



**NATURAL SCIENCES
ADMISSIONS ASSESSMENT**

D568/11

Wednesday 31 October 2018

80 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 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

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

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

All candidates should then complete **two** further parts chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology
Part E	Advanced Mathematics and Advanced Physics

Each part has 18 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 **three** 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 may NOT be used.

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

This question paper consists of 74 printed pages and 6 blank pages.

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PART A Mathematics

- 1 A group of drivers, consisting of 200 women and 300 men, was asked if they passed their driving test at the first attempt.

Altogether 167 of the group said they passed at the first attempt.

Of the women, 143 said they did not pass at the first attempt.

How many of the men said they passed at the first attempt?

- A 10
- B 24
- C 33
- D 57
- E 110
- F 133
- G 157

- 2 A cuboid has sides of length x , $\sqrt{2}x$ and $2x$, measured in cm.

The volume, in cm^3 , of the cuboid is numerically equal to twice the total surface area, in cm^2 , of the cuboid.

What is the value of x ?

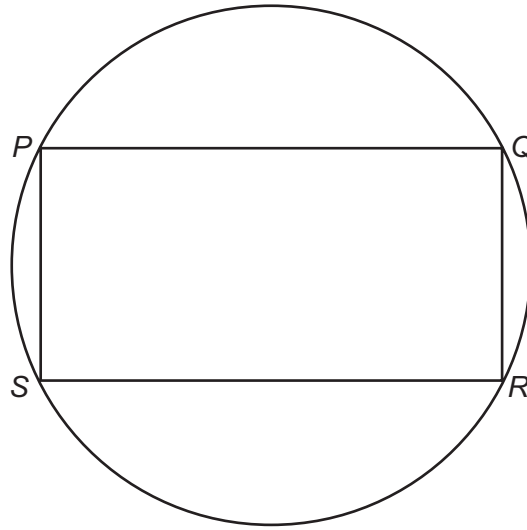
- A 10
- B $6 + 2\sqrt{2}$
- C 5
- D $3 + \sqrt{2}$
- E $\frac{5}{2}$
- F $\frac{3}{2} + \frac{1}{2}\sqrt{2}$

- 3 The line joining the points with coordinates $(p, p - 1)$ and $(1 - p, 2p)$ is parallel to the line with equation $2x + 3y + 1 = 0$

What is the value of p ?

- A -1
- B $-\frac{1}{7}$
- C $\frac{1}{9}$
- D $\frac{1}{8}$
- E 1
- F $\frac{5}{4}$
- G 2
- H 5

- 4 A rectangle $PQRS$ is drawn inside a circle, with its vertices on the circumference of the circle.



[diagram not to scale]

The ratio of the length of PQ to the length of QR is $2 : 1$

The area of the rectangle $PQRS$ is 96 cm^2 .

What is the radius, in cm, of the circle?

- A $\sqrt{6}$
- B 3
- C $3\sqrt{2}$
- D $2\sqrt{15}$
- E $4\sqrt{6}$
- F 12
- G $12\sqrt{2}$
- H $8\sqrt{15}$

- 5** The expected number of bottles of water sold in a day at a sports ground is directly proportional to the square of the average outside temperature, in degrees Celsius, for that day.

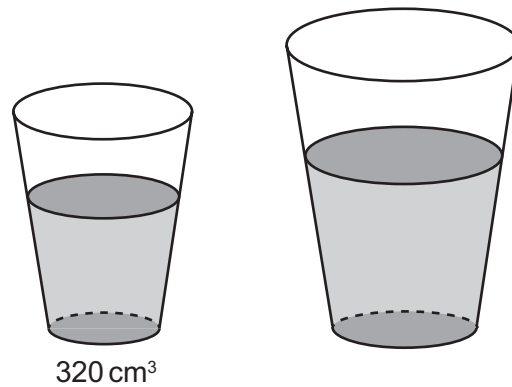
On a day when the average outside temperature is 16°C , 64 bottles of water, the expected number, are sold.

On a warmer day, when the average outside temperature is $T^{\circ}\text{C}$, 256 bottles of water are sold, which is 31 bottles more than the expected number for that day.

What is the value of T ?

- A** 7.5
- B** $\sqrt{450}$
- C** 30
- D** 32
- E** $\sqrt{1148}$
- F** 56.25

6



[diagram not to scale]

At a cinema, drinks are sold in regular and large sizes.

The cups for these are mathematically similar.

The ratio of the heights of the cups and the ratio of the depths of the drinks are both 4 : 5

The volume of drink in a regular size cup is 320 cm^3 .

What is the volume, in cm^3 , of drink in a large size cup?

- A** 384
- B** 400
- C** 500
- D** 576
- E** 625
- F** 640

- 7 The mean of n numbers is p

The mean of two of these numbers is q

The mean of the remaining numbers is 10

Which of the following is a correct expression for n in terms of p and q ?

A $\frac{2(q-10)}{(p-10)}$

B $\frac{2(q-10)}{(10-p)}$

C $\frac{2(q-10)}{(p+10)}$

D $\frac{2(10-q)}{(p+10)}$

E $\frac{2(10+q)}{(p-10)}$

F $\frac{2(10+q)}{(10-p)}$

- 8 The straight lines

$$5x + 2y = 20$$

$$y = 3x - 23$$

$$x = 0$$

enclose a region with area K square units.

What is the value of K ?

A 39

B 78

C 99

D 129

E 198

F 258

- 9 A scale model of a cylindrical pillar is to be made.

The full-sized pillar has a volume of $12\pi \text{ m}^3$.

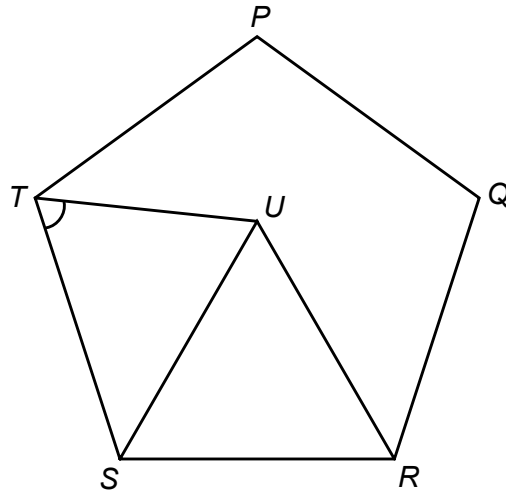
The model will use a length scale of 1 : 40

The model is to be a solid cylinder made of a plastic which has a density of $\frac{4}{3} \text{ g cm}^{-3}$.

What is the mass of the model in grams?

- A $\frac{9}{640}\pi$
- B $\frac{1}{40}\pi$
- C 40π
- D $\frac{1125}{8}\pi$
- E 250π
- F $10\,000\pi$
- G $225\,000\pi$
- H $400\,000\pi$

10



[diagram not to scale]

PQRST is a regular pentagon.

RSU is an equilateral triangle.

What is the size of angle *STU*?

- A** 48°
- B** 54°
- C** 60°
- D** 66°
- E** 84°

- 11 The original price of an item is p

The price is **increased by** 125%

The increased price is then **decreased by** 40% to q

The relationship between p and q can be expressed as $mp = q$

What is the value of m ?

A $\frac{7}{20}$

B $\frac{17}{20}$

C $\frac{27}{20}$

D $\frac{33}{20}$

E $\frac{37}{20}$

- 12 80% of a number is equal to two-thirds of a second number.

The whole number ratio of the first number to the second number in its lowest terms is $x:y$

What is the value of $x - y$?

A 7

B 2

C 1

D 0.2

E -0.2

F -1

G -2

H -7

- 13 Q is 5 km away from P on a bearing of 065°

R is 5 km away from Q on a bearing of 155°

What is the bearing of P from R ?

- A 070°
- B 110°
- C 225°
- D 270°
- E 290°
- F 315°
- G 335°

- 14 With school lunch, students can select tomato sauce, or mayonnaise, or both, or neither.

n students selected both.

$3n + 1$ students selected tomato sauce.

$3n - 1$ students selected **only** mayonnaise.

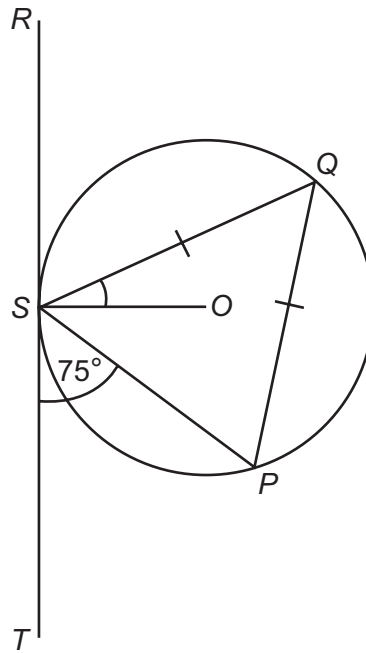
There were $7n + 5$ students in the group.

The probability of a student, chosen at random, selecting **only** mayonnaise is $\frac{1}{3}$

By finding n , what is the probability of a student, chosen at random, selecting **only** tomato sauce?

- A $\frac{3}{11}$
- B $\frac{7}{26}$
- C $\frac{13}{33}$
- D $\frac{3}{8}$
- E $\frac{7}{13}$

15



[diagram not to scale]

The line segment RT is a tangent at the point S to a circle with centre O

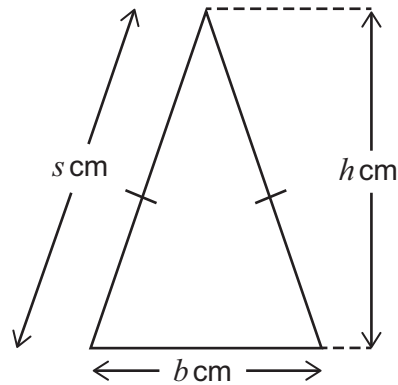
Q and P are points on the circumference of the circle such that $QS = QP$

Angle $PST = 75^\circ$

What is the size of angle QSO ?

- A** 15°
- B** 30°
- C** 37.5°
- D** 45°
- E** 52.5°
- F** 60°
- G** 67.5°
- H** 75°

16



[diagram not to scale]

The vertical height $h \text{ cm}$ of an isosceles triangle is 3 cm longer than the base length of $b \text{ cm}$.

The sloping side is of length $s \text{ cm}$.

The area of the triangle is 14 cm^2 .

There is one value of s which satisfies these conditions.

Within which range does this value of s lie?

- A** $5 < s < 6$
- B** $6 < s < 7$
- C** $7 < s < 8$
- D** $8 < s < 9$
- E** $9 < s < 10$
- F** $10 < s < 11$

- 17 The first five terms of a sequence in order are:

2 17 42 77 122

The n^{th} term of this sequence is $pn^2 + q$ where p and q are integers.

What is the value of $\frac{p-q}{p+q}$?

- A $\frac{1}{4}$
- B $\frac{1}{2}$
- C 1
- D $\frac{23}{17}$
- E $\frac{13}{7}$
- F 2
- G 4
- H 14

- 18 A bag contains 6 red and 6 green sweets. The sweets are identical apart from their colour.

A child takes a sweet at random from the bag.

If the sweet is red, the child stops taking sweets.

