NATURAL SCIENCES **D568/11**
ADMISSIONS ASSESSMENT

Wednesday 30 October 2019 **80 minutes**

SECTION 1

INSTRUCTIONS TO CANDIDATES

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

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

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

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

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

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

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

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

Each part has 18 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **three** parts. Each question is worth one mark.

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

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

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

Dictionaries and calculators are NOT permitted.

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

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

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Paper content

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PART A Mathematics

1   Evaluate

$$\left(\sqrt{7}+\sqrt{3}\right)^2 - \left(\sqrt{7}-\sqrt{3}\right)^2$$

A   0

B $2\sqrt{7}$

C $4\sqrt{7}$

D $2\sqrt{21}$

E   10

F $4\sqrt{21}$

G   20

2   Find the complete set of values of x which satisfy the inequality

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

A $x < -22$

B $x > -22$

C $x < -2.5$

D $x > -2.5$

E $x < 1.2$

F $x > 1.2$

G $x < 10$

H $x > 10$

3 The equation gives y in terms of x:

$$y = 3 - 4\left(1 - \frac{x}{2}\right)^2$$

Which one of the following is a rearrangement for x in terms of y?

A $\quad x = -2 \pm 2\sqrt{\dfrac{3-y}{4}}$

B $\quad x = -2 \pm 2\sqrt{\dfrac{4-y}{3}}$

C $\quad x = 1 \pm \sqrt{\dfrac{3-y}{4}}$

D $\quad x = 1 \pm 2\sqrt{\dfrac{3-y}{4}}$

E $\quad x = 2 \pm 2\sqrt{\dfrac{3-y}{4}}$

F $\quad x = 2 \pm 2\sqrt{\dfrac{4-y}{3}}$

G $\quad x = 2 \pm 2\sqrt{\dfrac{3+y}{4}}$

4 The resistance to the motion of a car is directly proportional to the square of the speed of the car.

The car increases its speed by 20%.

What is the percentage increase in the resistance to the motion of the car?

A 20%

B 24%

C 44%

D 120%

E 224%

F 240%

G 400%

5 The equation of a curve is $y = px^2 + qx$ where p and q are constants.

The curve passes through the points $(2, 6)$ and $(4, -4)$.

What is the value of $q - p$?

A 1

B 2

C 5

D 6

E 9

F 16

6 Which of the following is a simplification of

$$4 - \frac{x(3x+1)}{x^2(3x^2 - 2x - 1)}$$

A $\dfrac{12x^3 - 8x^2 - 7x - 1}{x(3x-1)(x-1)}$

B $\dfrac{4x^2 + 4x - 1}{x(x+1)}$

C $\dfrac{4x^2 + 4x + 1}{x(x+1)}$

D $\dfrac{4x^2 - 4x - 1}{x(x-1)}$

E $\dfrac{4x^2 - 4x + 1}{x(x-1)}$

F $\dfrac{12x^3 - 8x^2 - x + 1}{x(3x-1)(x-1)}$

7 The ball for a garden game is a solid sphere of volume $192\,\text{cm}^3$.

For the children's version of the game the ball is a solid sphere made of the same material, but the radius is reduced by 25%.

What is the volume, in cm^3, of the children's ball?

A 48

B 81

C 96

D 108

E 144

8 The diagram shows a right-angled triangle, with sides of length $x + 4$, $2x + 2$ and $3x$, all in cm.
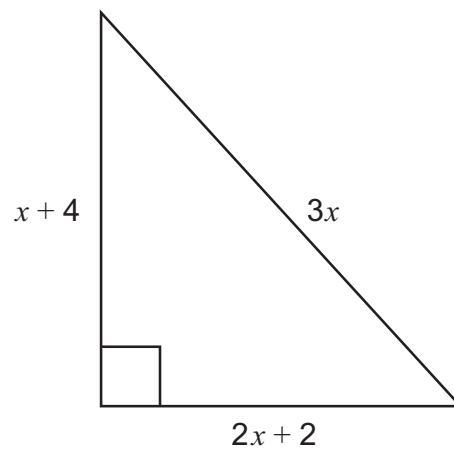
[diagram not to scale]

What is the area, in cm^2, of the triangle?

A 10

B 12

C 28

D 36

E 40

F 54

G 70

9 Given that

$$9^{2x-1} \times \frac{1}{27^x} = 81^x$$

what is the value of x?

A $-\dfrac{2}{3}$

B $-\dfrac{2}{5}$

C $-\dfrac{1}{3}$

D $-\dfrac{1}{4}$

E $-\dfrac{1}{5}$

10 *PR* and *QS* are the diagonals of a rhombus *PQRS*.

PR = $(3x + 2)$ cm

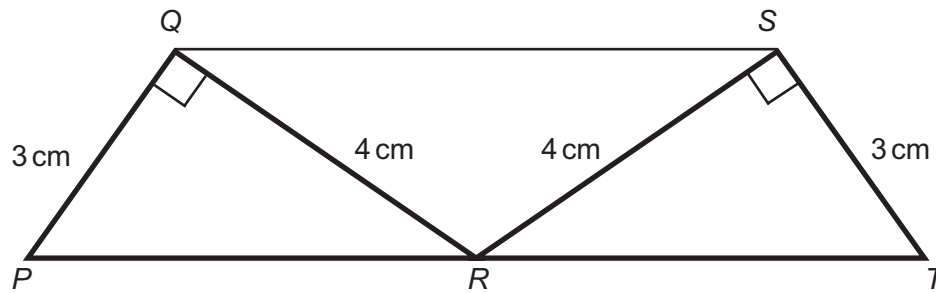*QS* = $(8 - 2x)$ cm

The area of *PQRS* is 11 cm².

What is the difference, in cm, between the two possible lengths of *PR*?

A $2\dfrac{2}{3}$

B $4\dfrac{1}{2}$

C $5\dfrac{1}{3}$

D 8

E 14

11

[diagram not to scale]

The diagram shows two congruent right-angled triangles *PQR* and *TSR* with right angles at *Q* and *S*, respectively.

PQ = *TS* = 3 cm

QR = *SR* = 4 cm

PRT is a straight line.

