the specific heat capacity of the solutions is $4\,\text{J}\,\text{g}^{-1}\,^{\circ}\text{C}^{-1}$, the density of dilute solutions is $1\,\text{g}\,\text{cm}^{-3}$, and all heat is transferred to the solution.)

A $3\,\text{kJ}\,\text{mol}^{-1}$

B $6\,\text{kJ}\,\text{mol}^{-1}$

C $30\,\text{kJ}\,\text{mol}^{-1}$

D $60\,\text{kJ}\,\text{mol}^{-1}$

E $120\,\text{kJ}\,\text{mol}^{-1}$

F $3000\,\text{kJ}\,\text{mol}^{-1}$

59 An electric current is the flow of charged particles.

In an electrolysis of aluminium oxide using inert electrodes, the current flows at 5.00×10^{-6} moles of electrons per second.

Assume that only aluminium oxide is present and the aluminium is a single isotope $^{27}_{13}Al$.

What mass of aluminium is produced in 48 seconds?

A 0.04 mg

B 0.09 mg

C 0.52 mg

D 1.04 mg

E 1.08 mg

F 2.16 mg

G 3.12 mg

H 6.48 mg

60 X is a solution of sulfuric acid.

$20.0 \, cm^3$ of X is diluted by adding distilled water to produce $500 \, cm^3$ of solution Y.

$10.0 \, cm^3$ of Y is exactly neutralised by $40.0 \, cm^3$ of $0.0500 \, mol \, dm^{-3}$ aqueous potassium hydroxide.

What is the concentration of sulfuric acid in X?

A $0.00100 \, mol \, dm^{-3}$

B $0.100 \, mol \, dm^{-3}$

C $0.200 \, mol \, dm^{-3}$

D $0.400 \, mol \, dm^{-3}$

E $1.25 \, mol \, dm^{-3}$

F $2.50 \, mol \, dm^{-3}$

G $5.00 \, mol \, dm^{-3}$

H $10.0 \, mol \, dm^{-3}$

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PART D Biology

**61** Which of the following **could** lead to phenotypic variation between a father and his son?

    1   time spent in sunlight

    2   their genomes

    3   their diets

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 cells do not contain mitochondria?

    1   bacterial cells

    2   embryonic stem cells

    3   mature red blood cells

    4   potato cells

A   1 only

B   2 only

C   3 only

D   4 only

E   1 and 2 only

F   1 and 3 only

G   1 and 4 only

H   2 and 4 only

63 A section of double-stranded DNA contains 4500 base pairs. 10% of the bases present are adenine.

Which of the following statements is/are correct?

1 There are 450 thymine bases present.

2 40% of the bases present are cytosine.

3 There are 3600 guanine bases 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

64 The diagram shows part of the carbon cycle.
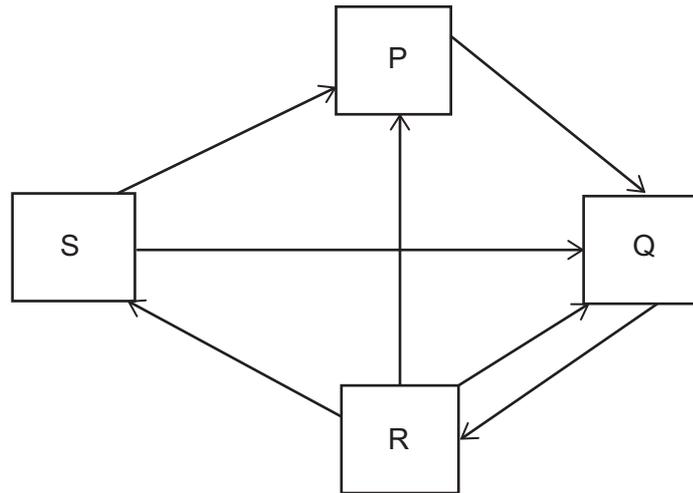
Which row identifies the correct descriptions for boxes P, Q, R and S?

	CO$_2$ in atmosphere	*carbon-rich compounds in animals*	*carbon-rich compounds in decomposers*	*carbon-rich compounds in plants*
A	P	Q	R	S
B	Q	P	S	R
C	S	Q	R	P
D	Q	S	P	R
E	S	R	Q	P
F	R	S	P	Q
G	P	R	Q	S
H	R	P	S	Q

65   The diagram shows two human gametes, cell P and cell Q, fusing to form cell R.

      Cell P carries an additional copy of one of its chromosomes so that it has one more
      chromosome than cell Q.

      Cell R divides to form two cells S and T.

   S and T grow into two separate individuals.
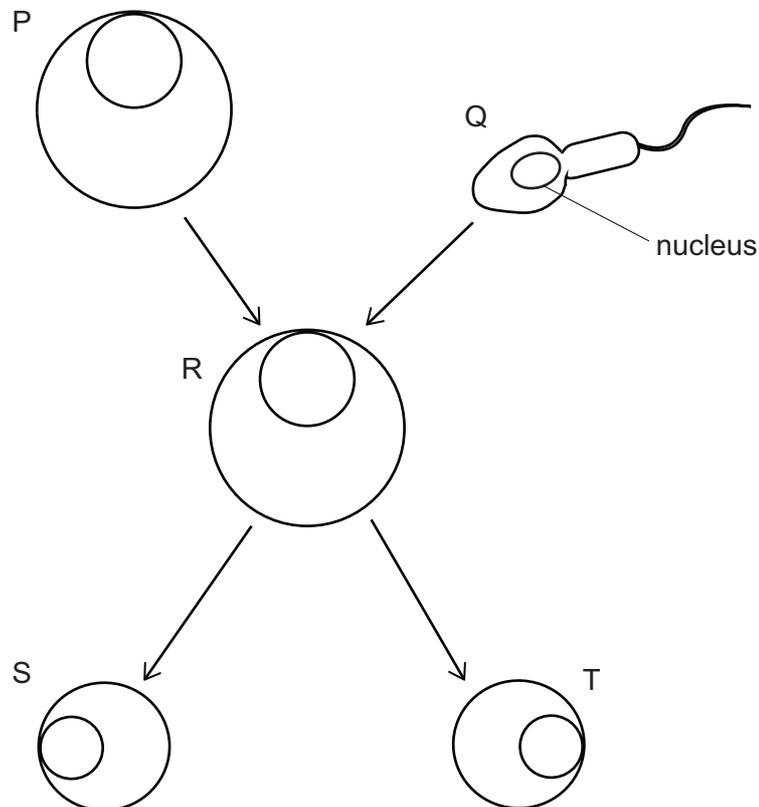
      Using this information, which row shows the correct number of chromosomes in the nucleus of
      cell R and in the nucleus of cell T?

	cell R	cell T
A	23	24
B	24	47
C	24	48
D	46	46
E	47	24
F	47	47
G	92	47
H	93	93

66   Pepsin and trypsin are both protease enzymes found in the human digestive system.

The graph shows how the activity of both enzymes varies with pH.

Key
——————— pepsin
- - - - - - - trypsin

percentage   100
of maximum
enzyme activity
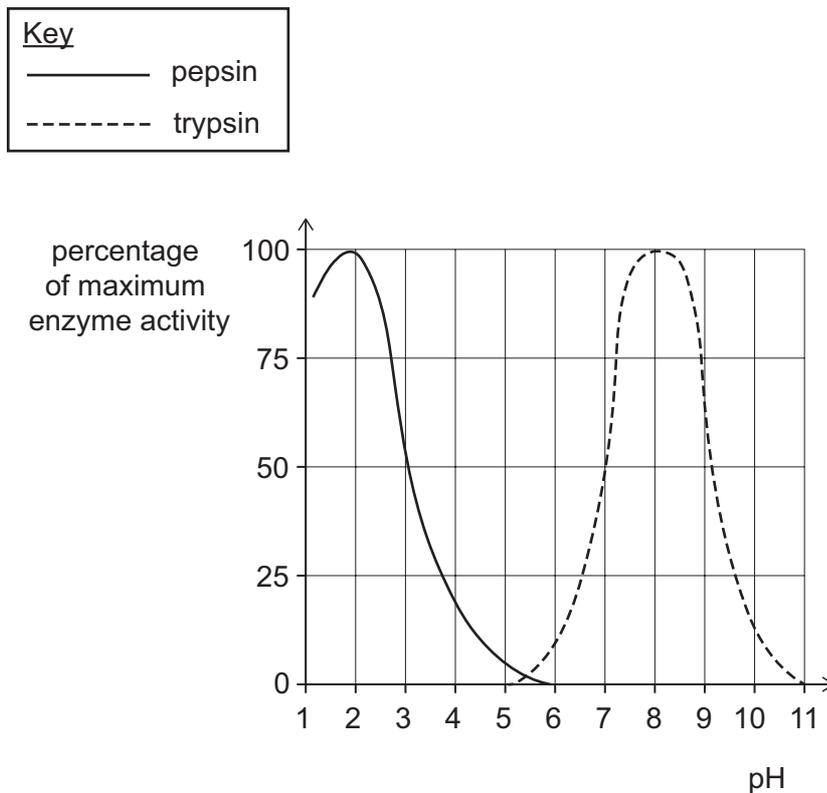
In the human digestive system:

1   pepsin is most active in the stomach.

2   trypsin would be inactive in the stomach.

3   pepsin could be a substrate for trypsin.

4   pepsin is most active at low acidity and trypsin most active at high acidity.

Which statements are correct?

A   1 and 2 only

B   1 and 3 only

C   1 and 4 only

D   2 and 3 only

E   2 and 4 only

F   3 and 4 only

G   1, 2 and 3 only

H   2, 3 and 4 only

67 The table shows concentrations of substances in blood entering and leaving three different organs of a person:

- kidney
- small intestine
- chambers of the right side of the heart

The blood sample was taken 10 minutes after the person had eaten a carbohydrate-rich meal.

organ	concentration in blood entering the organ			concentration in blood leaving the organ		
	glucose / mg dm^{-3}	oxygen / arbitrary units	urea / mg dm^{-3}	glucose / mg dm^{-3}	oxygen / arbitrary units	urea / mg dm^{-3}
1	9.0	65	3.0	9.0	65	3.0
2	9.0	85	3.0	9.0	70	2.4
3	9.0	85	3.0	12.0	70	3.0

Which row in the following table identifies the organs?

	organ 1	organ 2	organ 3
A	kidney	small intestine	chambers of the right side of the heart
B	kidney	chambers of the right side of the heart	small intestine
C	small intestine	kidney	chambers of the right side of the heart
D	small intestine	chambers of the right side of the heart	kidney
E	chambers of the right side of the heart	small intestine	kidney
F	chambers of the right side of the heart	kidney	small intestine

68 SCID is an inherited condition in humans.

In one type of SCID, the white blood cells are unable to make the functional enzyme ADA, which is necessary for these cells to divide by mitosis during an immune response.

Scientists have developed a gene therapy treatment whereby a gene is inserted into the DNA of stem cells taken from the bone marrow of a person with this condition. These cells can then be returned to the body of the person, and can divide and differentiate into white blood cells. If this gene therapy is successful, the number of white blood cells should increase significantly.

Which of the following statements correctly describe(s) how this method of gene therapy might work to help a person with this type of SCID?

1 Genetically altered stem cells differentiate into white blood cells that are able to produce functional ADA.

2 Genetically altered stem cells can differentiate into gametes so that offspring will not inherit SCID.

3 The sequence of the bases in the DNA of the white blood cells, derived from the genetically altered stem cells, has changed.

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

69 Which of the following could be a result of the addition of a large amount of organic material into a slow flowing river?

    1   A decrease in biodiversity in the river.

    2   A reduction in the oxygen concentration gradient between the air and the water.

    3   An increase in the size of at least one aquatic population.

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

70 The table shows information about a human genetic condition called sickle cell anaemia and an infection called malaria. Both sickle cell anaemia and malaria can be fatal.

genotype	phenotype	comment
MM	does not show sickle cell anaemia	can be infected with malaria
Mm	does not show sickle cell anaemia	shows resistance to malaria
mm	shows sickle cell anaemia	shows more resistance to malaria than Mm

Which of the following statements is/are correct?

1 In areas without malaria, human populations are likely to have a low number of people with the m allele.

2 In areas with malaria, only those individuals that are heterozygous will be able to pass on their alleles to the next generation.

3 Presence of malaria has caused a mutation of the M allele to the m allele leading to an increased chance of survival in the heterozygous state.

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 table shows the concentration of potassium ions in several different locations.

location	concentration of potassium ions
bacterial cell cytoplasm	30 mmol dm^{-3}
mammalian blood plasma	$4000 \text{ } \mu\text{mol dm}^{-3}$
mammalian heart cell cytoplasm	$1.0 \times 10^{2} \text{ mmol dm}^{-3}$
sea water	$3.0 \times 10^{4} \text{ } \mu\text{mol dm}^{-3}$
yeast cell cytoplasm	300 mmol dm^{-3}

Which of the following statements is/are correct?

1   A mammalian heart cell needs energy from respiration in order to obtain more potassium ions from blood plasma.

2   If a yeast cell is placed in sea water then it will lose potassium ions by osmosis.

3   There is no concentration gradient for potassium ions between a bacterial cell and sea water.

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 graph shows the mass of product produced over time for an enzyme-controlled reaction in two different conditions, X and Y. All other variables were kept constant.
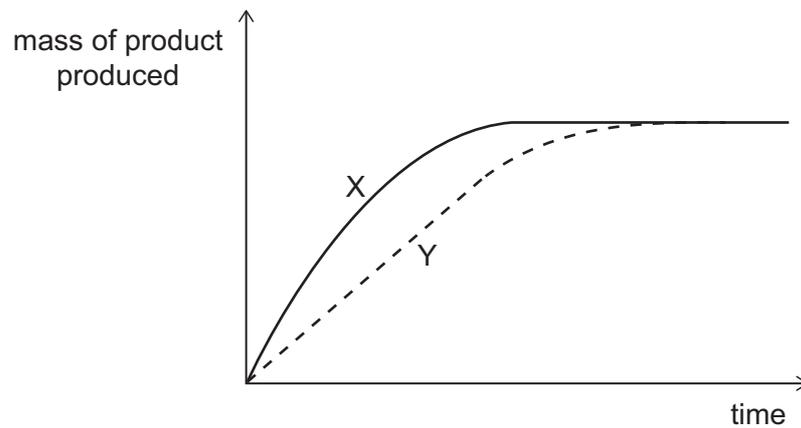
Which of the following could be correct for this graph?

