UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES ADMISSIONS ASSESSMENT **D568/11**

November 2021 **60 minutes**

SECTION 1

0624614274

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 72 printed pages and 4 blank pages.

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Paper content

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PART A Mathematics

1 Simplify fully

$$5xy^2 \times (5x^2y)^{-3} \times 5x^2y$$

where x and y are positive.

A $\dfrac{1}{125x^7y^2}$

B $\dfrac{1}{125x^6y^2}$

C $\dfrac{1}{25x^6y}$

D $\dfrac{1}{25x^4y}$

E $\dfrac{1}{5x^3}$

F $\dfrac{1}{5x^2}$

G $\dfrac{y}{x^2}$

H $5xy^2$

2 Which of the following is a simplification of

$$2 - \frac{x + 3x^2}{12x^2 + x - 1}$$

where $x > 1$?

A $\frac{7x - 1}{4x - 1}$

B $\frac{7x - 2}{4x - 1}$

C $\frac{7x + 1}{4x + 1}$

D $\frac{7x + 2}{4x + 1}$

E $\frac{9x - 1}{4x - 1}$

F $\frac{9x - 2}{4x - 1}$

G $\frac{9x + 1}{4x + 1}$

H $\frac{9x + 2}{4x + 1}$

3 Which of the following is a rearrangement of

$$\frac{p}{2} + \frac{3}{q} = \frac{4}{r}$$

so that q is the subject?

A $q = \dfrac{2r}{24 - 3pr}$

B $q = \dfrac{3r}{2r - p}$

C $q = \dfrac{6r}{4 - p}$

D $q = \dfrac{6r}{8 - pr}$

E $q = \dfrac{r - 2}{12p}$

F $q = \dfrac{3r - 6}{4p}$

G $q = \dfrac{pr - 8}{12p}$

H $q = \dfrac{3pr - 24}{4p}$

4 A circle has its centre at $(0, 0)$.

What is the equation of the tangent that touches the circle at the point $(4, 3)$?

A $3y + 4x = 25$

B $3y - 4x = 25$

C $3y - 4x = -7$

D $3y - 4x = 7$

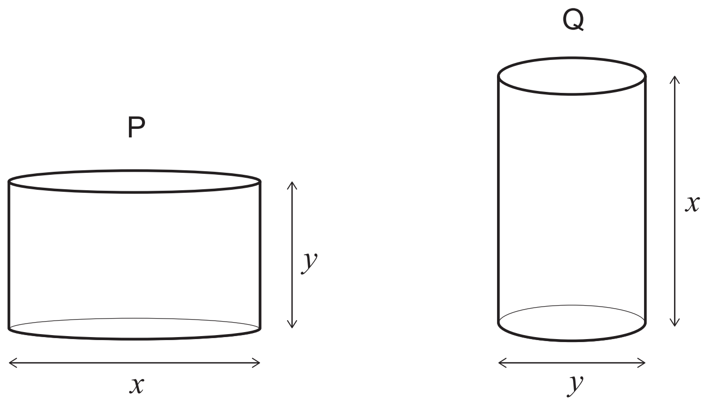
E $4y + 3x = 24$

F $4y - 3x = 24$

G $3y + 4x = 24$

H $3y - 4x = 24$

5 Two solid cylinders, P and Q, are shown, where $x > y$.



Cylinder P has diameter x and height y.

Cylinder Q has diameter y and height x.

What is the positive difference between the total surface areas of P and Q?

A 0

B $\frac{\pi}{4}(x^2 - y^2)$

C $\frac{\pi}{2}(x^2 - y^2)$

D $\pi(x^2 - y^2)$

E $2\pi(x^2 - y^2)$

F $\frac{\pi}{4}xy(x - y)$

G $\pi xy(x - y)$

6 Given that

$$8^x + 27^x = \frac{13}{36}$$

$$8^x - 27^x = \frac{5}{36}$$

what is the value of x?

A -4

B -3

C -2

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

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

F $-\frac{1}{2}$

G $-\frac{1}{3}$

H $-\frac{1}{4}$

7 The price of item P is reduced by 10%. The next day, the new price is increased by 10%.

The price of item Q is increased by 10%. The next day, the new price is reduced by 10%.

How does the final price of each item compare to the original price of that item?

	item P final price	*item Q final price*
A	lower than original	lower than original
B	lower than original	higher than original
C	higher than original	lower than original
D	higher than original	higher than original
E	the same as original	the same as original

8 Here is a pattern of numbers:

1						
2	3	4				
5	6	7	8	9		
10	11	12	13	14	15	16

The pattern of numbers is continued in the same way.

What number will appear directly below 196?

A 218

B 219

C 220

D 221

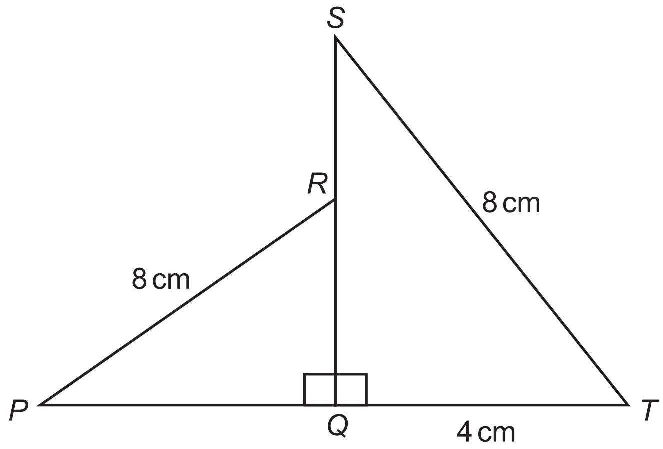
E 222

F 223

G 224

H 225

9



[diagram not to scale]

SQT is a right-angled triangle with the right angle at *Q*.

The point *R* is on *SQ* such that $SR : RQ = 1 : 3$

QRP is a right-angled triangle with the right angle at *Q*.

$PR = ST = 8$ cm

$QT = 4$ cm

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

A $2\sqrt{3}$

B $4\sqrt{3}$

C $\sqrt{19}$

D $\sqrt{37}$

E $\sqrt{55}$

F $\sqrt{61}$

10 Pat and Alex have a combined total of £63.

The ratio of Pat's money to Alex's money is 5 **:** 2

They each spend an equal amount on sweets.

The ratio of Pat's money to Alex's money is now 3 **:** 1

How much did Pat spend on sweets?

A £0.50

B £2.00

C £2.25

D £3.00

E £4.50

F £6.75

11 The curve with equation $y = x^2 - 4x + 5$ meets the straight line with equation $y = 2x + c$ at two points, which have x-coordinates p and q, where $q > p$.

Given that $q - p = 8$, what is the value of the constant c?

A –43

B –12

C –2

D 0

E 2

F 12

G 43

12 An online company sells storage containers.

The following items are available:

capacity of container	*number available*
2 litres	2
3 litres	3
7 litres	4
8 litres	1

A customer orders two containers at random from those available.

What is the probability that the two containers will have a combined capacity of exactly 10 litres?

A $\frac{7}{25}$

B $\frac{14}{25}$

C $\frac{7}{45}$

D $\frac{14}{45}$

E $\frac{7}{50}$

13 Given that

$$y = \frac{\sin 60° - 1}{\cos 60°}$$

what is the value of y^3?

A $-\frac{\sqrt{3}}{9}$

B $-5\sqrt{2}+10$

C $3\sqrt{3}-8$

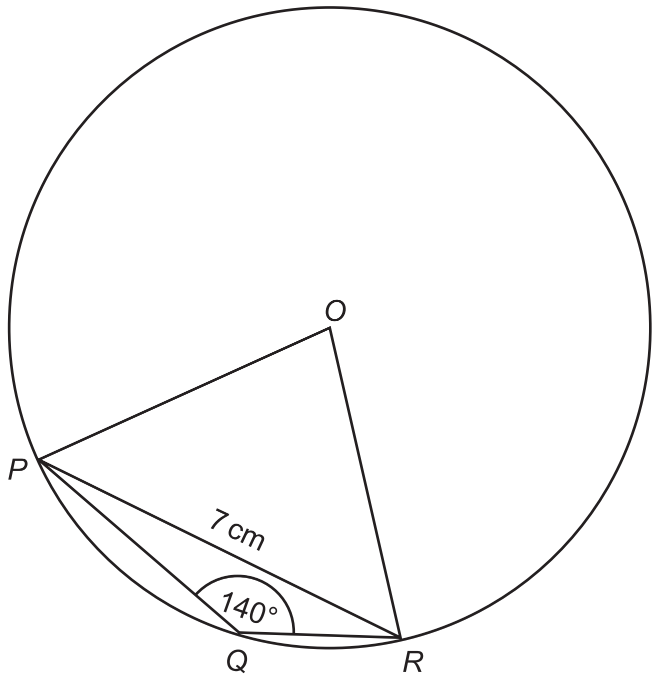
D $6\sqrt{3}-10$

E $14\sqrt{2}-20$

F $15\sqrt{3}-26$

G $21\sqrt{3}-38$

14 P, Q and R are points on the circumference of a circle with centre O as shown in the diagram.



[diagram not to scale]

Angle $PQR = 140°$

$PR = 7\,\text{cm}$

Which of the following expressions gives the radius of the circle, in cm?

A $7\sin 10°$

B $3.5\sin 55°$

C $3.5\sin 70°$

D $7\sin 55°$

E $\dfrac{3.5}{\sin 40°}$

F $\dfrac{7}{\sin 80°}$

G $\dfrac{3.5}{\sin 20°}$

H $\dfrac{7}{\sin 40°}$

15 Charlie has a bowl containing red sweets and green sweets only. The sweets are identical in all respects except colour.

There are nine sweets in total in the bowl.

Charlie eats two sweets from the bowl at random.

The probability of Charlie not eating any green sweets is $\frac{5}{12}$

What is the probability that Charlie eats two green sweets?

A $\frac{2}{27}$

B $\frac{1}{12}$

C $\frac{1}{9}$

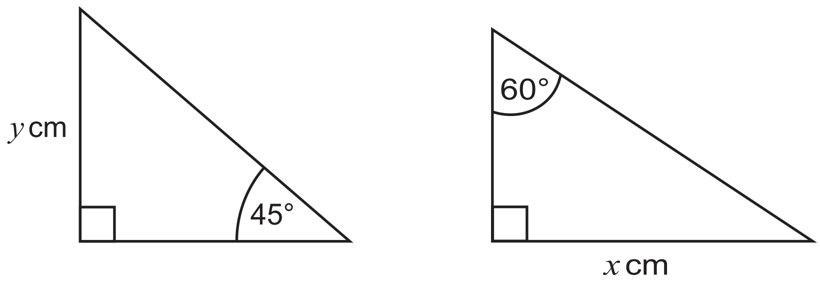
D $\frac{4}{27}$

E $\frac{1}{6}$

F $\frac{1}{4}$

G $\frac{7}{12}$

16 The following right-angled triangles have the same hypotenuse length.



[diagram not to scale]

Which of the following is a correct expression for y in terms of x?

A $y = \sqrt{2}\,x$

B $y = \dfrac{\sqrt{2}\,x}{2}$

C $y = \dfrac{\sqrt{2}\,x}{3}$

D $y = \dfrac{\sqrt{2}\,x}{6}$

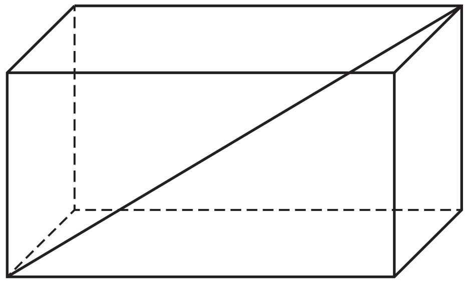
E $y = \sqrt{6}\,x$

F $y = \dfrac{\sqrt{6}\,x}{2}$

G $y = \dfrac{\sqrt{6}\,x}{3}$

H $y = \dfrac{\sqrt{6}\,x}{6}$

17 The greatest diagonal distance between the two vertices of a cuboid, as shown in the diagram, is $\sqrt{77}$ cm.



A similar cuboid has all its lengths exactly half the lengths of the original cuboid.

The sides of this smaller cuboid are 2 cm, 3 cm and x cm.

What is the value of x, in cm?

A $\frac{5}{2}$

B 5

C $\frac{5\sqrt{2}}{2}$

D $5\sqrt{2}$

E $\frac{\sqrt{102}}{2}$

F $\sqrt{102}$

18 Alex, Cameron and Sam are all taking part in a 400 m race.

They are each running at a different constant speed.

Alex is running 12% faster than Cameron, whilst Sam is running 2% slower than Cameron.

When Alex crosses the finish line, how many metres is Sam from the finish line?

A 9.6

B 14

C 24

D 25

E 28

F 50

G 56

19 A car journey is m miles long.

One kilometre is equivalent to x miles.

The car uses one litre of fuel to travel a distance of f kilometres.

Fuel for the car costs p pence per litre.

Which of the following expressions gives the cost of fuel for this journey, in pounds?

(There are 100 pence in one pound.)

A $100fmpx$

B $\frac{100fmp}{x}$

C $\frac{100mpx}{f}$

D $\frac{100mp}{fx}$

E $\frac{fmpx}{100}$

F $\frac{fmp}{100x}$

G $\frac{mpx}{100f}$

H $\frac{mp}{100fx}$

20 How many solutions are there to the equation

$$\tan x = 100x$$

where $-360 \leq x \leq 360$?

A 0

B 1

C 2

D 3

E 4

F 5

G infinitely many

PART B Physics

21 A resistor has a constant voltage of 9.00 V across it.

A total charge of 180 C passes through the resistor in 4.00 minutes.

What is the power dissipated in the resistor?

A 0.750 W

B 6.75 W

C 12.0 W

D 81.0 W

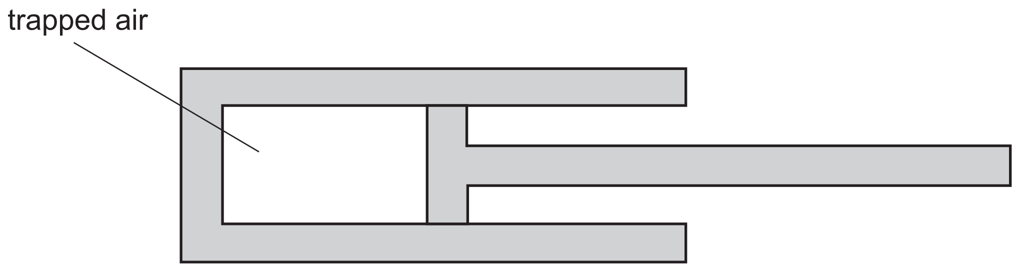
E 108 W

F 405 W

G 1620 W

H 6480 W

22 Air is trapped in a cylinder by a piston. The density of the air in the cylinder is ρ.



The piston is moved so that the pressure of the trapped air increases by 20%. The temperature of the trapped air does not change.

What is the new density of the trapped air?

(Assume that air is an ideal gas.)

A 0.69ρ

B 0.80ρ

C 0.83ρ

D 1.00ρ

E 1.20ρ

F 1.44ρ

23 A **non-ideal** transformer has 100 turns on the primary coil and 25 turns on the secondary coil.

It is provided with 3.0 kW of electrical power at a current of 12.5 A.

The voltage output is the same as for an ideal transformer, but the current in the output coil is 40 A.

What is the efficiency of the transformer?

A 20%

B 25%

C 31%

D 69%

E 75%

F 80%

G 91%

H 100%

24 A car of mass 1400 kg is towing a caravan of mass 1000 kg along a straight horizontal section of road at a constant speed.

The driving force from the engine is increased by 3000 N, causing the car and caravan to accelerate.

At one moment during this acceleration, the resistive force on the car has increased by 200 N and the resistive force on the caravan has increased by 400 N.

What is the acceleration of the car and caravan at this moment?

A $1.00\,\mathrm{m\,s^{-2}}$

B $1.25\,\mathrm{m\,s^{-2}}$

C $1.50\,\mathrm{m\,s^{-2}}$

D $2.00\,\mathrm{m\,s^{-2}}$

E $2.60\,\mathrm{m\,s^{-2}}$

25 A star is moving away from a space telescope positioned above the Earth. The star emits light of frequency f and wavelength λ at the speed of light c.

This light travels towards the space telescope through the vacuum of space until it is detected on the space telescope.

The frequency, the wavelength and the speed of the light measured at the telescope are f_T, λ_T and c_T respectively.

How do f_T, λ_T and c_T compare with f, λ and c?

	f_T	λ_T	c_T
A	equal to f	equal to λ	equal to c
B	equal to f	equal to λ	less than c
C	equal to f	greater than λ	equal to c
D	equal to f	greater than λ	less than c
E	less than f	equal to λ	equal to c
F	less than f	equal to λ	less than c
G	less than f	greater than λ	equal to c
H	less than f	greater than λ	less than c

26 Q is an element with several isotopes.

The nuclide ${}^{(3x-7)}_{x}\mathrm{Q}$ contains 6 neutrons more than the nuclide ${}^{(2x+3)}_{x}\mathrm{Q}$.

Another isotope of Q is the nuclide ${}^{(3x+1)}_{x}\mathrm{Q}$.

How many neutrons does the nuclide ${}^{(3x+1)}_{x}\mathrm{Q}$ contain?

A 9

B 16

C 19

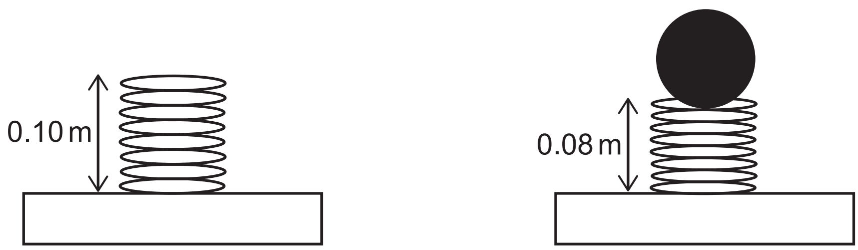
D 21

E 25

F 33

G 49

27 A light spring has an uncompressed length of 0.10 m. When an object of mass 0.5 kg rests in equilibrium on top of the spring, the length of the spring reduces to 0.08 m as shown.



What is the energy stored in the spring due to the compression?

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

A 0.005 J

B 0.02 J

C 0.05 J

D 0.1 J

E 0.2 J

F 0.4 J

28 A set of decorative lights consists of 20 lamps connected in series to a dc supply of constant voltage.

The total power transferred by all the lamps is P.

The set is designed so that if one of the lamps fails, that lamp becomes short-circuited and it then has zero resistance. The remaining lamps are still lit.

If this happens, with the set connected to the same supply, what is the new total power transferred by the remaining 19 lamps?

(Assume that the resistance of each functioning lamp remains constant.)