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

A   4

B $3\sqrt{2}$

C   5.2

D $4\sqrt{2}$

E   6.4

F   8.2

G   10

12 The total of three numbers p, q and r is 375

The ratio $p:q$ is $5:7$

The ratio $q:r$ is $4:11$

What is the value of $p + r$?

A 16

B 60

C 97

D 125

E 144

F 231

G 291

H 315

13 The straight line *P* has equation $3y - 2x = 12$ and intercepts the y-axis at the point $(0, p)$.

The straight line *Q* is parallel to *P*, passes through the point $(6, -1)$ and intercepts the y-axis at the point $(0, q)$.

What is the value of $p - q$?

A -9

B -7

C 1

D 9

E 14

F 17

14 The vertices of a rectangle have coordinates:

$$P(4,5) \qquad Q(4,8) \qquad R(10,8) \qquad S(10,5)$$

PQRS is transformed by a clockwise rotation of 90° about *P* followed by a reflection in the *x*-axis.

What are the coordinates of the final position of *R*?

A $(-8,-10)$

B $(-7,-1)$

C $(-4,1)$

D $(-1,11)$

E $(1,-11)$

F $(4,-1)$

G $(7,1)$

H $(8,10)$

15 Box A contains exactly 10 balls, of which 6 are red and 4 are blue.

Box B contains exactly 15 balls, of which 3 are red and 12 are blue.

All the balls are identical in every respect, apart from colour.

One of the two boxes is chosen at random by tossing two fair coins, as follows:

"If **both** coins show heads, box A is selected. Otherwise box B is selected."

One ball is then randomly taken from the selected box.

What is the probability that a red ball is taken?

A $\dfrac{9}{400}$
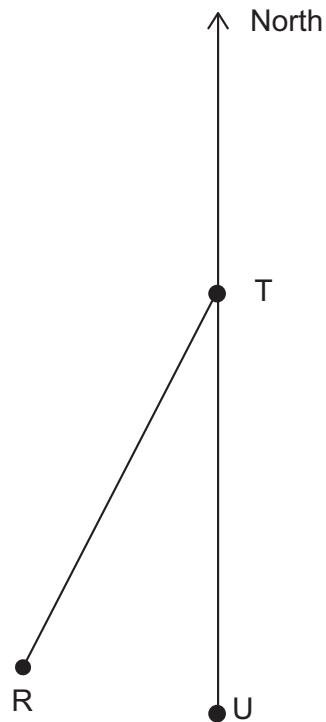
B $\dfrac{3}{25}$

C $\dfrac{3}{10}$

D $\dfrac{2}{5}$

E $\dfrac{1}{2}$

F $\dfrac{4}{5}$

G $\dfrac{323}{400}$

16 Three towns Ryeton, Tonbridge and Uphampton are represented on the diagram by the points labelled R, T and U, respectively.

[diagram not to scale]

The distance from Tonbridge to Ryeton is the same as the distance from Tonbridge to Uphampton.

Uphampton is south of Tonbridge.

Ryeton is on a bearing of 210° from Tonbridge.

What is the bearing of Uphampton from Ryeton?

A 030°

B 075°

C 105°

D 150°

E 300°

F 345°

17 A list of five numbers has mean x, median y and range z.

A sixth number is added to the list. This sixth number is greater than x.

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

    1   The median of the six numbers cannot be one of the numbers in the list.

    2   The mean of the six numbers is greater than x.

    3   The range of the six numbers is greater than z.

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

18

12 cm

h
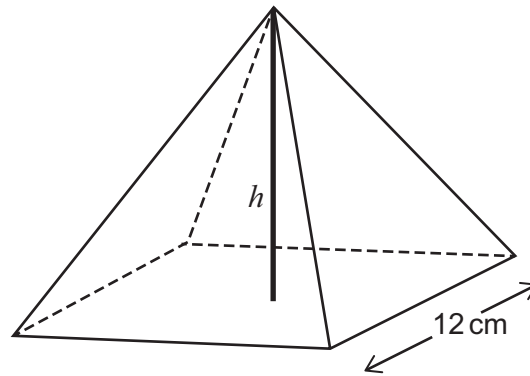
[diagram not to scale]

A solid pyramid has a square base of side length 12 cm and a vertical height of h cm.

The volume of the pyramid, in cm³, is equal to the total surface area of the pyramid, in cm².

What is the value of h?

(volume of pyramid $= \dfrac{1}{3} \times$ area of base $\times$ vertical height)

A $\quad \dfrac{72}{35}$

B $\quad 2\sqrt{3}$

C $\quad 6$

D $\quad \dfrac{144}{23}$

E $\quad 8$

F $\quad 2\sqrt{21}$

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PART B Physics

19 A transverse wave is travelling through a medium. The distance between successive wave peaks is 8.4 cm and the total distance travelled by a particle during one complete oscillation is 5.6 cm.

What is the amplitude and wavelength of the wave?

	amplitude / cm	wavelength / cm
A	1.4	4.2
B	1.4	8.4
C	2.1	2.8
D	2.1	5.6
E	2.8	4.2
F	2.8	8.4
G	4.2	2.8
H	4.2	5.6

20 A builder lifts bags of cement onto the back of a lorry. Each bag has a mass of 25 kg. It takes the builder 2.5 minutes to load ten bags.