1 Condition X is a higher pH than condition Y.

2 Condition X has less substrate supplied than condition Y.

3 Condition X is a lower pH than condition Y.

4 Condition X has more substrate supplied than condition Y.

A none of them

B 1 and 2 only

C 1 and 3 only

D 1 and 4 only

E 2 and 3 only

F 2 and 4 only

G 3 and 4 only

H 1, 2, 3 and 4

73 A student investigated the endothermic reaction of photosynthesis in pondweed. The student set up the apparatus as shown in the diagram.
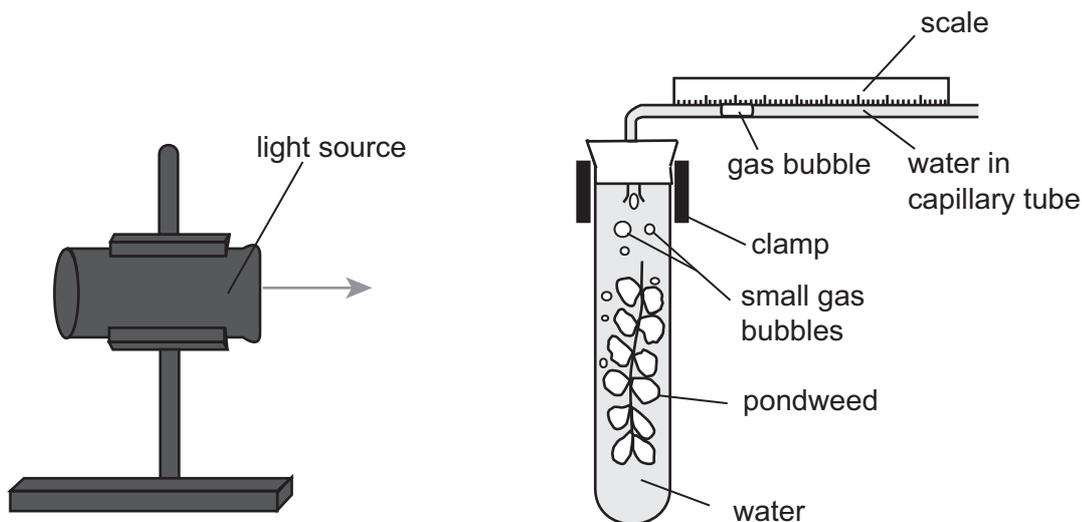

The experiment was left for 5 minutes and the distance moved by the gas bubble along a capillary tube of 2 mm diameter was recorded. Using these values, the rate of gas production is 2π mm^3 per minute.

Which row of the table is correct?

	total distance moved by the gas bubble during the experiment / mm	reason why the reaction is described as endothermic	observations if the light source was moved further from the pondweed
A	0.5	the reaction releases energy	the gas bubble moves more slowly to the right
B	0.5	the reaction takes in energy	the gas bubble moves more slowly to the left
C	2.0	the reaction releases energy	the gas bubble moves more slowly to the left
D	2.0	the reaction releases energy	the gas bubble moves more slowly to the right
E	2.5	the reaction takes in energy	the gas bubble moves more slowly to the left
F	2.5	the reaction takes in energy	the gas bubble moves more slowly to the right
G	10.0	the reaction releases energy	the gas bubble moves more slowly to the left
H	10.0	the reaction takes in energy	the gas bubble moves more slowly to the right

74   The abundance of a plant species in a habitat can be measured in different ways:

- the density (the number of that plant species per m^2)
- the frequency (the number of quadrats in which the plant species occurs)

The abundance of a plant species in a 100 m^2 area of grassland was measured. The diagram below represents this area of grassland. Each black circle represents one individual of the plant species in this area of grassland.
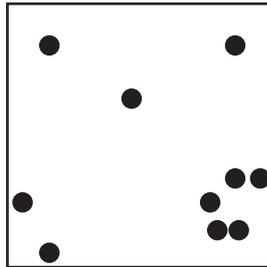
Two different size quadrats were used to sample the area:

- large quadrat (50 cm × 50 cm)
- small quadrat (10 cm × 10 cm)

The area is sampled randomly, first using 10 large quadrats and then a second time using 10 small quadrats.

Which of the following statements is/are correct?

1   The overall density in the grassland calculated from sampling with either size quadrat will always be the same.

2   The overall density in the grassland calculated from sampling will always be 1 plant per m^2.

3   The frequency obtained using the small quadrat will always be lower than that obtained with the large quadrat.

A   none of them

B   1 only

C   2 only

D   3 only

E   1 and 2 only

F   2 and 3 only

G   1 and 3 only

H   1, 2 and 3

75 The diagram shows the changes in the volume of the ventricles, and the ECG trace that accompanies those changes, during two consecutive heart beats.
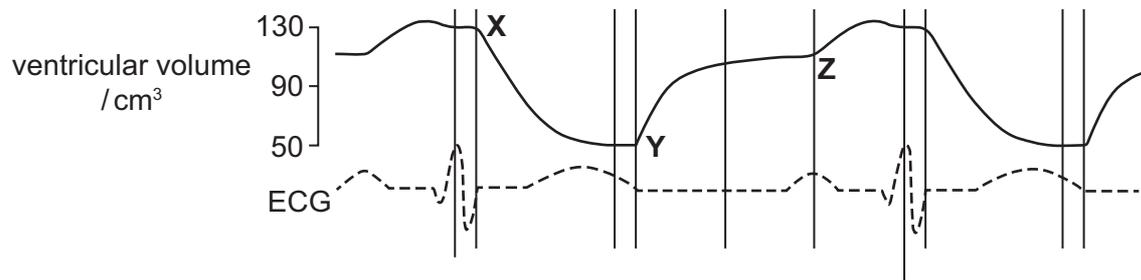

Which row is correct about the events happening at X, Y and Z?

	at X blood is being pumped into	at Y valves between atria and ventricles are	chambers of the heart contracting at Z
A	aorta	open	atria
B	aorta	closed	atria
C	atria	open	ventricles
D	atria	closed	ventricles
E	pulmonary artery	open	ventricles
F	pulmonary artery	closed	ventricles
G	pulmonary vein	open	atria
H	pulmonary vein	closed	atria

76   The placenta is an organ that develops during pregnancy. One function of the placenta is to allow the exchange of gases between the mother and the developing foetus.

The diagram represents the maternal and foetal blood flow between P and Q in a section of the placenta of a healthy small mammal. The concentration of oxygen in both maternal and foetal blood was measured at regular distances along this section.
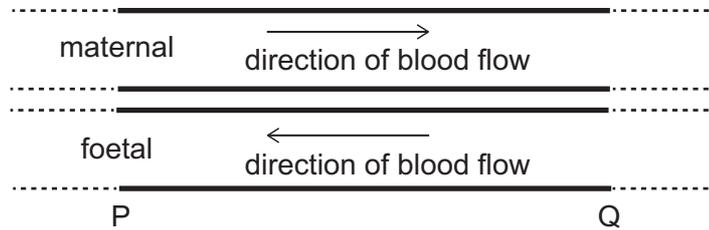
Which graph illustrates the concentration of oxygen in both maternal and foetal blood between P and Q?
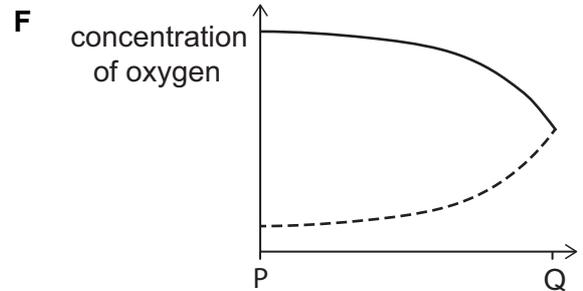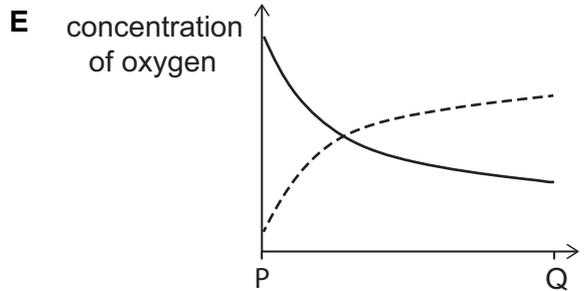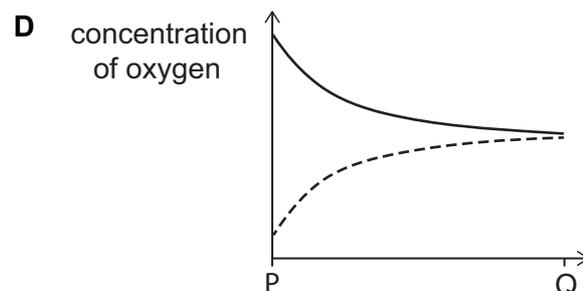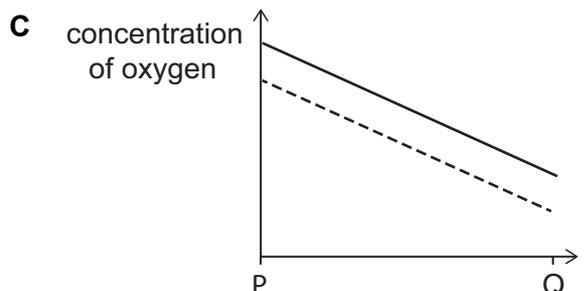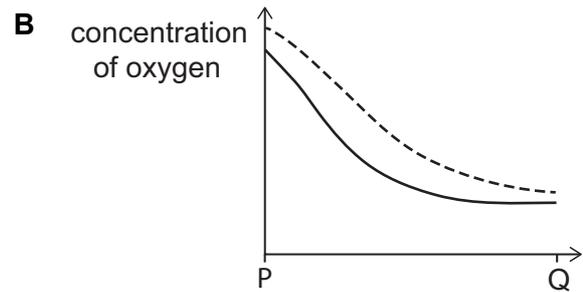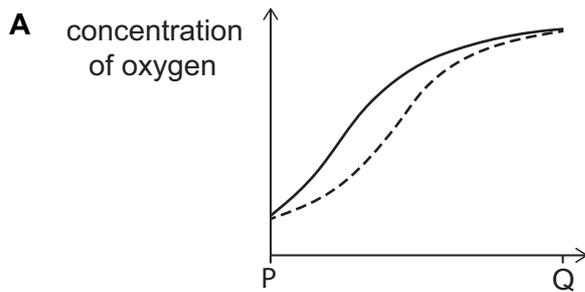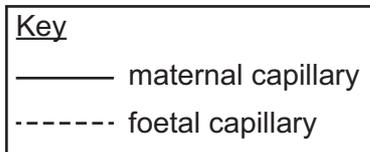
77 Catalase is an enzyme found inside plant and animal cells. When catalase is added to hydrogen peroxide, bubbles of oxygen gas are formed.

Red blood cells were placed into either water or plasma, and were placed in the dark.

Plant cells were placed into either water or $0.5\,mol\,dm^{-3}$ sucrose solution, and were placed in the dark.

Assume that hydrogen peroxide and catalase do not cross the cell surface membrane.

Which row shows the results when hydrogen peroxide was added?

Key

✓ = oxygen bubbles will form

x = oxygen bubbles will not form

	when hydrogen peroxide was added to			
	red blood cells in plasma	plant cells in a $0.5\,mol\,dm^{-3}$ sucrose solution	red blood cells in water	plant cells in water
A	✓	✓	x	x
B	x	x	✓	✓
C	x	x	✓	x
D	x	x	x	✓
E	✓	✓	✓	x
F	✓	✓	x	✓

78 Three different methods, X, Y and Z, of controlling pathogens in the human body are compared in the table.

method of controlling the pathogen	affects bacterial pathogens	affects viral pathogens	requires the movement of human cells to have an effect	uses a molecule released from human cells
X	yes	yes	yes	no
Y	yes	no	no	no
Z	yes	yes	no	yes

Which row in the following table is correct?

|	method of controlling the pathogen		
	X	Y	Z
A	may be stimulated by injections of inactivated pathogen	taking an antibiotic	may work by cells engulfing pathogens
B	may be stimulated by injections of inactivated pathogen	may work by cells engulfing pathogens	taking an antibiotic
C	taking an antibiotic	may be stimulated by injections of inactivated pathogen	may work by cells engulfing pathogens
D	taking an antibiotic	may work by cells engulfing pathogens	may be stimulated by injections of inactivated pathogen
E	may work by cells engulfing pathogens	may be stimulated by injections of inactivated pathogen	taking an antibiotic
F	may work by cells engulfing pathogens	taking an antibiotic	may be stimulated by injections of inactivated pathogen

79 In rabbits, there are two alleles concerned with dark pigment in the fur:

  • the dominant allele, B, for black colour

  • the recessive allele, b, for brown colour

Two male black rabbits of unknown genotype each mated with a different female brown rabbit.

What is the expected proportion of brown offspring if both male rabbits are heterozygous, and what is the expected proportion of brown offspring if only one male rabbit is heterozygous?

	expected proportion of brown offspring	
	if both male rabbits heterozygous	*if only one male rabbit heterozygous*
A	0.25	0.5
B	0.25	1
C	0.5	0.25
D	0.5	1
E	1	0.25
F	1	0.5

80 The three family trees show the inheritance of three different genetic conditions, each controlled by one gene with one dominant and one recessive allele.
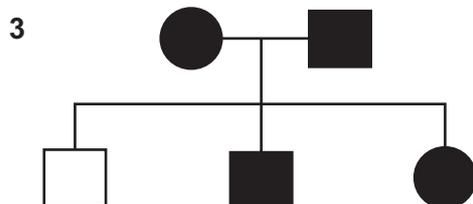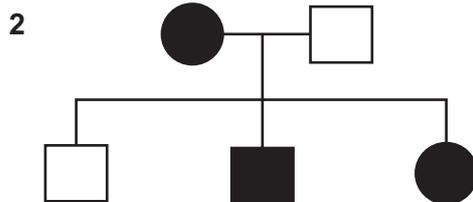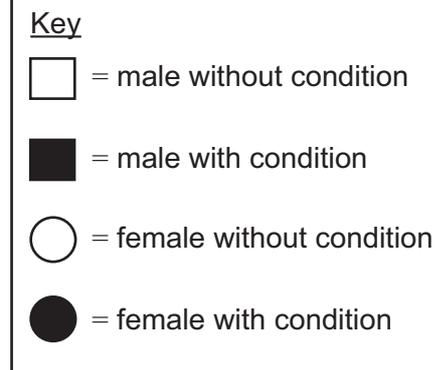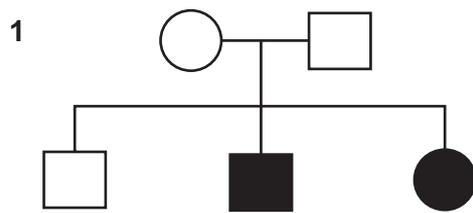
In which of the family trees **must** the male parent be heterozygous?

(Assume that no new mutations occur and that the genes are not found on the X 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

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NATURAL SCIENCES ADMISSIONS ASSESSMENT

D568/32

November 2020

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 67 printed pages and 5 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 Spring P has spring constant $1.0\,\mathrm{N\,cm^{-1}}$ and spring Q has spring constant $3.0\,\mathrm{N\,cm^{-1}}$.