A $\left(\frac{19}{20}\right)^2 P$

B $\left(\frac{19}{20}\right) P$

C P

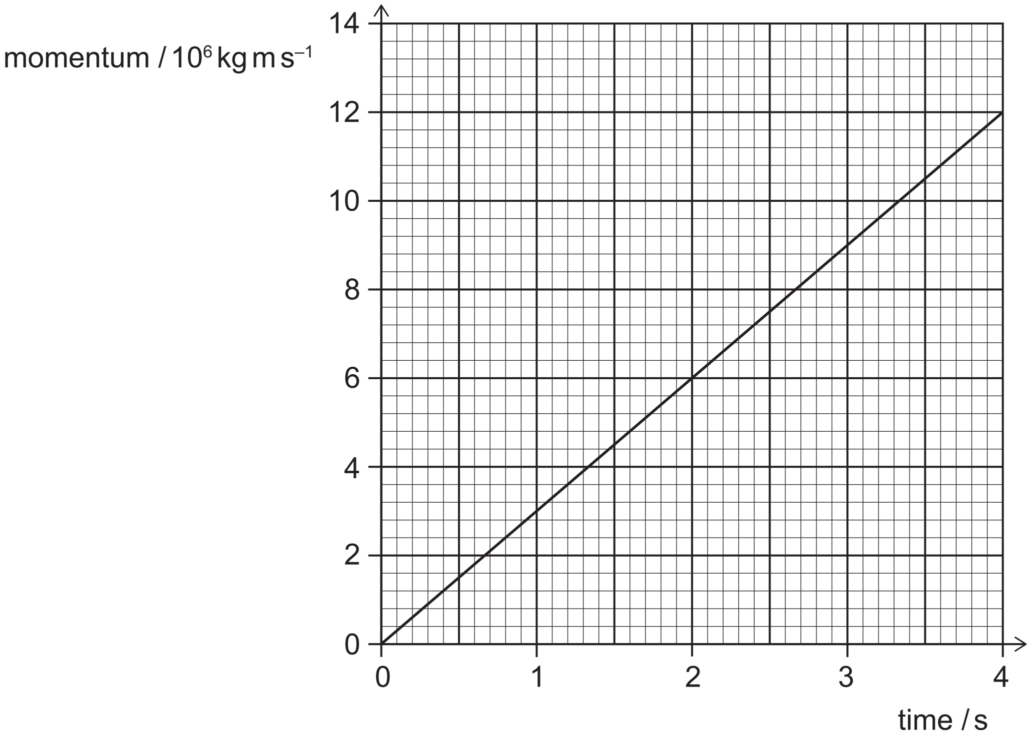
D $\left(\frac{20}{19}\right) P$

E $\left(\frac{20}{19}\right)^2 P$

29 A train accelerates from rest along a straight, horizontal section of track.

The force exerted on the train due to its motors is constant and there is a constant friction force of 1.8×10^7 N.

The graph shows how the momentum of the train changes with time.



What is the force exerted on the train due to its motors?

A 3.0×10^6 N

B 6.0×10^6 N

C 1.2×10^7 N

D 1.5×10^7 N

E 2.1×10^7 N

F 2.4×10^7 N

G 3.0×10^7 N

H 4.2×10^7 N

30 A ship travels into a wave that is travelling in the opposite direction to the ship.

The ship has a horizontal speed of $8.0\,\mathrm{m\,s^{-1}}$. The speed of the wave is $3.0\,\mathrm{m\,s^{-1}}$.

The front of the ship rises and falls with a time period of 8.0 s.

What is the wavelength of the wave?

A $\frac{3}{8}$ m

B $\frac{5}{8}$ m

C 1.0 m

D $\frac{11}{8}$ m

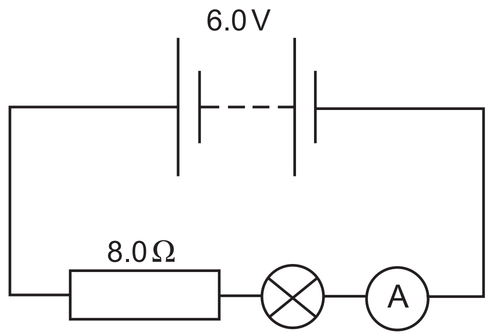
E 24 m

F 40 m

G 64 m

H 88 m

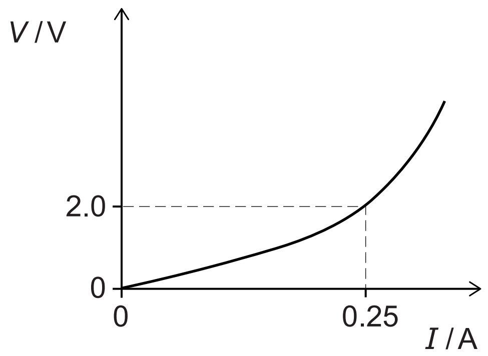
31 A 6.0 V battery is connected to an 8.0 Ω resistor and a filament lamp as shown in the circuit diagram.



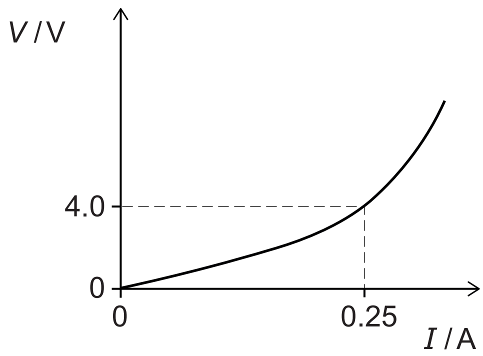
The reading on the ammeter is 0.25 A.

Which graph is a possible *V*–*I* graph for the filament lamp?

A



B



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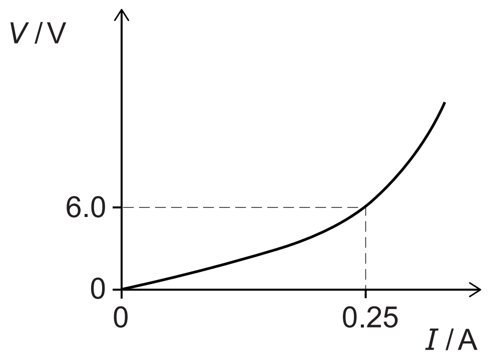

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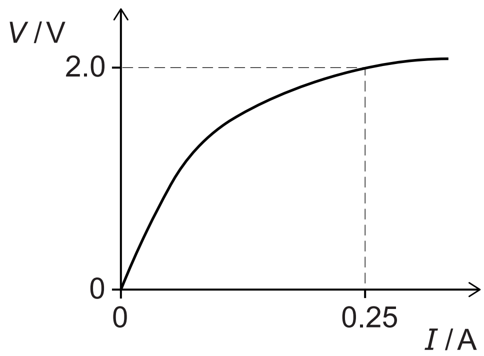
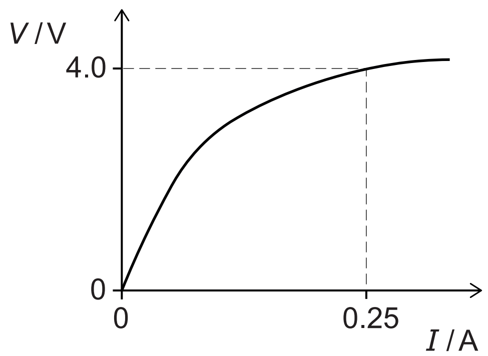
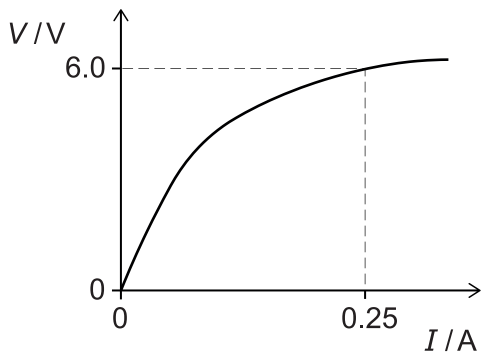


E



F



32 A uniform, horizontal magnetic field has magnetic field strength 0.60 T and a direction from west to east.

A horizontal wire is placed in a north–south direction, so that it is at 90° to the magnetic field.

The wire carries a constant current.

The wire has length 0.40 m and mass 0.018 kg.

The resultant force acting vertically on the wire is zero.

What are the magnitude and direction of the current in the wire?

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

	magnitude of current / A	*direction of current*
A	0.012	from north to south
B	0.012	from south to north
C	0.075	from north to south
D	0.075	from south to north
E	0.12	from north to south
F	0.12	from south to north
G	0.75	from north to south
H	0.75	from south to north

33 The wavelength range of visible light is 400-700 nm.

Light with a frequency of 6.0×10^{14} Hz is green.

Microwaves used in cooking have a wavelength of 12 cm.

Which of the following statements is/are correct?

1 Light with a frequency of 7.5×10^{14} Hz is red.

2 Microwaves used in cooking have a frequency of 2.5×10^{9} Hz.

3 Electromagnetic radiation with a frequency of 2.5×10^{15} Hz can be used in thermal imaging of a building.

(speed of light = $3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$)

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

34 There is a high-speed straight railway line between two cities that are 60 km apart. The train stops at both cities.

The train accelerates at a uniform rate of $1.5\,\mathrm{m\,s^{-2}}$ to a maximum speed of $120\,\mathrm{m\,s^{-1}}$.

When braking, it decelerates at a uniform rate of $2.0\,\mathrm{m\,s^{-2}}$.

What is the minimum time taken by the train to travel from one city to the other?

A 140 s

B 355 s

C 430 s

D 500 s

E 570 s

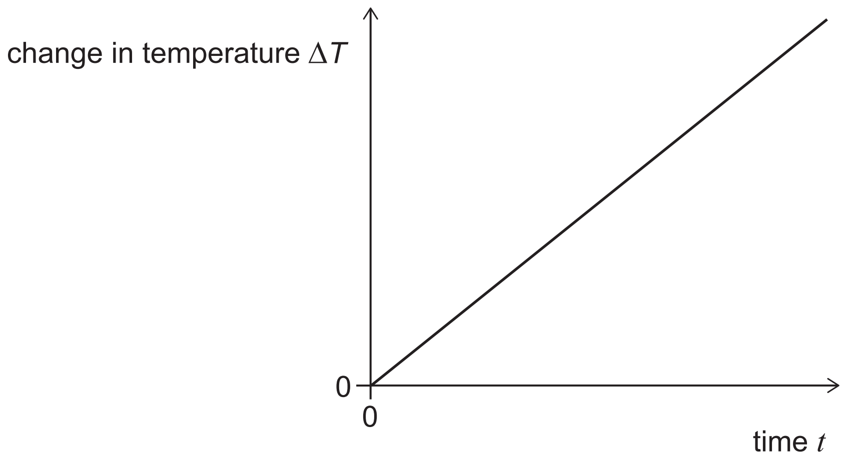
F 860 s

G 1000 s

35 A metal block has mass M.

Heat is transferred to the block at a constant rate P.

The graph shows how the change in temperature ΔT of the block from its initial temperature varies with time t.



The gradient of the line is k.

Which expression gives the specific heat capacity of the metal from which the block is made?

(Assume that no heat is transferred out of the block during the time interval shown by the graph.)

A $\frac{1}{MPk}$

B $\frac{M}{Pk}$

C $\frac{Mk}{P}$

D $\frac{P}{Mk}$

E $\frac{PM}{k}$

F $\frac{Pk}{M}$

G $\frac{k}{MP}$

H MPk

36 A skydiver of mass 80 kg is accelerating vertically downwards through the air. At one instant in time the skydiver has a speed of $5.0\,\mathrm{m\,s^{-1}}$. After travelling a further distance of 20 m downwards the skydiver's speed has increased to $10\,\mathrm{m\,s^{-1}}$.

What is the average force of air resistance acting on the skydiver over the 20 m?

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

A 600 N

B 650 N

C 750 N

D 790 N

E 950 N

37 A radioactive nuclide X decays in a single stage to a stable nuclide R.

A radioactive nuclide Y decays in a single stage to a stable nuclide S.

When a rock formed it contained equal numbers of atoms of all four nuclides X, Y, R and S.

The half-life of X is T years and the half-life of Y is $2T$ years.

What is the value of $\dfrac{\text{number of atoms of R}}{\text{number of atoms of S}}$ at a time $4T$ years after the rock has formed?

(Assume that no other processes add or remove X, Y, R or S from the rock during this time.)

A $\dfrac{1}{4}$

B $\dfrac{17}{20}$

C $\dfrac{31}{28}$

D $\dfrac{6}{5}$

E $\dfrac{5}{4}$

F 2

38 A beaker containing 180 g of water at 25 °C has a 20 g ice cube at 0 °C added to it.

No heat is transferred between the water and the surroundings (including the beaker).

What is the final temperature of all the water in the beaker after all the ice has melted?

(Take the specific heat capacity of water to be 4 $J\,g^{-1}\,°C^{-1}$ and the specific latent heat of fusion of water to be 300 $J\,g^{-1}$.)

A 2.5 °C

B 8.3 °C

C 10.0 °C

D 15.0 °C

E 16.7 °C

F 22.5 °C

39 Liquid X has density 0.80 $g\,cm^{-3}$ and liquid Y has density 1.0 $g\,cm^{-3}$.

80 cm^3 of liquid X and 100 cm^3 of liquid Y are poured into a cylindrical container and allowed to settle. The two liquids do not mix or react.

The internal cross-sectional area of the container is 20 cm^2. The base of the container rests on a horizontal surface.

What is the pressure due to the liquids at a height of 4.0 cm above the interior of the base of the container?

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

A 10 Pa

B 40 Pa

C 42 Pa

D 50 Pa

E 100 Pa

F 400 Pa

G 420 Pa

H 500 Pa

40 A pulse of ultrasound travels from one end of a solid uniform rod of length L, starting at time $t = 0$.

The pulse is partially reflected by a crack in the rod and partially by the far end of the rod.

These two reflected pulses travel back along the rod, arriving at the end from which they started at times t_1 and t_2, where $t_2 > t_1$.

What is the distance between the crack and the **far end** of the rod?

A $\frac{t_1}{t_2}L$

B $\frac{t_2}{t_1}L$

C $\frac{t_1}{2t_2}L$

D $\frac{t_2}{2t_1}L$

E $\frac{(t_2 - t_1)}{t_2}L$

F $\frac{(t_2 - t_1)}{2t_2}L$

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PART C Chemistry

41 The following equations represent the reactions of four metals M, Q, R and T:

$$M(s) + HCl(aq) \rightarrow \text{no reaction}$$

$$R(s) + TSO_4(aq) \rightarrow RSO_4(aq) + T(s)$$

$$M(s) + QNO_3(aq) \rightarrow MNO_3(aq) + Q(s)$$

$$T(s) + 2HCl(aq) \rightarrow TCl_2(aq) + H_2(g)$$

Which option lists the order of reactivity of the four metals, from the most to the least reactive?

A M, Q, R, T

B M, R, T, Q

C Q, M, T, R

D Q, R, T, M

E R, M, T, Q

F R, T, M, Q

G T, M, R, Q

H T, R, Q, M

42 Consider the following three ions of calcium observed in mass spectrometry:

$^{40}Ca^{2+}$ $^{42}Ca^{2+}$ $^{43}Ca^{+}$

Which of the following statements is/are correct?

1 All three ions have the electron configuration 2,8,8

2 $^{42}Ca^{2+}$ has more neutrons than $^{40}Ca^{2+}$

3 $^{42}Ca^{2+}$ has more protons than $^{43}Ca^{+}$

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 The relative isotopic abundances of a sample of magnesium are shown in the table.

isotope	*percentage abundance*
^{24}Mg	80
^{25}Mg	10
^{26}Mg	10

What is the relative atomic mass (A_r) of the magnesium?

A 24.0

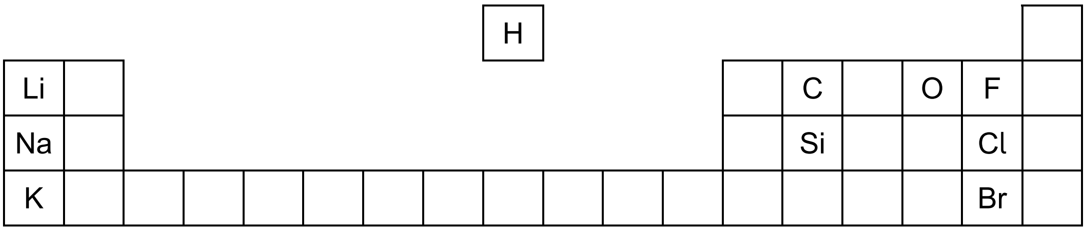
B 24.3

C 24.5

D 24.8

E 25.0

44 A portion of the Periodic Table is given:



Which one of these trends is correct?

A Boiling point: K > Na > Li

B Electrical conductivity: NaCl(l) > NaCl(s) > Na(s)

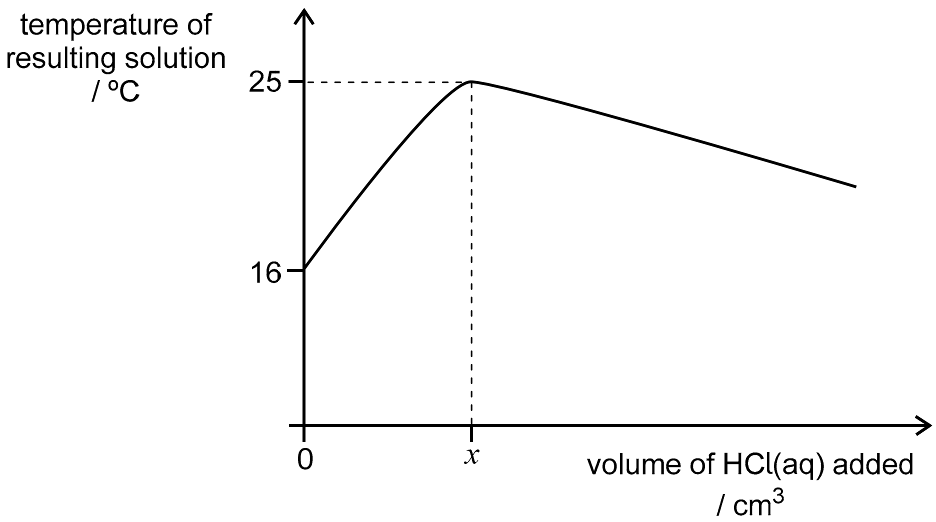
C Reactivity: Br_2 > Cl_2 > F_2

D Melting point: SiO_2 > H_2O > Na_2O

E Number of double bonds per molecule: CO_2 > O_2 > H_2O

45 1.0 mol dm^{-3} hydrochloric acid was slowly added from a burette into an insulated flask containing 50 cm^3 of aqueous sodium hydroxide. The flask was gently swirled and the temperature of the resulting solution measured continuously.

The two solutions had the same initial temperature and a graph was drawn of the temperature of the resulting solution against the volume of hydrochloric acid added.



Which of the following statements explains the shape of the graph?

A The reaction has reached a state of equilibrium.

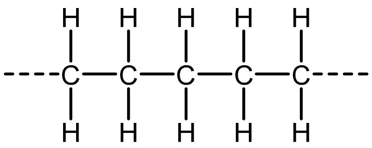
B An endothermic reaction occurs after x cm^3 of hydrochloric acid is added.

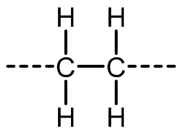
C The reaction rate decreases as the acid is used up.

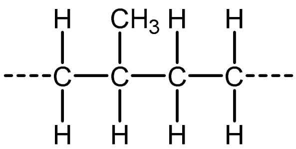
D The sodium hydroxide has been neutralised by x cm^3 hydrochloric acid.

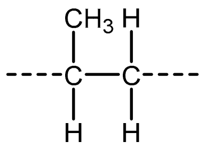
E The sodium hydroxide becomes a weaker base as the volume of the resulting solution increases.

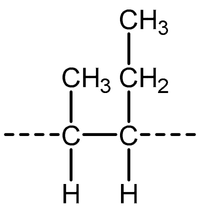
46 Which one of the following represents the repeating unit of poly(pent-2-ene)?

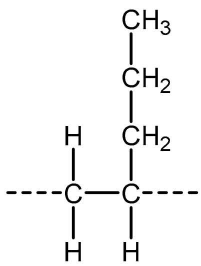
A 

B 

C 

D 

E 

F 

47 X is a gaseous element. X can react explosively with hydrogen to produce a single product. When dissolved in water, this product forms an acidic aqueous solution Y. When aqueous silver nitrate is added to solution Y, a white precipitate forms.

Solution Y reacts with substance Z to form two products only. One of these products forms a white precipitate when aqueous sodium hydroxide is added to it.

Which of the following could be X and Z?

	X	*Z*
A	Br_2	$CaCO_3$
B	Br_2	CuO
C	Br_2	Mg
D	Cl_2	$CaCO_3$
E	Cl_2	CuO
F	Cl_2	Mg
G	O_2	$CaCO_3$
H	O_2	Mg

48 Some students were trying to assign oxidation numbers to each of the four sulfur atoms in the tetrathionate ion, $S_4O_6^{2-}$.

Which of the following lists gives the possible oxidation states of the four sulfur atoms present?