1.5 m

bag of cement

25 kg

2.0 m
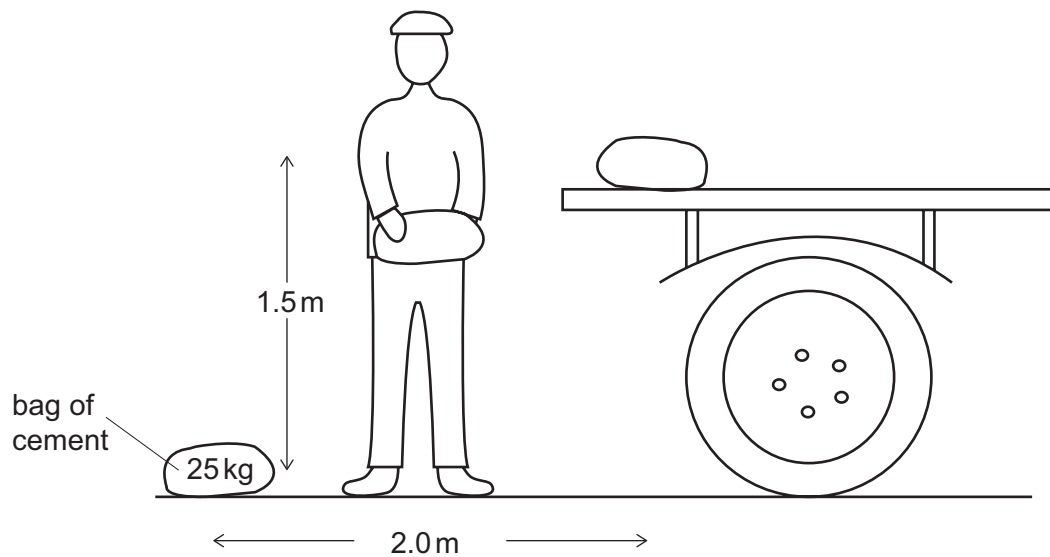
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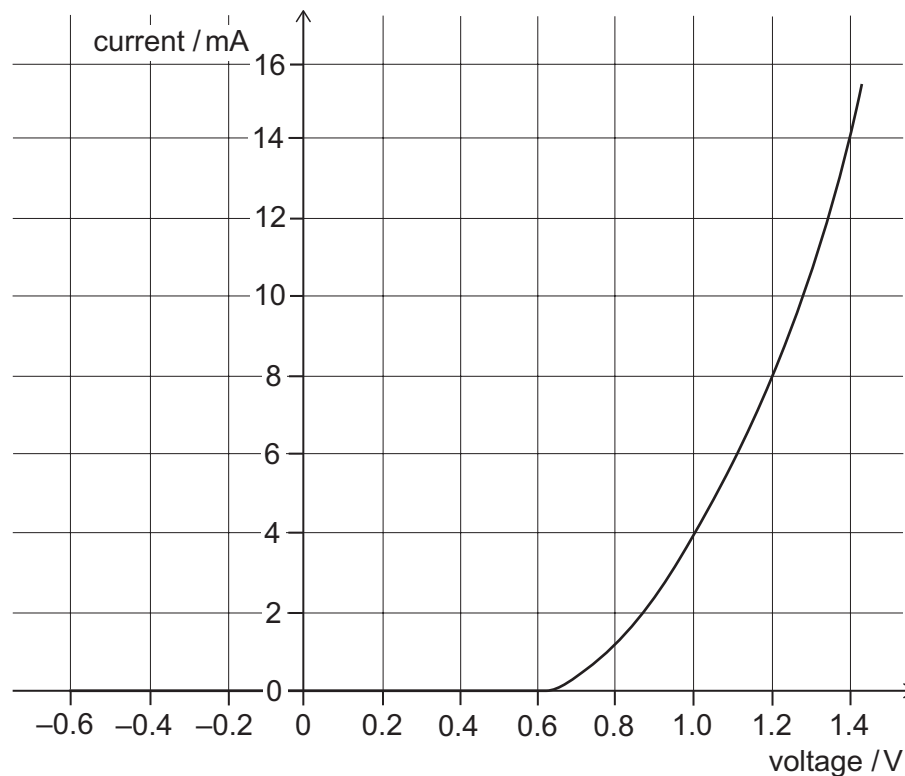
What are the total work done, *T*, on the ten bags and the average power required for *T*?

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

	total work done *T* / J	average power / W
A	375	2.5
B	375	150
C	625	4.2
D	625	250
E	3750	25
F	3750	1500
G	6250	42
H	6250	2500

21

21 The current–voltage graph for a diode is shown.

The diode is connected in series with a resistor and a 6.0 V battery. The current in the circuit is 8.0 mA.

What is the resistance of the resistor?

(Assume that the battery has negligible resistance.)

A 0.15 Ω

B 0.60 Ω

C 0.75 Ω

D 4.8 Ω

E 150 Ω

F 600 Ω

G 750 Ω

22 Two electromagnetic waves P and Q travel in a vacuum and the ratio of their wavelengths is:

$$\frac{\text{wavelength of P}}{\text{wavelength of Q}} = 1.0 \times 10^8$$

Which row in the table shows the ratio of their speeds, the ratio of their frequencies, and identifies the possible natures of P and Q?

	$\dfrac{speed\ of\ \text{P}}{speed\ of\ \text{Q}}$	$\dfrac{frequency\ of\ \text{P}}{frequency\ of\ \text{Q}}$	nature of P	nature of Q
A	1.0	1.0×10^{-8}	microwave	X-ray
B	1.0	1.0×10^{-8}	microwave	radio wave
C	1.0	1.0×10^{8}	infrared	ultraviolet
D	1.0	1.0×10^{8}	visible light	infrared
E	1.0×10^{8}	1.0	gamma	X-ray
F	1.0×10^{8}	1.0	gamma	infrared
G	1.0×10^{8}	1.0×10^{16}	infrared	radio wave
H	1.0×10^{8}	1.0×10^{16}	visible light	ultraviolet

23 A block of aluminium of mass 0.80 kg, initially at a temperature of $-21\,°C$, is supplied with 54 000 J of thermal energy.

The specific heat capacity of aluminium is $900\,J\,kg^{-1}\,°C^{-1}$.

What is the final temperature of the block?

(Assume that there is no other transfer of energy between the block and the surroundings.)

A 27 °C

B 39 °C

C 54 °C

D 75 °C

E 96 °C

24 A light spring is used to support a range of loads.

The spring obeys Hooke's law. The system is in equilibrium.

Which of the following statements is/are correct?

1 The tension in the spring is directly proportional to the length of the spring.

2 The tension in the spring and the weight of the load it supports are a Newton's third law pair of forces.

3 When the extension of the spring is doubled, the energy stored in the spring increases by a factor of four.

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

25 A water-tight cylinder with a thin, freely moving piston contains $2.0 \times 10^{-3}\,\text{m}^3$ of trapped air at atmospheric pressure of $1.0 \times 10^5\,\text{Pa}$.