The two springs are connected in series.

The springs are stretched by 6.0 cm in total.

What is the extension of spring P?

(The springs have negligible mass and obey Hooke's law.)

A 1.5 cm

B 2.0 cm

C 3.0 cm

D 4.0 cm

E 4.5 cm

2 A single strand of wire has a radius of 2.0×10^{-4} m and length 15 m. The resistivity of the material from which the wire is made is $4.8 \times 10^{-7}\,\Omega$ m.

Twelve strands of this wire are connected in parallel to make a cable.

What is the resistance of the cable?

A $\dfrac{\pi}{2160}\,\Omega$

B $\dfrac{\pi}{180}\,\Omega$

C $\dfrac{\pi}{15}\,\Omega$

D $\dfrac{15}{\pi}\,\Omega$

E $\dfrac{180}{\pi}\,\Omega$

F $\dfrac{2160}{\pi}\,\Omega$

3   A ray of light is directed into a semicircular transparent block, entering at P. The direction of the ray is adjusted until it strikes the centre of the flat face XY of the block at the critical angle and reflects to Q as shown.
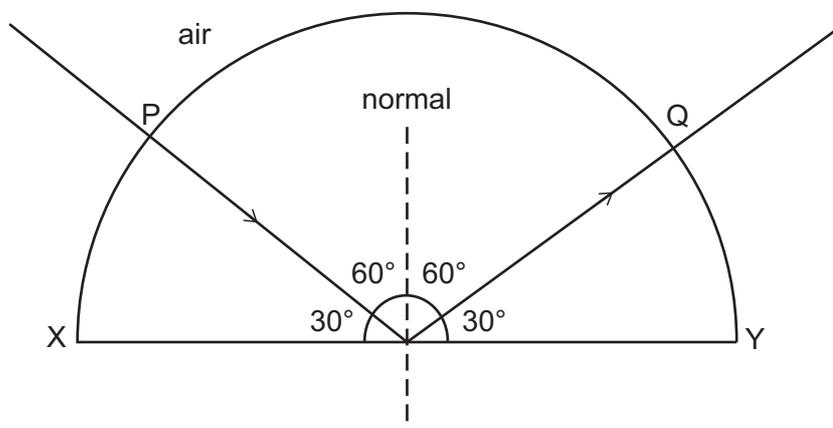
The length of XY is *L*.

The speed of light in air is c.

What is the time taken by the light to travel from P to Q in the block?

A $\dfrac{L\sqrt{3}}{2c}$

B $\dfrac{L}{c}$

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

D $\dfrac{L\sqrt{3}}{c}$

E $\dfrac{2L}{c}$

F $\dfrac{4L}{c\sqrt{3}}$

4 A solid cube with sides of length 20 cm is made from material with density 2000 kg m^{-3}. The cube is suspended, in equilibrium, from an initially unstretched spring, and this results in the spring gaining strain energy of 3.2 J.

What is the spring constant of the spring?

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

A 40 N m^{-1}

B 80 N m^{-1}

C 400 N m^{-1}

D 800 N m^{-1}

E 4000 N m^{-1}

F 8000 N m^{-1}

5 A projectile is fired upwards from the ground at an angle of 60° to the vertical at a speed of $20\,\mathrm{m\,s^{-1}}$.

It travels a horizontal distance d and lands with a downwards vertical component of velocity of $4.0\,\mathrm{m\,s^{-1}}$ on ground that is height h above the starting point of the projectile.

What are d and h?

(gravitational field strength $= 10\,\mathrm{N\,kg^{-1}}$; assume that air resistance is negligible)

	d / m	h / m
A	$6.0\sqrt{3}$	4.2
B	$6.0\sqrt{3}$	5.8
C	$10\sqrt{3} - 4.0$	4.2
D	$10\sqrt{3} - 4.0$	14.2
E	$10\sqrt{3} + 4.0$	5.8
F	$10\sqrt{3} + 4.0$	14.2
G	$14\sqrt{3}$	4.2
H	$14\sqrt{3}$	5.8

6 Diagram 1 shows the positions of nine equally spaced particles in a medium.
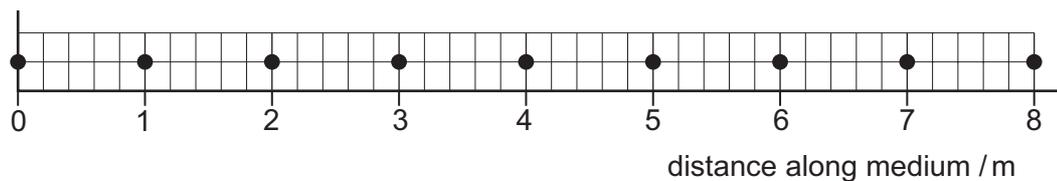

Diagram 1

Diagram 2 shows the positions of the same nine particles, at a particular time, while a longitudinal wave is travelling through the medium.
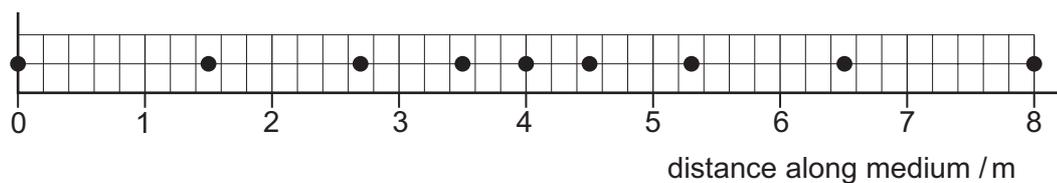
Diagram 2

What is the amplitude of the wave?

A 0.4 m

B 0.5 m

C 0.6 m

D 0.7 m

E 2.0 m

F 4.0 m

G 6.0 m

H 8.0 m

7   A spaceship with mass 8.0×10^4 kg travels at constant velocity and has 1.0×10^{12} J of kinetic energy.

An external impulse of 8.0×10^7 kg m s^{-1}, lasting for 2.0 s, is applied to the spaceship acting in the opposite direction to the motion of the spaceship.

What is the average rate of loss of kinetic energy of the spaceship during the application of the impulse?

A 9.5×10^{10} W

B 1.8×10^{11} W

C 2.2×10^{11} W

D 3.2×10^{11} W

E 3.6×10^{11} W

F 7.2×10^{11} W

8   The diagram shows a solid triangular prism.
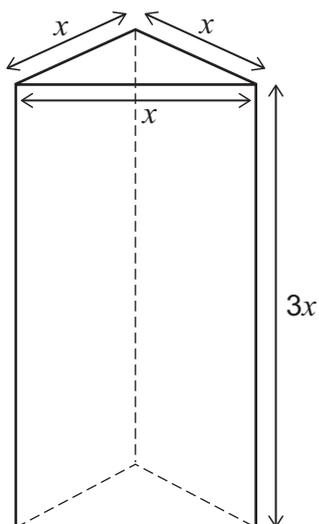
The sides of the triangular cross section of the prism are of length x.

The height of the prism is $3x$.

The uniform density of the prism is ρ.

The gravitational field strength is g.

What is the minimum pressure the prism can exert when it rests on level ground?

A $3\rho g$

B $3\rho g x$

C $\dfrac{\rho g}{4}$

D $\dfrac{\rho g x}{4}$

E $\dfrac{\sqrt{3}\rho g}{4}$

F $\dfrac{\sqrt{3}\rho g x}{4}$

9 An apple of mass m_a is placed on a uniform metre rule with the centre of gravity of the apple at the 10 cm mark. The rule is balanced on a pivot placed at the 35 cm mark.

The apple is replaced with an orange of mass m_o. The rule now balances with the pivot at the 40 cm mark.

What is the ratio $\dfrac{m_a}{m_o}$?

A $\quad\dfrac{5}{9}$

B $\quad\dfrac{4}{5}$

C $\quad\dfrac{5}{6}$

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

E $\quad\dfrac{5}{4}$

F $\quad\dfrac{9}{5}$

10 A cyclist travels at a constant speed of $12\,\mathrm{m\,s^{-1}}$ on level ground. During this time the power needed to maintain a constant speed is 900 W. The total weight of the cyclist and bicycle is 850 N.

The cyclist now cycles up a slope at the same constant speed. The slope is at an angle of 30° to the horizontal.

What is the driving force on the bicycle as it travels up the slope?

(Assume that the magnitude of the resistive forces is constant.)

A 75 N

B 350 N

C 500 N

D $\left(425\sqrt{3} - 75\right)$ N

E 775 N

F $\left(425\sqrt{3} + 75\right)$ N

G 925 N

11 Three identical resistors can be combined in four different arrangements.

One of the arrangements has a resistance of $18\,\Omega$.

A different arrangement has a resistance of $8.0\,\Omega$.

What are the resistances of the other two arrangements?

(All three resistors contribute to the total resistance in all arrangements.)

A $2.0\,\Omega$ and $4.0\,\Omega$

B $2.0\,\Omega$ and $9.0\,\Omega$

C $4.0\,\Omega$ and $12\,\Omega$

D $4.0\,\Omega$ and $36\,\Omega$

E $36\,\Omega$ and $162\,\Omega$

F $81\,\Omega$ and $162\,\Omega$

12 A 4.0 kΩ fixed resistor is connected in series with a light dependent resistor (LDR) across a 100 V dc power supply.

The current in the LDR is 5.0 mA.

The intensity of light falling on the LDR now decreases and the voltage across the fixed resistor changes by 50%.

What is the change in the resistance of the LDR as a result of the change in intensity?

A 8.0 kΩ

B 12 kΩ

C 16 kΩ

D 20 kΩ

E 32 kΩ

F 36 kΩ

13 An elastic cord with spring constant k is fixed to two points P and Q on the diameter of a ring so that the cord is taut but unstretched. The radius of the ring is r.
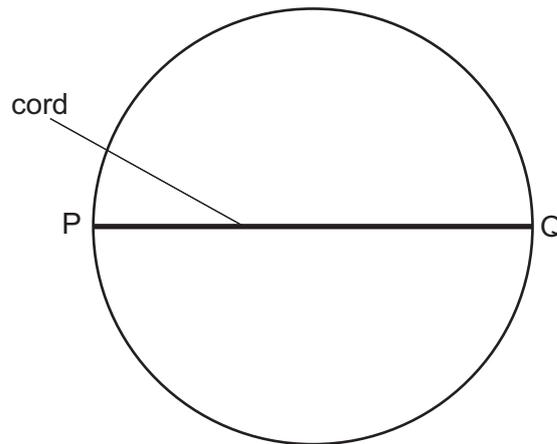
The midpoint of the cord is then pulled and fixed to a point on the ring halfway between P and Q.

What is the energy stored in the elastic cord?

A $\quad \dfrac{1}{2}kr^2$

B $\quad 2kr^2$

C $\quad \dfrac{1}{2}\left(\sqrt{2}-1\right)kr^2$

D $\quad 2\left(\sqrt{2}-1\right)kr^2$

E $\quad \dfrac{1}{2}\left(3-2\sqrt{2}\right)kr^2$

F $\quad 2\left(3-2\sqrt{2}\right)kr^2$

14 An object of mass M experiences a resultant force of magnitude F. The force acts in a single horizontal direction with a magnitude that varies with time t according to

$$F = X + Y\sqrt{t}$$

where X and Y are constants.

The object is at rest at $t = 0$.

What is the magnitude of the momentum of the object at time $t = T$?

A $T\left(X + \frac{2}{3}Y\sqrt{T}\right)$

B $T\left(X + Y\sqrt{T}\right)$

C $\frac{T}{M}\left(X + \frac{2}{3}Y\sqrt{T}\right)$

D $\frac{T}{M}\left(X + Y\sqrt{T}\right)$

E $\frac{Y}{2\sqrt{T}}$

F $\frac{Y}{2M\sqrt{T}}$

15 A trolley of mass 3.0 kg is moving horizontally along a smooth track. Its displacement x from a point at time t is given by the equation:

$$x = 8 + 4t + 2t^2$$

where x is in metres and t is in seconds.

How much work is done on the trolley between times $t = 0$ and $t = 5.0\,\text{s}$?

A   12 J

B   24 J

C   78 J

D   270 J

E   840 J

F   864 J

G   936 J

16 The diagram shows a ray of light passing through three mediums, P, Q and R. The boundaries between the three mediums are parallel.
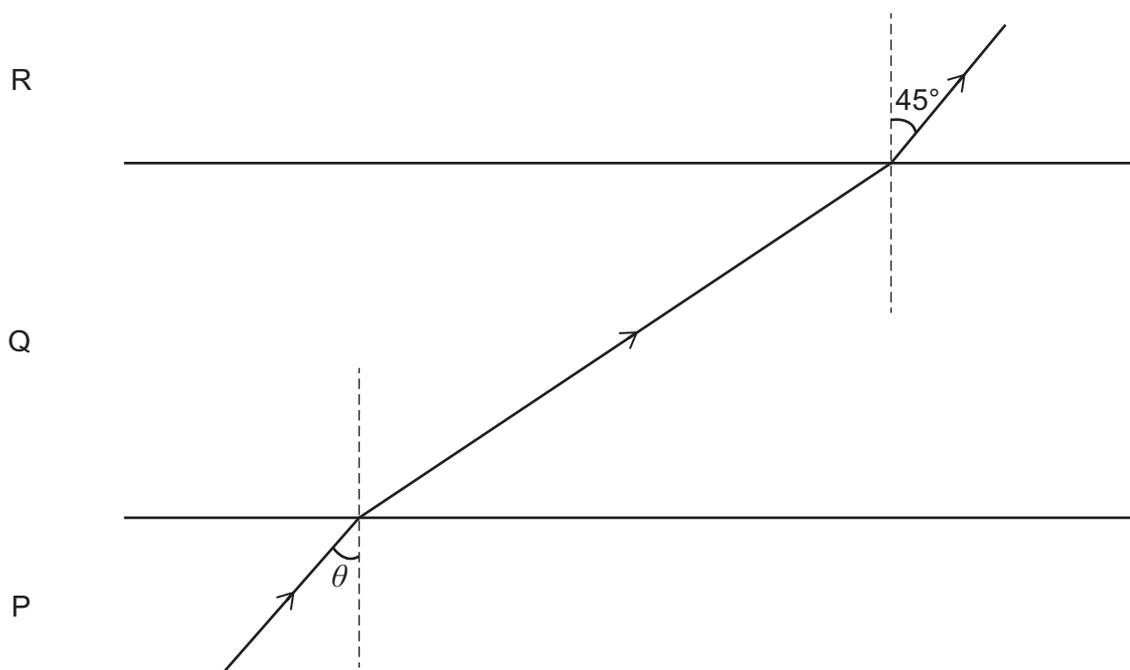

[diagram not to scale]

The ratio of the speed of light in medium P to the speed of light in medium Q is $2:\sqrt{5}$

The ratio of the speed of light in medium Q to the speed of light in medium R is $3:\sqrt{6}$

What is the value of $\sin\theta$?