If the sweet is green, it is not replaced and the child takes another sweet.

This continues until a red sweet is taken at which point the child stops taking sweets.

What is the probability that the child takes **more** green sweets than red sweets?

A $\frac{3}{22}$

B $\frac{5}{22}$

C $\frac{3}{11}$

D $\frac{1}{2}$

E $\frac{8}{11}$

F $\frac{17}{22}$

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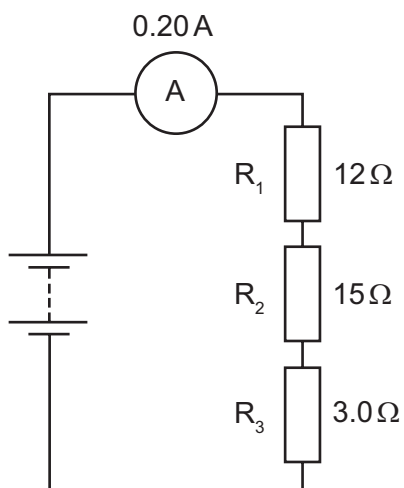
PART B Physics

- 19** An unstable nucleus X becomes a stable nucleus Y after a succession of decays, during which a total of 5 alpha particles and 2 beta (β^-) particles are emitted.

How many fewer protons does nucleus Y contain than nucleus X?

- A** 6
- B** 8
- C** 10
- D** 12
- E** 14
- F** 16
- G** 18
- H** 20

- 20** The diagram shows three resistors R_1 , R_2 and R_3 connected in series with a battery of constant voltage. The resistance of each resistor and the corresponding current are also shown.



Resistor R_3 is now removed and the circuit is reconnected.

What is the new current in the circuit?

- A** 0.20 A
- B** 0.22 A
- C** 0.33 A
- D** 0.40 A
- E** 0.50 A
- F** 2.0 A
- G** 6.0 A

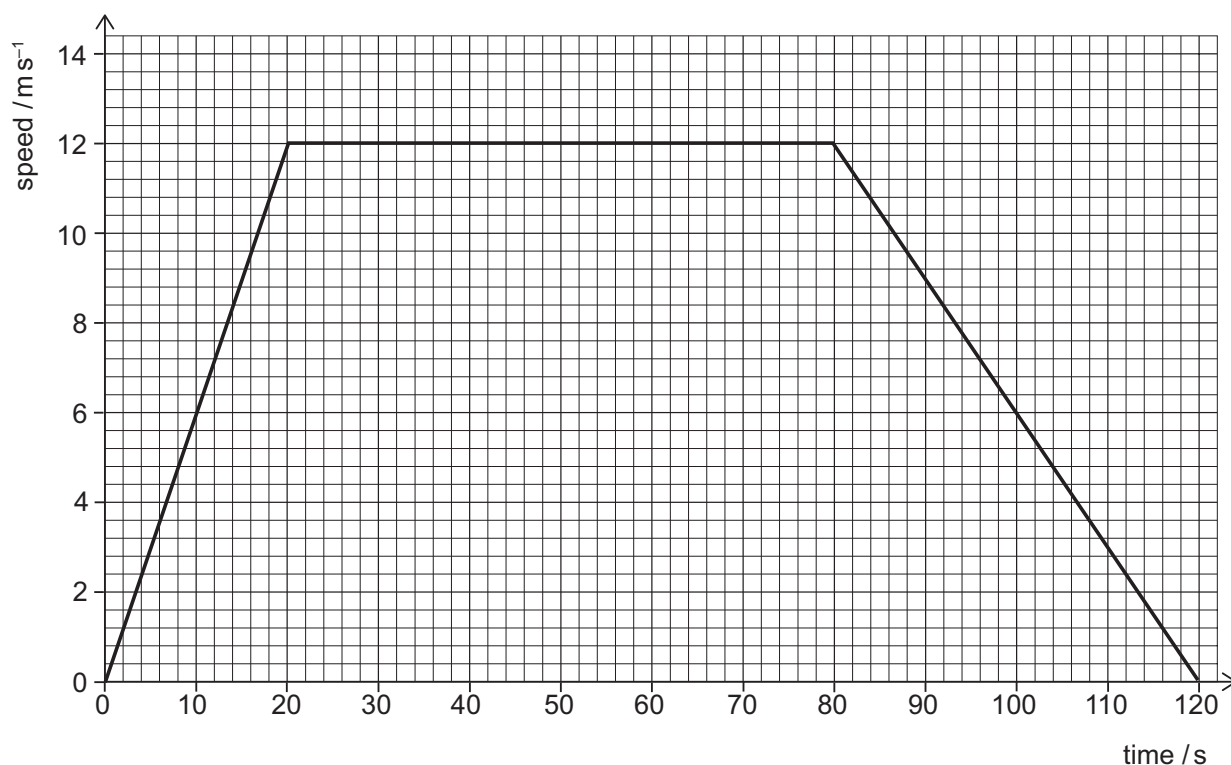
- 21** When travelling in a vacuum, visible light has a wavelength between 400 nm and 700 nm.

The speed of light in a vacuum is $3.0 \times 10^8 \text{ ms}^{-1}$.

What can be concluded about **ultraviolet** radiation from this information?

- A** It has a **maximum** frequency of $2.7 \times 10^{14} \text{ Hz}$
- B** It has a **maximum** frequency of $4.3 \times 10^{14} \text{ Hz}$
- C** It has a **maximum** frequency of $7.5 \times 10^{14} \text{ Hz}$
- D** It has a **maximum** frequency of $1.0 \times 10^{15} \text{ Hz}$
- E** It has a **minimum** frequency of $2.7 \times 10^{14} \text{ Hz}$
- F** It has a **minimum** frequency of $4.3 \times 10^{14} \text{ Hz}$
- G** It has a **minimum** frequency of $7.5 \times 10^{14} \text{ Hz}$
- H** It has a **minimum** frequency of $1.0 \times 10^{15} \text{ Hz}$

- 22 The graph is the speed–time graph for a bus travelling in a straight line between two stops.



What is the average speed of the bus during this time?

- A 3.0 m s⁻¹
- B 4.5 m s⁻¹
- C 6.0 m s⁻¹
- D 8.0 m s⁻¹
- E 9.0 m s⁻¹
- F 11 m s⁻¹
- G 12 m s⁻¹

- 23** A filament lamp working at its operating voltage converts electrical energy at a rate of 100 W.

The lamp has an efficiency of 5.0%.

How much energy is wasted by the lamp in 10 minutes?

- A** 50 J
- B** 950 J
- C** 1000 J
- D** 3000 J
- E** 57 000 J
- F** 60 000 J

- 24** A student is investigating heat flow along a solid uniform metal bar.

The bar has length l , cross-sectional area A , and has its ends maintained at temperatures T_1 and T_2 (where $T_1 > T_2$).

Which relationship represents the rate of heat flow P along the bar?

(Assume that there is no heat transfer through the sides of the bar.)

- A** $P \propto \frac{(T_1 - T_2)}{Al}$
- B** $P \propto \frac{(T_1 + T_2)}{Al}$
- C** $P \propto \frac{A(T_1 - T_2)}{l}$
- D** $P \propto \frac{A(T_1 + T_2)}{l}$
- E** $P \propto \frac{l}{A(T_1 - T_2)}$
- F** $P \propto \frac{l}{A(T_1 + T_2)}$
- G** $P \propto \frac{Al}{(T_1 - T_2)}$
- H** $P \propto \frac{Al}{(T_1 + T_2)}$

- 25** The potential difference across the motor in an electric car is 400 V and the current in the motor is 1250 A.

The car accelerates along a horizontal road from rest for 4.0 s.

The efficiency of the overall system is 45%.

What is the kinetic energy of the car at the end of the 4.0 s?

(Ignore energy losses due to air resistance and due to friction between the tyres and the road.)

- A** 225 000 J
- B** 500 000 J
- C** 900 000 J
- D** 1 250 000 J
- E** 2 000 000 J

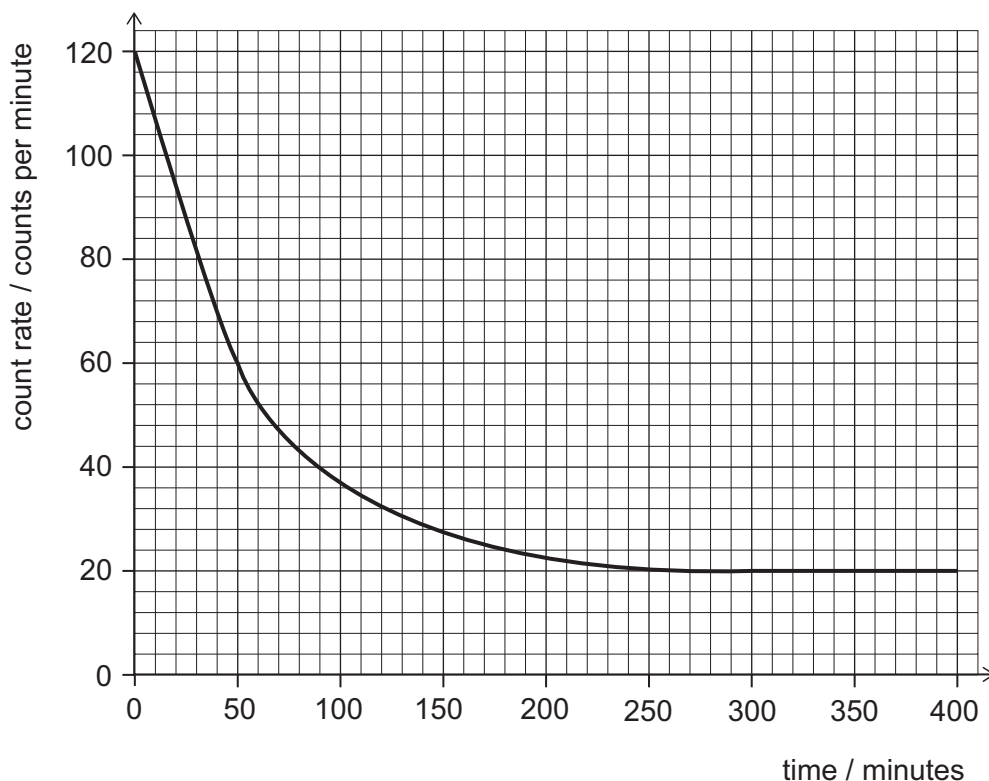
- 26** The momentum of a small object moving in a straight line is 24 kg ms^{-1} and its kinetic energy is 96 J.

What is the mass of the object?

- A** 3.0 kg
- B** 4.0 kg
- C** 6.0 kg
- D** 8.0 kg
- E** 12 kg

- 27** A radioactive isotope decays in a single step to a stable isotope.

A radiation detector is placed very near to a sample of the radioactive isotope in a laboratory. The count rate on the detector changes as time elapses. The graph shows how the measured count rate changes with time.



What is the background count rate and what is the half-life of the isotope?

	<i>background count rate</i> / counts per minute	<i>half-life of isotope</i> / minutes
A	20	40
B	20	50
C	20	60
D	20	65
E	120	40
F	120	50
G	120	60
H	120	65

- 28** A rock falling vertically experiences an air resistance force of 12 N at an instant when its acceleration is 2.0 m s^{-2} downwards.