A 0, 0, +6, +6

B +3, +3, +3, +3

C 0, +2, +6, +6

D 0, 0, +5, +5

E –2, –2, +7, +7

49 The table shows the reagents in three organic reactions.

Which of the rows correctly show(s) the product(s) obtained from the specified reactants?

	reactants	*product(s)*
1	$CH_3CH{=}CH_2$ and HBr	1,2-dibromopropane (only)
2	C_2H_5COOH and CH_3OH, in the presence of an H^+(aq) catalyst	methyl propanoate and water
3	C_2H_5OH and Na	sodium ethanoate and hydrogen

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 Chlorine gas reacts with hot concentrated aqueous sodium hydroxide to form sodium chloride, sodium chlorate(V) and water.

The **unbalanced** ionic equation for this reaction is:

$$u\mathrm{Cl_2} + v\mathrm{OH^-} \rightarrow w\mathrm{Cl^-} + x\mathrm{ClO_3^-} + y\mathrm{H_2O}$$

What is the simplest ratio of $w:x$ in the balanced equation?

A 1 : 1

B 1 : 2

C 2 : 1

D 1 : 5

E 5 : 1

F 1 : 7

G 7 : 1

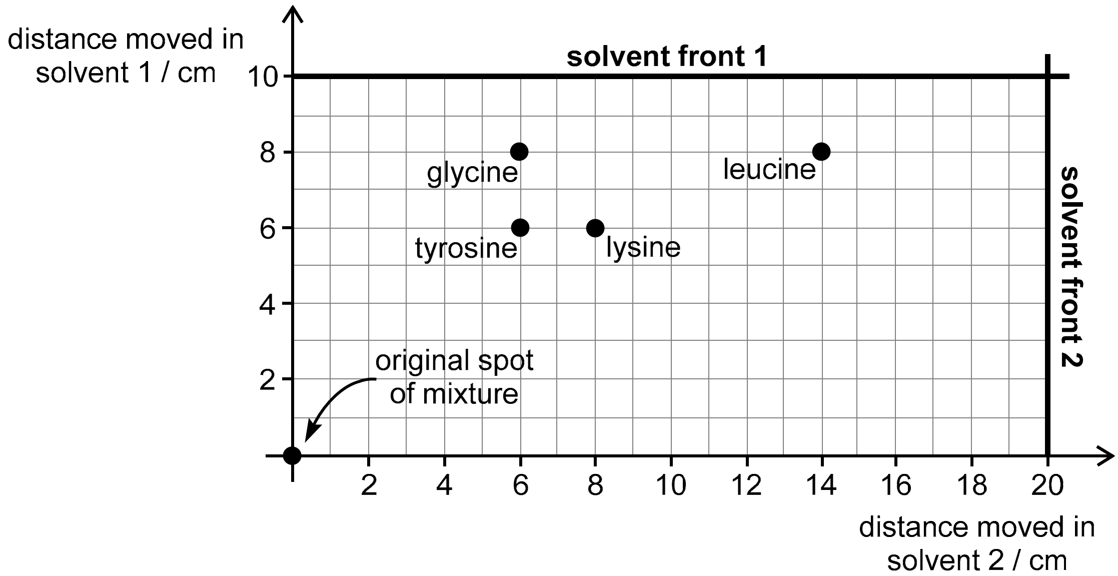
51 An experiment was carried out to separate the four amino acids present in a mixture of amino acids.

A spot of this mixture was placed on chromatography paper. The bottom of the paper was placed in solvent 1 and left until the solvent nearly reached the top of the paper.

The paper was then thoroughly dried and turned by 90°. The procedure was then repeated with solvent 2.

The amino acids were then identified with reference to known R_f values in the respective solvents.

The final positions of the amino acids on the chromatograph are shown on the following diagram.



Which of the following statements is correct?

A Leucine travels further relative to the solvent front in solvent 2 than in solvent 1.

B Lysine has a greater R_f value in solvent 1 than it has in solvent 2.

C Solvent 1 alone could be used to separate all four amino acids.

D Solvent 2 alone could be used to separate all four amino acids.

E The R_f value of tyrosine in solvent 1 is 0.6 and in solvent 2 is 0.7.

52 A reaction between copper and nitric acid produces a blue solution of copper(II) nitrate, water and substance X only.

Substance X does not contain copper or hydrogen.

The balanced equation for the reaction shows that 1 mole of copper reacts to produce 2 moles of water.

What is the identity of substance X?

A N_2

B NO

C NO_2

D NO_3

E N_2O_5

53 Ethanedioic acid, $(COOH)_2$, is a weak diprotic acid.

What is the minimum volume of a 2.50 mol dm^{-3} solution of ethanedioic acid required to neutralise 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide solution?

A 10.0 cm^3

B 12.5 cm^3

C 20.0 cm^3

D 25.0 cm^3

E 100 cm^3

54 Propene burns in air. For each mole of propene burned, 2000 kJ of heat is released.

2.10 g of propene is burned to heat a 1000 g sample of olive oil.

The olive oil has an initial temperature of 23.0 °C. It takes 2.00 J to heat one gram of olive oil by 1.0 °C.

Assume that all heat is transferred to the olive oil and none is lost to the surroundings.

What is the maximum temperature reached by the oil?

(M_r value: C_3H_6 = 42.0)

A 20.0 °C

B 43.0 °C

C 48.0 °C

D 50.0 °C

E 73.0 °C

F 100 °C

G 200 °C

H 223 °C

55 What is the calculated energy change for the following reaction using appropriate values from the data provided?

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

bond	*bond energy* / kJ mol^{-1}
H–H	440
O–H	460
C–H	430
C–O	360
C=O	800
C≡O	1070

A +200 kJ mol^{-1}

B −200 kJ mol^{-1}

C +720 kJ mol^{-1}

D −720 kJ mol^{-1}

E +1080 kJ mol^{-1}

F −1080 kJ mol^{-1}

56 The balanced equation for an oxidation of ammonia is:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

50.0 dm^3 of ammonia and 50.0 dm^3 of oxygen, both at 850 °C and 1 atmosphere pressure, are mixed and allowed to react to form the products shown in the equation. No other reactions occur.

What is the maximum total volume of gases (at 850 °C and 1 atmosphere pressure) after the reaction?

(Assume that all gases have the same volume at the given temperature and pressure.)

A 100 dm^3

B 110 dm^3

C 111 dm^3

D 125 dm^3

E 200 dm^3

57 The electrolysis of molten potassium chloride in an inert atmosphere produces potassium at the negative electrode and chlorine at the positive electrode.

The electrolysis of aqueous copper(II) sulfate solution deposits copper on the negative electrode.

The masses of potassium, chlorine and copper produced or deposited in these experiments were recorded.

Assume that the same number of electrons is transferred during the electrolysis of molten potassium chloride and aqueous copper(II) sulfate solution.

Which of the following gives the elements arranged in order of the mass produced/deposited during these electrolysis experiments, from lowest mass to highest mass?

(A_r values: Cl = 35.5; K = 39.0; Cu = 63.5)

A chlorine, copper, potassium

B chlorine, potassium, copper

C copper, chlorine, potassium

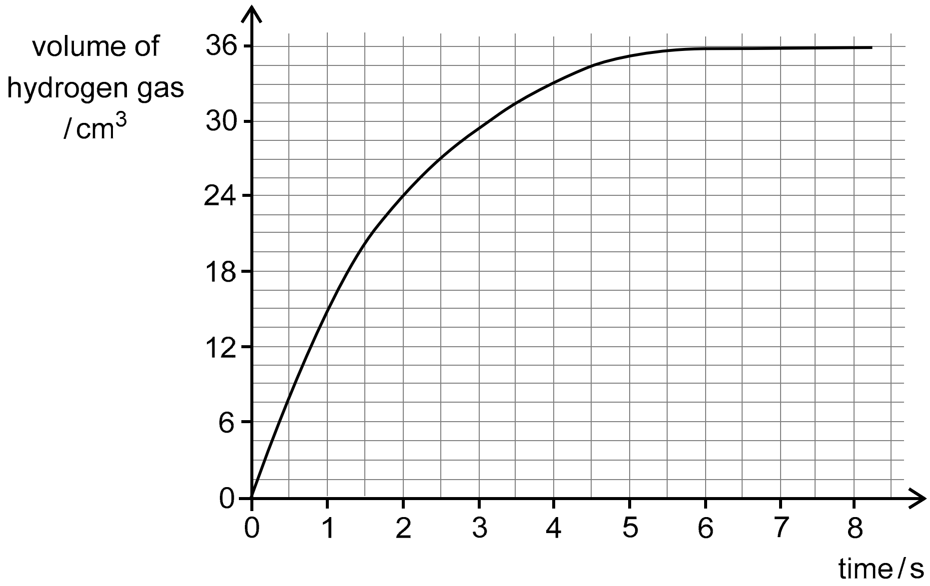
D copper, potassium, chlorine

E potassium, chlorine, copper

F potassium, copper, chlorine

58 0.500 g of magnesium (an excess) was added to dilute hydrochloric acid.

The following graph shows the total volume of the gas released over time as the reaction progresses. All volumes were measured in cm^3 at room temperature and pressure.



What is the mass of magnesium remaining after two seconds?

(A_r value: Mg = 24. Assume that the volume of one mole of gas at room temperature and pressure is 24.0 dm^3.)

A 0.024 g

B 0.036 g

C 0.048 g

D 0.452 g

E 0.464 g

F 0.476 g

59 A mixture of both sodium nitrate and barium bromide solids, with a combined mass of 6.36 g, was stirred into water and completely dissolved.

An excess of aqueous silver nitrate was added and a precipitate formed. The precipitate was filtered and dried. The mass of dry precipitate was 3.76 g.

What was the mass of sodium nitrate in the original mixture?

(M_r values: $NaNO_3$ = 85; $BaBr_2$ = 297; AgBr = 188)

A 0.42 g

B 0.85 g

C 1.70 g

D 2.97 g

E 3.39 g

F 5.94 g

60 A spoonful of magnesium carbonate powder was added to excess hydrochloric acid in an open conical flask on an electronic balance.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

The mass of the flask and its contents was measured initially and at 1-minute intervals. The total mass of gas produced was then calculated.

The reaction stopped at 5 minutes.

Which row in the following table could represent the total mass of gas calculated after each measurement?

	1 minute	*2 minutes*	*3 minutes*	*4 minutes*	*5 minutes*
A	5 g	9 g	12 g	14 g	15 g
B	1 g	3 g	6 g	10 g	15 g
C	3 g	6 g	9 g	12 g	15 g
D	11 g	12 g	13 g	14 g	15 g
E	6 g	10 g	13 g	15 g	15 g

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PART D Biology

61 A selection pressure is a biological or physical factor in an environment that may result in evolution.

Which of the following situations result in selection pressures on one or more organisms?

1 clearing rainforests to grow palm oil plantations

2 introduction of a predator to islands with seabird colonies

3 long-term use of antibiotics in hospital wards

4 using an insecticide to kill the mosquitoes that spread malaria

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 1, 2 and 3 only

E 2, 3 and 4 only

F 1, 2, 3 and 4

62 A particular cell has the following features:

- a cell wall
- a cell membrane
- no mitochondria

Which of the following statements about this cell is correct?

A It may be an animal cell.

B It may have no nucleus.

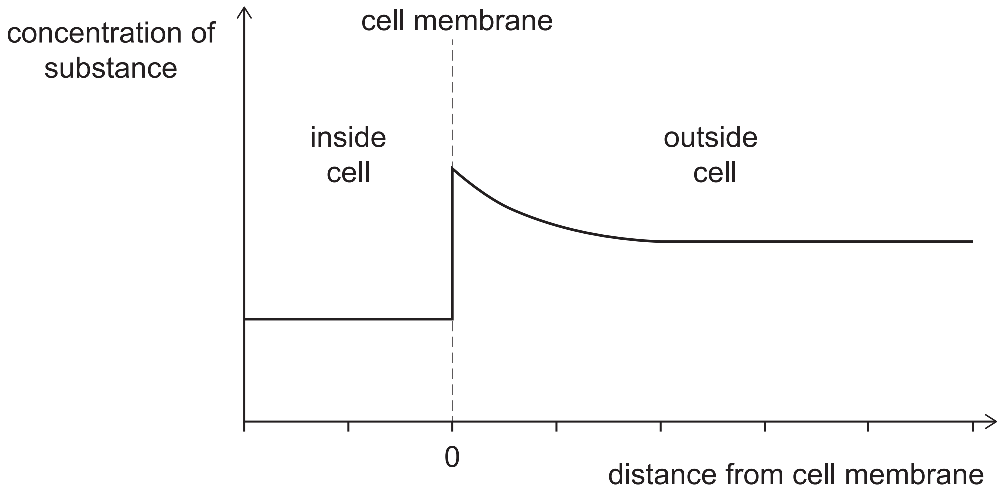
C It may contain chloroplasts.

D It contains X and Y chromosomes.

E It is not able to respire.

63 A cell is studied. The graph shows the concentration of a substance at different distances from the cell membrane.

The concentrations shown are maintained over time.



Which of the following processes is/are responsible for maintaining the difference in the concentration of the substance across the membrane?

1 active transport

2 diffusion

3 osmosis

A none of them

B 1 only

C 2 only

D 3 only

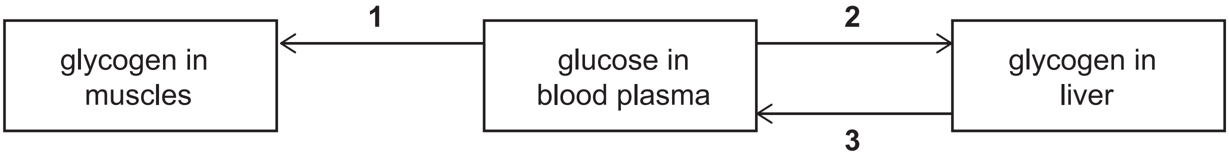
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3 only

64 The diagram shows some of the ways in which glucose can be added to or removed from blood plasma in humans.

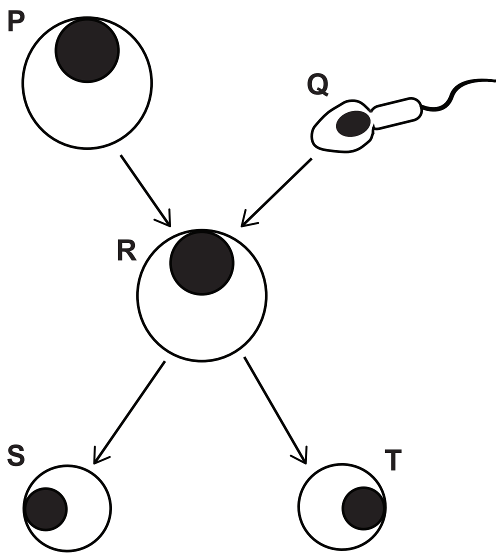


Which hormones stimulate the processes shown by the arrows?

	process 1	*process 2*	*process 3*
A	adrenaline	glucagon	insulin
B	adrenaline	adrenaline glucagon	glucagon
C	insulin	adrenaline	glucagon
D	insulin	insulin	adrenaline glucagon
E	glucagon	insulin	glucagon
F	glucagon	glucagon	insulin

65 The diagram shows two gametes, gamete P and gamete Q, fusing to form cell R in a healthy human. R divides to form two cells, S and T.

S and T grow into two separate individuals.



Which of the following statements is/are correct?

1 The number of double strands of DNA is the same in gamete P and cell T.

2 If gamete Q contains a Y chromosome, then both individuals that grow from cells S and T will be genetically male.

3 A mutation in the DNA in cell R before mitosis will always change the phenotype of cell S.

A none of them

B 1 only

C 2 only

D 3 only

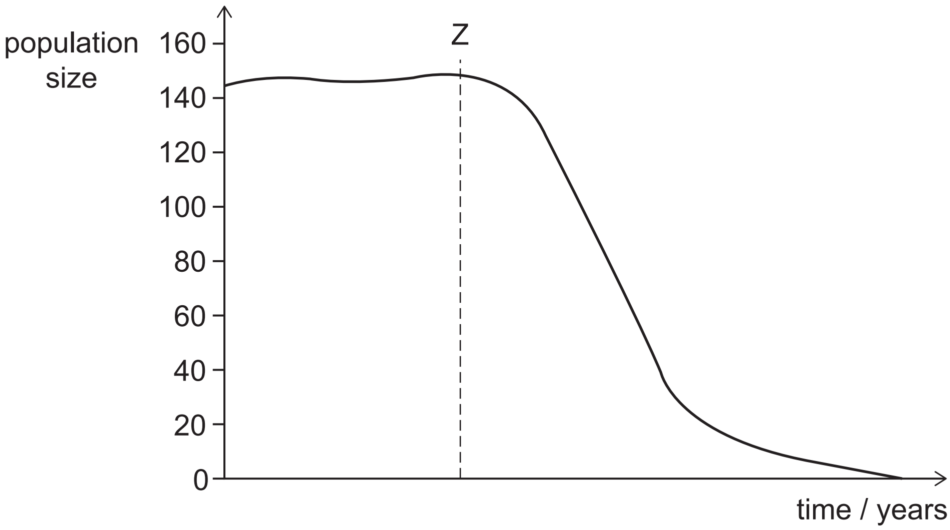
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

66 The graph shows changes in population size (number of individuals) of a species of tortoise over the last century. These tortoises are only found on one small island in the Galapagos.



Which of the following could account for the change in population shown after time Z on the graph?

1 reduced rainfall

2 reduced availability of resources

3 failure to adapt to competition from an introduced species

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

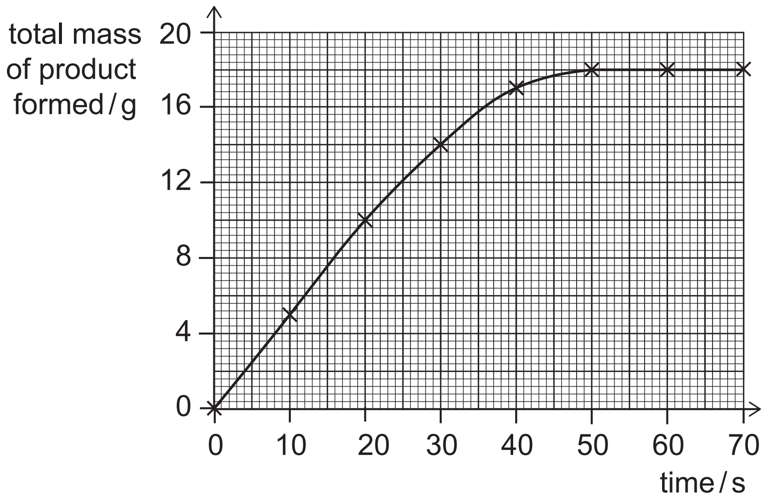
F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

67 An enzyme-catalysed reaction was studied and the mass of product formed was measured over time.

The results are shown in the graph.



Which of the following statements is/are correct?

1 The enzymes may have been used up in the reaction.

2 The initial rate of reaction is 120 g min^{-1}.

3 At high concentrations, the product formed may inhibit the enzymes.

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

68 A person ran on a treadmill for 360 seconds. Their rates of aerobic and anaerobic respiration were measured at the start and at the end of the time. The table shows the results.

	time = 0 seconds	time = 360 seconds
rate of aerobic respiration / arbitrary units	1.01	5.77
rate of anaerobic respiration / arbitrary units	0.01	3.67

Physiological changes occured in the person during this time.

Which of the following statements is/are correct during the 360 seconds?

1 There was an increase in pH that caused a change in the shape of the respiratory enzyme's active sites.

2 Part of the increase in the rate of cellular respiration may have been due to a temperature increase in the muscles.

3 More carbon dioxide needed to be removed from the muscle cells.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

69 Coat colour variation in a particular population of mice is only affected by one gene with two alleles, R and r. This gene is not on a sex chromosome.

Heterozygous mice have yellow fur. Embryos that are homozygous dominant do not survive.

A yellow male and a yellow female mouse were mated several times and a large number of offspring were produced. Some of the offspring were grey in colour and others were yellow.