A $\dfrac{\sqrt{2}}{2}$

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

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

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

E $\dfrac{\sqrt{15}}{5}$

F $\dfrac{\sqrt{15}}{6}$

23

17 Water in a wide river flows at a constant speed of $0.50\,\mathrm{m\,s^{-1}}$. A swimmer swims around a square path of side 30 m marked out by 4 posts R, S, T and U which are fixed to the river bed, as shown.

The swimmer has a constant speed of $1.0\,\mathrm{m\,s^{-1}}$ relative to the water.

30 m

S → T

30 m ↑

R ← U

0.50 m s⁻¹

river
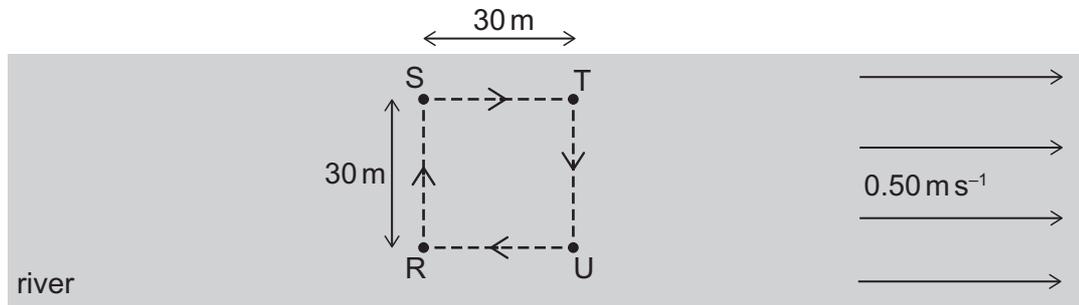
How long does it take for the swimmer to swim around the square path once?

A $(60 + 24\sqrt{5})\,\mathrm{s}$

B $(60 + 40\sqrt{3})\,\mathrm{s}$

C $(80 + 24\sqrt{5})\,\mathrm{s}$

D $(80 + 40\sqrt{3})\,\mathrm{s}$

E $120\,\mathrm{s}$

F $140\,\mathrm{s}$

18 The stress in a steel cable increases with time and is then maintained at a constant value, as shown. The wire does not reach its limit of proportionality.
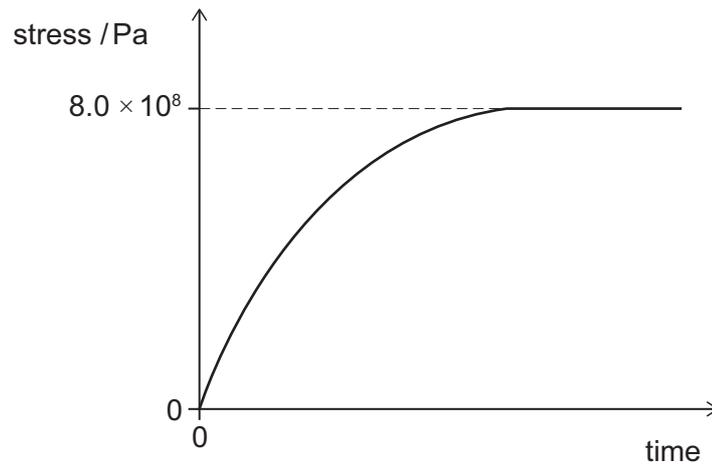

The table shows properties of the steel used in the cable and the dimensions of the cable.

| length / m	cross-sectional area / m^2	Young modulus / Pa
4.0	2.0×10^{-4}	2.0×10^{11}

How much work was done to stretch the cable?

A 320 J

B 1.28 kJ

C 2.56 kJ

D 320 kJ

E 640 kJ

F 1.60 MJ

G 6.40 MJ

19 The following graph shows how the displacement of an object travelling along a straight, horizontal track varies with time.
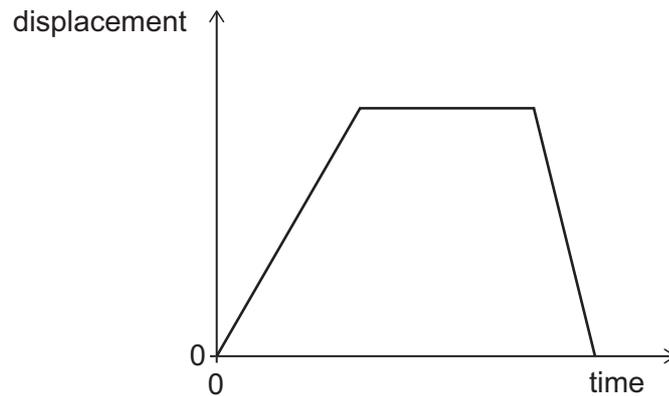
Which graph shows the velocity of this object against displacement?

A

B

C

D

E

F

G

H
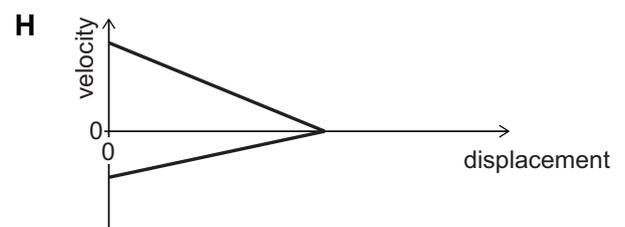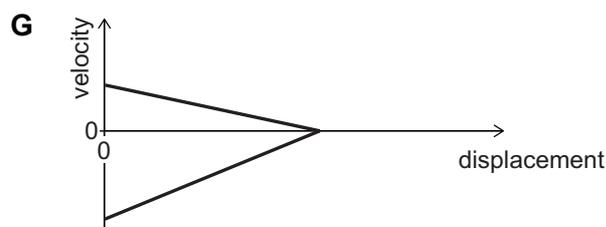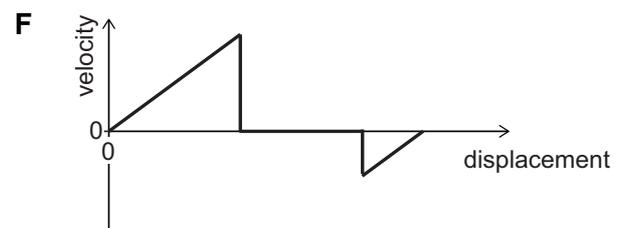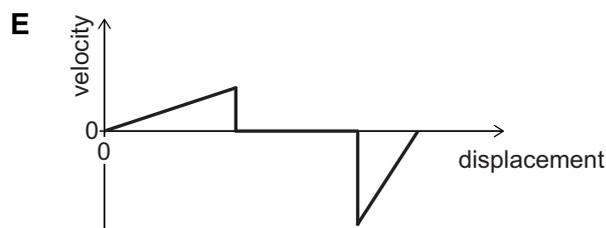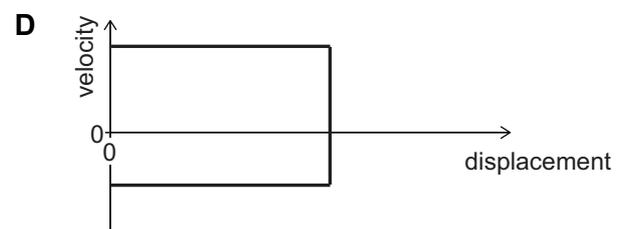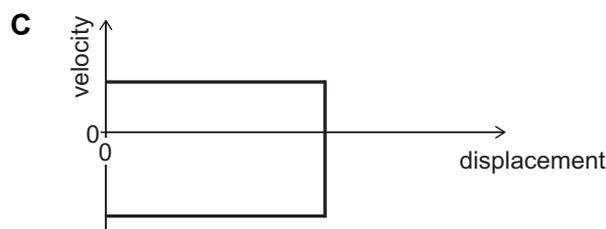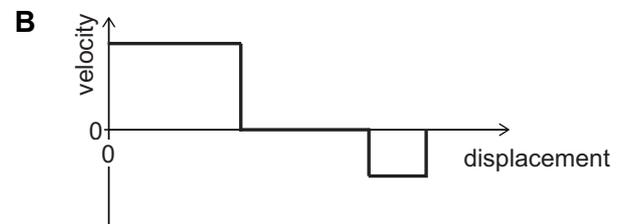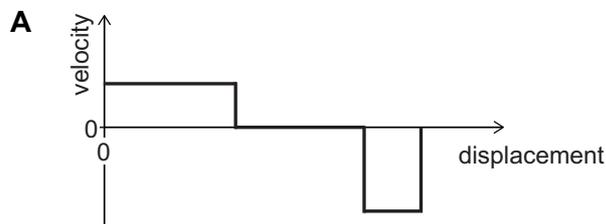
20 A cell has emf E and internal resistance r that varies with current I according to:

$$r = kI^2$$

where k is a constant.

A variable resistor is connected to the terminals of the cell. The resistance of the variable resistor is adjusted.

Which expression gives the resistance of the variable resistor, in terms of k and E, that causes maximum power dissipation in it?

A $\quad 3\left(\dfrac{kE^2}{2}\right)^{\frac{1}{3}}$

B $\quad 3\left(\dfrac{kE^2}{4}\right)^{\frac{1}{3}}$

C $\quad 3\left(\dfrac{kE^2}{9}\right)^{\frac{1}{3}}$

D $\quad 3\left(\dfrac{kE^2}{16}\right)^{\frac{1}{3}}$

E $\quad \left(2kE^2\right)^{\frac{1}{3}}$

F $\quad \left(4kE^2\right)^{\frac{1}{3}}$

G $\quad \left(9kE^2\right)^{\frac{1}{3}}$

H $\quad \left(16kE^2\right)^{\frac{1}{3}}$

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PART Y Chemistry

21 The table gives standard enthalpy change data measured at 25 °C.

reaction	standard enthalpy change / $kJ\,mol^{-1}$
$H(g) + Br(g) \rightarrow HBr(g)$	−366
$H(g) + Br(g) \rightarrow H^+(g) + Br^-(g)$	+968
$HBr(g) \rightarrow H^+(aq) + Br^-(aq)$	−92

What is the standard enthalpy change for the following reaction at 25 °C?

$$H^+(g) + Br^-(g) \rightarrow H^+(aq) + Br^-(aq)$$
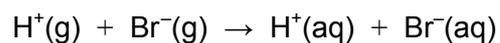
A $-510\,kJ\,mol^{-1}$

B $+510\,kJ\,mol^{-1}$

C $-694\,kJ\,mol^{-1}$

D $+694\,kJ\,mol^{-1}$

E $-1242\,kJ\,mol^{-1}$

F $+1242\,kJ\,mol^{-1}$

G $-1426\,kJ\,mol^{-1}$

H $+1426\,kJ\,mol^{-1}$

22 Alpha-linolenic acid is a polyunsaturated straight-chain carboxylic acid.

0.001 mol of the acid reacts exactly with $15\,cm^3$ of $0.2\,mol\,dm^{-3}$ aqueous bromine.

Alpha-linolenic acid contains 18 carbon atoms per molecule.

Which of the following is a formula for the acid?

A $C_{17}H_{35}COOH$

B $C_{17}H_{34}COOH$

C $C_{17}H_{33}COOH$

D $C_{17}H_{32}COOH$

E $C_{17}H_{31}COOH$

F $C_{17}H_{30}COOH$

G $C_{17}H_{29}COOH$

H $C_{17}H_{28}COOH$
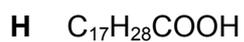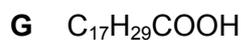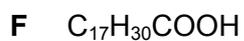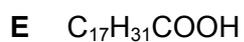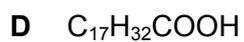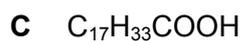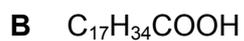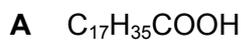
23   25.0 g of compound X contains 9.75 g of potassium, 0.25 g of hydrogen and 12.0 g of oxygen.

When heated strongly, compound X produces a gas that turns limewater cloudy.

The chemical formula of X is the same as its empirical formula.

Compound X is the only product formed between substance Y and two further substances. One of these is the fourth most abundant gas in clean dry air, and the other changes the colour of anhydrous copper(II) sulfate from white to blue.

Which of the following could be the identity of substance Y?

(A_r values: H = 1; C = 12; O = 16; K = 39)

A   K

B K_2CO_3

C K_2O_3

D $KHCO_3$

E CH_3COOK

24 Strontium (Sr) is a Group 2 metal.

Strontium hydride is an ionic compound made up of strontium and hydrogen only.

When a small mass of strontium hydride is added to 180 g of water in an insulated container and stirred, the temperature of the water rises by 25 °C and hydrogen gas is given off.

Assume that:

- the standard enthalpy change of the reaction is $-360\,kJ\,mol^{-1}$ of strontium hydride.

- the specific heat capacity of water (and the solution formed) is $4\,J\,g^{-1}\,°C^{-1}$. Ignore any change in mass of the water due to the reaction.

- all heat is transferred to the water only.

- all measurements are made at atmospheric pressure, with all reactants and products in their standard states.

- one mole of a gas occupies $24\,dm^3$ at room temperature and pressure.

What is the maximum volume of hydrogen (measured at room temperature) that could be released?

A $1.20\,dm^3$

B $1.80\,dm^3$

C $2.40\,dm^3$

D $240\,dm^3$

E $480\,dm^3$

F $2400\,dm^3$

25 Element X forms the most soluble hydroxide of the hydroxides of the Group 2 elements in the range Mg to Ba.

$50\,cm^3$ of a $0.2\,mol\,dm^{-3}$ aqueous solution of an acid Y is exactly neutralised by $400\,cm^3$ of a $0.05\,mol\,dm^{-3}$ aqueous solution of potassium hydroxide.

$100\,cm^3$ of a $0.1\,mol\,dm^{-3}$ aqueous solution of Y is titrated with an aqueous solution of the hydroxide of X until the acid is exactly neutralised.

Which statement about one product of the titration could be correct?

A 0.005 mol of barium chloride is formed.

B 0.05 mol of barium chloride is formed.

C 0.005 mol of magnesium chloride is formed.

D 0.05 mol of magnesium chloride is formed.

E 0.01 mol of barium sulfate is formed.

F 0.1 mol of barium sulfate is formed.

G 0.01 mol of magnesium sulfate is formed.

H 0.1 mol of magnesium sulfate is formed.

26 In the presence of a suitable catalyst, $30.0\,cm^3$ of a $0.10\,mol\,dm^{-3}$ aqueous solution of $Na_2C_2O_4$ reacts exactly with $40.0\,cm^3$ of a $0.15\,mol\,dm^{-3}$ aqueous solution of $Ce(SO_4)_2$.