What is the mass of the rock?

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

- A** 1.0 kg
- B** 1.2 kg
- C** 1.5 kg
- D** 6.0 kg
- E** 10 kg
- F** 12 kg
- G** 15 kg
- H** 60 kg

- 29** A transverse wave with an amplitude of 4.0 cm and a frequency of 10 Hz travels along a rope at a speed of 2.4 m s^{-1} .

What is the total distance travelled by a particle in the rope in a time of 20 s?

- A** 2.4 m
- B** 4.8 m
- C** 8.0 m
- D** 16 m
- E** 32 m
- F** 48 m

- 30** A student places a measuring cylinder on a balance. She pours a volume V of water into the measuring cylinder, and finds that the mass of the measuring cylinder and water together is 290 g.

She then empties the measuring cylinder and dries it before putting it back on the balance.

She now pours the same volume V of olive oil into the measuring cylinder, and finds that the mass of the measuring cylinder and olive oil together is 270 g.

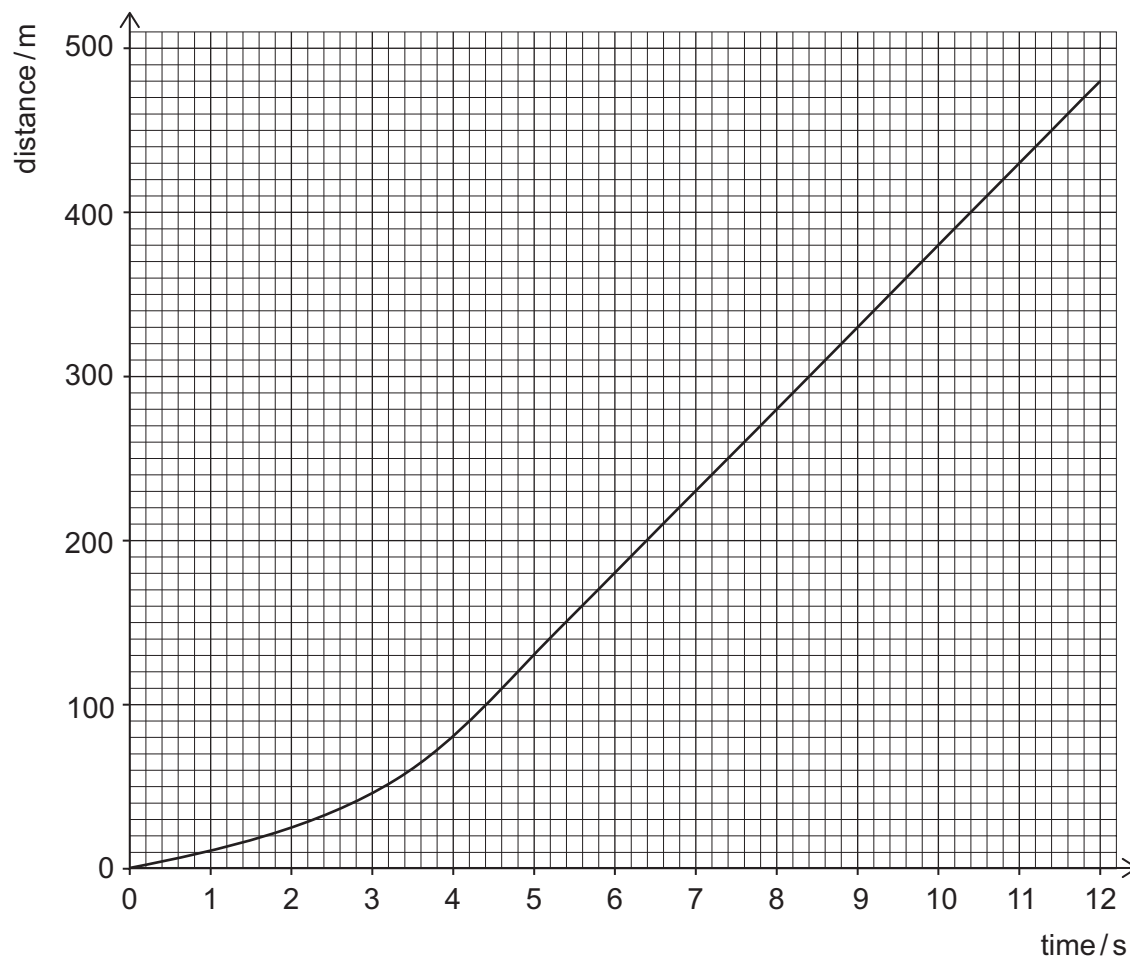
What is the mass of the measuring cylinder?

(densities: olive oil = 0.90 g cm^{-3} ; water = 1.0 g cm^{-3})

- A** 18 g
- B** 20 g
- C** 90 g
- D** 180 g
- E** 200 g

- 31** A skydiver of weight 1000 N falls vertically.

The distance–time graph for the skydiver is shown below.



The air resistance F (in N) acting on the skydiver travelling at velocity v (in m s^{-1}) is given by the equation

$$F = kv^2$$

where k (in $\text{N m}^{-2} \text{s}^2$) is a constant.

What is the numerical value of k for the skydiver?

- A** 0.050
- B** 0.40
- C** 0.63
- D** 2.5
- E** 20

- 32** A source generates water waves of fixed frequency that have a wavelength of 1.5 cm.

As they cross a boundary into shallower water their frequency does not change, but their speed is reduced by 18 cm s^{-1} .

The new wavelength is 1.2 cm.

What is the speed of the waves in the shallower water?

- A** 42 cm s^{-1}
- B** 50 cm s^{-1}
- C** 54 cm s^{-1}
- D** 60 cm s^{-1}
- E** 72 cm s^{-1}
- F** 90 cm s^{-1}

- 33** A neutron is absorbed by a uranium-235 ($^{235}_{92}\text{U}$) nuclide.

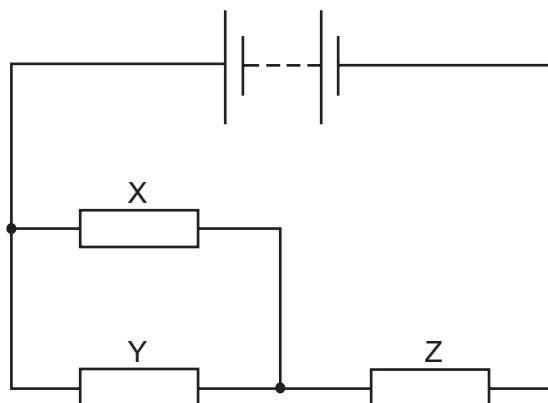
The resulting nuclide undergoes fission to produce a bromine-88 ($^{88}_{35}\text{Br}$) nuclide, a lanthanum-145 nuclide and some neutrons.

The lanthanum-145 nuclide is radioactive and emits a beta (β^-) particle.

How many neutrons are emitted in the fission reaction and how many protons are there in the nuclide formed by the decay of lanthanum-145?

	<i>neutrons</i>	<i>protons</i>
A	2	55
B	2	56
C	2	57
D	2	58
E	3	55
F	3	56
G	3	57
H	3	58

- 34** The diagram shows a circuit containing a battery and three identical resistors X, Y and Z.



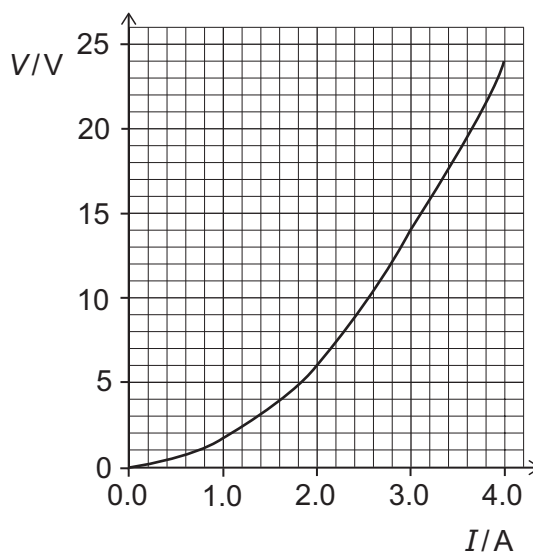
The total power supplied by the battery is 18 W.

What is the power dissipated as heat in resistor X?

- A** 1.5 W
- B** 2.0 W
- C** 3.0 W
- D** 4.5 W
- E** 6.0 W
- F** 8.0 W
- G** 12 W

- 35** A filament lamp and a $0\text{--}10\,\Omega$ variable resistor are connected in series with a power supply of constant voltage.

The graph shows the voltage–current (V – I) characteristic of the filament lamp.



When the resistance of the variable resistor is $4.0\,\Omega$, the current in the lamp is $2.0\,\text{A}$.

What is the power dissipated in the lamp when the resistance of the variable resistor is zero?

- A** 12 W
- B** 14 W
- C** 16 W
- D** 28 W
- E** 42 W
- F** 96 W

- 36** Three detectors X, Y and Z are separated by large distances.

Each of the detectors records a seismic wave from the same earthquake whose epicentre (source) is very close to the surface of the Earth.

The wave travels out from the epicentre at 4.0 km s^{-1} .

Detectors X and Y start to detect the wave at the same time, but detector Z starts to detect it one minute later.

Which of the following statements **must** be correct?

- 1** The epicentre is at the midpoint of the line XY.
 - 2** Z is equidistant from X and Y.
 - 3** Z is no more than 240 km away from X and from Y.
-
- 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

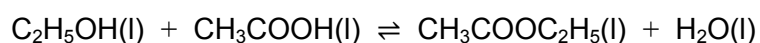
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PART C Chemistry

- 37 Which row in the following table gives the numbers of protons, neutrons and electrons in ${}^{64}_{29}\text{Cu}^{2+}$?

	<i>number of protons</i>	<i>number of neutrons</i>	<i>number of electrons</i>
A	27	33	27
B	27	35	29
C	29	35	27
D	29	35	29
E	31	33	29
F	31	35	29

- 38 The following exothermic reaction reaches equilibrium at room temperature.



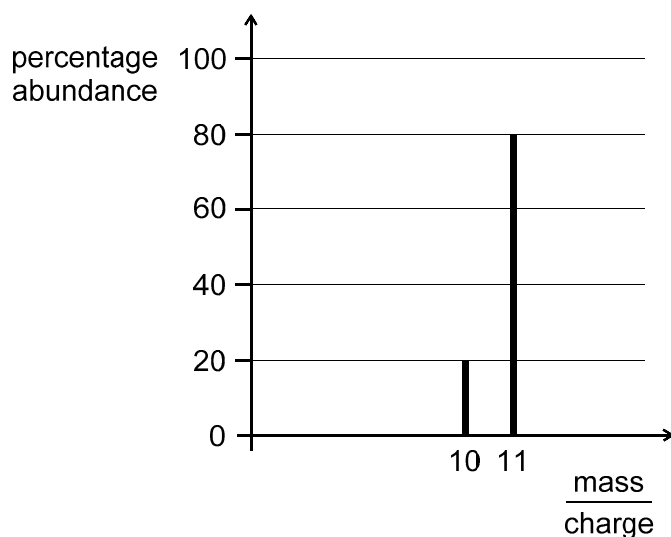
Which of the following changes, when applied independently, will alter the position of the equilibrium?