When the cylinder is submerged in water of constant density $1000\,\text{kg}\,\text{m}^{-3}$, the volume of air in the cylinder decreases to $4.0 \times 10^{-4}\,\text{m}^3$.

The piston is at a depth h below the surface of the water and the water surface is open to the atmosphere.

What is the depth h?

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

A 40 m

B 50 m

C 60 m

D 400 m

E 500 m

F 600 m

26 The secondary coil of an ideal, 100% efficient transformer is connected to a resistor by cables of total resistance $1500\,\Omega$. The current in the primary coil is $4.0\,\text{A}$. There are 240 turns in the primary coil and 4800 turns in the secondary coil.

What is the power produced as heat in the cables?

A 60 W

B 300 W

C 6000 W

D 24 000 W

E 120 000 W

F 9 600 000 W

27 Heat is supplied to an initially solid substance at a rate of 60 W.

The graph shows the variation of the temperature of the substance with time.
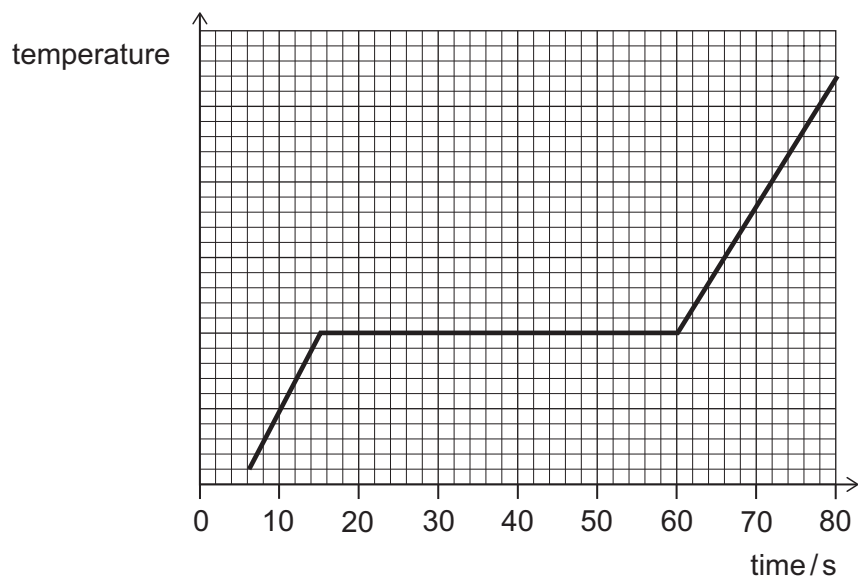
What is the mass of the substance?

(specific latent heat of fusion of substance $= 100\,\mathrm{J\,g^{-1}}$; assume that there is no heat transferred to the surroundings)

A 0.013 g

B 0.60 g

C 3.0 g

D 9.0 g

E 27 g

F 36 g

28 Two tanks of water are connected by a solid cylindrical copper bar of length l and diameter d.

The bar is insulated.

One tank contains water at 90 °C and the other tank contains water at temperature θ.
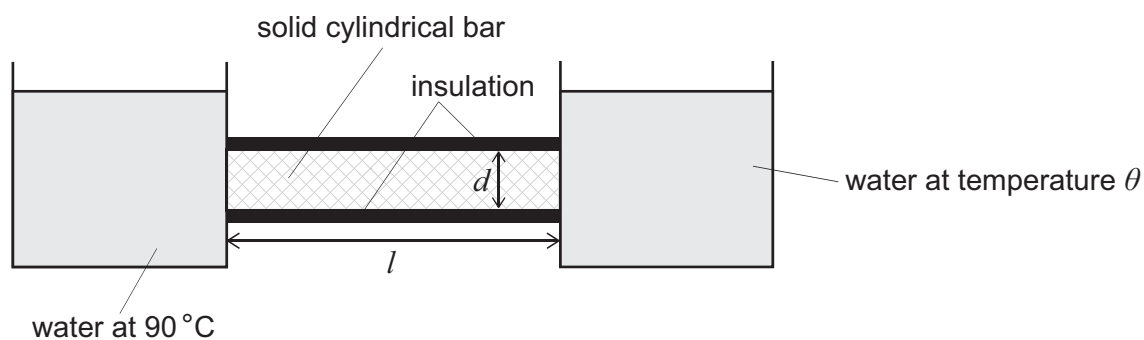
For which of the following conditions is thermal energy conducted along the bar at the lowest rate?

	l / m	d / cm	θ / °C
A	0.40	4.0	20
B	0.40	4.0	40
C	0.40	8.0	20
D	0.40	8.0	40
E	0.80	4.0	20
F	0.80	4.0	40
G	0.80	8.0	20
H	0.80	8.0	40

29 A U-shaped permanent magnet rests on a balance.

A straight, horizontal wire of length 5.0 cm is fixed in position between the poles of the magnet, perpendicular to the horizontal magnetic field.

There is a current of 2.0 A in the wire and the reading on the balance is 202 g.

When the direction of the 2.0 A current is reversed, the reading changes to 198 g.

What is the strength of the magnetic field?

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

A   0.020 T

B   0.040 T

C   0.20 T

D   0.40 T

E   200 T

F   400 T

30 The radioactive isotope X becomes the stable isotope Y after a succession of decays involving only the emission of alpha and beta (β^-) particles.

During the decay of one nucleus from X to Y, a total of seven particles are emitted. It is known that more of these particles are alpha particles than beta particles.

The atomic number of X is Z and the mass number of X is A.

Which row in the table could give the atomic number and the mass number of Y?

	atomic number of Y	mass number of Y
A	$Z - 2$	$A - 12$
B	$Z - 5$	$A - 8$
C	$Z - 8$	$A - 20$
D	$Z - 10$	$A - 24$
E	$Z - 11$	$A - 16$

31 The kinetic energy of an object of mass 4.0 kg, travelling in a straight line, increases from 32 J to 200 J in 3.0 seconds due to a constant resultant force.