The only products of the reaction are another cerium salt, a different water-soluble salt and carbon dioxide.

What is the cerium ion formed by this reaction?

A Ce^+

B Ce^{2+}

C Ce^{3+}

D Ce^{4+}

E Ce^{5+}

27 Consider all of the structural isomers of C_4H_9Br and the ways that they could react with hydroxide ions from aqueous sodium hydroxide.

How many different organic products (including all structural and *E/Z* isomers only) containing four carbons could be made?

A 4

B 5

C 6

D 7

E 8

F 9

28 In which of the following conversions does the stated bond angle decrease?

1 hydrogen–nitrogen–hydrogen bond angle in the conversion from NH_3 to NH_4^+

2 fluorine–iodine–fluorine bond angle in the conversion from IF_4^- to IF_6^+

3 chlorine–aluminium–chlorine bond angle in the conversion from $AlCl_3$ to $AlCl_4^-$

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

29 Ethanol combines with ethanoic acid to form ethyl ethanoate according to the following reaction.

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l) \qquad \Delta H = -6\,kJ\,mol^{-1} \text{ at } 25\,°C$$
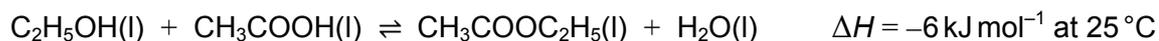
A mixture of 9.2 g ethanol, 12 g ethanoic acid and 8.8 g ethyl ethanoate is allowed to react and reach equilibrium.

The resulting equilibrium mixture is found to contain 4.8 g ethanoic acid at 25 °C and K_c was calculated.

What will happen to the value of K_c when the temperature is increased from 25 °C to 45 °C?

(M_r values: $C_2H_5OH = 46$; $CH_3COOH = 60$; $CH_3COOC_2H_5 = 88$; $H_2O = 18$)

A　It increases from an initial value of 0.242

B　It decreases from an initial value of 0.242

C　It increases from an initial value of 1.833

D　It decreases from an initial value of 1.833

E　It increases from an initial value of 2.750

F　It decreases from an initial value of 2.750

G　It increases from an initial value of 4.125

H　It decreases from an initial value of 4.125

30 Compound Z is known to have percentage composition by mass C: 80.0%, H: 6.7%, O: 13.3%. The mass spectrum of compound Z is given showing the mass-to-charge ratio (m/z) of the molecular ion and its fragments.


 and are representations of the same molecule
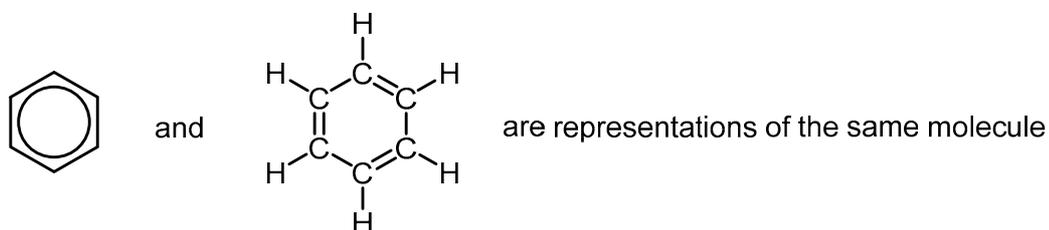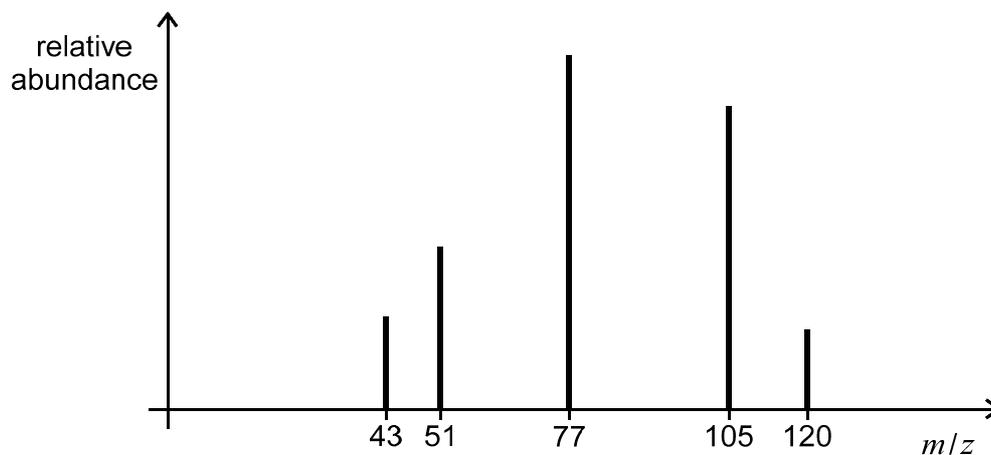
Which of the following could be the structure of Z?

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

A

B

C $CH_3CH_2CH_2CH(OH)CH(OH)CH_3$

D $CH_2=CHCH=CHCH=CH-CH=C=O$

E

F
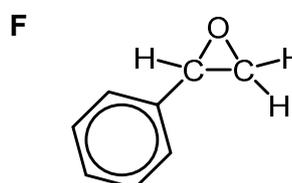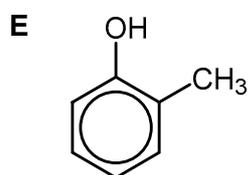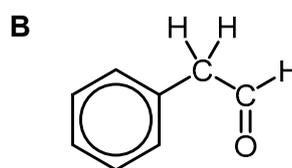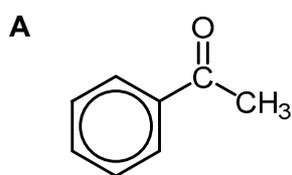
31 The time it takes the ion $^{1}_{1}\text{H}^{+}$ to travel through the flight tube in a time-of-flight mass spectrometer is t.

How long would it take the ion $^{2}_{1}\text{H}^{+}$ to travel through the same flight tube?

A $\dfrac{1}{4}t$

B $\dfrac{1}{2}t$

C $\dfrac{1}{\sqrt{2}}t$

D $\sqrt{\dfrac{2}{3}}\,t$

E $\sqrt{\dfrac{3}{2}}\,t$

F $\sqrt{2}\,t$

G $2t$

H $4t$

32 A paper coffee cup is lined with a thin layer of plastic to make it waterproof. This plastic makes up 5% of the mass of the cup and has the following molecular structure.
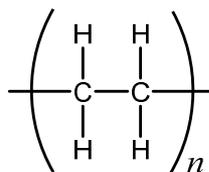
960 dm³ of a gaseous hydrocarbon monomer (measured at room temperature and pressure) was used to make a certain number of plastic-lined cups.

It is proposed that a more environmentally-friendly, biodegradable plastic, poly(lactic acid), could be used instead in the same proportions by mass (5%). Assume that any polymerisation reaction has a 100% yield.
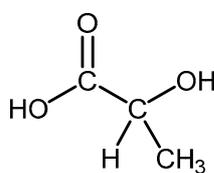
lactic acid

What mass of lactic acid ($M_r = 90$) is required to make the same number of biodegradable cups?

(A_r values: H = 1; C = 12; O = 16. Assume that one mole of a gas occupies 24 dm³ at room temperature and pressure.)

A 896 g

B 1120 g

C 1200 g

D 1400 g

E 1500 g

F 3000 g

G 3600 g

33 In which of the following pairs do **both** molecules possess permanent dipoles in the gaseous state?

    1 methylamine (CH_3NH_2) and dichlorine monoxide (Cl_2O)

    2 difluoroethyne (C_2F_2) and sulfur hexafluoride

    3 phosphorus trichloride and xenon tetrafluoride

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

34 At high temperatures, carbon dioxide reacts partially with solid carbon and forms the following equilibrium.

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g)$$
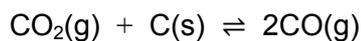
In an experiment, 1.0 mol of carbon dioxide is placed in a flask of capacity $V\,dm^3$ containing no air and an excess of carbon. It is then heated to a high temperature where an equilibrium between carbon dioxide and carbon monoxide is established. At this temperature, x mol of carbon dioxide converts to carbon monoxide and the value of the equilibrium constant, K_c, is $2.0\,mol\,dm^{-3}$.

As it is a solid, carbon is not included in the equilibrium constant expression.

What is the relationship between the value of x and V?

A $\quad x = \dfrac{-V + \sqrt{V^2 + 32V}}{16}$

B $\quad x = \dfrac{-V + \sqrt{V^2 + 8V}}{4}$

C $\quad x = \dfrac{-2 + \sqrt{4V^2 + 8V}}{4}$

D $\quad x = \dfrac{-2V + \sqrt{4V^2 - 2V}}{2}$

E $\quad x = \dfrac{-2 + \sqrt{4 - 32V}}{4V}$

35 A student carried out an experiment to find the mass of the active ingredient calcium carbonate ($M_r = 100$) in an indigestion tablet. The student crushed the tablet and placed it in a beaker.

The student added $20.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ hydrochloric acid, an excess, to the tablet. When the reaction was complete, the reaction mixture was all transferred to a volumetric flask and deionised water added to make the solution up to $250\,cm^3$.

$25.0\,cm^3$ samples of the solution in the volumetric flask were titrated against $0.100\,mol\,dm^{-3}$ sodium hydroxide solution. The mean titre was $26.40\,cm^3$ of sodium hydroxide solution.

Assuming that all other ingredients in the tablet are inert, what is the mass of calcium carbonate in the tablet?

A 0.264 g

B 0.680 g

C 1.36 g

D 1.87 g

E 2.72 g

36   Ellingham diagrams show how the quantity ΔG for a reaction varies over a range of temperatures.

The ΔG values for different reactions can be combined using Hess's law.

For a reaction to be able to occur, the overall value of ΔG must be less than zero.
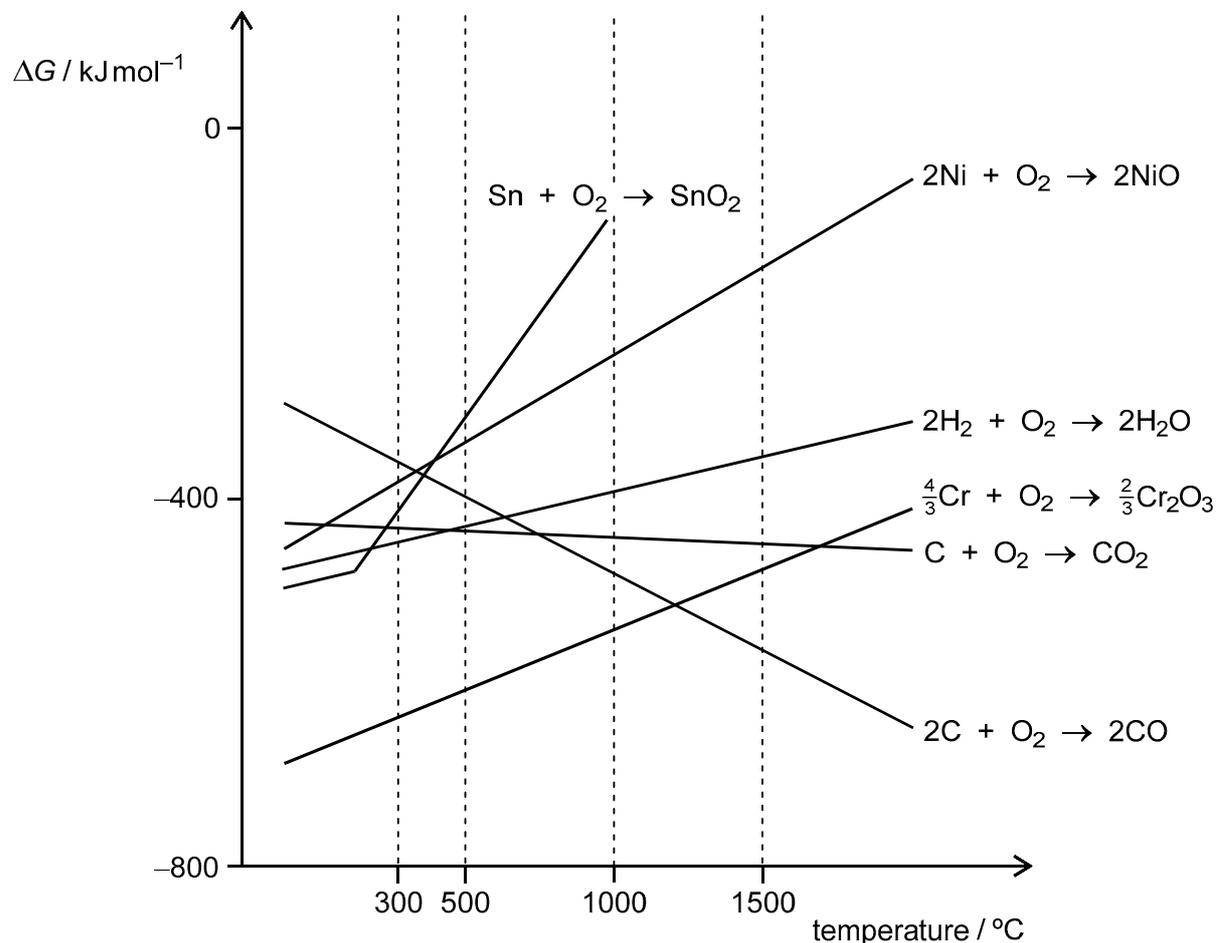
Using the Ellingham diagram shown, which one of the following statements is correct?

A   Nickel can reduce tin(IV) oxide at 300 °C.

B   Carbon can reduce chromium(III) oxide at 1500 °C forming carbon dioxide and chromium.

C   Chromium(III) oxide and nickel oxide will decompose to their elements at all the temperatures shown.

D   Chromium will react with steam at all the temperatures shown.

E   Nickel oxide can be reduced by carbon at 300 °C forming carbon monoxide and nickel.

37 SO_3^{2-}(aq) ions can cause the reduction of VO_3^-(aq) ions to VO^{2+}(aq) in acidic solution. During this process, the SO_3^{2-}(aq) ions are oxidised to SO_4^{2-}(aq) ions.

What is the minimum volume of $1.00\,mol\,dm^{-3}$ sulfuric acid required to provide sufficient hydrogen ions to allow Na_2SO_3(aq) to reduce $40.0\,cm^3$ of $0.100\,mol\,dm^{-3}$ VO_3^-(aq) ions completely to VO^{2+}(aq)?

A no sulfuric acid is required

B $4.0\,cm^3$

C $6.0\,cm^3$

D $6.6\,cm^3$

**E** $8.0\,cm^3$

F $12.0\,cm^3$

G $13.2\,cm^3$

38 Sodium chloride is an ionic compound which forms highly ordered crystals of ions when in the solid state. This is called a lattice.