Assuming that no new mutations have occurred, which of the following is correct?

A 25% of the live offspring will be grey in colour.

B All grey mice have a homozygous genotype for coat colour.

C Offspring with XY chromosomes are all heterozygous for coat colour.

D The live offspring of a cross between a yellow and a grey mouse will always be yellow.

E There is a 3 **:** 1 ratio of dominant to recessive alleles for this gene in the live offspring.

70 One strand of a section of DNA has the following sequence of bases:

AATCGGTCTTGCGGCCAAGGCCCTT

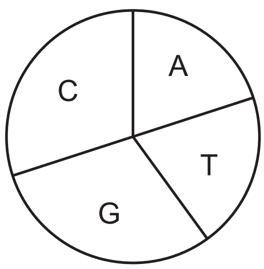
The complementary strand is not shown.

The charts show the proportions of the four bases A, C, G and T.

Which chart shows the correct proportions of bases for this section of double-stranded DNA?

(Assume no mutations.)

A



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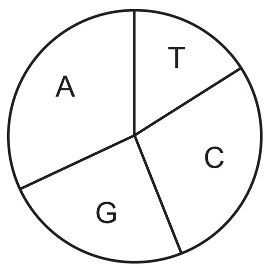

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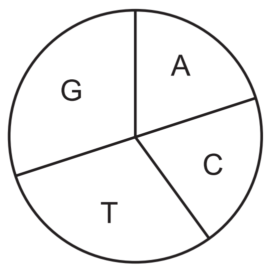

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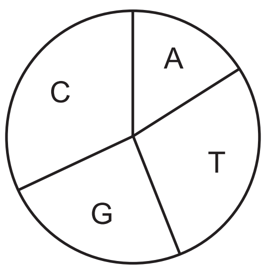

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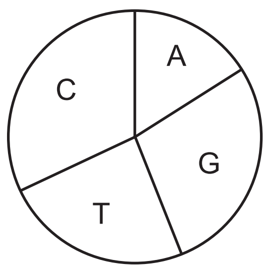

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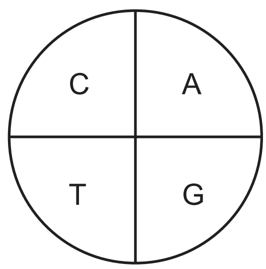
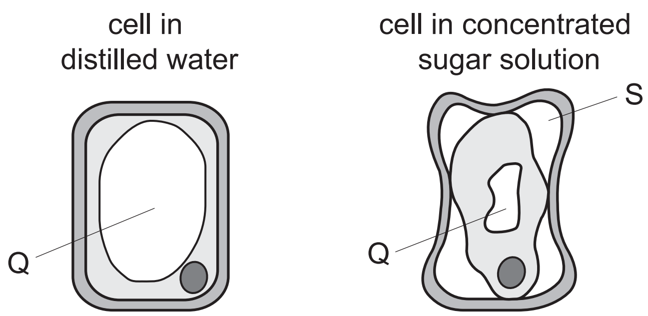


71 Two identical plant cells were removed from a leaf. One was placed in a concentrated sugar solution and the other was placed in distilled water, and both were left for 2 hours.

All other factors were kept constant during the experiment. The diagram shows the results, with regions of each cell labelled Q and S.



Which of the following statements is/are correct?

1 In the cell in distilled water, Q contains only distilled water.

2 In the cell in concentrated sugar solution, the number of solute particles in Q increased over the two hours.

3 S is a vacuum.

A none of them

B 1 only

C 2 only

D 3 only

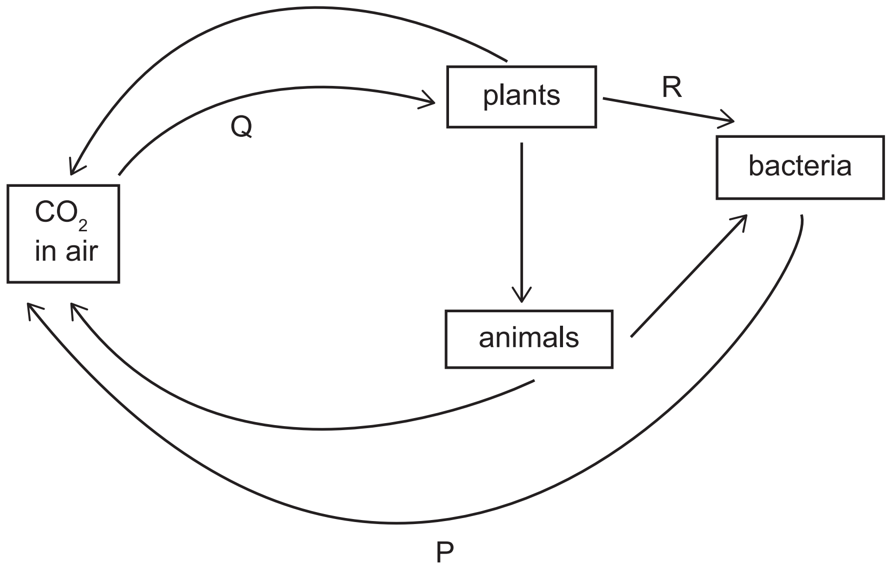
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

72 The diagram shows some chemical processes involved in the carbon cycle. Three of these multi-stage processes are labelled P, Q and R.



Which of the following statements is/are correct?

1 P requires the presence of mitochondria.

2 Overall, Q releases heat.

3 R is sensitive to changes in pH and temperature.

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

73 Two different cells, cell L and cell M, were studied using a microscope and then drawn. The drawings are not shown.

Some of the data collected is shown in the table.

	cell L	*cell M*
actual maximum length of cell / μm	400	40
maximum length of cell in drawing / cm	2	1

Which of the following statements is/are correct?

1 Cell L has been magnified 50 times.

2 Cell M has been magnified 5 times as much as cell L.

3 Both cells could have a cell wall.

A none of them

B 1 only

C 2 only

D 3 only

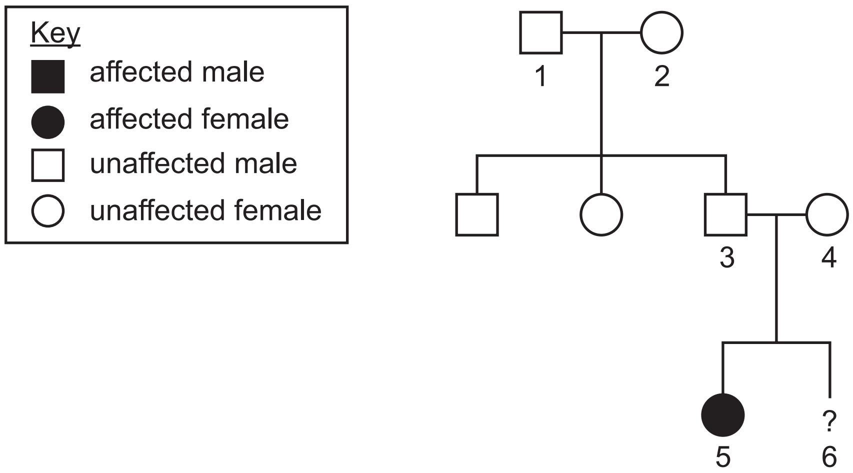
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

74 The pedigree diagram shows the inheritance of a phenotypic feature caused by a recessive allele.



What is the probability that individual 6 is an unaffected male?

A 12.5%

B 25%

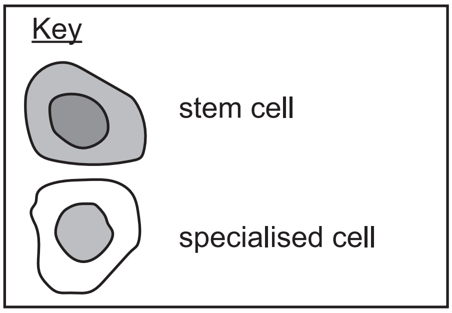
C 37.5%

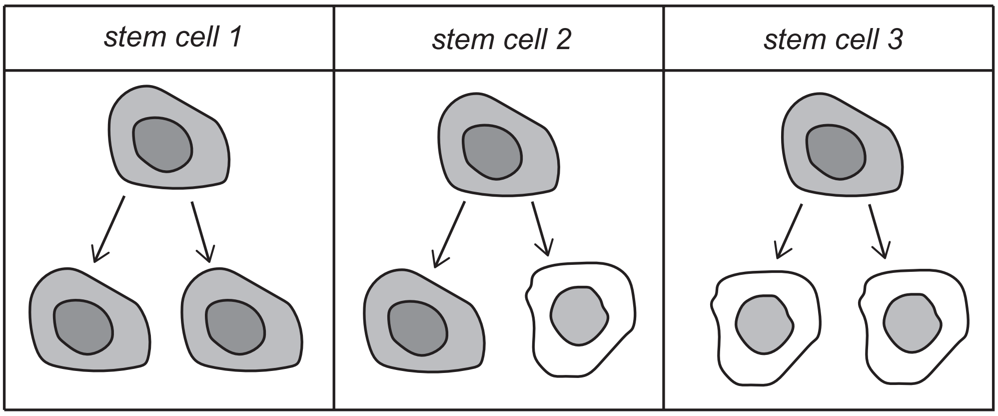
D 50%

E 62.5%

F 75%

75 The diagrams show the daughter cells produced when three different stem cells divide.





Which of the following statements is correct?

A Only stem cell 1 shows division by mitosis.

B Some cancers result from divisions like that shown for stem cell 1.

C The total number of stem cells increases if they divide like stem cell 2.

D Stem cells in adults divide like stem cell 3.

E The total number of stem cells is maintained if they divide like stem cell 3.

76 A fungus feeds by releasing amylase onto starchy food. The soluble products of the breakdown of starch are absorbed by the fungus.

Test tubes were set up containing a mixture of starch solution and fungus. Each test tube was maintained at a different temperature between 5 °C and 45 °C.

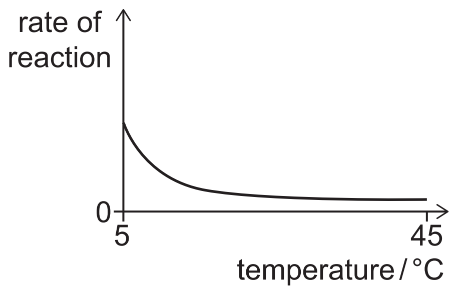
Samples of the mixture were removed early in the experiments to determine the initial rates of this enzyme-catalysed reaction.

The results were plotted.

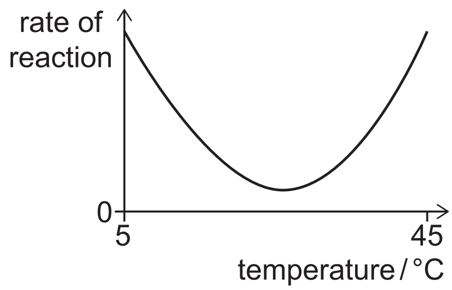
All of the other variables were kept constant.

Which graph shows the expected results?

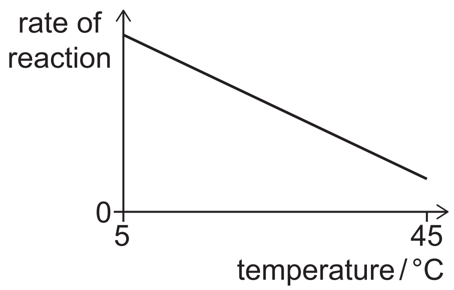
A



B



C



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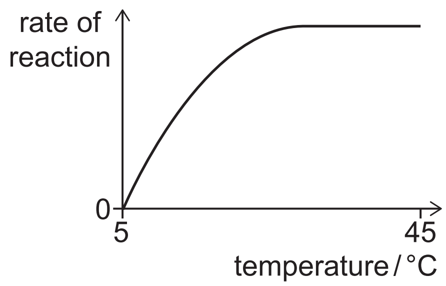
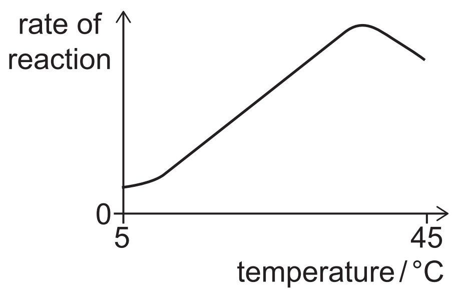


E



77 Red blood cells are produced by stem cells in the bone marrow.

A 1 mm^3 sample of blood from a healthy person was found to contain 4×10^6 red blood cells.

The person has a consistent average total blood volume of 0.006 m^3. Their total red blood cell count does not change and, on average, red blood cells have a lifespan of 100 days.

Which of the following statements is/are correct?

1 Red blood cells are phagocytic cells.

2 The average rate of production of red blood cells is 1×10^{10} cells per hour.

3 The stem cells that produce red blood cells do not have nuclei.

A none of them

B 1 only

C 2 only

D 3 only

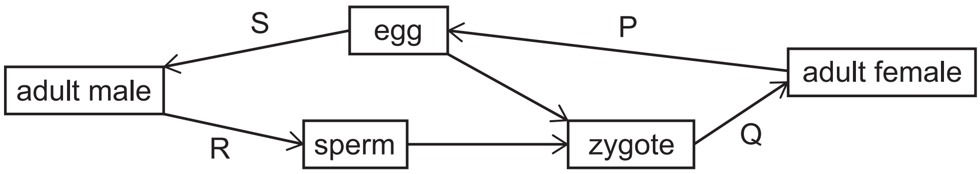
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

78 The diagram shows the life cycle of one species of ant, in which males are haploid and females are diploid.



Which of the letters on the diagram represent(s) meiosis?

A P only

B Q only

C R only

D S only

E P and Q only

F P and R only

G P and S only

H Q and R only

79 A student compared the properties of different cells from one healthy human.

Which of the following statements is/are correct?

(Assume that no mutations occur.)

1 A cheek cell contains the same alleles as an embryonic stem cell.

2 A sperm cell contains the same genome as a cheek cell.

3 A white blood cell contains the same number of DNA bases as a mature red blood cell.

4 An embryonic stem cell produces all of the same proteins as a white blood cell.

A 1 only

B 2 only

C 3 only

D 4 only

E 1 and 2 only

F 1 and 3 only

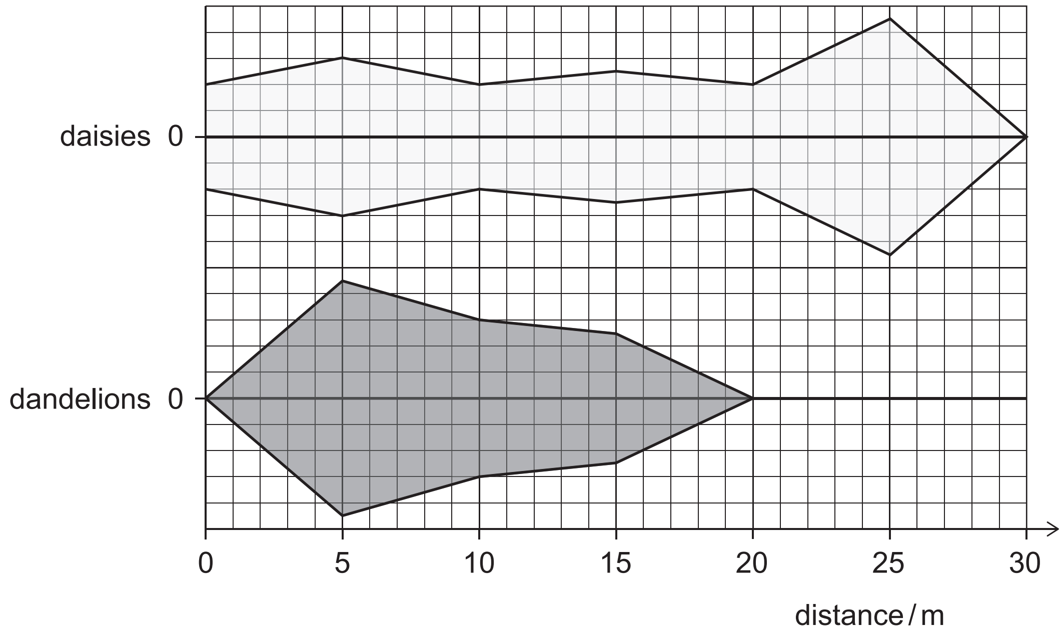
G 2 and 4 only

H 3 and 4 only

80 The kite diagram shows the distribution of dandelions and daisies along a transect in a field.

A quadrat with sides of 0.5 m was used to collect the data.

Each square on the vertical axis represents 1 plant. For example, in the quadrat centred at 5 m there were 6 daisies.



Which of the following statements about the data is/are correct?

1 Across the transect, the number of dandelions is proportional to the number of daisies.

2 Repeating the experiment along a different transect would result in an identical pattern.

3 The density of dandelions at 5 m is 36 plants per square metre.

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

Cambridge Assessment
Admissions Testing

NATURAL SCIENCES ADMISSIONS ASSESSMENT

D568/12

November 2021 **60 minutes**

SECTION 2

1787338421

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.

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Paper content

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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 Two loudspeakers are positioned 8.0 m apart as shown.

The loudspeakers emit sound waves of the same single frequency. The wave emitted by one loudspeaker is 180° out of phase with the wave emitted by the other loudspeaker.

A point P is in front of the loudspeakers. P is 18.0 m from one loudspeaker and 24.0 m from the other loudspeaker. As a result of superposition of the two waves arriving at P, the amplitude of the sound at position P is a minimum.

The speed of the sound is 336 m s^{-1}.

What is the lowest possible frequency of the sound?

A 21 Hz

B 28 Hz

C 42 Hz

D 56 Hz

E 63 Hz

F 84 Hz

2 A block is at rest on a rough inclined plane.

The acute angle between the plane and the horizontal is greater than 45°.

The forces acting on the block are: friction (F), weight (W) and normal contact force (N).

How do the magnitudes of the three forces compare?

A $F < N < W$

B $F < W < N$

C $N < F < W$

D $N < W < F$

E $W < F < N$

F $W < N < F$

3 A dc power supply, a resistor of constant resistance 50 Ω and a piece of resistance wire are connected in series.

The length of the resistance wire is 20 m and its cross-sectional area is 0.10 mm^2. The wire is made from a material with resistivity 1.0×10^{-7} Ω m and the current in it is 200 mA.

What is the voltage across the terminals of the power supply?

A 4.0 V

B 6.0 V

C 9.9 V

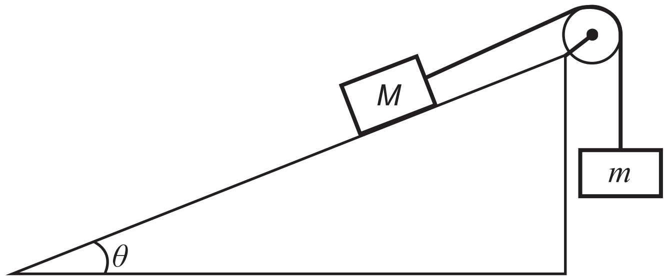
D 10.0 V

E 10.1 V

F 12.0 V

G 14.0 V

4 Two objects of mass M and m are connected by a rope over a pulley on an inclined plane as shown.



[diagram not to scale]

There is no friction between the plane and the object. The pulley is smooth, and the rope has negligible mass.

The angle θ of the plane to the horizontal is such that $\sin\theta = 0.80$ and $\cos\theta = 0.60$.

The object with mass M accelerates down the slope.

Which expression describes the full range of possible values of M compared with m?

A $M > \frac{3}{5}m$

B $M > \frac{4}{5}m$

C $M > m$

D $M > \frac{5}{4}m$

E $M > \frac{5}{3}m$

5 An object P falls vertically from rest through air and reaches terminal velocity.

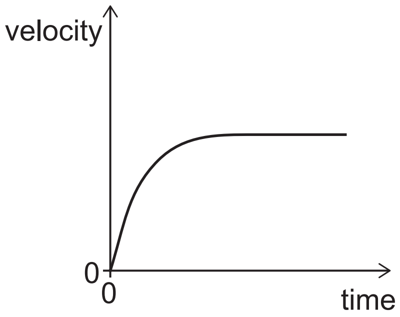
An identical object Q is projected vertically upwards from the ground.