- 1 increasing the temperature by 25 °C
 - 2 adding 20 cm³ of water to the equilibrium mixture
 - 3 adding a catalyst
 - 4 adding an extra 0.5 mol of ethanol (C₂H₅OH)
- A** 1 only
- B** 1 and 3 only
- C** 1, 2 and 4 only
- D** 2 and 4 only
- E** 1, 2, 3 and 4

39 What is the overall process that takes place at the cathode (negative electrode) in the electrolysis of dilute aqueous sodium sulfate?

- A** $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$
B $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$
C $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$
D $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$
E $\text{SO}_4^{2-} \rightarrow \text{SO}_2 + \text{O}_2 + 2\text{e}^-$

40 A mass spectrum of a sample of element X with atomic number 5 is shown.



Using the data, which row in the following table best describes the position of X in the Periodic Table and the relative atomic mass of this sample of X?

	<i>Period</i>	<i>Group</i>	<i>relative atomic mass</i>
A	1	15	10.2
B	1	15	10.8
C	2	13	10.2
D	2	13	10.8
E	3	2	10.2
F	3	2	10.8

- 41** The gases nitrogen, oxygen and argon can be separated from liquefied air by fractional distillation.

Given the data in the table, in which order would the gases be collected?

	<i>melting point / °C</i>	<i>boiling point / °C</i>
nitrogen	–210	–196
oxygen	–218	–183
argon	–189	–186

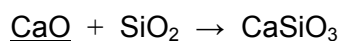
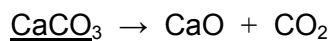
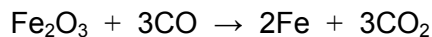
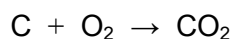
- A** nitrogen, oxygen, argon
- B** nitrogen, argon, oxygen
- C** oxygen, nitrogen, argon
- D** oxygen, argon, nitrogen
- E** argon, nitrogen, oxygen
- F** argon, oxygen, nitrogen
- 42** Concentrated aqueous sodium chloride was electrolysed. After a few minutes, the remaining electrolyte solution was tested with a pH probe at 25 °C.

The gases produced at the electrodes were collected and tested with a colourless aqueous solution of sodium bromide.

Which row in the following table best describes the observations in these tests?

	<i>pH of the remaining solution</i>	<i>test of gas from anode (positive electrode)</i>	<i>test of gas from cathode (negative electrode)</i>
A	2	no observable change	no observable change
B	2	no observable change	orange solution forms
C	7	orange solution forms	no observable change
D	7	orange solution forms	orange solution forms
E	12	orange solution forms	no observable change
F	12	no observable change	orange solution forms

- 43 The following equations show the main reactions that take place in a blast furnace during the extraction of iron and the removal of the impurities:



Which row in the following table correctly identifies whether the underlined substance is oxidised, or reduced, or neither?

	CO_2	CaCO_3	CaO
A	oxidised	reduced	neither
B	oxidised	neither	neither
C	oxidised	reduced	oxidised
D	oxidised	neither	oxidised
E	reduced	reduced	neither
F	reduced	neither	neither
G	reduced	reduced	oxidised
H	reduced	neither	oxidised

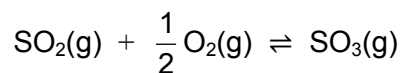
- 44 X, Y and Z have the **same** electron configuration.

X is an atom, Y is a monatomic anion and Z is a monatomic cation.

Which of the following statements is **always** correct?

- A Anion Y has fewer protons than atom X.
- B Cation Z has more electrons than protons.
- C X, Y and Z are in the same group of the Periodic Table.
- D X, Y and Z have consecutive atomic numbers.
- E X, Y and Z have the same mass number.

- 45** In the Contact process, sulfur dioxide reacts with oxygen to make sulfur trioxide in a reversible reaction.



When 5.00 mol of SO_2 and 11.0 mol of O_2 are allowed to reach equilibrium at 450°C , 80.0% of the SO_2 is converted to SO_3 .

What is the volume of the resulting mixture?

(Assume that temperature and pressure are constant, and that at this temperature the volume of one mole of gas is 60.0 dm^3 .)

- A** 240 dm^3
- B** 336 dm^3
- C** 600 dm^3
- D** 720 dm^3
- E** 840 dm^3
- F** 960 dm^3

- 46** The non-metallic element phosphorus forms two stable chlorides: PCl_3 (boiling point 76°C) and PCl_5 (boiling point 161°C).

Which of the following statements explain(s) the difference in boiling points?

- 1** There are more covalent bonds in PCl_5 so more energy is required to break them.
- 2** The forces between the molecules in liquid PCl_5 are stronger.
- 3** The covalent bonds in PCl_3 are weaker so less energy is required to break them.

- 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** A student calculated the mass of anhydrous copper(II) sulfate (CuSO_4) required to make 250 cm^3 of an aqueous solution of concentration 0.200 mol dm^{-3} .

However, the student mistakenly made the solution using the same mass of hydrated copper(II) sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) instead.

What is the concentration, in mol dm^{-3} , of the solution made with the hydrated copper(II) sulfate?

(A_r values: $\text{Cu} = 64$; $\text{S} = 32$; $\text{O} = 16$; $\text{H} = 1.0$)

- A** 0.128 mol dm^{-3}
B 0.160 mol dm^{-3}
C 0.180 mol dm^{-3}
D 0.200 mol dm^{-3}
E 0.223 mol dm^{-3}
F 0.313 mol dm^{-3}

48 Bromine is an element in Group 17 of the Periodic Table.

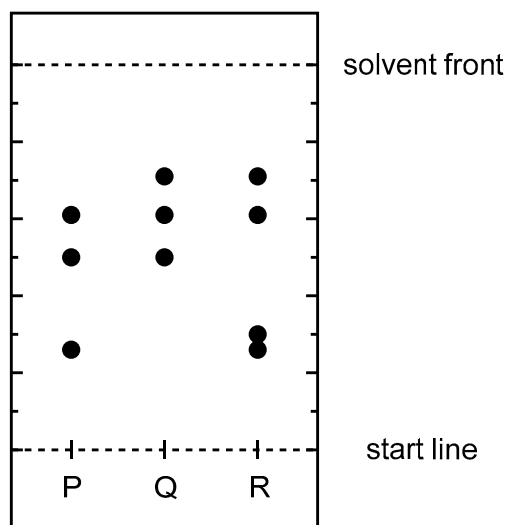
Which of the following statements is/are correct about the element bromine?

- 1** Bromine will oxidise chloride ions in aqueous solution to form chlorine.
- 2** Bromine has a lower boiling point than chlorine.
- 3** Bromine reacts with calcium (Group 2) to form a compound containing 80% bromine by mass.

(A_r values: Cl = 35.5; Ca = 40; Br = 80)

- 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 Paper chromatography was used to separate three mixtures of amino acids. The mixtures were labelled P, Q and R.



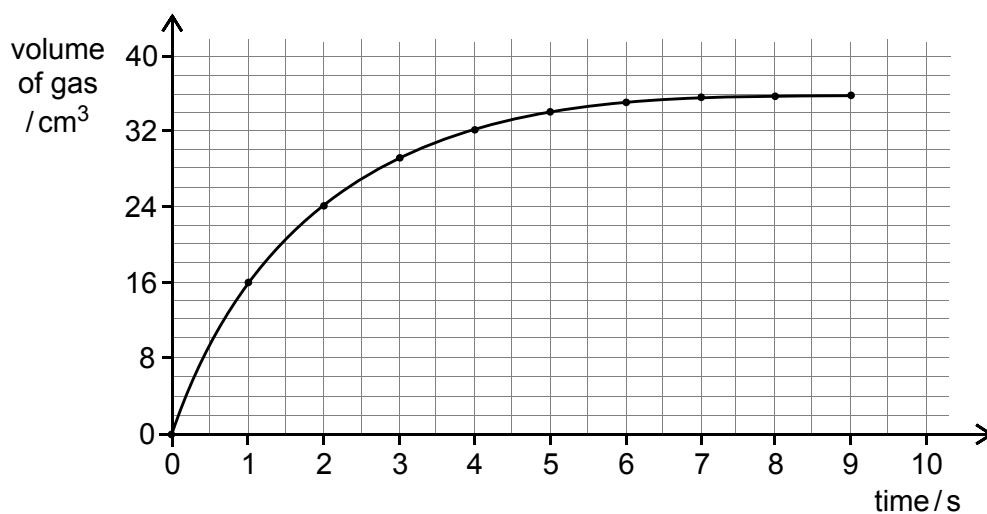
Each mixture contains some of the five amino acids in the following table. The R_f values were measured for each amino acid with the solvent used to produce the chromatogram.

<i>amino acid</i>	R_f value
asparagine	0.50
glutamic acid	0.30
glycine	0.26
leucine	0.71
valine	0.61

Which of the following statements is/are correct?

- 1 Mixture P contains valine and glycine.
 - 2 Leucine is found in all three mixtures.
 - 3 Glutamic acid is the least mobile amino acid with this solvent.
 - 4 Mixtures P and Q both contain asparagine.
- A** 1 and 2 only
- B** 1 and 4 only
- C** 2 and 3 only
- D** 3 only
- E** 4 only

- 50 Dilute hydrochloric acid and magnesium were mixed and the total volume of gas released was measured over time.

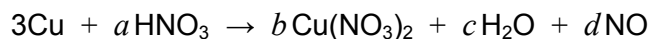


What is the average rate of reaction, in g s^{-1} , with respect to the magnesium over the first **two** seconds?

(A_r value: $\text{Mg} = 24$. Assume that the volume of one mole of gas is 24 dm^3 .)

- A 0.012 g s^{-1}
- B 0.024 g s^{-1}
- C 0.048 g s^{-1}
- D 12 g s^{-1}
- E 24 g s^{-1}
- F 48 g s^{-1}

- 51 Copper can react with concentrated nitric acid to form the gas nitrogen monoxide.



What is the value of a when the equation is balanced?

- A 6
- B 7
- C 8
- D 9
- E 10
- F 11
- G 12

- 52 A small amount of a solid mixture, containing calcium carbonate and an inert substance, was added to 50.00 cm^3 dilute hydrochloric acid of concentration $0.1000\text{ mol dm}^{-3}$.



After all of the calcium carbonate had reacted, the solution was heated to drive off the carbon dioxide.

The resulting solution was neutralised by 12.50 cm^3 of $0.1000\text{ mol dm}^{-3}$ sodium hydroxide solution.

What was the mass of calcium carbonate in the mixture added to the hydrochloric acid?

(M_r value: $\text{CaCO}_3 = 100.0$)

- A 0.06250 g
- B 0.1250 g
- C 0.1875 g
- D 0.3750 g
- E 0.6250 g
- F 0.7500 g

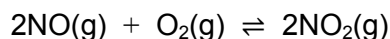
- 53** 2.80 g of lithium metal is placed in a closed system with 1.20 dm³ of pure oxygen gas (volume measured at room temperature and pressure).

If a complete reaction occurs between the lithium and the oxygen, what is the maximum mass of lithium oxide that can be formed?