What is the value of this resultant force?

A 2.0 N

B 4.0 N

C 8.0 N

D 24 N

E 28 N

F 56 N

32 In the following circuit, all five resistors have the same resistance.
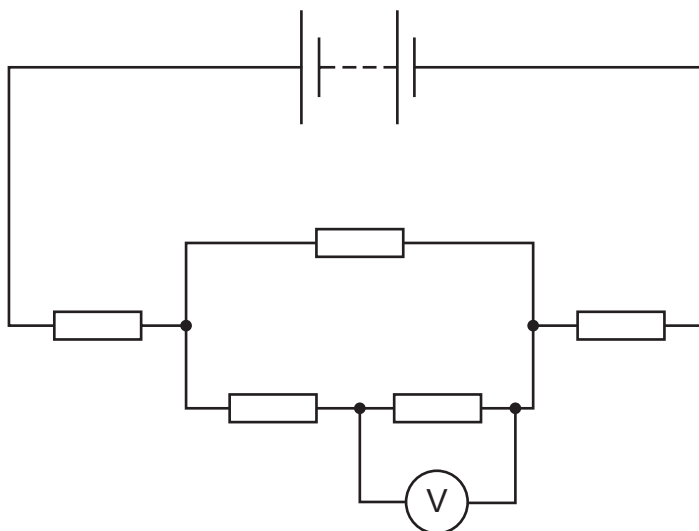
The reading on the voltmeter is 1.0 V.

What is the voltage across the battery?

A 4.0 V

B 5.0 V

C 6.0 V

D 7.0 V

E 8.0 V

F 9.0 V

G 10 V

33 Two hovercraft travel horizontally in opposite directions along the same straight line. The mass and speed of each hovercraft are shown in the diagram. Horizontal resistive forces acting on each hovercraft are negligible.

hovercraft M
mass 1000 kg
speed 20 m s⁻¹ ⟶

hovercraft N
mass 2000 kg
⟵ speed 10 m s⁻¹
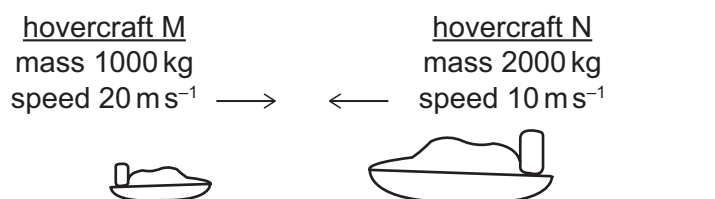
The hovercraft collide and stick together. The collision lasts for 0.10 s.

Just before the collision, what is the total kinetic energy and the magnitude of the total momentum of the two hovercraft, and what is the magnitude of the average force acting horizontally on each hovercraft during the collision?

	total initial kinetic energy / kJ	total initial momentum / kg m s⁻¹	average force on each hovercraft / kN
A	100	0	2.0
B	100	0	200
C	100	4.0×10^4	2.0
D	100	4.0×10^4	200
E	300	0	2.0
F	300	0	200
G	300	4.0×10^4	2.0
H	300	4.0×10^4	200

34 The graph shows how a car's velocity changes in 85 seconds.
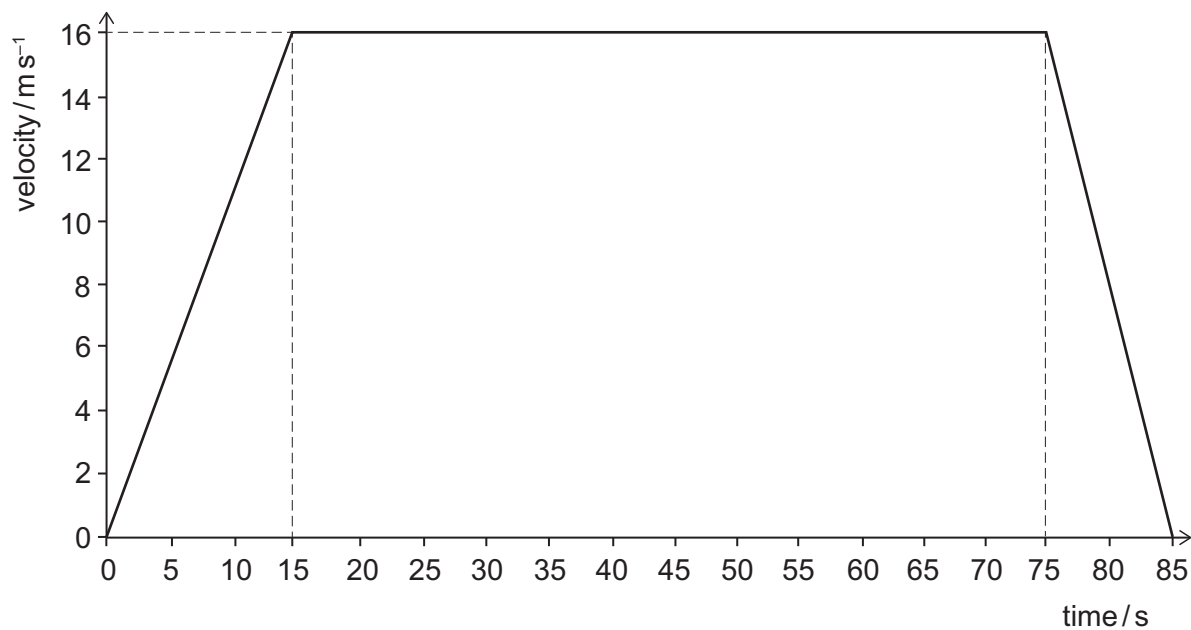
What proportion of the total distance is travelled at constant velocity?