When Q reaches its maximum height, P collides with it. The two objects join together in such a way that there is no change to the area of cross section passing through the air.

The two combined objects then fall through the air as one object.

Which sketch graph shows the variation of velocity with time for object P before and after the collision?

A



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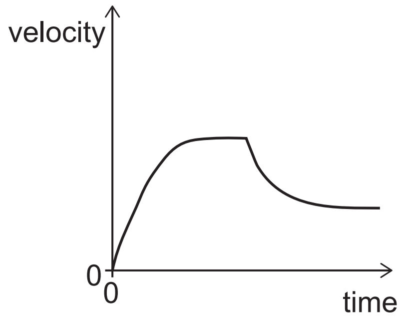

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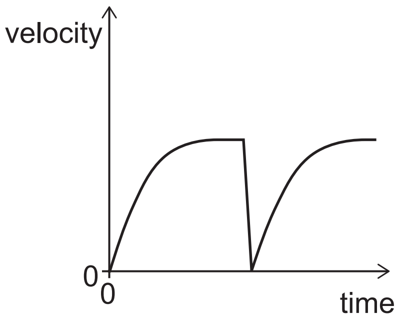

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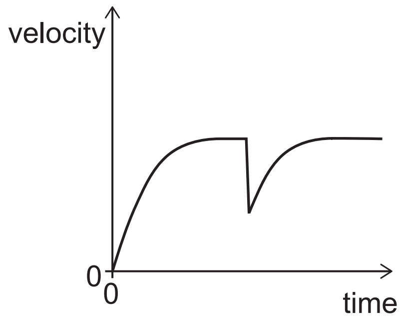

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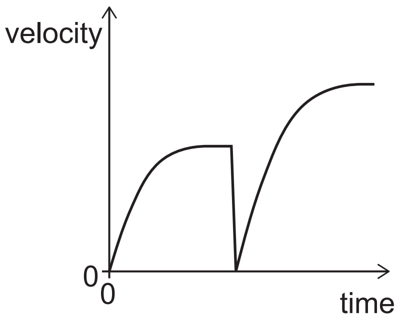

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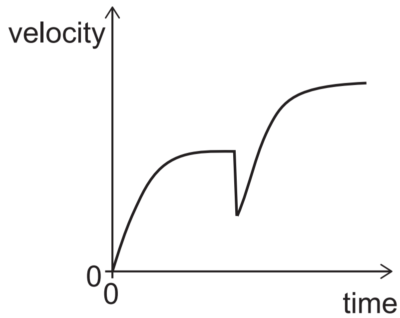


6 A lorry of mass m has an engine that develops a constant mechanical output power P.

The lorry is accelerated from rest by the engine in a horizontal straight line. The lorry experiences a total resistive force that is always proportional to the square of its speed.

The process is repeated for different values of P, and the maximum speed of the lorry is found to be proportional to P^n, where n is a constant.

What is the value of n?

A $\frac{1}{3}$

B $\frac{1}{2}$

C 1

D 2

E 3

7 A battery pack consists of 6 cells, each with an emf of 1.50 V and each with an internal resistance of 0.20 Ω.

The cells are arranged in two rows connected in parallel. Each row contains 3 cells connected in series.

The battery pack is connected to an external resistor of resistance 1.20 Ω.

What is the electrical power transferred in the external resistor?

A 2.7 W

B 3.6 W

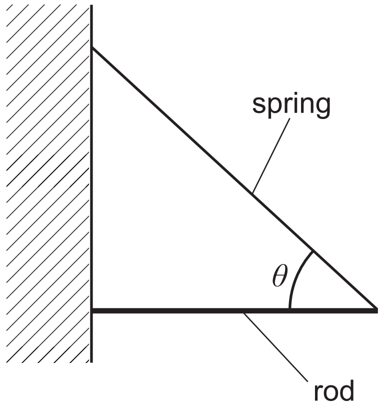
C 7.5 W

D 10.8 W

E 13.5 W

F 43.2 W

8 A light spring is used to support a uniform rod horizontally against a wall as shown. The angle between the spring and the rod is θ.



The spring constant of the spring is $20\,\mathrm{N\,m^{-1}}$ and the weight of the rod is 16 N.

The angle θ is such that $\cos\theta = \dfrac{3}{5}$ and $\sin\theta = \dfrac{4}{5}$.

How much energy is stored in the spring?

A 1.6 J

B 2.5 J

C 3.2 J

D 4.4 J

E 5.0 J

F 6.4 J

G 10 J

H 40 J

9 An object of mass 2.0 kg moves in a straight line under the action of a resultant force.

The displacement x of the object from its position at time $t = 0$ is given by

$$x = 4.0\,t^3$$

where x is in metres and t is in seconds.

At $t = 5.0$ s, what is the rate of change of momentum of the object?

A 6.7 kg m s^{-2}

B 66.7 kg m s^{-2}

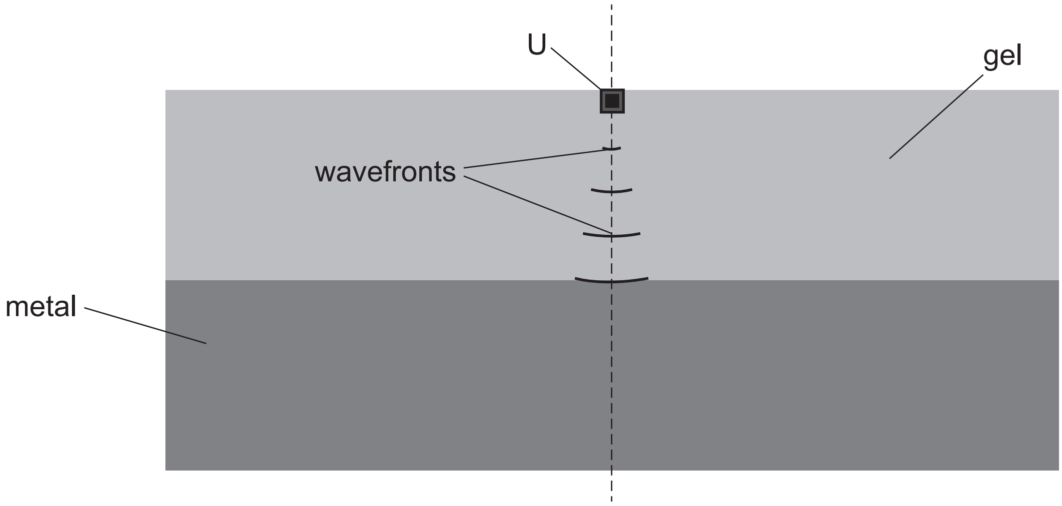
C 120 kg m s^{-2}

D 240 kg m s^{-2}

E 600 kg m s^{-2}

10 In an industrial process to test the purity of a metal, a narrow beam of ultrasound passes into a block of the metal. The ultrasound generator U is immersed in a gel that is in contact with the metal. The ultrasound passes from the gel into the metal.

The arcs of circles shown in the gel are lines that represent the positions of the compressions (known as wavefronts) of the ultrasound wave that comes from U.



Ultrasound travels faster in the metal than in the gel.

The wavefronts in the metal are circular arcs with their centre at a point X that is on the dashed line.

Where on the dashed line is X?

A above U

B at U

C in the gel below U

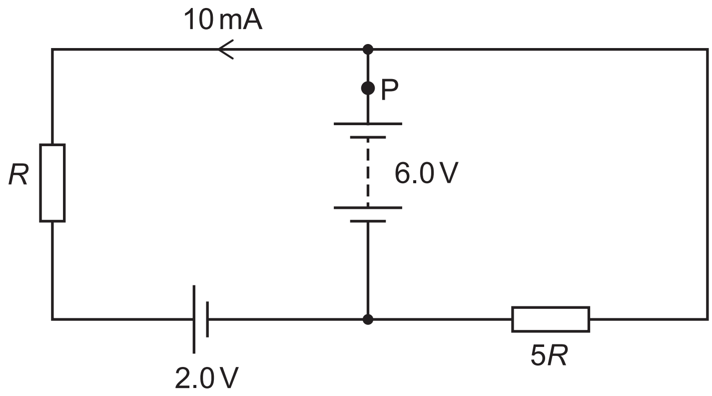
D on the boundary between the gel and the metal

E in the metal

11 The diagram shows a circuit containing two power supplies with negligible internal resistance and two resistors with resistances *R* and 5*R*.

The emfs of the power supplies and the magnitude and direction of the current in one part of the circuit are shown.

One point in the circuit is labelled P.



What is the magnitude of the current at P?

A 3.0 mA

B 7.0 mA

C 8.5 mA

D 11.5 mA

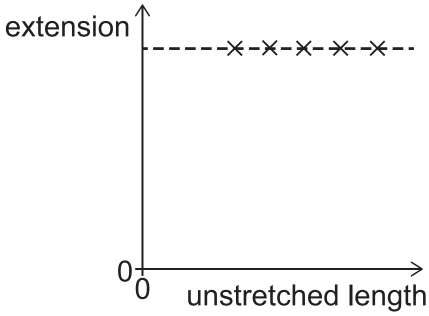
E 13 mA

F 25 mA

12 A selection of five wires made from the same metal have different unstretched lengths but equal masses. The wires are all subjected to the same small tension force and each wire extends within its limit of proportionality.

Which graph shows the relationship between the extension of the wires and the unstretched length of the wires?

A



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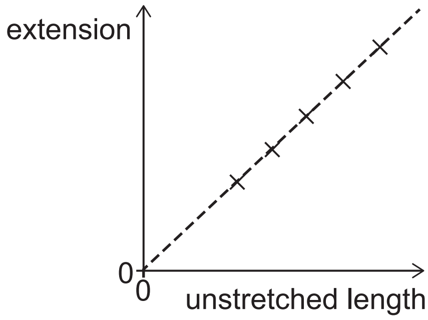

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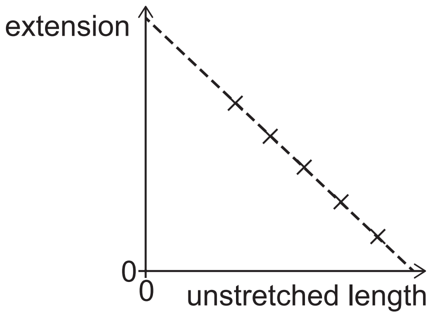

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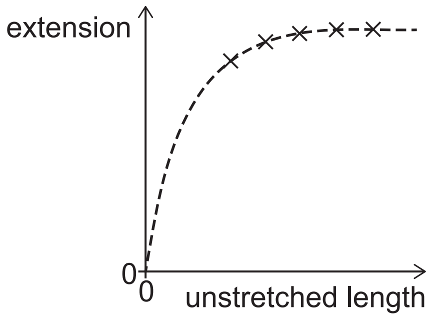

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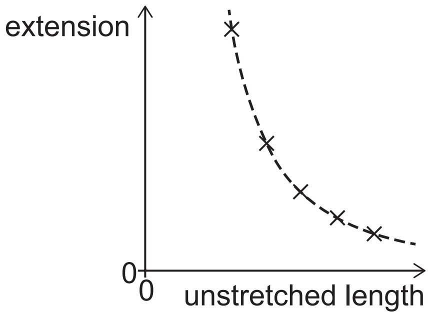

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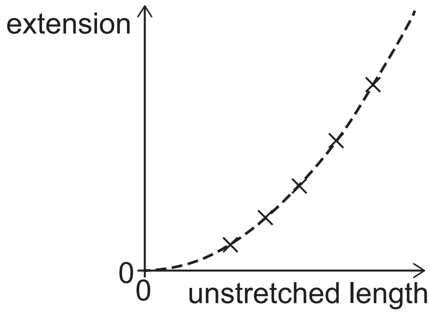


13 Water enters a horizontal pipe of cross-sectional area 0.0040 m^2 at constant speed 0.50 $m\,s^{-1}$. At the end of the pipe the cross-sectional area reduces to 0.0020 m^2 and the water leaves the pipe as shown. The density of water is 1000 $kg\,m^{-3}$.

How much power must be supplied to the water to maintain the flow in this section of the pipe?

(Assume that the water is incompressible and that frictional forces can be neglected.)

A 0.25 W

B 0.50 W

C 0.75 W

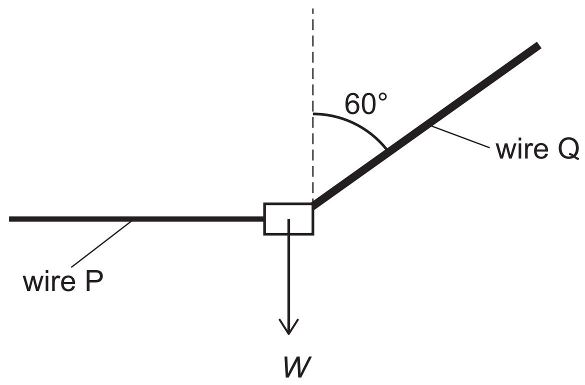
D 1.0 W

E 1.25 W

F 1.5 W

G 3.75 W

14 Two light wires P and Q support a load of weight W in equilibrium as shown. Wire P is horizontal and wire Q is at an angle of 60° to the vertical. The wires are made from the same material.



The radius of wire Q is twice the radius of wire P.

What is the ratio

$$\frac{\text{strain in wire P}}{\text{strain in wire Q}}?$$

(The wires do not exceed their limits of proportionality.)

A $\frac{\sqrt{3}}{8}$

B $\frac{\sqrt{3}}{4}$

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

D $\sqrt{3}$

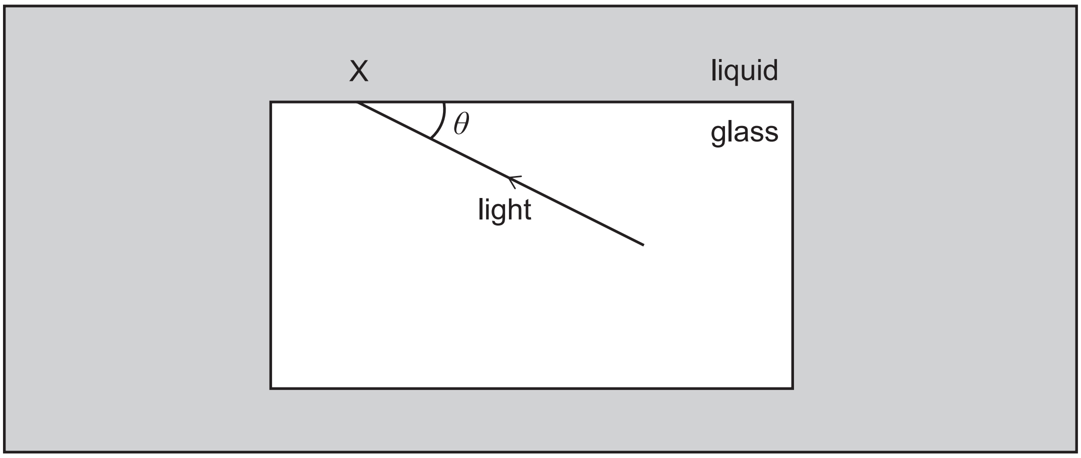
E $2\sqrt{3}$

F $\frac{4}{\sqrt{3}}$

G $\frac{8}{\sqrt{3}}$

15 The speed of light in a block of glass is $2.0 \times 10^8\,\text{m s}^{-1}$. The block of glass is immersed in a liquid of refractive index 1.2.

The diagram shows a ray of light travelling in the glass block striking the side of the block at the point labelled X. The acute angle between the ray and the side of the block is θ.



What is the full range of values of the acute angle θ for which light is refracted at X?

(The speed of light in a vacuum is $3.0 \times 10^8\,\text{m s}^{-1}$.)

A $0° < \theta < \cos^{-1}\left(\frac{2}{3}\right)$

B $0° < \theta < \cos^{-1}\left(\frac{\sqrt{5}}{3}\right)$

C $0° < \theta < \cos^{-1}\left(\frac{3}{5}\right)$

D $0° < \theta < \cos^{-1}\left(\frac{4}{5}\right)$

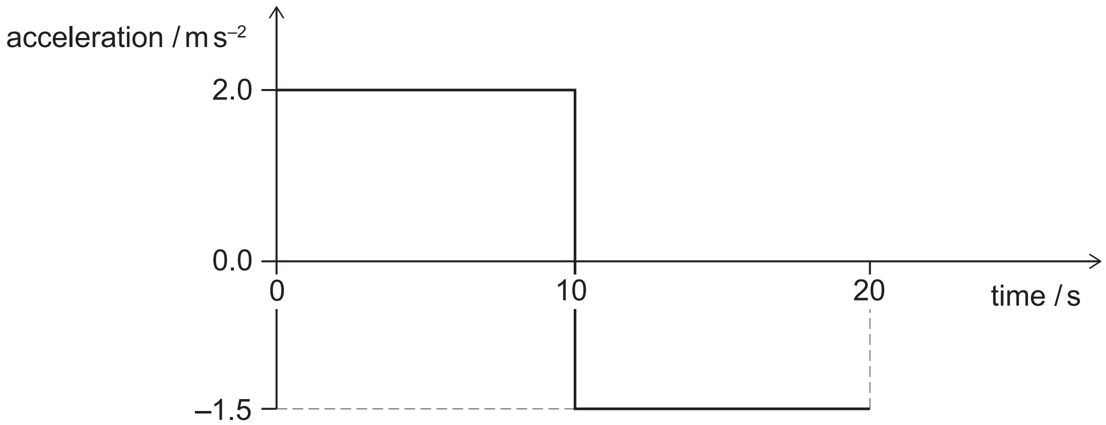
E $\cos^{-1}\left(\frac{2}{3}\right) < \theta < 90°$

F $\cos^{-1}\left(\frac{\sqrt{5}}{3}\right) < \theta < 90°$

G $\cos^{-1}\left(\frac{3}{5}\right) < \theta < 90°$

H $\cos^{-1}\left(\frac{4}{5}\right) < \theta < 90°$

16 A car is at rest on a straight horizontal road. At time $t = 0$ s the car starts to move along the road. The graph shows how its acceleration varies from $t = 0$ s to $t = 20$ s.



What is the displacement of the car from its starting position when $t = 20$ s?

A 5.0 m

B 25 m

C 35 m

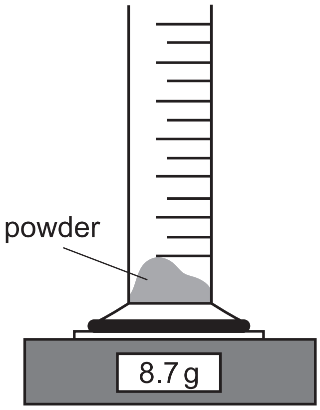
D 175 m

E 225 m

F 375 m

17 An empty measuring cylinder is placed on a balance, and the balance reading is then set to zero.

A mass of 8.7 g of a powder is poured into the measuring cylinder as shown in the diagram.



Liquid is poured into the cylinder to cover the powder completely. The powder does not dissolve. The reading on the measuring cylinder and the reading on the balance are recorded.

More liquid is added and a second pair of readings is recorded.

The table shows the two pairs of readings.

reading on measuring cylinder / cm^3	*reading on balance* / g
10.0	15.0
25.0	27.6

What is the density of the material from which the powder is made?

A 0.414 g cm^{-3}

B 1.16 g cm^{-3}

C 1.31 g cm^{-3}

D 1.45 g cm^{-3}

E 2.00 g cm^{-3}

F 2.50 g cm^{-3}

G 3.48 g cm^{-3}

H 6.00 g cm^{-3}

18 A stone of mass 100 g is fired horizontally from an 80 m high vertical cliff. The ground below the cliff is horizontal.

The kinetic energy of the stone when it hits the ground is 125 J.

What is the distance from the bottom of the cliff to the point where the stone hits the ground?