(A_r values: Li = 7; O = 16. Assume that one mole of gas occupies 24.0 dm³ at room temperature and pressure.)

- A** 1.50 g
- B** 3.00 g
- C** 3.90 g
- D** 4.60 g
- E** 6.00 g
- F** 12.0 g
- G** 15.6 g

- 54** The following reaction between nitrogen oxide and oxygen releases 116 kJ of energy as heat for each mole of oxygen that reacts.



An excess of NO and y moles of oxygen are mixed in a sealed container. The reaction reaches equilibrium in one hour.

At equilibrium, there are z moles of NO₂.

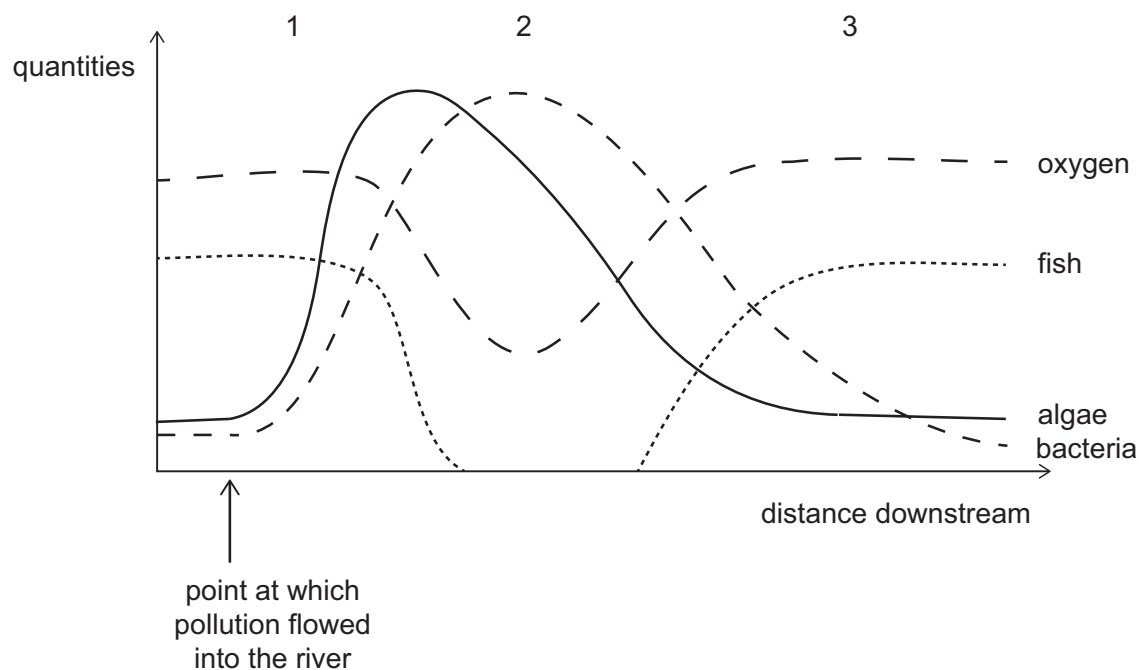
Assume that the pressure is constant throughout the experiment.

How much heat will be released over this hour?

- A** 0 kJ
- B** $58y$ kJ
- C** $116y$ kJ
- D** $232y$ kJ
- E** $58z$ kJ
- F** $116z$ kJ
- G** $232z$ kJ

PART D Biology

- 55** The graph shows how four variables change with the distance down a river, after a source of pollution flowed in.



Which indicator species could be expected to be found in large numbers at 1, 2 and 3?

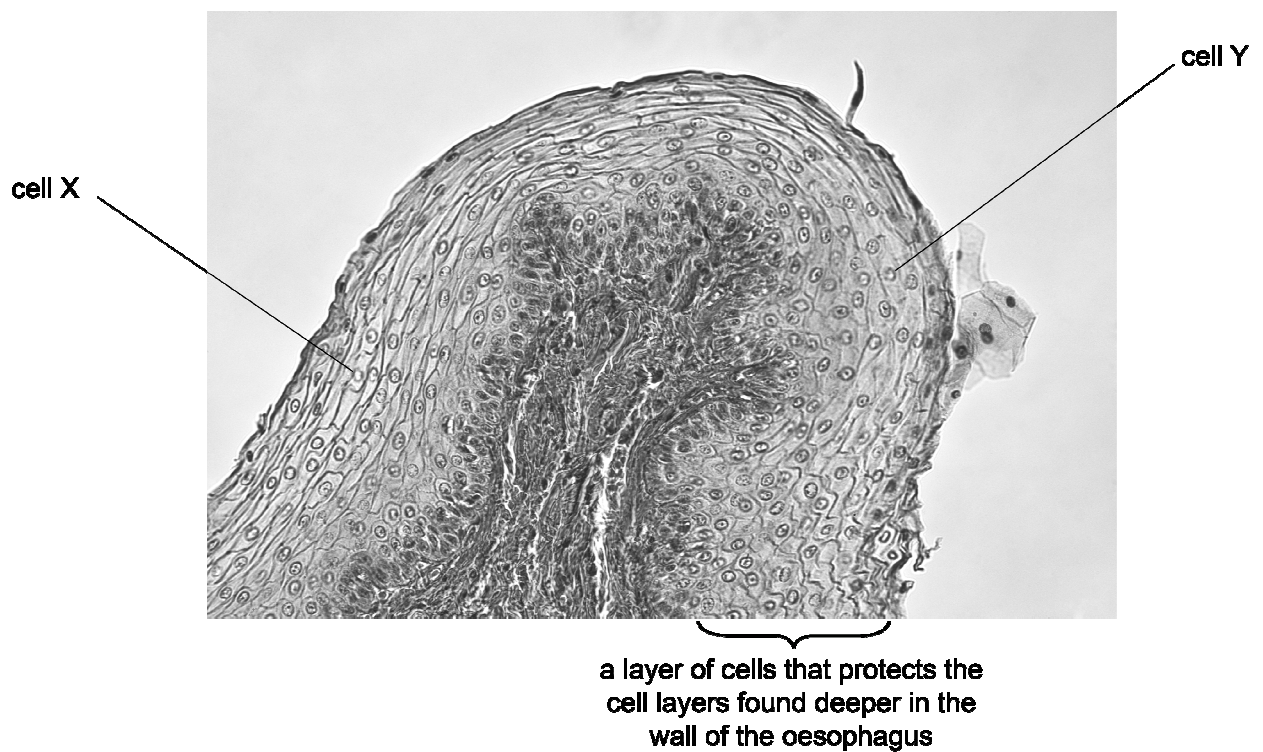
	1	2	3
A	bloodworm	bloodworm	bloodworm
B	bloodworm	bloodworm	stonefly
C	bloodworm	stonefly	bloodworm
D	bloodworm	stonefly	stonefly
E	stonefly	bloodworm	bloodworm
F	stonefly	bloodworm	stonefly
G	stonefly	stonefly	bloodworm
H	stonefly	stonefly	stonefly

- 56** Sickle cell anaemia is a recessive genetic condition that results in abnormally-shaped red blood cells due to the production of a faulty type of haemoglobin. Children born with sickle cell anaemia rarely live to adulthood without significant medical intervention. Carriers, who only have one copy of the sickle cell allele, have greater resistance to the disease malaria than people with two copies of the allele for normal functional haemoglobin.

Using this information, which of the following statements is/are correct?

- 1** People with sickle cell anaemia would have reduced anaerobic respiration in their muscle cells.
 - 2** In areas with malaria the percentage of people surviving with sickle cell anaemia increases.
 - 3** In parts of Africa where malaria is more common you would expect to find more people with a sickle cell allele.
- 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

- 57 A student studied this photograph of part of an organ.



The student drew the following conclusions about the two cells labelled X and Y.

- 1 Both cells X and Y are found in the same tissue.
- 2 Both cells X and Y were produced by mitosis.
- 3 Both cells X and Y have a cell wall.

Which of these conclusions is/are correct?

- 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** A student investigated the tadpole population in a large pond.

A net with a rectangular opening measuring $0.1\text{ m} \times 0.2\text{ m}$ was swept through the water for a fixed distance of 1 m. This was repeated 10 times.

All the sweeps were made at the edge of the pond as the student had no waders or boat.

The number of tadpoles in each sweep was recorded in the table.

<i>sweep number</i>	1	2	3	4	5	6	7	8	9	10
<i>number of tadpoles</i>	20	12	32	0	4	8	4	8	12	20

The student made the following statements.

- 1** Each sweep sampled 0.02 m^3 of water.
- 2** The frequency of occurrence of the tadpoles was 90%.
- 3** An accurate estimate of the population size of tadpoles in the pond could be calculated using this data if the total volume of water was known.

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

- 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

- 59** A breeding experiment was carried out using rats.

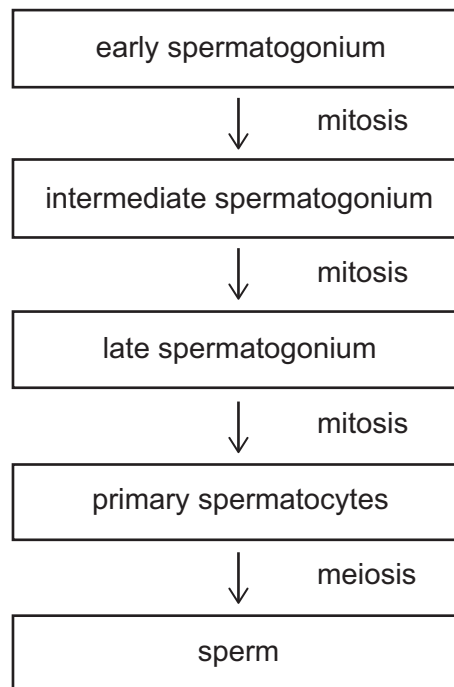
A pair of rats has eight offspring per litter. The offspring breed freely amongst each other within the same generation. Each female is only allowed to have one litter of eight.

The expected ratio of male to female offspring in this breeding population is the same in rats as in humans, and is seen in every generation.

In the 4th generation of offspring, how many individuals would be expected to have the XY genotype?

- A** 16
- B** 32
- C** 64
- D** 128
- E** 256
- F** 512
- G** 1024

- 60** The diagram shows four steps in the process of human sperm production. For each step only one complete division takes place.



Assuming no mutations and that all of the cells survive, what will be the maximum number of haploid cells originating from a single early spermatogonium?

- A** 1
- B** 2
- C** 8
- D** 16
- E** 32
- F** 64

61 Which of the following conditions is/are required by the cells near the tip of a plant shoot in order for the tip to grow towards light from one direction?

- 1** sufficient glucose
- 2** uneven distribution of plant hormone
- 3** sufficient oxygen

- 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 A cell from the epithelium of an animal was removed. The cytoplasm of this cell can be considered as a 2% sugar solution. The living cell was placed in a 4% sugar solution.

Which of the following statements is/are correct?

- 1** At equilibrium, the sugar concentration in the cell was 6%.
- 2** Water continued to move across the cell membrane after equilibrium was reached.
- 3** Osmosis was most rapid when the cell was first placed in the solution.