A lattice can be thought of as a stack of layered planes of ions.

In the following diagrams, the shaded and non-shaded circles represent sodium and chloride ions, respectively.

Which of the following is **not** a representation of a plane present in a sodium chloride lattice?
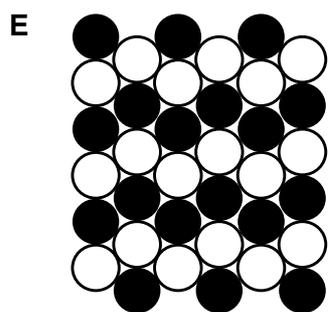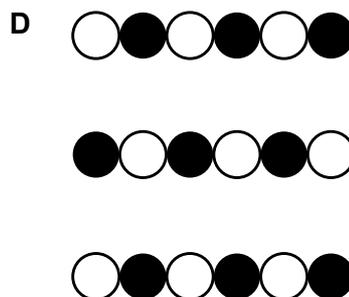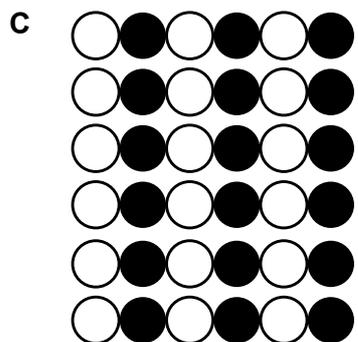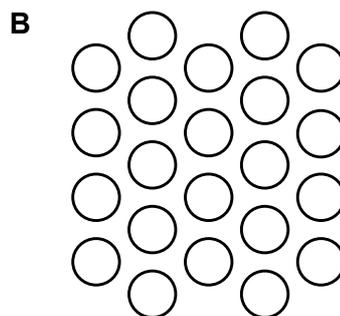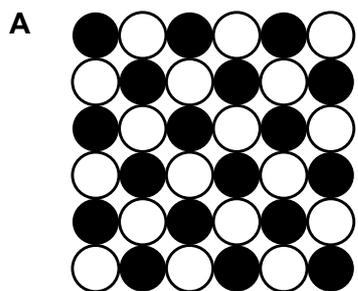
39 When bromine reacts with (*Z*)-pent-2-ene, an intermediate called a bromonium ion forms. This is then attacked by the bromide ion to give the 2,3-dibromopentane addition product.

The mechanism is shown:

$$(Z)\text{-pent-2-ene} \longrightarrow \text{bromonium ion intermediate} \longrightarrow \text{2,3-dibromopentane}$$
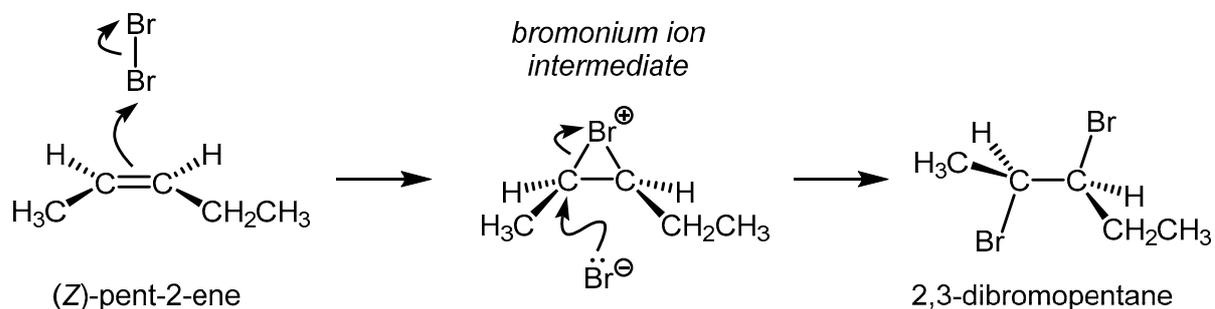
In a different reaction **(*E*)-but-2-ene** is reacted with bromine in an addition reaction. This reaction also occurs via a bromonium ion intermediate.

Which of the following structures show the final product of the reaction of **(*E*)-but-2-ene** with bromine?

1   **2**

3   **4**
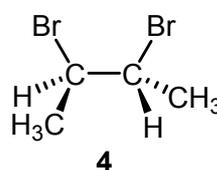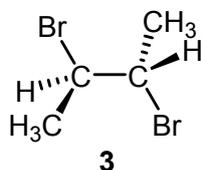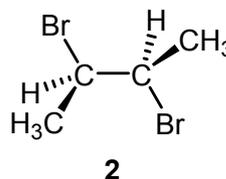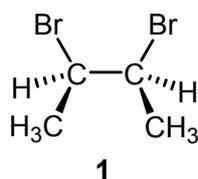
A structures 1 and 2 only

B structures 1 and 3 only

C structures 1 and 4 only

D structures 2 and 3 only

E structures 2 and 4 only

F structures 3 and 4 only

G structures 1, 2, 3 and 4

40   Both oxygen and carbon monoxide bind reversibly to haemoglobin.

For the purposes of this question, assume that only one molecule of either oxygen or carbon monoxide can bind to haemoglobin at any one time.

Within the human body, carbon monoxide is 200 times more effective than oxygen in binding to haemoglobin available in human blood. The *binding efficiency* is the equilibrium constant for this process and you may assume that the system is at equilibrium.

The effects of carboxy-haemoglobin in humans can typically be observed when it reaches 5% of the concentration of oxy-haemoglobin in their blood.

Assume that oxygen and carbon monoxide have the same molar solubility in blood.

What is the minimum proportion of carbon monoxide molecules in dry air, expressed as parts per million (ppm), that will result in a 5% ratio of carboxy-haemoglobin molecules to oxy-haemoglobin molecules in blood?

A   10 ppm

B   21 ppm

C   52.5 ppm

D   210 ppm

E   1000 ppm

F   5250 ppm

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PART Z Biology

41 The diagram shows the inheritance of a characteristic controlled by a single gene. Two organisms reproduce sexually and have four offspring, one offspring at a time.
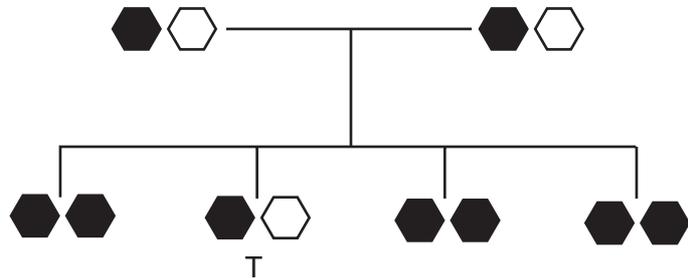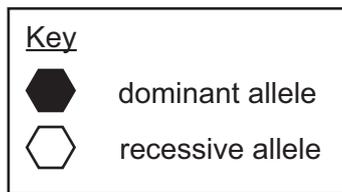
Individual T goes on to have a single offspring with an unrelated individual who has a recessive phenotype. The offspring of T has a dominant phenotype.

What is the ratio of dominant to recessive alleles for all of the individuals in this diagram, as well as T's mate and their one offspring?

A   3:5

B   5:3

C   7:1

D   1:7

E   3:1

F   1:3

G   2:1

H   1:2

42 The average healthy mature red blood cell contains 200 000 000 molecules of haemoglobin.

If a red blood cell is saturated with dissolved oxygen, each haemoglobin molecule carries a total of 4 molecules of oxygen.

Haemoglobin molecules in red blood cells in the pulmonary artery are on average 65% saturated with oxygen.

How many oxygen molecules are carried by the average red blood cell in the pulmonary artery, and is the level of oxygen saturation greater in the aorta or the pulmonary artery?

	number of oxygen molecules carried	*level of oxygen saturation*
A	8.0×10^8	aorta > pulmonary artery
B	8.0×10^8	aorta < pulmonary artery
C	5.2×10^8	aorta > pulmonary artery
D	5.2×10^8	aorta < pulmonary artery
E	2.8×10^8	aorta > pulmonary artery
F	2.8×10^8	aorta < pulmonary artery
G	1.3×10^8	aorta > pulmonary artery
H	1.3×10^8	aorta < pulmonary artery

43 Graphs P and Q were plotted using data collected in an investigation into the effect of temperature from 0 to 60 °C on an enzyme-controlled reaction. All other variables were controlled.

graph P   graph Q
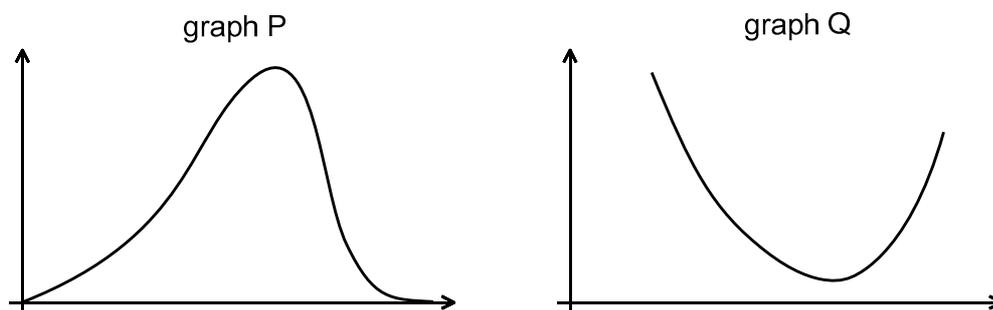
Which two rows correctly identify the variables plotted on the horizontal and vertical axes of these graphs?

row	graph	horizontal axis	vertical axis
1	P	temperature	time taken for reaction
2	P	temperature	rate of reaction
3	P	time taken for reaction	temperature
4	P	time taken for reaction	rate of reaction
5	Q	temperature	time taken for reaction
6	Q	temperature	rate of reaction
7	Q	time taken for reaction	temperature
8	Q	time taken for reaction	rate of reaction

A   1 and 6

B   1 and 7

C   2 and 5

D   2 and 6

E   3 and 5

F   3 and 8

G   4 and 7

H   4 and 8

44 A recessive condition is found within a human population. There were 5000 births in this population within one year. Of these births, 8% had the condition and 32% were homozygous dominant.

One healthy cheek cell is analysed from each person born in this year.

How many recessive alleles and dominant alleles are present?

(Assume that no new mutations occur.)

	recessive alleles	dominant alleles
A	400	1600
B	400	4600
C	3400	1600
D	3400	4600
E	3400	6200
F	3800	1600
G	3800	4600
H	3800	6200

45 A study was carried out into the effect of liver protein Z on the risk of developing coronary heart disease, which is often associated with high blood cholesterol. Z binds to another protein in the membrane of liver cells that transports cholesterol from the blood into cells. This binding blocks the function of the transport protein.

Blood cholesterol levels were measured in three different groups of people. One group was a control group and contained no mutations in the gene for Z. The second group all had the same mutation in the gene (called mutation 1). This mutation occurs in the final section of the gene. A third group all had a different mutation in the gene (called mutation 2), but this was in the first section of the gene. The results are shown in the graph.
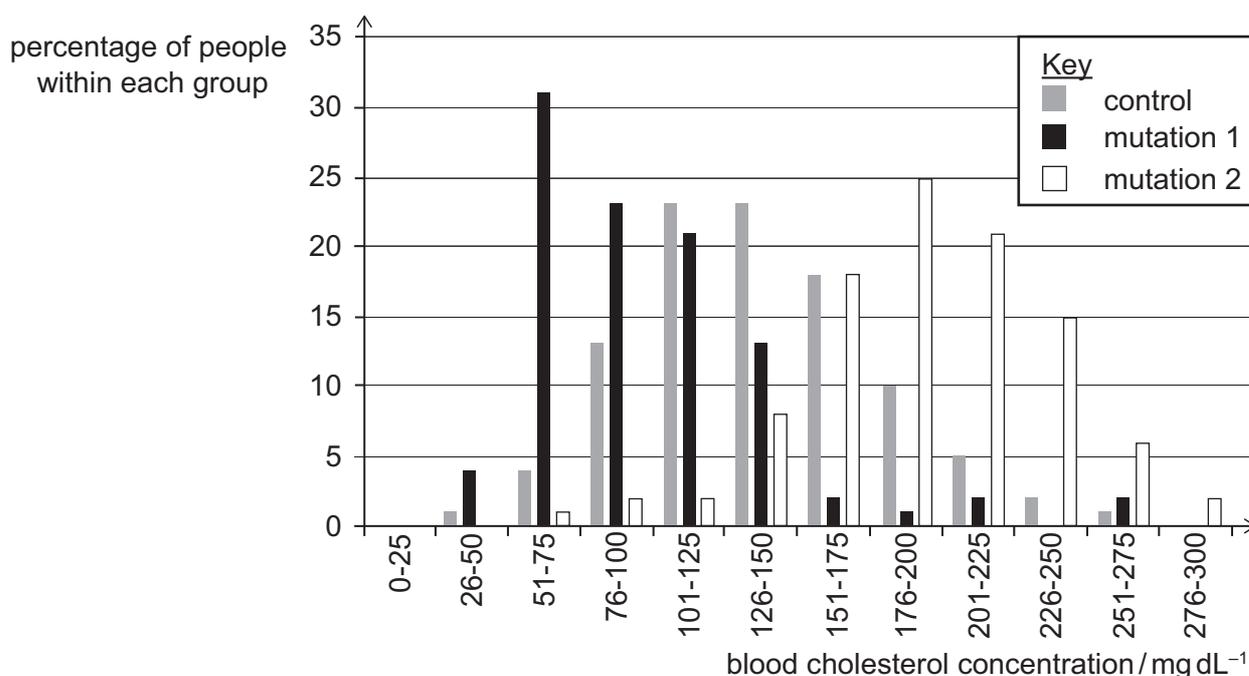
Which of the following can be correctly concluded from these results?

1 Changes in the first section of protein Z stop it from binding to the cholesterol transport protein.

2 Mutation 1 could result in an increase in the concentration of cholesterol inside liver cells.

3 Of the three groups, people in the control group are least likely to develop coronary heart disease.

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

56

46 Equal-sized, rectangular blocks of a raw potato were cut and their mass measured. The blocks were then placed in equal volumes of different concentrations of sucrose solutions for the same length of time. All other variables were kept constant.