(gravitational field strength = $10\,N\,kg^{-1}$; ignore air resistance and any effect of wind)

A 60 m

B 80 m

C 120 m

D 160 m

E 200 m

19 An electrical component is connected to a switch and a power supply which has a constant terminal potential difference V. The switch is initially open. At time $t = 0$ the switch is closed.

When the switch is closed, the current I in the component increases with time t as given by the equation

$$I = kt^2$$

where k is a positive constant.

When the current reaches a value I_F the component fails and the current falls instantly to zero.

How much electrical energy has been transferred to the component by the time it fails?

(All quantities are in standard SI units.)

A $\frac{Vk}{3}\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

B $Vk\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

C $3Vk\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

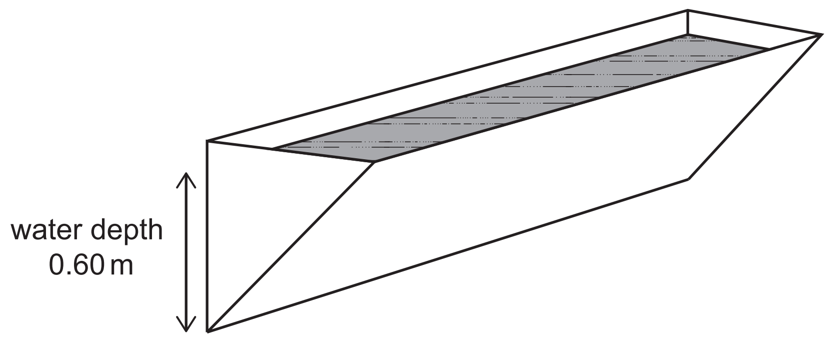
D $\frac{Vk}{3}\left(\frac{I_F}{k}\right)$

E $Vk\left(\frac{I_F}{k}\right)$

F $3Vk\left(\frac{I_F}{k}\right)$

20 A water trough has the shape of a prism, with a cross section that is a right-angled isosceles triangle.

One rectangular face and the two triangular ends of the trough are vertical, as shown.



[diagram not to scale]

The trough contains water of depth 0.60 m measured on the vertical rectangular face.

What is the force exerted by the water on one triangular end of the trough?

(density of water = 1000 kg m^{-3}; gravitational field strength = 10 N kg^{-1})

A 180 N

B 270 N

C 360 N

D 540 N

E 720 N

F 1080 N

G 6000 N

H 12 000 N

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PART Y Chemistry

21 A Group 1 metal hydrogencarbonate contains the HCO_3^- ion and decomposes at 200 °C.

When dilute hydrochloric acid is added to the residue from the thermal decomposition of this metal hydrogencarbonate, a gas is released that turns limewater cloudy. The residue also gives a yellow-orange colour in a flame test.

8.4 g of this metal hydrogencarbonate is heated to constant mass at 200 °C.

How much mass is lost in this reaction?

(A_r values: H = 1; C = 12; O = 16; Li = 7; Na = 23; K = 39)

A 2.2 g

B 2.6 g

C 3.1 g

D 4.0 g

E 4.4 g

F 5.3 g

G 6.2 g

22 Which of the following statements is correct for the bond angle (θ) in gaseous germanium(II) chloride, $GeCl_2$, molecules as predicted by the VSEPR model?

A $\theta = 90°$

B $90° < \theta < 120°$

C $\theta = 120°$

D $120° < \theta < 180°$

E $\theta = 180°$

23 Propanal can be reduced to propan-1-ol with hydrogen gas at high pressure and a platinum catalyst.

Radioactive propan-1-ol can be made if the hydrogen gas is replaced by pure tritium gas. Tritium, ^{3}H, is the radioactive isotope of hydrogen.

All of the atoms other than ^{3}H in the radioactive propan-1-ol are the most abundant isotope for the element. The most abundant isotopes of carbon, hydrogen and oxygen are ^{12}C, ^{1}H and ^{16}O.

How many neutrons are there in one molecule of this radioactive propan-1-ol?

A 26

B 28

C 30

D 32

E 34

F 40

G 42

24 A sample of hydrated cobalt(II) sulfate, $CoSO_4 \cdot xH_2O$, with a mass of 5.62 g, was heated to convert the sample completely to 3.10 g of anhydrous cobalt(II) sulfate.

What is the value of x?

(A_r values: H = 1.0; O = 16.0; S = 32.1; Co = 58.9)

A 2

B 3

C 4

D 5

E 6

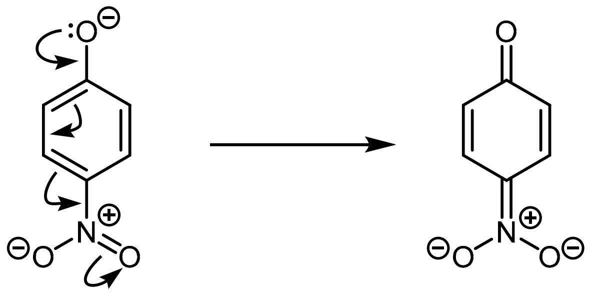
F 7

G 8

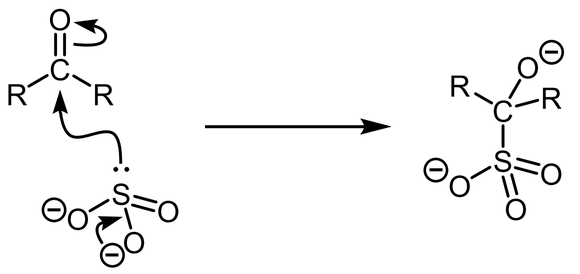
H 9

25 Which of the following does **not** give the species shown?

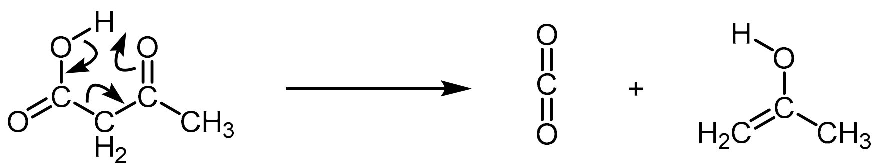
A



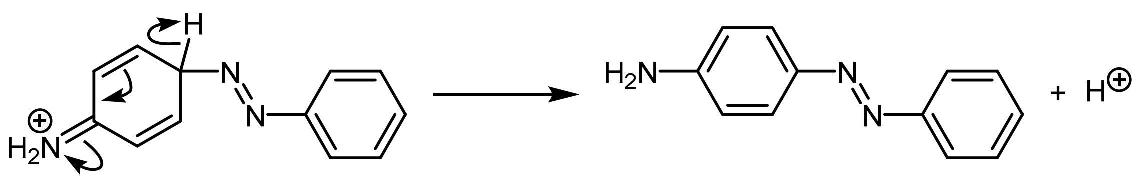
B



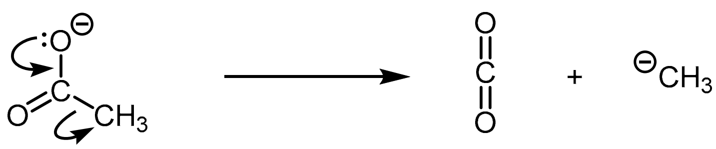
C



D



E



26 0.4 mol of a halogenoalkane reacted completely with hot, ethanolic potassium hydroxide to give 28 g of a single organic product X in 100% yield.

What percentage of all of the structural isomers with both the same functional group and molecular formula as X would show geometric (*E*/*Z*) isomerism?

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

A 17%

B 20%

C 25%

D 33%

E 40%

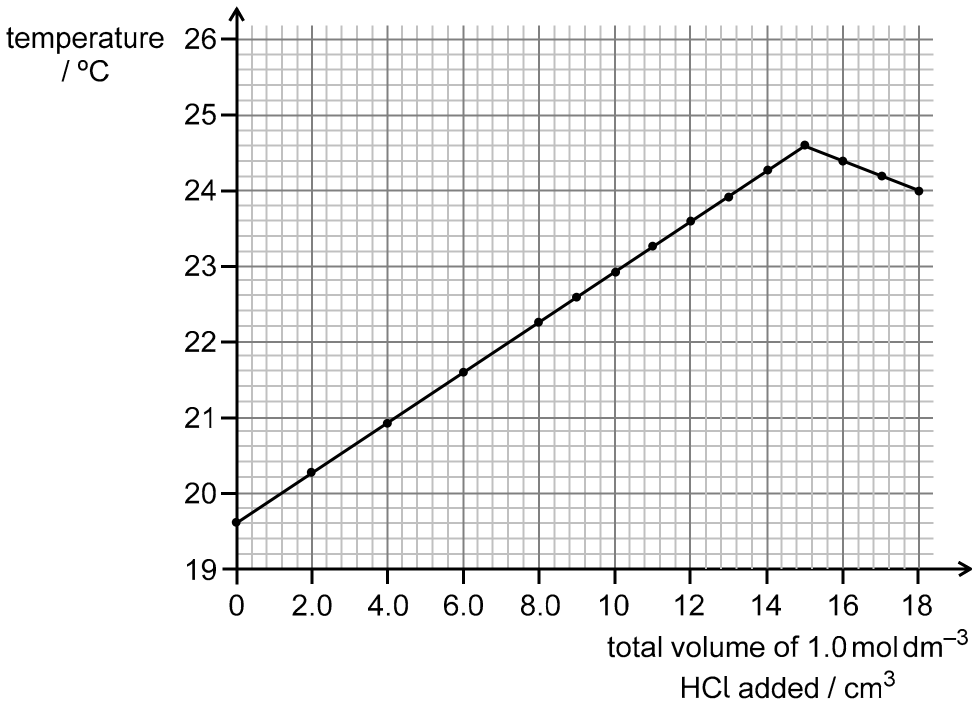
F 50%

27 25.0 cm^3 of sodium hydroxide solution is placed in a polystyrene cup with a thermometer.

1.00 mol dm^{-3} hydrochloric acid is added from a burette to the stirred solution of sodium hydroxide.

Both solutions are at the same temperature before mixing.

The temperature is recorded each time a measured amount of hydrochloric acid is added, and the data is plotted on a graph.



Assuming that no heat is lost from the cup, what is the enthalpy change of reaction when one mole of aqueous sodium hydroxide is neutralised?

(Assume that all solutions have density 1.0 g cm^{-3} and specific heat capacity 4.2 J g^{-1} °C^{-1}.)

A –56.0 kJ

B –49.3 kJ

C –35.0 kJ

D –33.6 kJ

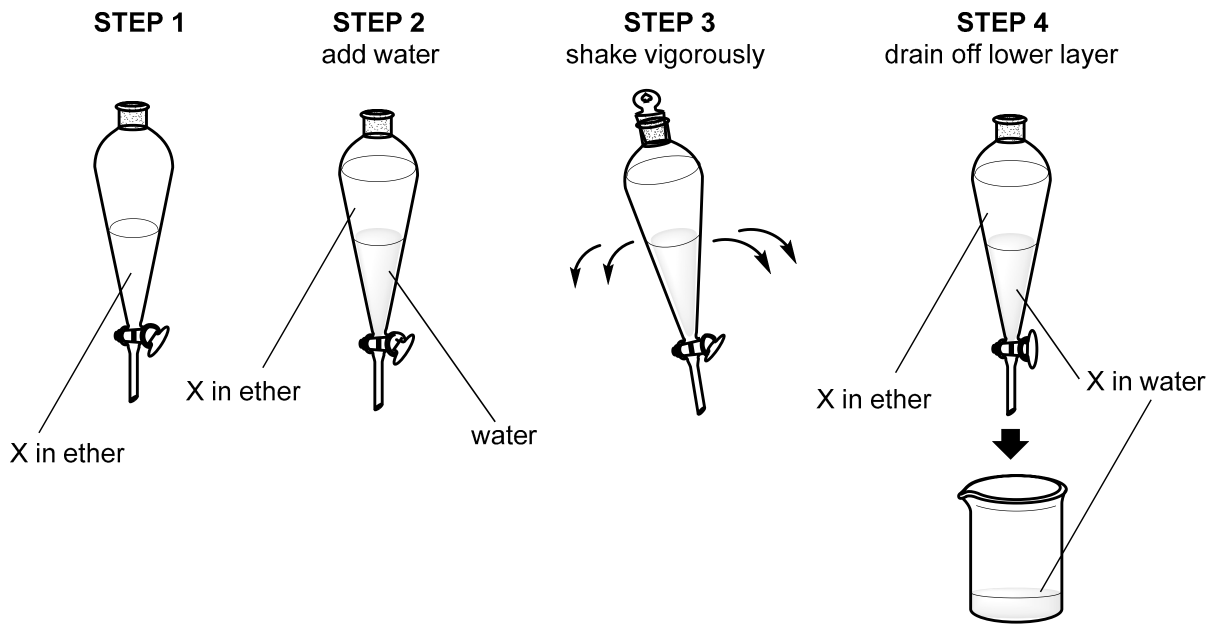
E –21.0 kJ

28 Consider the distribution of a solute X between two immiscible solvents: water and ether.

$$X(aq) \rightleftharpoons X(ether)$$

The equilibrium constant, K_c, is 0.15 at 25 °C.

50 cm^3 of a solution of X in ether at 25 °C contains 21.5 g of X. 100 cm^3 of water is added, shaken with the ether solution and allowed to reach equilibrium at 25 °C.



What is the maximum mass of X that can be transferred into the aqueous layer?

A 4.96 g

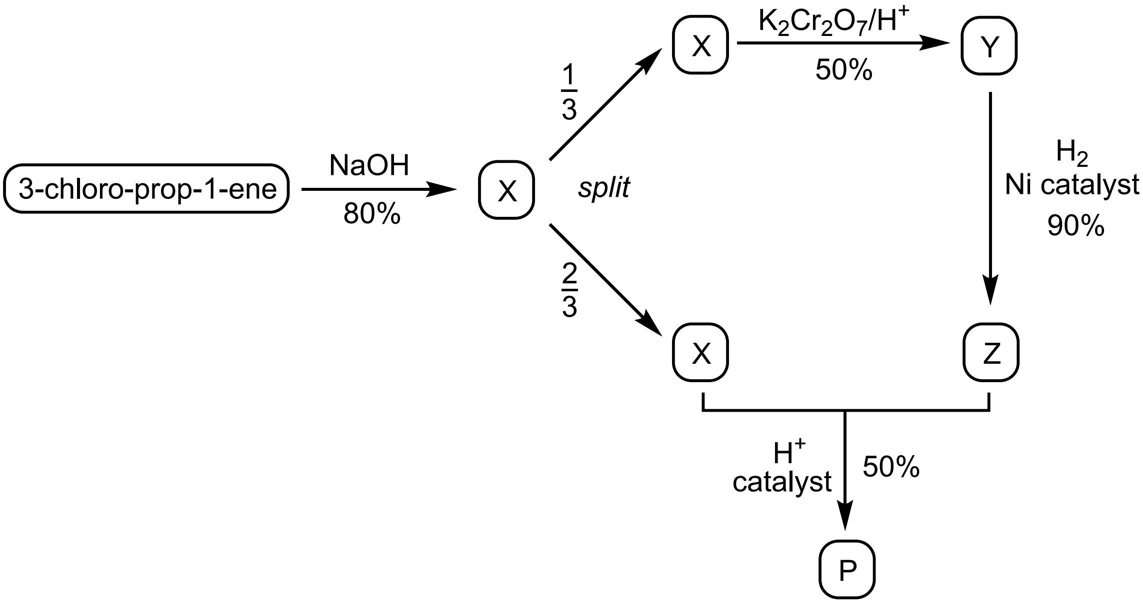
B 14.3 g

C 18.7 g

D 20.0 g

E 20.5 g

29



5.0 mol of 3-chloro-prop-1-ene (M_r = 76.5) was reacted with excess sodium hydroxide to form a single product X in 80% yield.

One third of compound X was heated with excess acidified potassium dichromate(VI) under reflux to form a single product Y in 50% yield.

All of compound Y was reacted with hydrogen gas at high temperature in the presence of nickel to form a single product Z in 90% yield.

The remaining quantity of compound X was reacted with all of compound Z in the presence of an acid catalyst to form product P in 50% yield.

What is the maximum mass of product P that could be produced from this synthesis?

(A_r values: H = 1; C = 12; O = 16; Cl = 35.5)

A 2.74 g

B 5.48 g

C 23.0 g

D 34.2 g

E 114 g

F 123 g

G 152 g

30 Iron(II) sulfate is used as a moss treatment on lawns and sports pitches. The recommended amount of iron is 2.5 kg per $10^4\,m^2$.

Analysis of a particular sports pitch showed it to contain 0.05 g of iron per m^2.

A pitch care company supplies three hydrated formulations:

- $FeSO_4 \cdot 7H_2O$ which contains 20% of iron by mass
- $FeSO_4 \cdot 4H_2O$ which contains 25% of iron by mass
- $FeSO_4 \cdot H_2O$ which contains 33% of iron by mass

A 25 kg sack of one of the iron(II) sulfate formulations is to be used on the sports pitch but unfortunately it has lost its label. A small sample was heated to constant mass to form a white solid, and the mass of the sample decreased by more than 40% in this process.

The sports pitch is 90 m long and 60 m wide.

What mass of the iron(II) sulfate formulation (in kg) should be added to ensure that the iron content is at the recommended level?

(M_r values: $FeSO_4$ = 152; H_2O = 18)

A 1.08 kg

B 1.35 kg

C 3.60 kg

D 4.32 kg

E 5.40 kg

F 6.75 kg

31 A compound contains potassium cations, and anions that contain only boron and fluorine. Each anion contains one boron atom.

0.630 g of this compound contains 0.195 g of potassium and 0.055 g of boron.

What is the shape of the anions in this compound?

(A_r values: B = 11; F = 19; K = 39)

A linear

B bent (V-shaped)

C trigonal planar

D trigonal pyramidal

E tetrahedral

F square planar

32 The first ionisation energy of five elements is measured.

Which row matches the five elements to their first ionisation energy?

	first ionisation energy / kJ mol^{-1}				
	577	736	1000	1060	1680
A	F	Mg	Al	P	S
B	F	P	S	Mg	Al
C	F	P	S	Al	Mg
D	Mg	Al	S	P	F
E	Mg	Al	P	S	F
F	Al	Mg	P	S	F
G	Al	Mg	S	P	F
H	S	P	Al	Mg	F

33 A yellow precipitate is formed when alkaline aqueous iodine reacts with alcohols that have the structure R-CH(OH)CH_3, where R is a carbon chain or H.

There are a number of structural isomers with the molecular formula $C_5H_{12}O$ that are alcohols.

Of these structural isomeric alcohols:

(i) how many will form a yellow precipitate when reacted with alkaline aqueous iodine;

(ii) how many, following mild oxidation and immediate distillation, will produce a silver mirror with Tollens' reagent?

	(i) *forms yellow precipitate*	(ii) *produces silver mirror*
A	1	1
B	2	3
C	2	4
D	2	7
E	3	3
F	3	4
G	3	7
H	4	4

34 The standard enthalpy change of formation of hydrogen iodide is +26 kJ mol^{-1}.

For the reaction of gaseous iodine with hydrogen

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

the enthalpy change of reaction can be calculated using bond enthalpy values.

The bond enthalpies are:

bond	*bond enthalpy* / kJ mol^{-1}
H−H	436
I−I	151
H−I	299

The sublimation of iodine is represented by: $I_2(s) \rightarrow I_2(g)$

Using the data provided, what is the enthalpy change for the sublimation of iodine?

(All data is given at room temperature and pressure.)

A −262 kJ mol^{-1}

B −236 kJ mol^{-1}

C −41 kJ mol^{-1}

D +37 kJ mol^{-1}

E +41 kJ mol^{-1}

F +63 kJ mol^{-1}

G +236 kJ mol^{-1}

35 Sodium hydrogencarbonate, $NaHCO_3$, and sodium carbonate are both used as antacids. They react with hydrochloric acid in the stomach to form the same products.

The contents of a person's stomach has a pH of 1.0, which is a concentration of $0.1\,mol\,dm^{-3}$ HCl. The stomach contained $80\,cm^3$ of aqueous solution when the pH was measured.