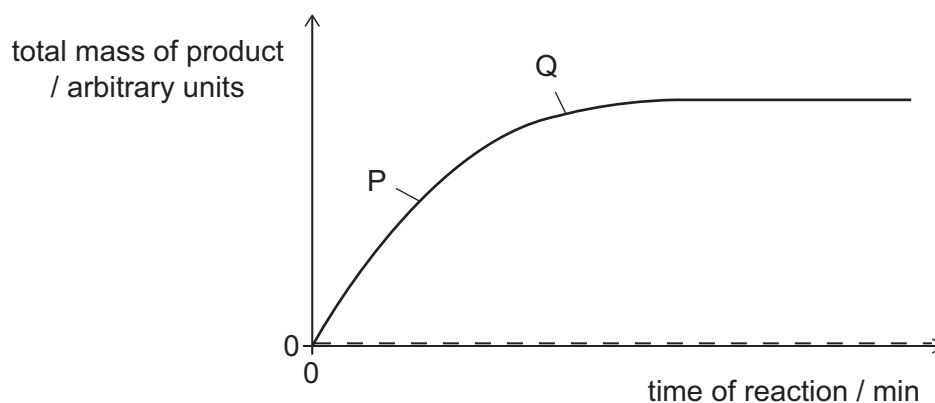
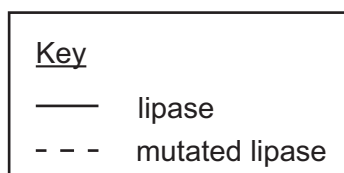
- A** none of them
- B** 1 only
- C** 2 only
- D** 3 only
- E** 1 and 2 only
- F** 1 and 3 only
- G** 2 and 3 only
- H** 1, 2 and 3

- 63** A piece of DNA is made up of two complementary strands, each 25 bases long.
14% of the bases are adenine.

Which two statements are correct?

- 1** Adenine and cytosine together make up 25 bases.
 - 2** Adenine and guanine together make up 50% of the bases.
 - 3** There are 14 thymine bases present.
 - 4** 36 of the bases are guanine.
- 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

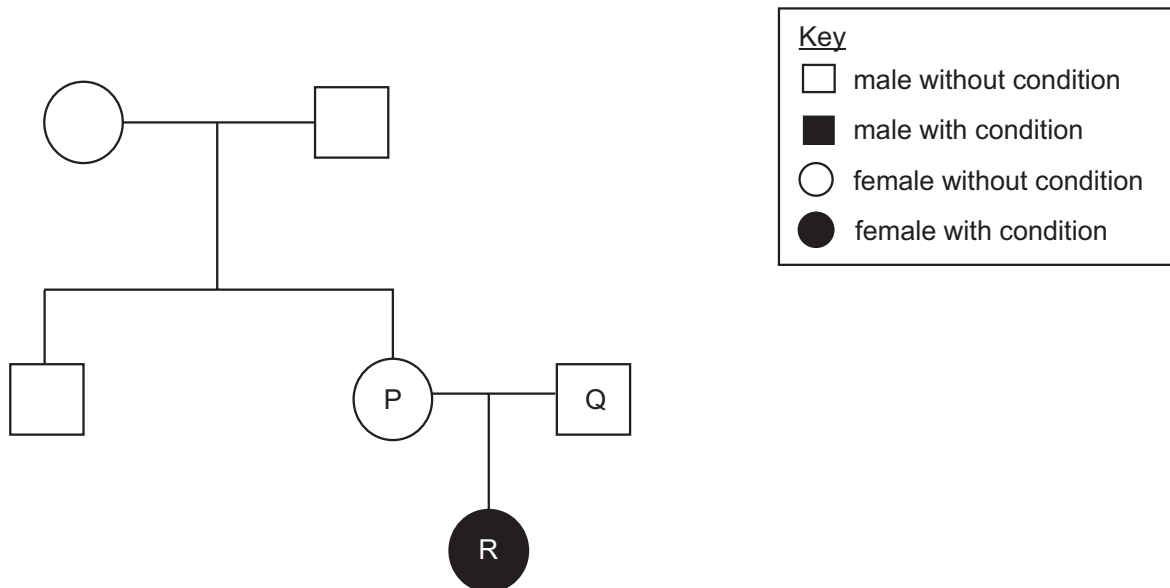
- 64** In a laboratory, the activity of two lipase enzymes on the same type of lipid was studied. One lipase enzyme was produced from a mutation in the gene that coded for the original enzyme. The mutation occurred in the sequence for three adjacent amino acids called serine, aspartic acid and histidine. The graph shows the results of this study.



Which of the following statements is/are correct?

- 1 The serine, aspartic acid and histidine amino acids could be in the active site of the enzyme.
 - 2 All mutations affecting the region coding for serine, aspartic acid and histidine amino acids will be expected to have the same effect.
 - 3 At point Q on the graph, the pH of the reaction mixture will be higher than at P.
- A** none of them
- B** 1 only
- C** 2 only
- D** 3 only
- E** 1 and 2 only
- F** 1 and 3 only
- G** 2 and 3 only
- H** 1, 2 and 3

- 65** The family tree shows a family affected by a dominant genetic condition. All people who carry the mutation show symptoms of the condition.

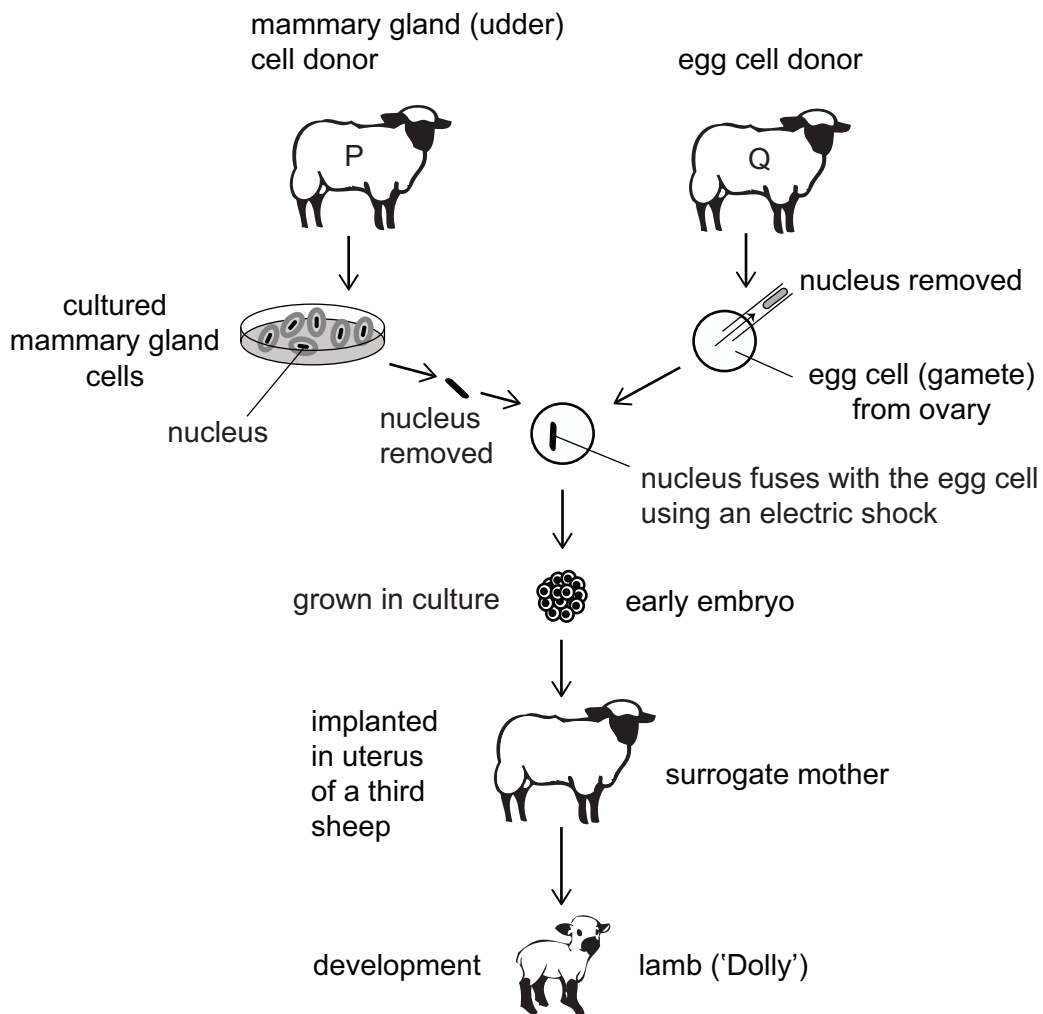


Which of the following statements could explain the presence of the dominant condition in female R?

- 1 The mutation occurs in P.
 - 2 The mutation occurs in Q's father.
 - 3 The mutation occurs in R.
- A** none of them
- B** 1 only
- C** 2 only
- D** 3 only
- E** 1 and 2 only
- F** 1 and 3 only
- G** 2 and 3 only
- H** 1, 2 and 3

66 Dolly the sheep was born in 1996. She was unusual because she had no biological father.

The diagram shows how she was produced.

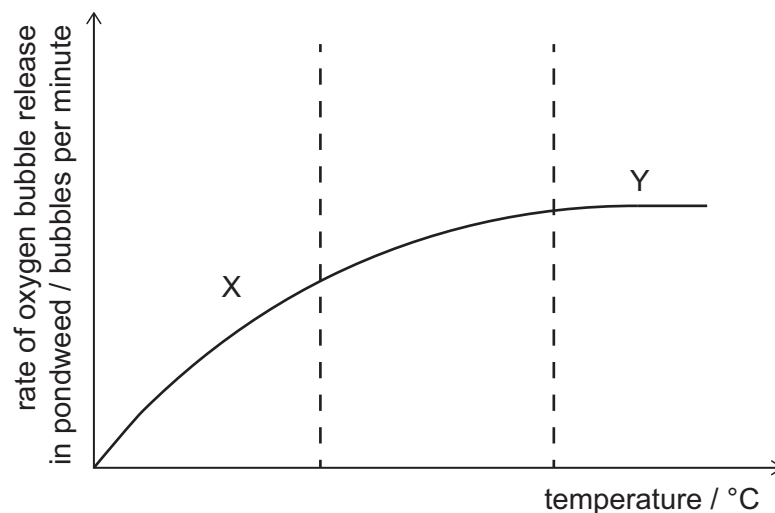


Which of the following processes had to occur to produce Dolly?