A $\dfrac{5}{29}$

B $\dfrac{5}{17}$

C $\dfrac{12}{17}$

D $\dfrac{24}{29}$

E $\dfrac{8}{9}$

F $\dfrac{16}{17}$

35 A block is designed with a cylindrical channel to accommodate a hot-water pipe. The block is 100 cm long and it has a square cross-section of side 22.0 cm with a cylindrical hole in the middle, as shown in the diagram:
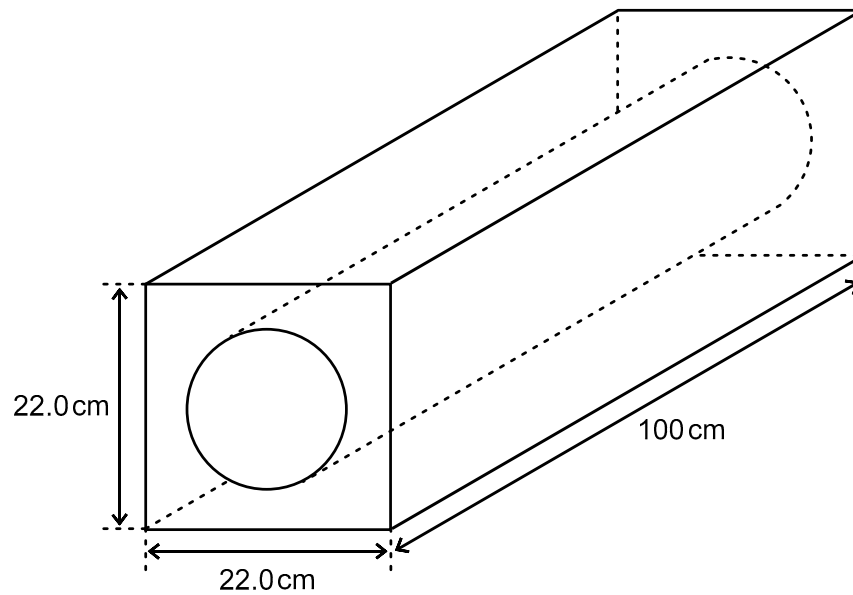
[diagram not to scale]

The diameter of the cylindrical hole is 14.0 cm and the density of the material from which the block is made is 0.100 g cm^{-3}.

What is the mass of the block?

(take π to be $\dfrac{22}{7}$)

A 1.32 kg

B 3.30 kg

C 13.2 kg

D 33.0 kg

E 132 kg

F 330 kg

G 1320 kg

H 3300 kg

36   A sample initially contains equal numbers of atoms of a radioactive isotope X and a stable isotope Y.

Isotope X has a half-life of 3 years and decays in a single stage to the stable isotope Y.

What is the ratio

number of atoms of X **:** *number of atoms of* Y

in the sample 6 years later?

A   The sample contains only isotope Y.

B   1**:**7

C   1**:**4

D   1**:**3

E   7**:**4

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PART C Chemistry

37 HBr reacts with pent-2-ene in an addition reaction.

Which of the following products is/are formed in the reaction?

   1 $CH_3CHBrCH_2CH_2CH_3$

   2 $CH_2BrCH_2CH_2CH_2CH_3$

   3 $CH_3CH_2CHBrCH_2CH_3$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

38 In which of the following solids does the bonding consist of single covalent bonds **only**?

   1 graphite

   2 SiO_2

   3 Al_2O_3

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

39 Four samples, labelled W, X, Y and Z, were investigated using paper chromatography with a solvent that caused any mixtures present to be fully separated. The results are shown in the chromatogram.
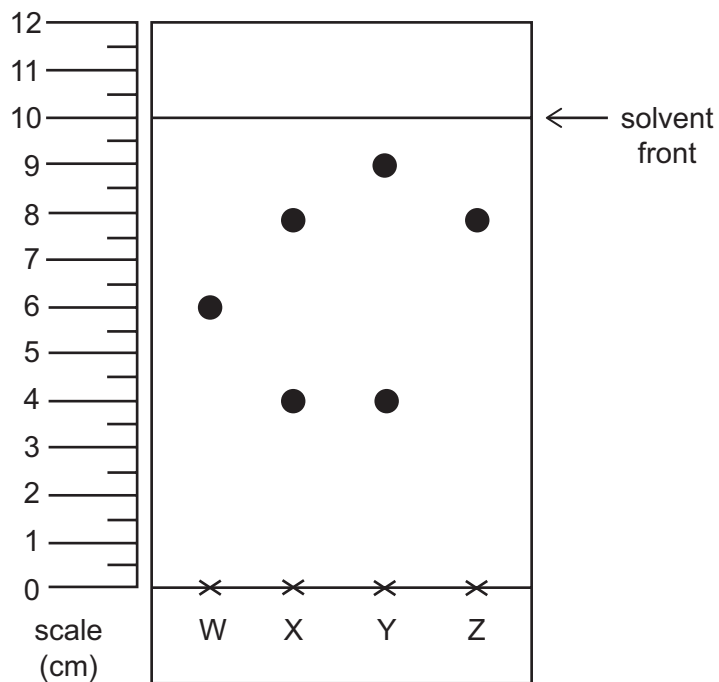
What is the R_f value of the spot with the strongest attraction to the mobile phase relative to the stationary phase **and** that is from a sample containing only one substance?

A 0.50

B 0.60

C 0.67

D 0.75

E 0.80

F 0.90

40 A mass spectrometer is a device that can measure the mass of isotopes. It shows this data as a spectrum, giving both the relative mass and the percentage abundance of each isotope.