After this time, the blocks were blotted on paper and then their masses were measured again. The percentage change in mass of each block was calculated and the results are shown in the graph.
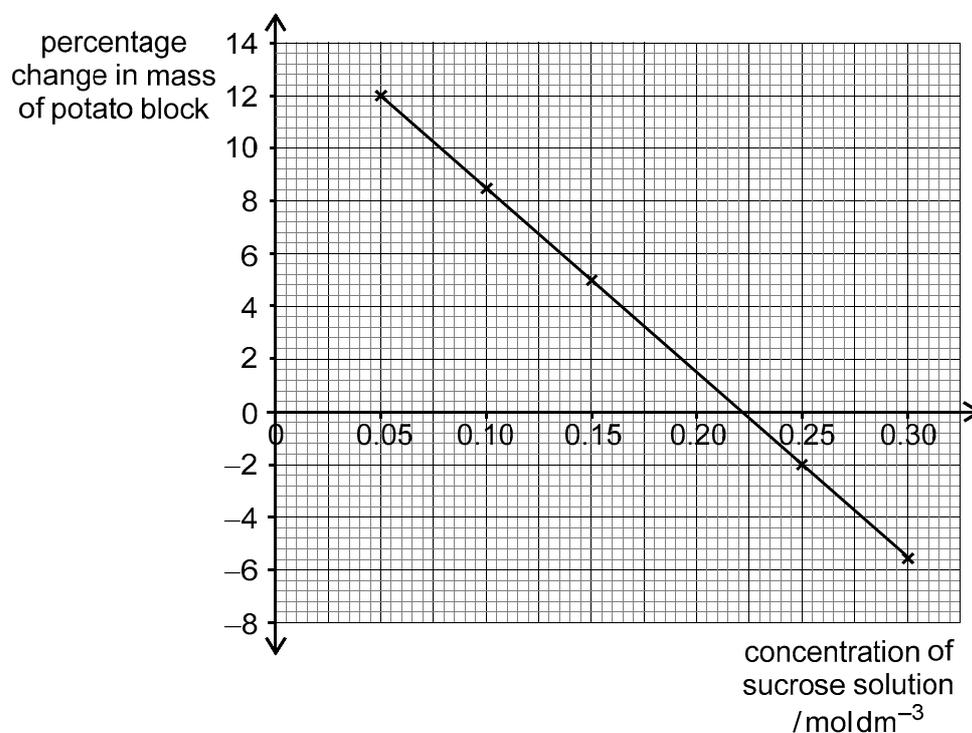
Which of the following statements is/are correct?

1 In $0.10\,mol\,dm^{-3}$ sucrose solution, there was some movement of sucrose molecules by osmosis across the membrane out of the potato block.

2 If the initial mass of the block in $0.25\,mol\,dm^{-3}$ sucrose solution is $1.800\,g$ then its final mass will be $1.764\,g$.

3 Repeating the experiment at a temperature that was 10°C lower should not affect the point at which the graph crosses the x-axis.

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 shows the sources of water lost in one particular day from a healthy human.

percentage of the water that is lost	source
16	exhaled air
4	faeces
20	sweat
60	urine

On another day, the percentage of water lost in urine decreased by a sixth.

The percentage of water lost in exhaled air and in faeces remained the same.

The total volume of water lost was 2500 cm^3 on both days.

What is the percentage increase in the volume of sweat produced and the reason for the decrease in the volume of urine?

	percentage increase in the volume of sweat	reason for the decrease in the volume of urine
A	33	a decrease in ADH
B	33	an increase in ADH
C	50	a decrease in ADH
D	50	an increase in ADH
E	150	a decrease in ADH
F	150	an increase in ADH

48 The diagram shows the production of sperm cells in a healthy mammal. Cell P divides. One daughter cell goes on to replace cell P, and the other daughter cell is called Q in the diagram.
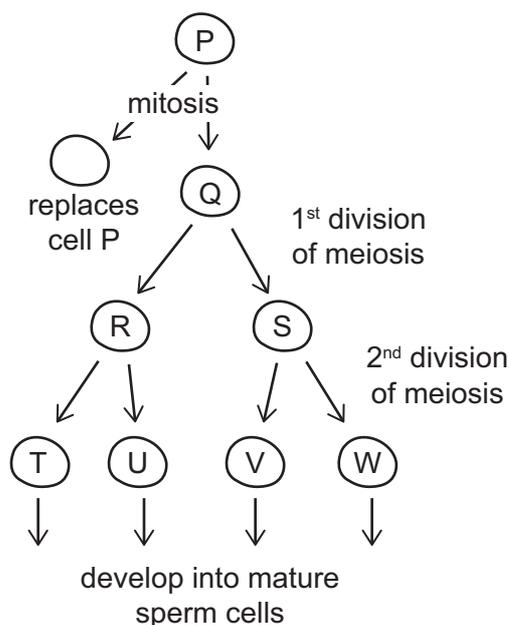
Each mitotic cell cycle takes 14 hours.

The diploid number of chromosomes in this mammal is 68.

Which of the following statements is/are correct?

    1   Cell P is a type of stem cell.

    2   Cells T, U, V and W each contain 23 chromosomes.

    3   In 112 hours, 128 replacements of cell P 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

49 In the disease emphysema the walls of the alveoli break down so that several smaller alveoli fuse to form a single large alveolus.

The diagram shows a model of the effect of emphysema on spherical alveoli.

radius of each alveolus $= x$ radius of alveolus $= 2x$
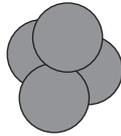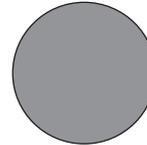
4 healthy alveoli   1 alveolus from a
person with emphysema

Which of the following statements is/are correct?

1 The surface area-to-volume ratio of the four healthy alveoli is twice that of the single emphysema alveolus.

2 For the same concentration gradient, the rate of diffusion of oxygen into the blood from a single healthy alveolus will be greater than for a single emphysema alveolus.

3 Oxygen molecules will only move across the alveolus wall from the inside to the outside of an alveolus.

(surface area of a sphere $= 4\pi r^2$; volume of a sphere $= \dfrac{4}{3}\pi r^3$, where r is the radius)

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 Experiments were carried out to investigate the rate at which products were formed by two digestive enzymes, P and Q over a period of 30 minutes.

P and Q have similar optimum conditions for function. Only the enzyme and its substrate were changed between each reaction.

The results are shown in the graphs.
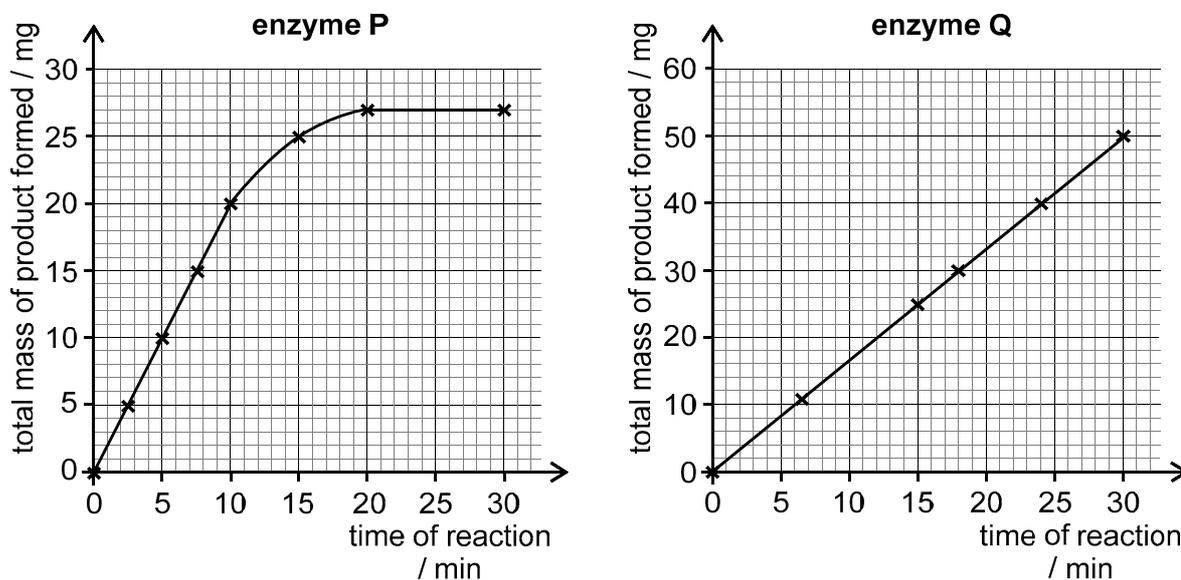
Which of the following statements is/are correct?

1 During the first 10 minutes, the rate of reaction ($mg\,min^{-1}$) with enzyme P is double the rate with enzyme Q.

2 A possible explanation for the difference in the shape between the graphs is that the product of the reaction catalysed by P significantly alters the pH of the solution.

3 The percentage change in mass of product formed by enzyme Q is more than 5 times greater between 6.5 and 15 minutes than it is between 24 and 29 minutes.

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 An experiment was performed to investigate whether capillary action could account for the movement of water from roots to leaves in a plant.

The diagram shows apparatus used to model this effect using narrow glass capillary tubing. The inner diameter of the capillary tubing is 0.5 mm.

glass capillary tubing

water rises in capillary tubing

height of water recorded after 2 minutes

beaker of water
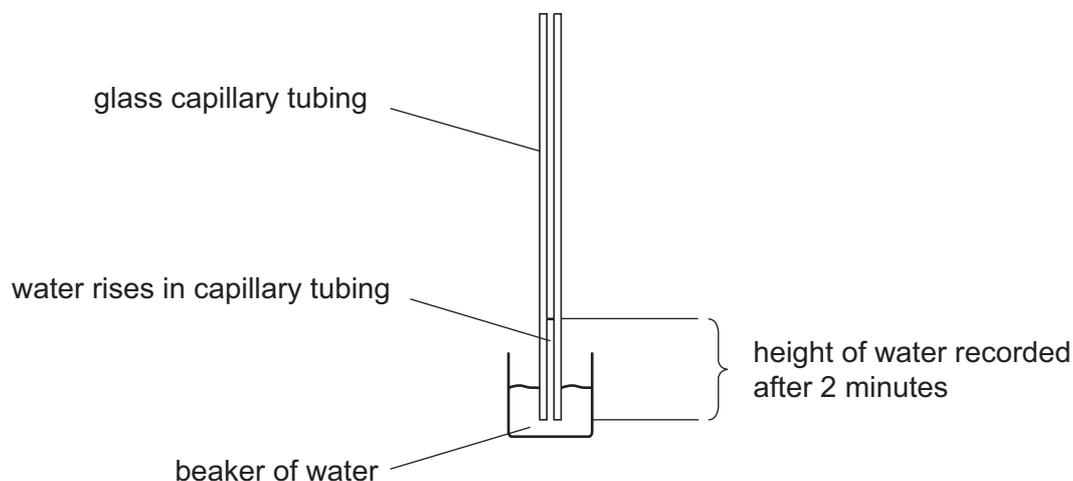
The initial height of the water in the tubing was recorded as 0.2 cm. After 2 minutes the height was recorded as 1.8 cm.

The model assumes the rate of movement is constant.

What is the rate of water movement in $mm^3\,min^{-1}$ and what vessel type transfers water from roots to leaves in a real plant?

	rate of water movement / $mm^3\,min^{-1}$	vessel type
A	0.5π	xylem
B	0.5π	phloem
C	π	xylem
D	π	phloem
E	2π	xylem
F	2π	phloem
G	4π	xylem
H	4π	phloem

52   Two healthy human cells with no mutations were modelled as shown in the diagrams below. The cells were not dividing. Both cells contain a single nucleus and are diploid.

liver cell   white blood cell

20 µm

20 µm

20 µm

diameter = 6 µm
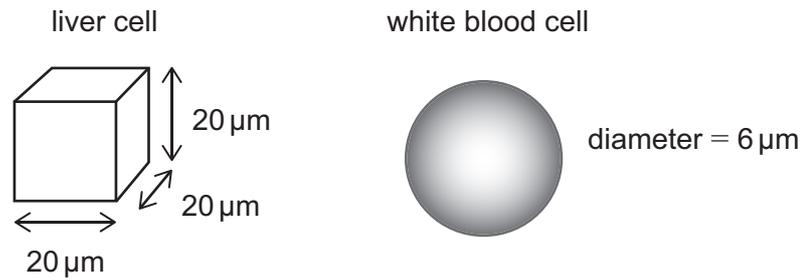
[diagram not to scale]

A study estimates that mitochondria account for 12% of the volume of both types of cells.

Using this estimate for all cells, which of the following is/are correct?

(The volume of a sphere is given by $\dfrac{4}{3}\pi r^3$, where r is the radius. Use the value 3.14 for π)

1   The larger number of mitochondria in the liver cell will produce more lactic acid than those in the white blood cell.

2   The liver cell is larger and so will contain a greater mass of nuclear DNA than the white blood cell.

3   The mitochondria in the white blood cell occupy $14\,\mu m^3$ to the nearest whole number.

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

53 Bacterial cells were grown in a laboratory experiment and the number of cells was recorded at regular intervals. The bacteria in this experiment reproduced asexually using a form of cell division. The growth medium was sterilised before it was used and the vessel containing the bacterial cells was sealed so that no other cells could enter.

The graph shows the results of the experiment.
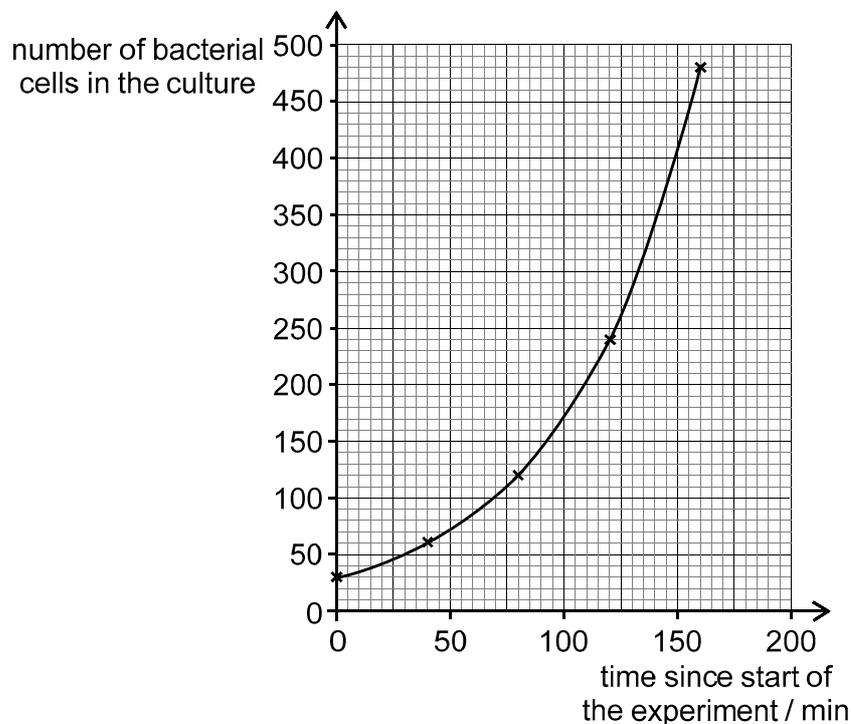
Which of the following statements is/are correct?

1 After 4 hours, assuming that the rate of growth continues on the same curve, the predicted number of cells in the experiment is 1920.