- 1 genetic engineering
- 2 mitosis
- 3 meiosis
- 4 differentiation

- A** 1 and 2 only
- B** 2 and 3 only
- C** 1, 2 and 4 only
- D** 1, 3 and 4 only
- E** 2, 3 and 4 only

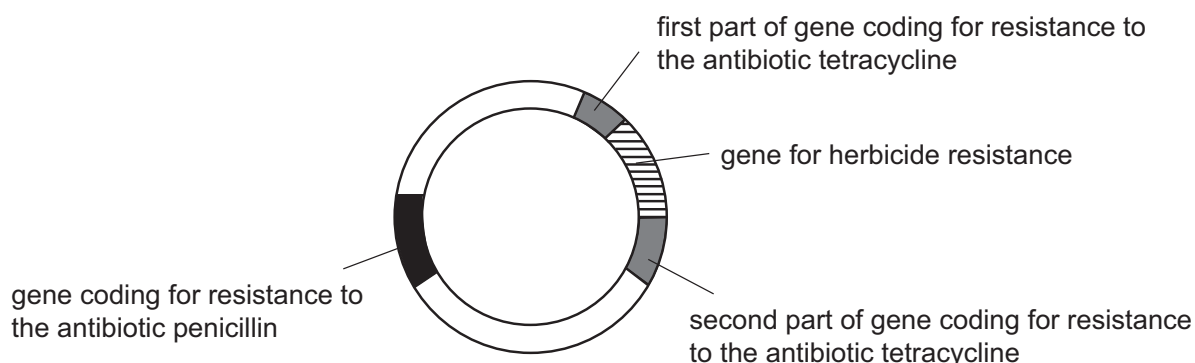
- 67** A student investigated the rate of oxygen bubble release from a pondweed plant at different temperatures. The rates are shown below, with two sections of the graph marked X and Y. In each investigation all other factors were kept constant.



Which of the following statements about sections X and Y is/are correct?

- 1 In section X, the kinetic energy of the reaction molecules is increasing with increasing temperature.
 - 2 In section Y, temperature is the factor which limits that rate of oxygen production.
 - 3 In section Y, the plant's enzymes may have denatured.
 - 4 Section Y represents the plant's maximum possible rate of oxygen production under any conditions.
- A** 1 only
B 2 only
C 3 only
D 4 only
E 1 and 2 only
F 1 and 4 only
G 2 and 3 only
H 3 and 4 only

- 68** The diagram below shows a circular piece of bacterial DNA called a plasmid that has been made recombinant by the insertion of a plant gene for herbicide resistance.



Bacteria containing only the recombinant plasmid had to be identified from bacteria that contained only the original plasmid. The original plasmid contained a gene coding for resistance to the antibiotic penicillin and a gene coding for resistance to the antibiotic tetracycline.

These bacteria were grown on two sets of agar plates. One set used agar that contained the antibiotic penicillin and the other set used agar that contained the antibiotic tetracycline.

Which row in the table correctly shows the growth of these bacteria on the two sets of agar?

	<i>bacteria containing only</i>	<i>growth on agar containing penicillin</i>	<i>growth on agar containing tetracycline</i>
A	recombinant plasmid	yes	yes
	original plasmid	no	no
B	recombinant plasmid	yes	yes
	original plasmid	yes	no
C	recombinant plasmid	yes	no
	original plasmid	yes	yes
D	recombinant plasmid	no	no
	original plasmid	yes	yes
E	recombinant plasmid	yes	yes
	original plasmid	no	yes
F	recombinant plasmid	no	no
	original plasmid	no	no
G	recombinant plasmid	yes	no
	original plasmid	no	yes

- 69** A student analysed a gene sequence that had been identified in four different types of organism. The gene codes for a functional protein. A section of the gene's DNA is shown below. The rest of the DNA from this gene (not shown) is identical in all four different types of organism.

<i>organism</i>	<i>DNA sequence</i>					
human	ACG	CCT	CGT	CAC	GCT	AAA
oak tree	ACG	GAA	TAT	GTA	GCT	AAA
mushroom	ACG	GAA	CTC	TTA	GCT	AAA
<i>E.coli</i> bacterium	ACG	TAC	GAT	GGG	GCT	AAA

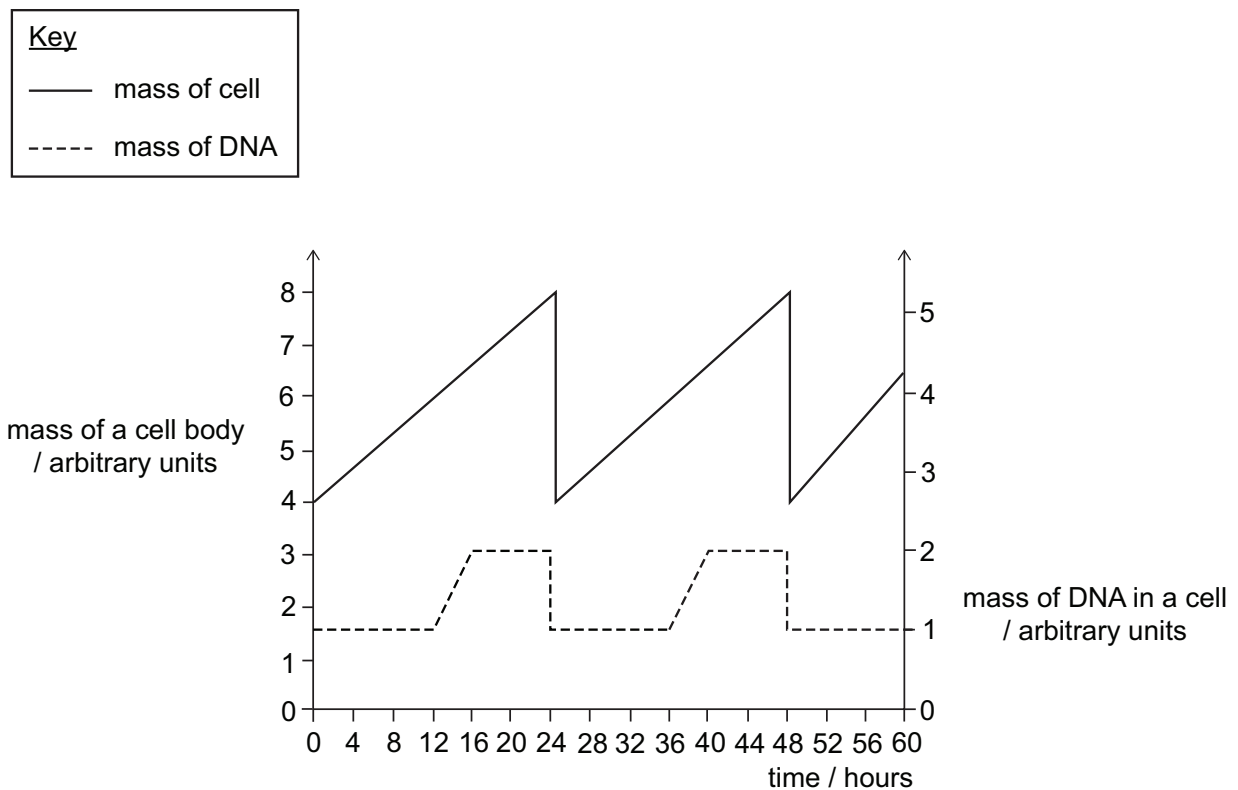
The student then made the following conclusions:

- 1** This gene does not code for chlorophyll.
- 2** This gene may be found in the nucleus or cytoplasm.
- 3** The protein that this gene codes for is likely to be more similar in plants and fungi than in the other organisms.

Which of these conclusions is/are correct?

- 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 graphs represent the changes in the mass of a healthy human body cell and in the mass of the DNA of that cell over time.



Using the graph, which of the following statements is/are correct?

- 1** Mitosis takes place at 12 and 36 hours.
 - 2** The graph shows two cell divisions.
 - 3** The next cell division should take place at 72 hours.
- 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** Bt pesticide is used by farmers to kill insect pests. However, widespread use has resulted in the evolution of resistance to this pesticide. A recessive allele causes resistance.

Scientists have suggested that in areas where the Bt pesticide is used, a small number of fields are left untreated. These untreated fields are known as *refugia*. This method has been shown to slow down evolution of resistance to the pesticide.

Which of the following statements explain why refugia could slow down the evolution of resistance to Bt pesticide?

- 1** When resistant insects breed with pesticide-sensitive insects that do not have the allele for resistance, the offspring produced will be sensitive to the pesticide.
 - 2** When fewer insects are exposed to pesticide, fewer mutations occur that produce alleles for resistance.
 - 3** The refugia help to maintain genetic variation in the population of insect pests.
- 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 A diploid plant cell divides by mitosis.

After mitosis of this cell, a mutation occurs that changes the genotype of **one** of the daughter cells. This mutant daughter cell produces a non-functional enzyme instead of the functional enzyme produced by the other daughter cell. This mutation has no effect on the phenotype of the plant or the number or length of chromosomes in the plant cell.

Which of the following statements describe the daughter cells after the mutation has occurred?

- 1** The chromosomes in the nucleus of each daughter cell will contain the same genes.
 - 2** Both daughter cells will contain the same alleles for every gene.
 - 3** The sequence of bases along each allele will be the same in each daughter 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

PART E Advanced Mathematics and Advanced Physics

NOTE: questions in this part that are not covered by the ESAT content specification are indicated by a cross through the question number.

- 73** Curve C has equation $y = 9 - x^2$

Line L has equation $y = 5$

What is the area enclosed between C and L ?

- A** $\frac{32}{3}$
- B** $\frac{62}{3}$
- C** $\frac{92}{3}$
- D** $\frac{122}{3}$
- E** $\frac{152}{3}$

- X** An aircraft moves from rest with uniform acceleration along a horizontal runway. After travelling 1600 m it reaches a speed of 80 ms^{-1} .

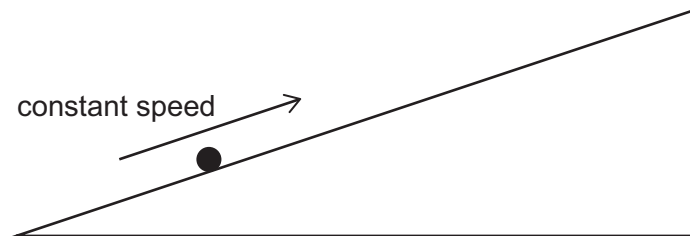
What is the acceleration of the aircraft?

- A** 0.025 ms^{-2}
- B** 0.050 ms^{-2}
- C** 0.10 ms^{-2}
- D** 0.50 ms^{-2}
- E** 2.0 ms^{-2}
- F** 4.0 ms^{-2}
- G** 10 ms^{-2}
- H** 20 ms^{-2}

75 How many solutions of the equation $2\sin^3 \theta = \sin \theta$ lie in the interval $-\frac{\pi}{2} \leq \theta \leq \pi$?

- A 2
- B 3
- C 4
- D 5
- E 6
- F 7

~~76~~ The diagram represents a mass that is moving in a straight line at constant speed up a slope of constant gradient.



Which statement about the forces acting on the mass **must** be correct?

- A All the forces acting on the mass are equal in magnitude.
- B Only three forces act on the mass.
- C The force of friction on the mass is equal to the driving force.
- D The weight of the mass acts in the opposite direction to the contact force.
- E There is no air resistance acting on the mass.
- F There is no resultant force acting on the mass.

- 77 The line $y = x + k$, where k is a constant, is a tangent to the curve $y = 3x^2 - 2x + 1$

What is the value of k ?

- A -2
- B -1
- C $\frac{1}{4}$
- D $\frac{1}{3}$
- E $\frac{1}{2}$
- F $\frac{3}{4}$
- G 1
- H 2

- ~~78~~ The diagram shows four objects W, X, Y and Z, of masses 3.0 kg, 4.0 kg, 6.0 kg and 2.0 kg respectively, connected by light, inextensible rods.

The objects are pulled along a smooth, horizontal surface by a constant force of 30 N in the direction indicated.