The charts indicate the relative mass and percentage abundance for lithium atoms, carbon atoms and oxygen atoms found in a sample taken from a nuclear reactor.
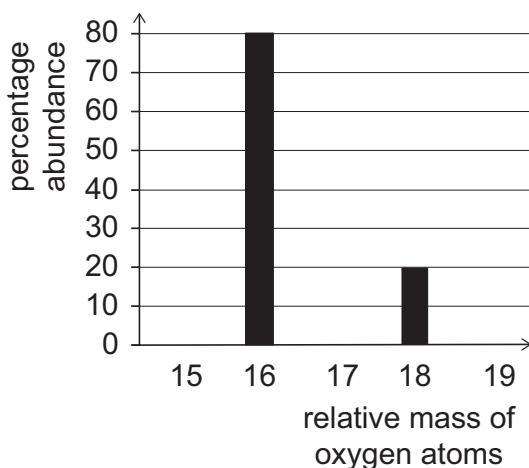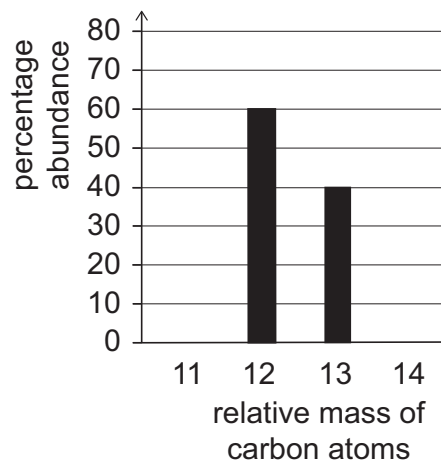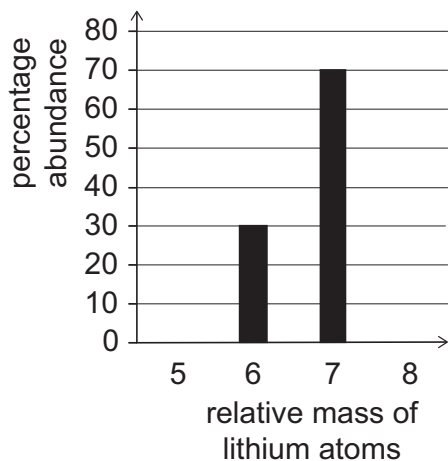
Using this data, what is the largest possible relative molar mass of lithium carbonate?

A 35

B 38

C 45

D 67

E 74

F 75

G 81

41 The following information about metals labelled P, Q, R and S is given.

- Metals P and S can be extracted by electrolysis, but not by reaction with carbon.

- Metals Q and R can be extracted by reaction with carbon.

- Metal S forms positive ions more readily than metal P.

- Metal R reacts with the oxide of metal Q.

What is the order of reactivity of these four metals, starting with the most reactive?

A P, S, Q, R

B P, S, R, Q

C Q, R, P, S

D Q, R, S, P

E R, Q, P, S

F R, Q, S, P

G S, P, Q, R

H S, P, R, Q

42 A simple ion of an element with atomic number x has a mass number of $(2x + 2)$.

The ion has a charge of -2.

How many protons, neutrons and electrons are present in this ion?

	protons	neutrons	electrons
A	$x - 2$	$x + 4$	$x - 2$
B	$x - 2$	$x + 4$	x
C	$x - 2$	$x + 4$	$x + 2$
D	x	$x + 2$	$x - 2$
E	x	$x + 2$	x
F	x	$x + 2$	$x + 2$

43 A 116 g sample of an oxide of iron contains 84 g of iron.

Which of the following is the empirical formula of this oxide of iron?

(A_r values: O = 16; Fe = 56)

A FeO

B Fe_2O_2

C Fe_3O_2

D Fe_2O_3

E Fe_3O_4

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

   1 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

   2 $Al^{3+} + 3e^- \rightarrow Al$

   3 $2Ag^+ + 2OH^- \rightarrow Ag_2O + H_2O$
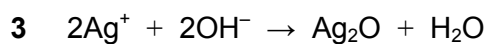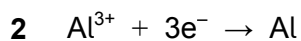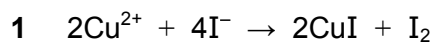
A none of them

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 X is an anhydrous salt of iron containing one type of cation and one type of anion.

An aqueous solution of X gives a white precipitate when aqueous barium chloride is added in the presence of hydrochloric acid.

On adding aqueous sodium hydroxide to an aqueous solution of X, a brown precipitate formed immediately.

The relative atomic mass of iron is 56, and its atomic number is 26.

What is the relative molar mass of X?

(A_r values: C = 12; N = 14; O = 16; S = 32; Cl = 35.5; Br = 80)

A 127

B 152

C 162.5

D 208

E 264

F 272

G 360

H 400

46 In the electrolysis of dilute sulfuric acid, hydrogen gas is formed at the negative electrode (cathode) and oxygen gas is formed at the positive electrode (anode).

If 100 g of hydrogen gas is formed in the electrolysis of dilute sulfuric acid, what mass of oxygen gas is also formed?

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

A 50 g

B 100 g

C 200 g

D 800 g

E 1600 g

47 0.005 mol of a chloride of element X was dissolved in water and then reacted with excess silver nitrate solution to form a precipitate of silver chloride, AgCl. This precipitate is the only product of this reaction that contains chlorine.

After filtering, washing and drying, the mass of the precipitate was recorded to be 1.435 g.

Which of the following could be the formula of the chloride of X?

(M_r value: AgCl = 143.5)

A X_5Cl

B X_2Cl

C XCl

D XCl_2

E XCl_5

48 A chemical equation that represents the reaction of phosphorus with concentrated nitric acid is:

$$P_4 + w\,HNO_3 + H_2O \rightarrow x\,H_3PO_4 + y\,NO + z\,NO_2$$
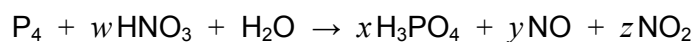
What is the value of the sum $w + x + y + z$?

A 24

B 28

C 30

D 32

E 36

49 A 2.40 g lump of magnesium was added to 500 cm^3 of a 2.00 mol dm^{-3} solution of HCl in a conical flask that was on an electronic balance. The neck of the flask was plugged with cotton wool, and the decrease in mass of the flask and its contents was recorded at regular intervals.

The mass of the hydrogen released (equal to the mass loss recorded) was plotted against time. The result is line 1 on the graph.
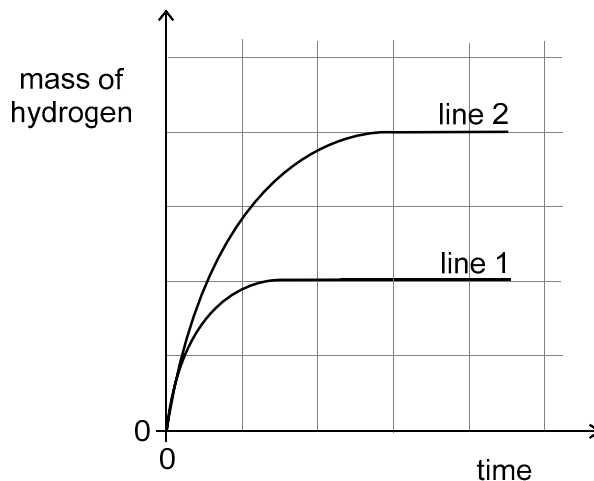
Which of the following experiments performed under the same conditions would give line 2?