Which of the following amounts of sodium hydrogencarbonate would bring the stomach contents into the normal range of pH 2.0-3.0?

(A_r values: H = 1; C = 12; O = 16; Na = 23)

A 0.0038 mol

B 0.0075 mol

C 0.0080 mol

D 0.016 mol

E 0.095 mol

36 X is a **di**carboxylic acid. When in aqueous solution, 2.36 g of X reacts with excess sodium carbonate to produce 480 cm^3 of carbon dioxide, measured at room temperature and pressure. Assume that no gas dissolves in the water present.

Y is a liquid organic compound containing only one functional group. 1 mol of Y reacts exactly with 1 mol of sodium, giving off a gas that pops with a lighted splint. Aqueous Y does not change the colour of blue or red litmus papers.

When 50.0 cm^3 of gaseous Y is combusted in excess oxygen, 150 cm^3 of carbon dioxide and 200 cm^3 of water vapour are the only products formed. All volumes are measured at the same temperature and pressure.

When heated in the presence of concentrated sulfuric acid, 1 mol of X reacts completely with 2 mol of Y to give 1 mol of organic product Z. Water is also produced in the reaction.

What is the relative molar mass of Z?

(A_r values: H = 1; C = 12; O = 16. Assume that one mole of gas occupies 24 dm^3 at room temperature and pressure.)

A 101

B 160

C 166

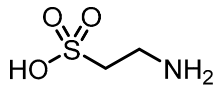
D 170

E 202

F 220

37 Cats are unable to synthesise the amino acid taurine in their bodies, so they must obtain it from their food. It is often added to cat food as an additive.

Taurine is a monoprotic acid with the following molecular structure:



$M_r = 125$

Dietary studies suggest that a cat should consume 10 mg of taurine per kilogram of body mass per day.

Brand X cat food contains taurine at a level of 0.008% by mass, but this level is too low for a cat to acquire a sufficient amount from a healthy amount of food.

Magnesium taurate is an ionic salt which liberates taurine in the body. 8 cm^3 of a 0.5 $mol\,dm^{-3}$ aqueous solution of magnesium taurate was added to a 10 kg bag of brand X cat food and thoroughly mixed.

A particular cat bowl can hold a 50 g serving of cat food. A particular cat of mass 4000 g always eats a full serving.

What is the minimum number of bowls of cat food that this cat must eat to ensure that it has consumed its daily requirement of taurine?

(Assume that the addition of the solution does not significantly alter the total mass of the bag of cat food.)

A 2

B 3

C 4

D 5

E 6

F 7

G 8

38 Analysis of hydrocarbon P showed it to contain 0.60 g of carbon and 0.10 g of hydrogen, and to have a relative molecular mass of 70.

P reacts with hydrogen bromide to form a mixture of Q and R. However, the main product was Q.

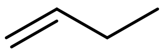
Q reacts with warm, aqueous sodium hydroxide to form S.

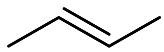
S reacts with warm, acidified potassium dichromate(VI) to form T. T does not produce a silver mirror with Tollens' reagent and does not produce bubbles when sodium carbonate is added.

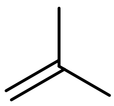
S undergoes dehydration on reaction with hot, concentrated sulfuric acid to form the original hydrocarbon P and a new compound U. Both P and U do not have stereoisomers.

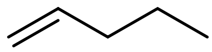
What is the structure of compound U?

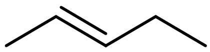
(A_r values: H = 1; C = 12)

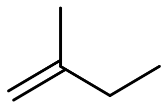
A 

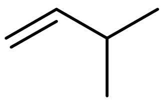
B 

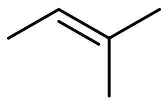
C 

D 

E 

F 

G 

H 

39 Lanthanum iodate(V), $La(IO_3)_3$, decomposes when heated to 600 °C to give a product that contains the ion Q.

An **unbalanced** ionic equation for the reaction is:

$$IO_3^- \rightarrow \text{ion Q} + I_2 + O_2$$

Ion Q contains only iodine in the +7 oxidation state and oxygen in the −2 oxidation state.

The oxidation state of the lanthanum does not change in the reaction.

0.005 mol of $La(IO_3)_3$ is fully decomposed by heating. The iodine produced is titrated against a 0.4 mol dm^{-3} solution of sodium thiosulfate ($Na_2S_2O_3$). 30.0 cm^3 of the sodium thiosulfate solution is needed to reach the end-point. The equation for the reaction between iodine and sodium thiosulfate is:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

What is the formula of the product that contains ion Q?

A $LaIO_5$

B $LaIO_6$

C $La(IO_4)_3$

D $La_3(IO_6)_5$

E $La_5(IO_4)_3$

F $La_5(IO_6)_3$

40 Consider the following chemical equation:

$$vQ + wP_4 + xH_2O \rightarrow yPH_4I + zH_3PO_4$$

where Q is a binary compound.

The molecules of Q are hexatomic and contain phosphorus in the +2 oxidation state.

Using the lowest integer values for all the coefficients v, w, x, y and z, what is the value of w when the equation is balanced?

A 1

B 2

C 13

D 16

E 24

F 26

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PART Z Biology

41 Cystic fibrosis and sickle cell anaemia are both recessive genetic conditions and the genes for these conditions are found on different non-sex chromosomes.

The following statements are true for one set of parents who have only one child:

- Both parents are heterozygous for cystic fibrosis.
- One parent is homozygous recessive for sickle cell anaemia.
- One parent is heterozygous for sickle cell anaemia.

What is the probability of this child having both conditions?

A 0.75

B 0.5

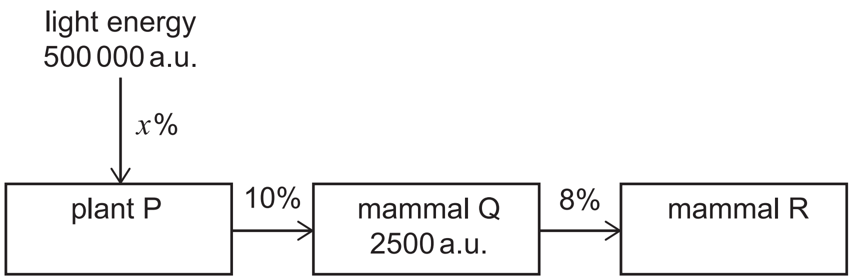
C 0.375

D 0.25

E 0.125

F 0.0625

42 The diagram shows a food chain. The numbers represent energy available and are in arbitrary units (a.u.), and the percentages represent efficiency of energy transfer.



The energy transfer between trophic levels is not 100% efficient.

Which row is correct for this food chain?

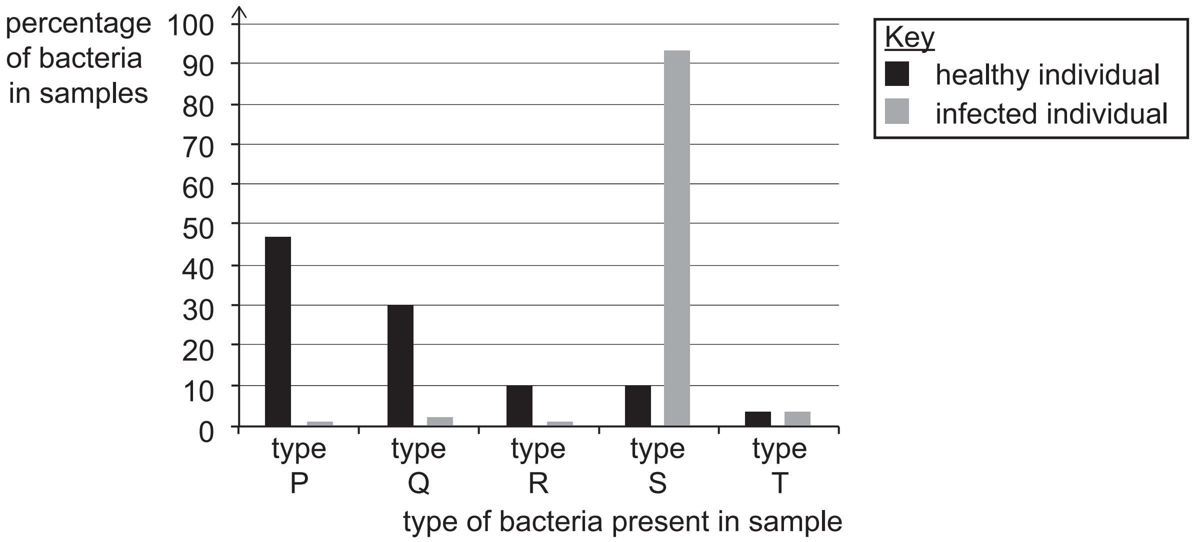
	efficiency of energy transfer x	*a reason for inefficiency of energy transfer from Q to R*
A	1%	energy lost as heat
B	1%	cellulose not digested
C	1%	some wavelengths of light not used
D	5%	energy lost as heat
E	5%	cellulose not digested
F	5%	some wavelengths of light not used

43 A number of patients in a hospital were infected with the same bacterial pathogen. The symptoms of this infection included pain in the abdomen, sickness and loss of appetite partly resulting from decreased production of acid in the stomach.

The bacteria present in their digestive systems were compared with those of healthy volunteers.

Samples were taken from each person and examined in order to identify the type of bacteria present and their relative proportions.

The results of the study are shown in the chart.



Which of the following statements could be correct?

1 Type S and type T feed on different biological molecules.

2 The DNA sequence of bacterial genes was used to classify the bacteria.

3 Type P, type Q and type R reduce in number because they require an alkaline environment.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

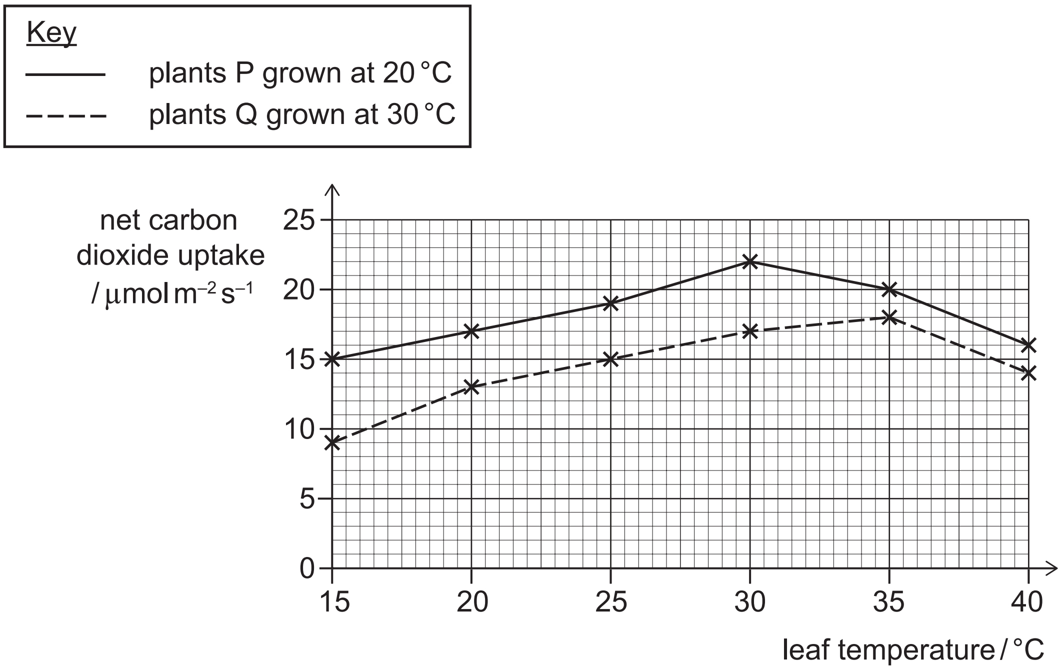
G 2 and 3 only

H 1, 2 and 3

44 A scientist studied one species of plant and grew some at 20 °C (plants P) and some at 30 °C (plants Q). All other variables were kept constant.

The scientist then placed plants from each group into six separate temperature-controlled cabinets, each at a different temperature. The plants were left for 15 minutes to adjust to their new temperature. The scientist then measured the rate of net carbon dioxide uptake by the leaves on the plants. All other variables were kept constant.

The results are shown in the graph.



Which of the following statements is/are correct?

1 At 35 °C, a 200 cm^2 leaf of plant P would take up 1.44×10^7 µmol of carbon dioxide in one hour.

2 Assuming that their respiration rates are the same, the rate of oxygen production in a leaf from plant P at 20 °C will be approximately equal to that in a leaf of the same size from plant Q at 30 °C.

3 The optimum temperature for maximum rate of photosynthesis in plant P must be 30 °C.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

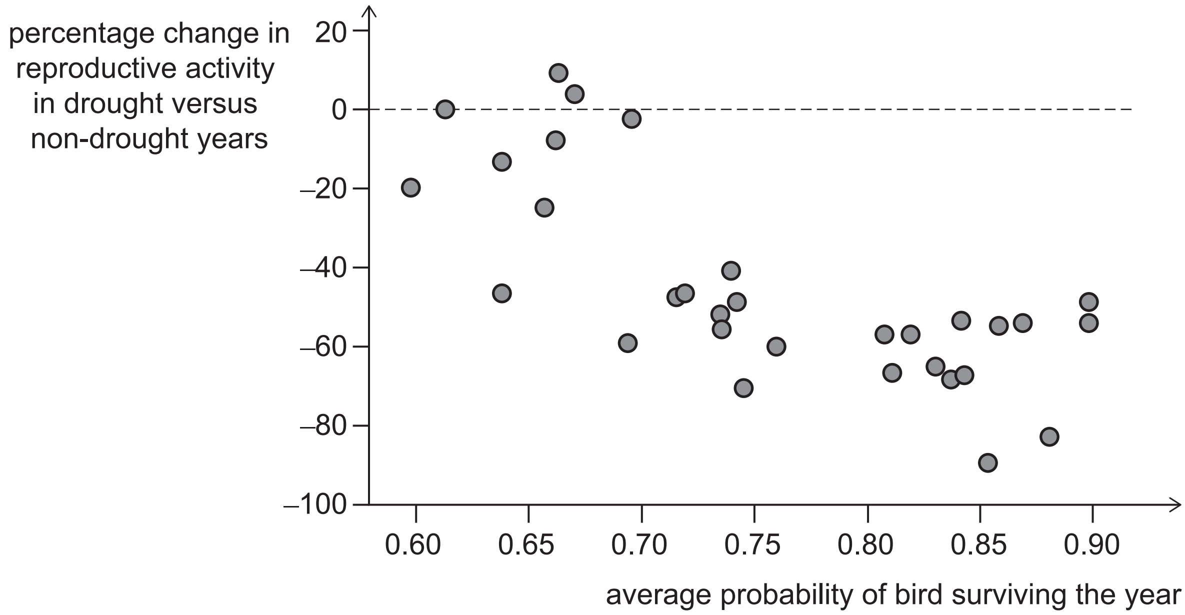
F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

45 A group of scientists studied the effect of droughts on the reproduction rate and lifespan of different species of birds.

The graph shows their results. Each data point refers to a different species.



Which of these statements is/are correct?

1 The overall trend for this data shows that birds with shorter life expectancies tended to change their reproduction rates less in drought years.

2 Some birds were found to reproduce more in drought years than in non-drought years.

3 These birds were being studied for the effect of a biotic factor on their population size.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

46 The average volume of a mammalian mitochondrion is $0.5\,\mu m^3$. The density of the enzymes within the mitochondria is 450 mg of enzymes per mm^3 of mitochondrial volume.

What is the mass, in mg, of enzyme inside an average mammalian mitochondrion, and how would a decrease in enzyme density within all mitochondria inside a cell change the rate of anaerobic respiration in the cell as a whole?

(Assume that the overall metabolic rate of the cell remains constant.)

	mass of enzyme inside an average mammalian mitochondrion / mg	*change in the rate of anaerobic respiration in the cell as a whole that may occur if the enzyme density decreases*
A	2.25×10^{-7}	decreases
B	2.25×10^{-7}	increases
C	2.25×10^{-3}	decreases
D	2.25×10^{-3}	increases
E	2.25×10^{-1}	decreases
F	2.25×10^{-1}	increases
G	2.25×10^{2}	decreases
H	2.25×10^{2}	increases

47 At a certain time, the percentage of oxygen carried in the blood entering the right atrium is 40% of its maximum capacity.

At this time, a section of a human pulmonary artery is 5 cm long and has a lumen diameter of 2.8 mm.

Another artery in the human body is the renal artery.

What is the volume of blood in this pulmonary artery section, and the oxygen level in the blood in the renal artery, at this time?

	volume of blood in the lumen of this pulmonary artery section / mm^3	*percentage of oxygen carried in the blood in the renal artery*
A	$5 \times (0.14)^2 \times \pi$	less than 40%
B	$50 \times (1.4)^2 \times \pi$	less than 40%
C	$2.8 \times (25)^2 \times \pi$	less than 40%
D	$5 \times (0.14)^2 \times \pi$	40%
E	$50 \times (1.4)^2 \times \pi$	40%
F	$5 \times (0.14)^2 \times \pi$	greater than 40%
G	$50 \times (1.4)^2 \times \pi$	greater than 40%
H	$2.8 \times (25)^2 \times \pi$	greater than 40%

48 A 1 cm^3 sample of blood was taken from an infected patient. This sample was added to saline solution to make a total volume of 50 cm^3.

This diluted sample was then viewed using a haemocytometer, a special microscope slide that allows the number of blood cells in a known volume to be counted. The volume analysed using the haemocytometer was 1.0×10^{-4} cm^3.

The type and number of cells counted is shown.

cell type	*number of cells*
mature red blood cell	12
white blood cell	4
bacterial cell	5

Using this data only, how many cells with nuclei were present in the 1 cm^3 sample from the patient?

A 4.0×10^4

B 9.0×10^4

C 1.6×10^5

D 2.0×10^6

E 4.5×10^6

F 6.0×10^6

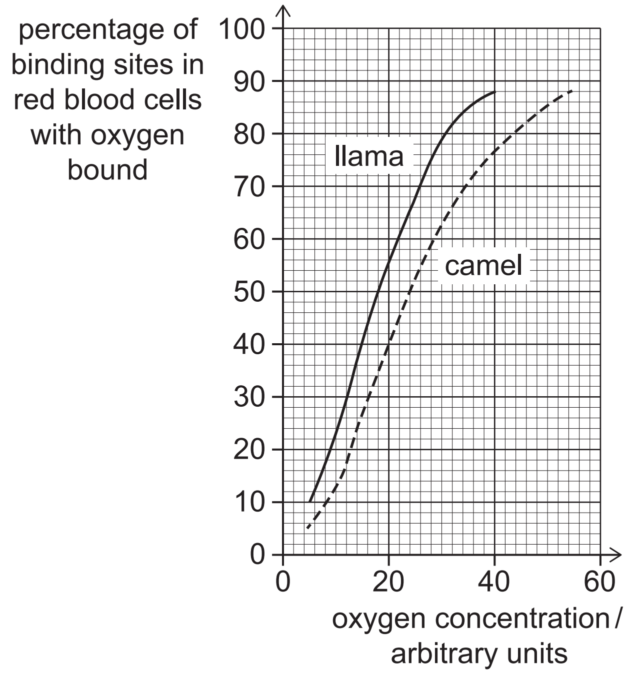
G 8.0×10^6

H 1.05×10^7

49 The oxygen saturation of red blood cells is the percentage of haemoglobin binding sites in red blood cells with oxygen bound to them.

Camels and llamas have evolved from the same ancestor. Camels live at low altitude and llamas live at high altitude.

The graph shows the effect of oxygen concentration on the oxygen saturation of red blood cells in camels and llamas.



Which of the following statements is/are correct?

1 The difference in oxygen binding properties of the red blood cells of camels and llamas is an example of different phenotypes.

2 The different oxygen binding properties evolved because of mutations caused by different oxygen concentrations.

3 50% oxygen saturation of llama red blood cells occurs at $\frac{3}{4}$ of the oxygen concentration required for 50% oxygen saturation of camel red blood cells.