What is the tension in the rod connecting X and Y?

- A 8.0 N
- B 10 N
- C 12 N
- D 14 N
- E 16 N

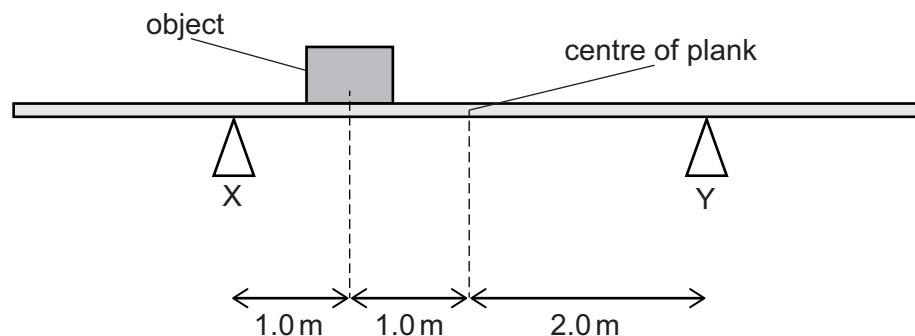
79 In a particular arithmetic progression:

- the 13th term is six times the 1st term
- the 11th term is 1 less than twice the 5th term

What is the 3rd term of the progression?

- A -14.5
 B -11
 C $\frac{29}{19}$
 D 3.5
 E 11
 F 14.5

 An object of mass 40 kg is placed on a uniform, horizontal plank of mass 10 kg between two supports X and Y as shown in the diagram.



What is the contact force at X?

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

- A 15 N
 B 35 N
 C 150 N
 D 250 N
 E 300 N
 F 350 N
 G 375 N

81 Evaluate

$$\log_2\left(\frac{5}{4}\right) + \log_2\left(\frac{6}{5}\right) + \log_2\left(\frac{7}{6}\right) + \cdots + \log_2\left(\frac{64}{63}\right)$$

- A -2
- B 3
- C 4
- D 6
- E $\log_2(3!)$
- F $\log_2 60$

 An object X of mass 2.0 kg is initially moving at a speed of 4.5 m s^{-1} on a smooth, horizontal surface.

A 5.0 N force is applied to X in the direction of its motion for 3.0 seconds.

A short time later it collides head on with, and sticks to, a stationary object Y of mass 3.0 kg.

What is the speed of X and Y as they move off together after the collision?

- A 1.8 m s^{-1}
- B 3.0 m s^{-1}
- C 3.6 m s^{-1}
- D 4.8 m s^{-1}
- E 5.4 m s^{-1}

- 83** Circle C has equation $(x + 3)^2 + (y - 2)^2 = 5$

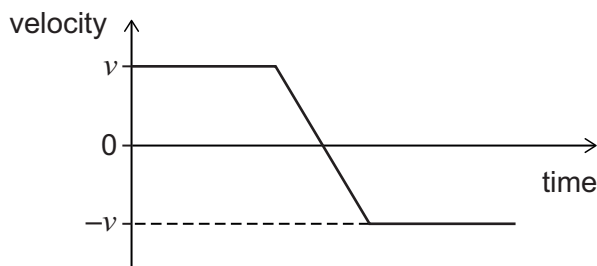
The length of the tangent from the circle C to the point P is $5\sqrt{3}$

What is the shortest distance from P to C ?

- A** $5\sqrt{3}$
- B** $5\sqrt{3} + \sqrt{5}$
- C** $3\sqrt{5}$
- D** 5
- E** 10

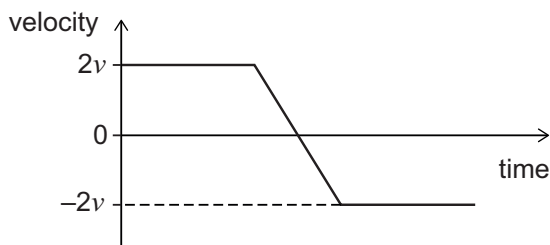
- ✖ Two solid spheres X and Y have masses m and $2m$ respectively. They travel in opposite directions towards each other along the same line with speeds v and $2v$ respectively and collide head on.

The graph shows the variation of velocity with time for sphere X before, during, and after the collision.

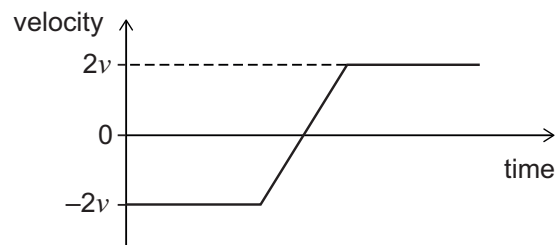


Which sketch shows the variation of velocity with time for sphere Y?

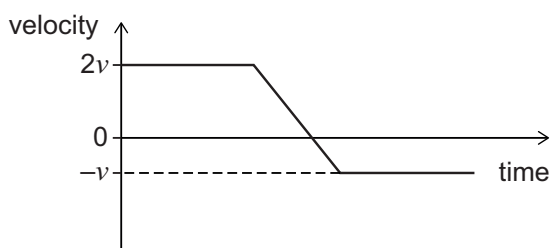
A



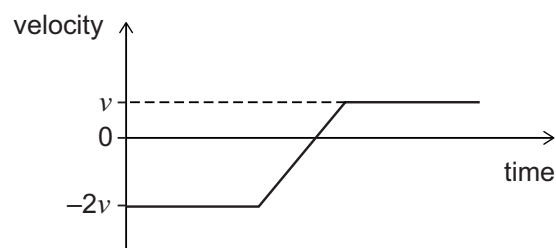
B



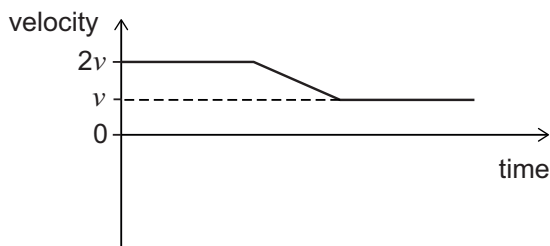
C



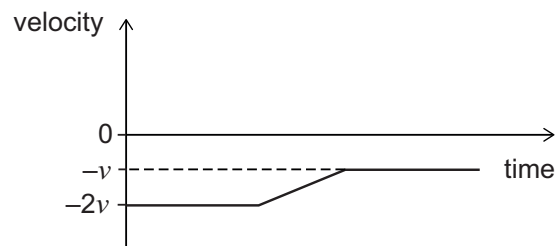
D



E



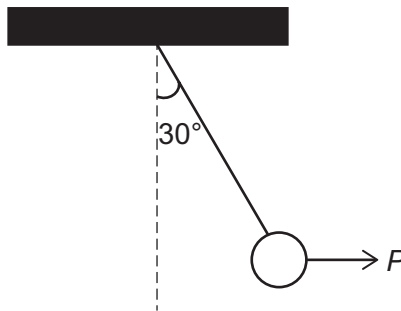
F



85 What is the coefficient of x^3 in the expansion of $(1 - 2x)^5(1 + 2x)^5$?

- A -6400
- B -640
- C -80
- D 0
- E 80
- F 800
- G 960

86 A metal ball suspended from a steel cable is held at rest by a horizontal force P . The cable makes an angle of 30° to the vertical as shown in the diagram. The cable exerts a force T on the ball.



What is the magnitude of P ?

- A $\frac{T}{2}$
- B T
- C $2T$
- D $\frac{T}{\sqrt{2}}$
- E $\frac{T}{\sqrt{3}}$
- F $\frac{2T}{\sqrt{3}}$
- G $\frac{\sqrt{3}T}{2}$

87 Given that

$$\int_0^2 x^m dx = \frac{16\sqrt{2}}{7}$$

and

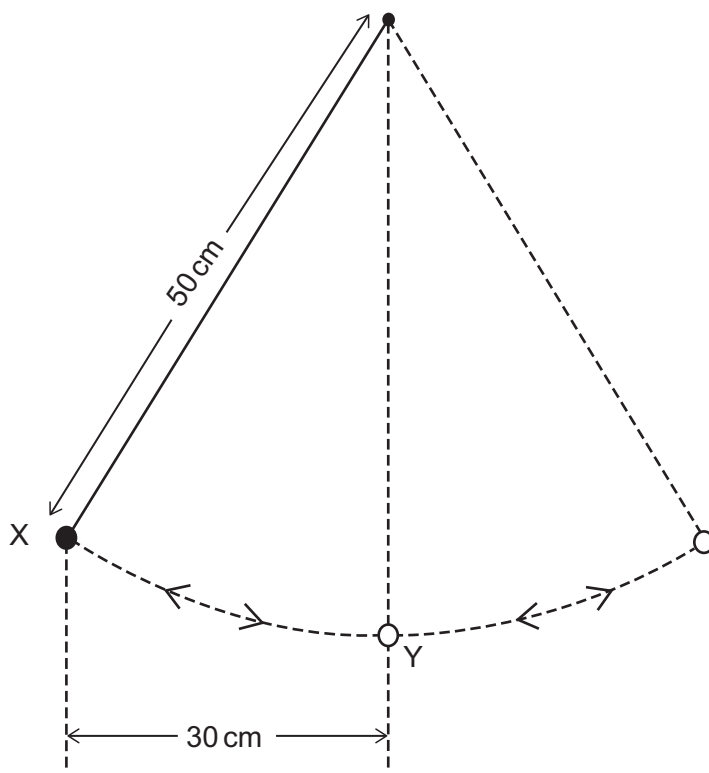
$$\int_0^2 x^{m+1} dx = \frac{32\sqrt{2}}{9}$$

what is the value of m ?

- A $-\frac{11}{2}$
- B $-\frac{9}{2}$
- C $-\frac{22}{29}$
- D $\frac{7}{22}$
- E $\frac{5}{2}$
- F $\frac{7}{2}$

- ~~86~~ A pendulum bob of mass 10 g is suspended by a light, inextensible string of length 50 cm.

The bob is released from rest at position X.



What is the speed of the bob as it passes through position Y?

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

- A $\sqrt{2} \text{ ms}^{-1}$
- B $\sqrt{4} \text{ ms}^{-1}$
- C $\sqrt{6} \text{ ms}^{-1}$
- D $\sqrt{8} \text{ ms}^{-1}$
- E $\sqrt{10} \text{ ms}^{-1}$

- 89** The dimensions of a solid cuboid, in cm, are x , $2x$ and y

The volume of the cuboid is 576 cm^3 .

At this volume, the surface area of the cuboid has its maximum value.

What is the area, in cm^2 , of the face that has the largest area?

A $2(288)^{\frac{2}{3}}$

B 72

C 96

D 432

E $4(144)^{\frac{2}{3}}$

- ~~**90**~~ An object is thrown vertically upwards from ground level with an initial velocity of 40 m s^{-1} .

2.0 seconds later another object is released from a height above the ground and falls vertically from rest.

Both of the objects hit the ground at the same time.

From what height above the ground was the second object released?

(gravitational field strength $g = 10\text{ N kg}^{-1}$; air resistance can be ignored)

A 80 m

B 180 m

C 320 m

D 500 m

E 900 m

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