2 During the 80 minutes after the start of the experiment there was a 400% increase in the number of cells.

3 The growth curve is of the form $y = 30k^x$

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

54 Three samples of cells were taken from the same healthy human: one sample from the blood, one sample from a kidney, and one sample from a testis.

Each sample contained five cells, three of one type and two of a different type. None of the cells were dividing.

In each sample, the mean number of chromosomes per cell was calculated. The results are shown in the table.

sample	mean number of chromosomes per cell
1	18.4
2	32.2
3	46.0

Which row in the following table identifies the samples from the kidney and the testis?

(Assume that no mutations occur in any of the cells in the samples.)

	kidney	testis
A	1	2
B	1	3
C	2	1
D	2	3
E	3	1
F	3	2

55 The graph shows the mean mass of DNA of a population of cells dividing at the same time, measured in femtograms (10^{-15} g) per cell.
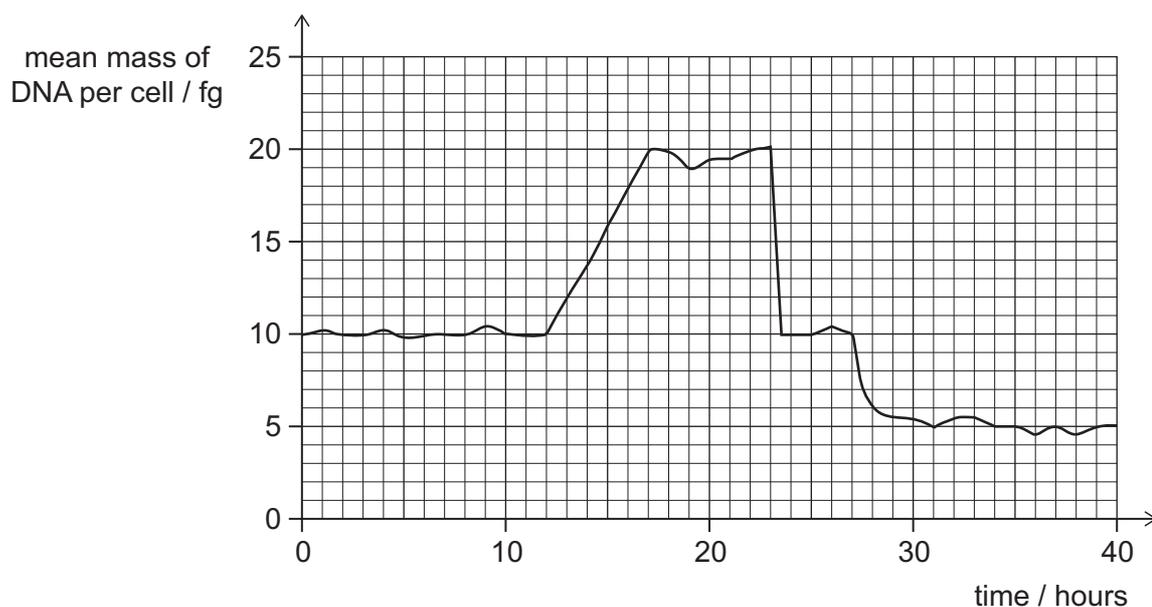
Which row in the table is correct?

	type of cell division taking place	rate of DNA synthesis per cell between 12 and 17 hours / fg h^{-1}	period that could be part of interphase
A	meiosis	2	0 to 17 hours
B	meiosis	0.5	0 to 17 hours
C	meiosis	2	12 to 24 hours
D	meiosis	0.5	12 to 24 hours
E	mitosis	2	0 to 17 hours
F	mitosis	0.5	0 to 17 hours
G	mitosis	2	12 to 24 hours
H	mitosis	0.5	12 to 24 hours

56 A plasmid contains genes Q and R. Gene Q codes for resistance to the antibiotic *q*. Gene R codes for resistance to antibiotic *r*.

The plasmid was genetically engineered to contain the human gene P. This gene was inserted into gene Q in the plasmid preventing gene Q from working.
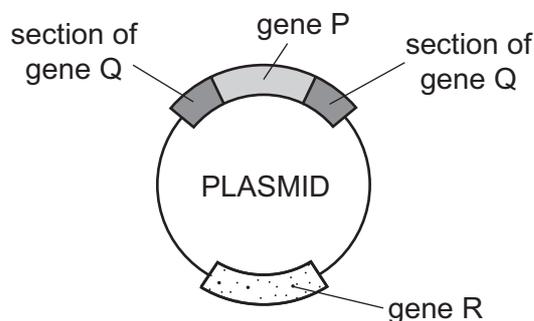
A mixture of the original plasmid and the genetically-engineered plasmid were available to be taken up by bacterial cells. The bacterial cells took up either the original plasmid, or the genetically-engineered plasmid, or neither of the plasmids.

All these bacteria were allowed to grow and form colonies on agar plates in the absence of both antibiotics.

40 colonies formed.

Cells from each of the 40 colonies were grown on three agar plates with different contents.

The table shows the number of colonies that grew on each of the three plates.

contents of agar plate	number of bacterial colonies able to survive on the agar plate
no antibiotic	40
antibiotic *q* only	8
antibiotic *r* only	24

What percentage of the original 40 bacteria now contain gene P?

(Assume that no mutations occur.)

A   16%

B   20%

C   33%

D   40%

E   60%

F   80%

57 One form of genetic variation within a population depends on the number of alleles per gene.

Four populations of the same animal species each have the same gene in the same position on a chromosome.

Each population has a different number of alleles for this gene as shown in the table.

population	number of alleles for the same gene
P	3
Q	4
R	5
S	6

Assume that in the heterozygous state, the genotype is the same whether an allele is inherited from the mother or the father.

Which of the following is/are correct for this gene?

(Assume that no mutations occur in this gene.)

1 The theoretical number of different genotypes in population S is 6 more than in population R.

2

theoretical number of different homozygous genotypes in population			
P	Q	R	S
3	4	5	6

3 In populations P, Q and R, there are more different homozygous combinations than there are different heterozygous combinations.

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 diagram shows a cylinder with two compartments, X and Y, separated by a sliding partially permeable membrane which is impermeable to glucose.
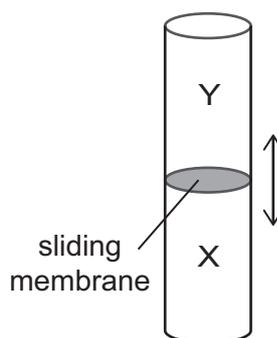
Compartment X contains $100\,\text{mmol}\,\text{dm}^{-3}$ glucose solution and compartment Y contains $200\,\text{mmol}\,\text{dm}^{-3}$ glucose solution. The initial volume of the solution in each of the two compartments is the same, $10\,\text{cm}^3$.

After three hours, there is no further change in the volumes of X and Y.

Which of the following statements describe(s) the results of the experiment?

1 The volume of Y increases during the first three hours.

2 During the first three hours, the average rate of osmosis is $\dfrac{10}{9}\,\text{cm}^3$ per hour.

3 During the first three hours, the average rate of change in glucose concentration in compartment X is $50\,\text{mmol}\,\text{dm}^{-3}$ per hour.

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

59 A fertilised egg cell is spherical and has a volume of $0.12\,\mu m^3$.

In the initial stages of development, the fertilised egg cell undergoes several rounds of cleavage. During cleavage, cells divide by mitosis but do not grow. Assume that when cells undergo cleavage, the daughter cells are spherical and are identical to each other.

Which of the following statements about the cells present after three rounds of cleavage is/are correct?

1 Each cell will contain $\dfrac{1}{8}$ of the DNA present in the fertilised egg cell.

2 The volume of each cell will be $0.03\,\mu m^3$.

3 The diameter of the cells is 50% of that of the fertilised egg cell.

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

60 The genetic code is read in groups of three bases when coding for the synthesis of a protein. The diagram shows the base triplets within DNA that correspond to specific amino acids.

The diagram is read from the inside out. For example, the base triplets CAT and CAC both code for the amino acid histidine (His).
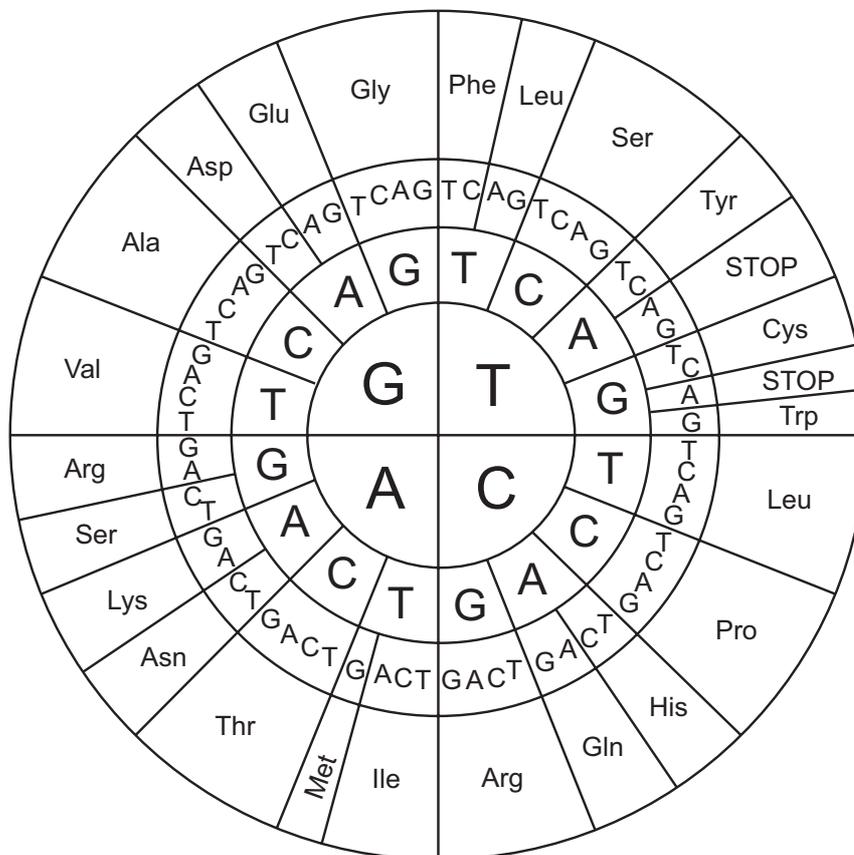
Assume that it is equally likely that mutations can change any base to any other base, and that the probability of this resulting in a change in any particular base during one cell division is 2×10^{-9}.

What is the probability that a triplet that codes for **Met** changes to code for **Pro** in one round of division?

A $\dfrac{4}{9} \times 10^{-18}$

B $\dfrac{4}{9} \times 10^{-9}$

C $\dfrac{2}{3} \times 10^{-18}$

D $\dfrac{2}{3} \times 10^{-9}$

E 4×10^{-18}

F 4×10^{-9}

TZ3	Answer_key	Part 1a		TZ3	Answer_key	Part 1b		TZ3	Answer_key	Part 1c		TZ3	Answer_key	Part 1d
Q1	D	MATH		Q21	B	PHYS		Q41	E	CHEM		Q61	H	BIOL
Q2	G	MATH		Q22	C	PHYS		Q42	F	CHEM		Q62	F	BIOL
Q3	A	MATH		Q23	A	PHYS		Q43	F	CHEM		Q63	G	BIOL
Q4	A	MATH		Q24	F	PHYS		Q44	B	CHEM		Q64	D	BIOL
Q5	C	MATH		Q25	D	PHYS		Q45	E	CHEM		Q65	F	BIOL
Q6	B	MATH		Q26	A	PHYS		Q46	B	CHEM		Q66	G	BIOL
Q7	B	MATH		Q27	D	PHYS		Q47	F	CHEM		Q67	F	BIOL
Q8	F	MATH		Q28	E	PHYS		Q48	A	CHEM		Q68	E	BIOL
Q9	A	MATH		Q29	F	PHYS		Q49	D	CHEM		Q69	F	BIOL
Q10	E	MATH		Q30	C	PHYS		Q50	C	CHEM		Q70	B	BIOL
Q11	F	MATH		Q31	C	PHYS		Q51	D	CHEM		Q71	F	BIOL
Q12	B	MATH		Q32	B	PHYS		Q52	E	CHEM		Q72	C	BIOL
Q13	E	MATH		Q33	E	PHYS		Q53	D	CHEM		Q73	H	BIOL
Q14	A	MATH		Q34	D	PHYS		Q54	G	CHEM		Q74	A	BIOL
Q15	F	MATH		Q35	H	PHYS		Q55	C	CHEM		Q75	A	BIOL
Q16	E	MATH		Q36	C	PHYS		Q56	E	CHEM		Q76	C	BIOL
Q17	B	MATH		Q37	D	PHYS		Q57	G	CHEM		Q77	C	BIOL
Q18	D	MATH		Q38	G	PHYS		Q58	D	CHEM		Q78	F	BIOL
Q19	C	MATH		Q39	A	PHYS		Q59	F	CHEM		Q79	C	BIOL
Q20	D	MATH		Q40	G	PHYS		Q60	F	CHEM		Q80	F	BIOL

TZ3	Answer_key	Part 2a		TZ3	Answer_key	Part 2a		TZ3	Answer_key	Part 2a
Q1	E	PHYS		Q21	G	CHEM		Q41	B	BIOL
Q2	D	PHYS		Q22	G	CHEM		Q42	C	BIOL
Q3	C	PHYS		Q23	B	CHEM		Q43	C	BIOL
Q4	E	PHYS		Q24	C	CHEM		Q44	H	BIOL
Q5	G	PHYS		Q25	E	CHEM		Q45	C	BIOL
Q6	D	PHYS		Q26	C	CHEM		Q46	G	BIOL
Q7	B	PHYS		Q27	E	CHEM		Q47	D	BIOL
Q8	F	PHYS		Q28	D	CHEM		Q48	B	BIOL
Q9	F	PHYS		Q29	H	CHEM		Q49	B	BIOL
Q10	C	PHYS		Q30	A	CHEM		Q50	G	BIOL
Q11	D	PHYS		Q31	F	CHEM		Q51	A	BIOL
Q12	D	PHYS		Q32	D	CHEM		Q52	D	BIOL
Q13	F	PHYS		Q33	B	CHEM		Q53	F	BIOL
Q14	A	PHYS		Q34	B	CHEM		Q54	F	BIOL
Q15	E	PHYS		Q35	B	CHEM		Q55	A	BIOL
Q16	E	PHYS		Q36	D	CHEM		Q56	D	BIOL
Q17	D	PHYS		Q37	C	CHEM		Q57	E	BIOL
Q18	B	PHYS		Q38	E	CHEM		Q58	D	BIOL
Q19	C	PHYS		Q39	B	CHEM		Q59	D	BIOL
Q20	D	PHYS		Q40	C	CHEM		Q60	A	BIOL