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 Water in a particular plant moves from a high water potential to a low (more negative) water potential. Water potential is measured in MPa.

Which row correctly describes the most direct pathway for water movement into, through, and out of this plant?

	water potential in soil / MPa	*water potential in plant root* / MPa	*tissue in plant for water transport*	*water potential in leaf* / MPa	*water potential in atmosphere* / MPa	*a mechanism for water leaving the leaf*
A	−75	−1.5	xylem	−0.1	−0.033	diffusion
B	−0.033	−0.1	xylem	−1.5	−75	diffusion
C	−0.033	−0.1	phloem	−1.5	−75	diffusion
D	−75	−1.5	phloem	−0.1	−0.033	osmosis
E	−1.5	−75	phloem	−0.033	−0.1	osmosis
F	−0.033	−0.1	xylem	−1.5	−75	osmosis

51 On a cool spring day (day 1), a healthy human produces 1500 cm^3 of urine.

The concentration of urea in the urine was measured as 2.00 g per 100 cm^3.

On a similar day (day 2), the same person plays a game of hockey and produces 20% less urine. However, the mass of urea excreted in the urine remains the same.

The volume of urine produced is affected by the movement of water in the nephron.

Which row shows the urea concentration in the urine, in $g\,dm^{-3}$, on day 1 and day 2, and the explanation for the change in urine volume?

	urea concentration / $g\,dm^{-3}$		*explanation for change in urine volume*	
	day 1	*day 2*	*change in ADH (vasopressin)*	*change in water movement in the nephron*
A	20.0	16.7	decrease	decrease in secretion of water
B	20.0	16.7	increase	increase in reabsorption of water
C	20.0	25.0	decrease	decrease in secretion of water
D	20.0	25.0	increase	increase in reabsorption of water
E	30.0	25.0	decrease	decrease in secretion of water
F	30.0	25.0	increase	increase in reabsorption of water
G	30.0	36.0	decrease	decrease in secretion of water
H	30.0	36.0	increase	increase in reabsorption of water

52 A scientist conducts an experiment to study a single-celled organism in a growth tube.

The organism divides once every 50 minutes using binary fission. Binary fission produces the same number of daughter cells per division as a cell dividing by mitosis.

The scientist starts with 150 cells. The experiment is left for 300 minutes.

The average volume of every cell is $5\,\mu m^3$.

To ensure there are sufficient nutrients available for the cells, the final volume of cells within the tube must not be more than 1% of the total volume of material inside the tube.

What is the minimum volume of nutrient solution required inside the growth tube at the start of the experiment?

(Assume that all the cells are alive and capable of dividing.)

A $4.8 \times 10^{-3}\,mm^3$

B $9.5 \times 10^{-3}\,mm^3$

C $3.1 \times 10^{-1}\,mm^3$

D $4.8 \times 10^{-1}\,mm^3$

E $9.5 \times 10^{-1}\,mm^3$

F $9.5 \times 10^{2}\,mm^3$

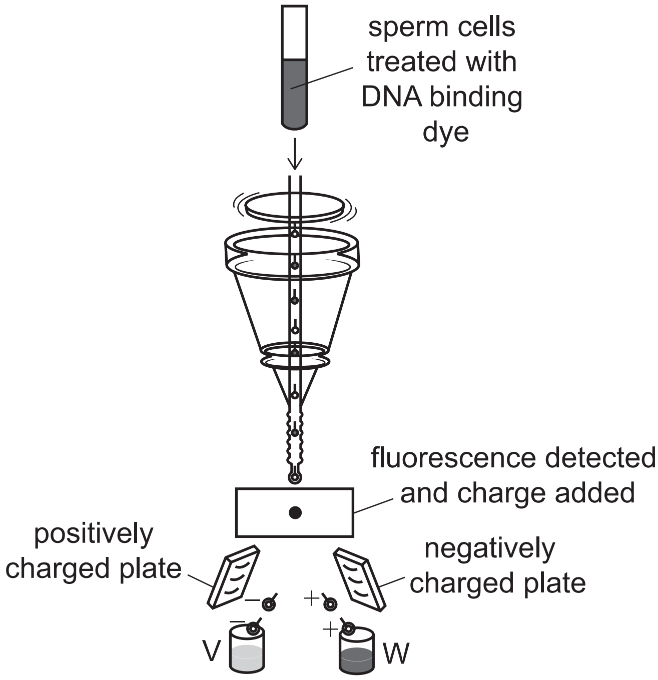
G $4.8 \times 10^{3}\,mm^3$

H $3.1 \times 10^{5}\,mm^3$

53 Sex determination in cows is identical to that in humans. To maximise productivity, dairy farmers want their cows to have female calves only.

Sperm cells can be sorted using their DNA content. This method is used to ensure the sex of calves born to dairy cows following artificial insemination. The method used is described below:

- The sperm cells are treated with a DNA binding dye.
- The greater the DNA content, the brighter the binding dye fluoresces.
- The brighter sperm cells are given a positive charge and the remaining sperm cells are given a negative charge.
- The charged sperm cells pass through a pair of charged plates and are attracted to the plate with the opposite charge.
- The sperm cells are collected in beakers below the plates.



Assume that all the separated sperm cells are alive and capable of fertilisation, no mutations have occurred, and the method of separation is 100% efficient.

Which of the following statements is/are correct?

1 Sperm cells in beaker V have fewer chromosomes.

2 For maximum productivity, dairy farmers should only use positively charged sperm cells.

3 The chance of obtaining a female calf using sperm cells from beaker W will be double that of using unseparated sperm cells.

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 In a sample of four healthy human cells, three rounds of division occur. After the three divisions, there are a total of 1472 chromosomes present in the sample.

The diploid number in human cells is 46.

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

1 The cells could all be fertilised eggs that divided by mitosis only.

2 The cell divisions could be two rounds of mitosis and then one round of complete meiosis.

3 If a single mutation occurred in one allele just before the second division in one cell, then the final percentage of the cells with this mutation would be 12.5%.

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 Samples of solution removed from different positions inside a nephron are analysed.

The rate of flow of the solution through the nephron is measured at each position where the samples are taken.

The rate of flow is the volume of solution passing a particular point per unit time.

In the Bowman's capsule, the concentration of sodium ions is the same as in the blood. The rate of flow is 100 arbitrary units.

At the collecting duct, the concentration of sodium ions is twice that in the blood. The rate of flow is 1 arbitrary unit.

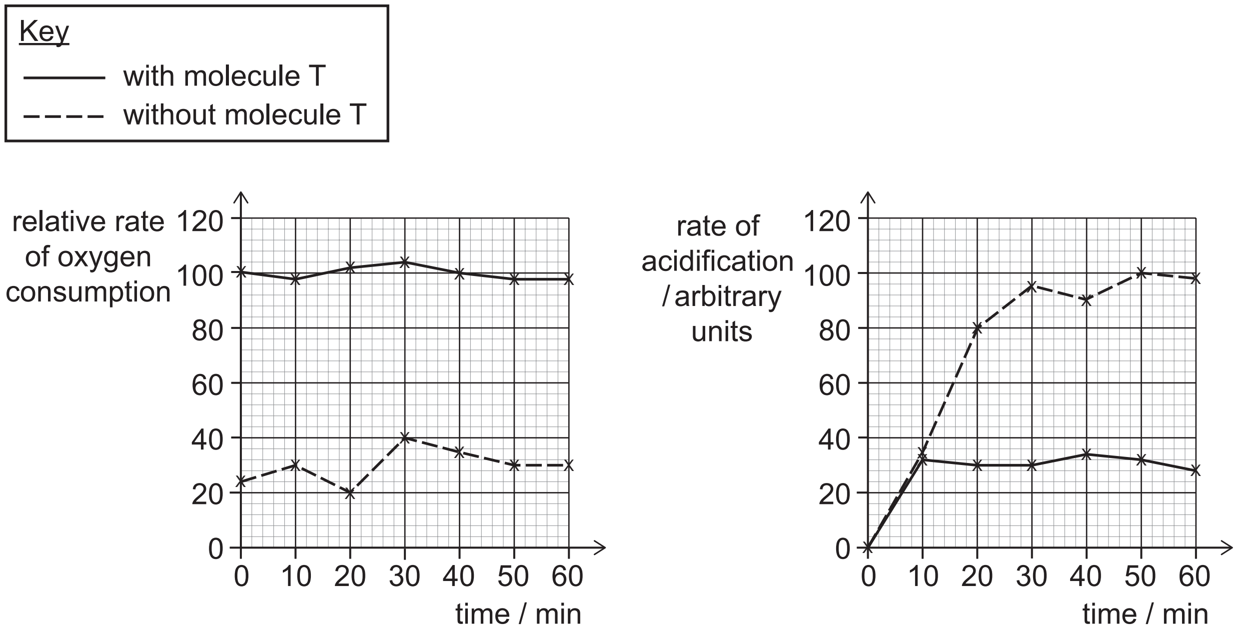
Which row in the table is correct?

	percentage sodium ions reabsorbed in the nephron	*a process by which sodium ions can be reabsorbed from the nephron*
A	2%	active transport
B	2%	diffusion
C	50%	osmosis
D	50%	diffusion
E	98%	active transport
F	98%	osmosis

56 Mutations can occur in the genes coding for some of the enzymes that catalyse respiration reactions. This can result in mitochondria that do not function correctly.

Scientists studying this tested a molecule, T, for its ability to restore the function to these mitochondria in human cells.

The graphs show the rate of oxygen consumption, measured relative to the percentage of healthy mitochondria, and the rate of acidification of the cellular environment, over time.



Which of the following statements is/are correct?

1 Molecule T could reduce the rate of lactic acid production in the cells.

2 Between 20 and 30 minutes, the oxygen consumption rate without molecule T increases by 50%.

3 The concentration gradient for oxygen between the cell cytoplasm and the mitochondria is steeper with molecule T compared to without molecule T.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

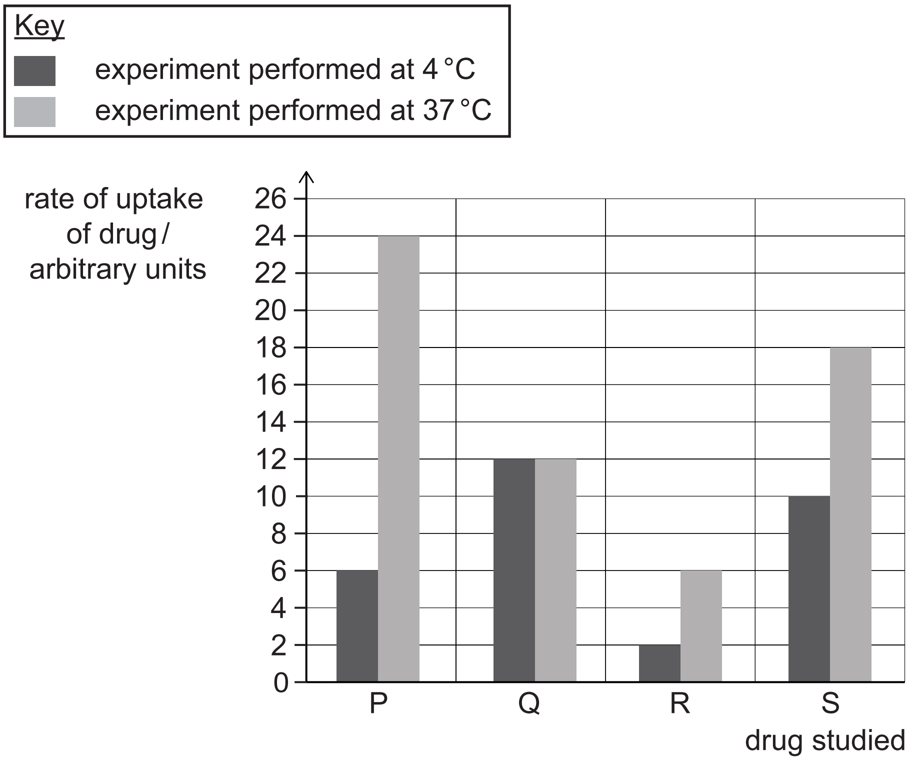
F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

57 Scientists studied the processes by which drugs cross the cell membrane and enter cells.

The rate of uptake of four drugs, P, Q, R and S, was studied at 4 °C and at 37 °C. The results are shown in the chart. All other variables were kept constant.



Which of the following conclusions can be drawn from the results?

1 The percentage increase in rate of uptake of R from 4 °C to 37 °C is 2.5 times more than the percentage increase in the rate of uptake of S.

2 The concentration of Q must be the same inside and outside the cell.

3 P must be transported across the cell membrane using active transport only.

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 Commercial varieties of tomato are produced from wild varieties of tomato.

The genetic diversity of tomatoes can be measured and expressed as a number.

A population of wild varieties of tomato was found to have a genetic diversity of 0.30.

The table shows the genetic diversity of a population of commercial tomatoes grown at different times.

year	*genetic diversity*
pre-1960	0.10
1960	0.05
1980	0.20
2000	0.30

Which of the following statements about these tomatoes could be correct?

1 Selective breeding of tomatoes occurred before 1960.

2 The addition of genetic material, enabling the tomatoes to produce memory cells so that they are resistant to diseases, increased the genetic diversity from 1960 onwards.

3 The average rate of increase in genetic diversity per day between 1960 and 2000 is approximately $\frac{25}{1\,460\,000}$.

4 The increase in genetic diversity was 50% greater during the 1960 to 1980 period than the 1980 to 2000 period.

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 1, 2 and 3 only

G 1, 3 and 4 only

H 2, 3 and 4 only

59 A mathematical test can be used to determine whether there is a statistically significant difference between the expected and the observed number of individuals with each phenotype in a population.

The value required for this test is calculated using the following expression:

$$\frac{(\text{observed} - \text{expected})^2}{\text{expected}} + \ldots + \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

where each term uses the observed number of individuals and expected number of individuals with each phenotype in turn.

In a monohybrid cross between two individuals that showed the same phenotype, 160 offspring were produced. 36 of these offspring showed a different phenotype to both parents for the same characteristic.

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

Which of the following expressions calculates the value required for the mathematical test for this cross?

(Assume no mutations and that no genotype results in the death of individuals.)

A $\frac{4}{120} + \frac{4}{40}$

B $\frac{4}{124} + \frac{4}{36}$

C $\frac{16}{120} + \frac{16}{40}$

D $\frac{16}{124} + \frac{16}{36}$

E $\frac{32}{160}$

F $\frac{44}{124} + \frac{44}{36}$

G $\left(\frac{44^2}{80}\right) + \left(\frac{44^2}{80}\right)$

H $\left(\frac{44^2}{124}\right) + \left(\frac{44^2}{36}\right)$

60 An investigation was carried out to discover the evolutionary relationships between three different species of mammal, a human, a monkey and a hedgehog, as shown in the flow diagram:

Stage 1	→	Stage 2	→	Stage 3
Some human blood was injected into a rabbit. The rabbit's white blood cells produced antibodies that reacted with the human blood.	→	Some of the rabbit's blood was removed and divided into three samples.	→	One sample of rabbit blood was mixed with human blood. The second sample was mixed with monkey blood and the third sample was mixed with hedgehog blood. The amount of precipitate formed for each mixture of blood was measured.

When an antigen binds to an antibody, a precipitate is formed, which is measured in stage 3.

Some of the results for stage 3 are shown in the table.

P and Q each represent one of the non-human mammals.

species of mammal	*amount of precipitate formed* / arbitrary units
P	58
Q	17

Which row is correct for this investigation?

	biological molecules that form antibodies in stage 1	*the amount of precipitate formed for the sample with human blood in stage 3* / arbitrary units	*species Q*
A	amino acids	greater than 58	monkey
B	amino acids	greater than 58	hedgehog
C	amino acids	less than 17	monkey
D	amino acids	less than 17	hedgehog
E	nucleotides	greater than 58	monkey
F	nucleotides	greater than 58	hedgehog
G	nucleotides	less than 17	monkey
H	nucleotides	less than 17	hedgehog

Cambridge Assessment
Admissions Testing

NSAA Section 1 Answer Key

TZ1	Answer_key	Part		TZ1	Answer_key	Part
Q1	E	MATH		Q41	F	CHEM
Q2	B	MATH		Q42	C	CHEM
Q3	D	MATH		Q43	B	CHEM
Q4	A	MATH		Q44	E	CHEM
Q5	C	MATH		Q45	D	CHEM
Q6	E	MATH		Q46	E	CHEM
Q7	A	MATH		Q47	F	CHEM
Q8	F	MATH		Q48	D	CHEM
Q9	D	MATH		Q49	C	CHEM
Q10	E	MATH		Q50	E	CHEM
Q11	F	MATH		Q51	B	CHEM
Q12	D	MATH		Q52	C	CHEM
Q13	F	MATH		Q53	A	CHEM
Q14	E	MATH		Q54	E	CHEM
Q15	B	MATH		Q55	A	CHEM
Q16	G	MATH		Q56	B	CHEM
Q17	A	MATH		Q57	C	CHEM
Q18	F	MATH		Q58	F	CHEM
Q19	H	MATH		Q59	E	CHEM
Q20	F	MATH		Q60	A	CHEM
Q21	B	PHYS		Q61	F	BIOL
Q22	E	PHYS		Q62	B	BIOL
Q23	F	PHYS		Q63	B	BIOL
Q24	A	PHYS		Q64	D	BIOL
Q25	G	PHYS		Q65	C	BIOL
Q26	F	PHYS		Q66	H	BIOL
Q27	C	PHYS		Q67	D	BIOL
Q28	D	PHYS		Q68	G	BIOL
Q29	E	PHYS		Q69	B	BIOL
Q30	H	PHYS		Q70	A	BIOL
Q31	B	PHYS		Q71	A	BIOL
Q32	G	PHYS		Q72	D	BIOL
Q33	C	PHYS		Q73	H	BIOL
Q34	E	PHYS		Q74	C	BIOL
Q35	D	PHYS		Q75	B	BIOL
Q36	B	PHYS		Q76	E	BIOL
Q37	C	PHYS		Q77	C	BIOL
Q38	D	PHYS		Q78	A	BIOL
Q39	G	PHYS		Q79	A	BIOL
Q40	E	PHYS		Q80	D	BIOL

NSAA Section 2 Answer Key

TZ1	Answer_key	Part		TZ1	Answer_key	Part
Q1	D	PHYS		Q41	E	BIOL
Q2	C	PHYS		Q42	D	BIOL
Q3	G	PHYS		Q43	E	BIOL
Q4	D	PHYS		Q44	C	BIOL
Q5	F	PHYS		Q45	E	BIOL
Q6	A	PHYS		Q46	B	BIOL
Q7	D	PHYS		Q47	G	BIOL
Q8	B	PHYS		Q48	D	BIOL
Q9	D	PHYS		Q49	F	BIOL
Q10	C	PHYS		Q50	B	BIOL
Q11	E	PHYS		Q51	D	BIOL
Q12	F	PHYS		Q52	A	BIOL
Q13	C	PHYS		Q53	G	BIOL
Q14	E	PHYS		Q54	H	BIOL
Q15	H	PHYS		Q55	E	BIOL
Q16	E	PHYS		Q56	F	BIOL
Q17	G	PHYS		Q57	B	BIOL
Q18	C	PHYS		Q58	G	BIOL
Q19	A	PHYS		Q59	C	BIOL
Q20	C	PHYS		Q60	B	BIOL
Q21	C	CHEM				
Q22	B	CHEM				
Q23	C	CHEM				
Q24	F	CHEM				
Q25	D	CHEM				
Q26	B	CHEM				
Q27	A	CHEM				
Q28	D	CHEM				
Q29	D	CHEM				
Q30	E	CHEM				
Q31	E	CHEM				
Q32	G	CHEM				
Q33	C	CHEM				
Q34	F	CHEM				
Q35	B	CHEM				
Q36	E	CHEM				
Q37	D	CHEM				
Q38	H	CHEM				
Q39	F	CHEM				
Q40	C	CHEM				