(A_r value: Mg = 24.0)

A a 2.40 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} H$_2$SO$_4$

B 2.40 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

C a 2.40 g lump of magnesium added to 1000 cm^3 of 2.00 mol dm^{-3} HCl

D a 4.80 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} HCl

E 4.80 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

50 A technician needs to separate three liquids (X, Y and Z) which have been accidentally mixed together. None of the liquids react with each other.

liquid	X	Y	Z
boiling point / °C	65	51	100
density / g cm^{-3}	0.79	0.68	1.00

X and Z are miscible, but Y is immiscible with both X and Z.

The technician uses a separating funnel to separate the upper and lower layers of the mixture.

What should the technician do next to maximise separation of the three liquids?

A distil the lower layer at 51 °C

B distil the lower layer at 65 °C

C distil the lower layer at 100 °C

D distil the upper layer at 51 °C

E distil the upper layer at 65 °C

F distil the upper layer at 100 °C

51 In each of the following procedures an excess of the metal is added to $1.0\,dm^3$ of a $1.0\,mol\,dm^{-3}$ solution of the acid.

copper added to sulfuric acid

iron added to hydrochloric acid

magnesium added to sulfuric acid

zinc added to hydrochloric acid

Which row in the following table identifies combinations of metal and acid that will react and produce the largest, and the smallest, theoretical mass of anhydrous salt?

(M_r values: $CuSO_4$ = 160; $FeCl_2$ = 127; $MgSO_4$ = 120; $ZnCl_2$ = 136)

	reaction that produces the largest mass of salt	*reaction that produces the smallest mass of salt*
A	Cu and H_2SO_4	Fe and HCl
B	Cu and H_2SO_4	Mg and H_2SO_4
C	Fe and HCl	Zn and HCl
D	Mg and H_2SO_4	Fe and HCl
E	Mg and H_2SO_4	Zn and HCl
F	Zn and HCl	Mg and H_2SO_4

52 3.4 g of an impure sample of silicon tetrachloride is reacted with water. The mixture is then filtered and the resulting solution made up to $250\,cm^3$.

$$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$$
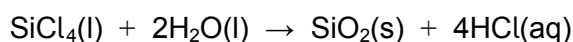
$12.5\,cm^3$ of this solution is neutralised exactly by $20.0\,cm^3$ of $0.100\,mol\,dm^{-3}$ sodium hydroxide.

What is the percentage purity of the silicon tetrachloride?

(M_r value: $SiCl_4$ = 170. Assume that the impurity does not react.)

A 1.7%

B 2.5%

C 10%

D 32%

E 50%

53 The Haber process is represented by the following chemical equation:

$$N_2 \; + \; 3H_2 \; \rightarrow \; 2NH_3$$
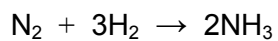
What is the overall enthalpy change for the reaction?

(Bond enthalpies: $N \equiv N = 945 \, kJ \, mol^{-1}$; $H-H = 435 \, kJ \, mol^{-1}$; $N-H = 390 \, kJ \, mol^{-1}$)

A $+90 \, kJ \, mol^{-1}$

B $-90 \, kJ \, mol^{-1}$

C $+990 \, kJ \, mol^{-1}$

D $-990 \, kJ \, mol^{-1}$

E $+1080 \, kJ \, mol^{-1}$

F $-1080 \, kJ \, mol^{-1}$

54 The diagram shows the electrolysis of molten lead(II) bromide, $PbBr_2$, using graphite electrodes to separate the compound into its elements.

molten lead(II) bromide
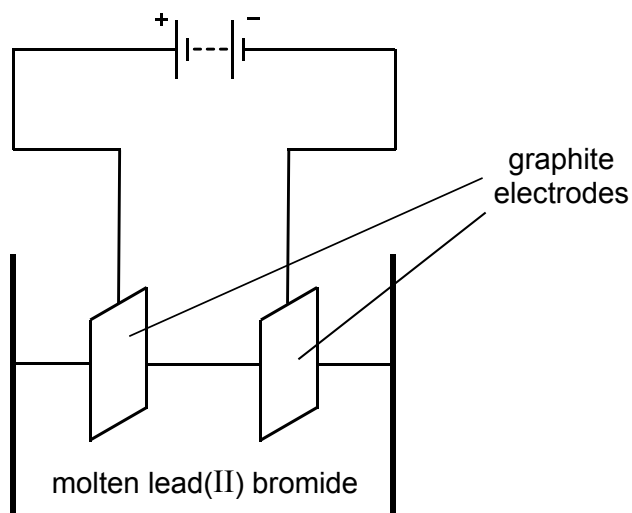
Which of the following statements about this electrolysis is/are correct?

1 Lead is formed at the negative electrode.

2 Electrons flow through the external circuit away from the positive electrode towards the negative electrode.

3 Bromine molecules and lead are produced in a 2:1 molar ratio.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

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PART D Biology

55 Which of the following statements is/are correct for both bacterial cells and sperm cells?

    1 The cell can divide.

    2 The cell contains DNA.

    3 The cell has a cell wall.

    4 The cell has a nucleus.

    5 The cell can carry out respiration.

A 2 only

B 4 only

C 1 and 2 only

D 2 and 5 only

E 3 and 4 only

F 3 and 5 only

G 1, 2 and 5 only

H 1, 3 and 4 only

56 Which one of the following statements about cells or tissues is correct?

A Any adult stem cells can naturally give rise to all tissue.

B Endocrine glands secrete enzymes into the bloodstream.

C Embryonic stem cells divide by meiosis to form all cell types.

D Receptor cells send chemical impulses along neurones.

E The stomach wall contains a tissue that enables movement of food.

57   The diagram represents a section of DNA.
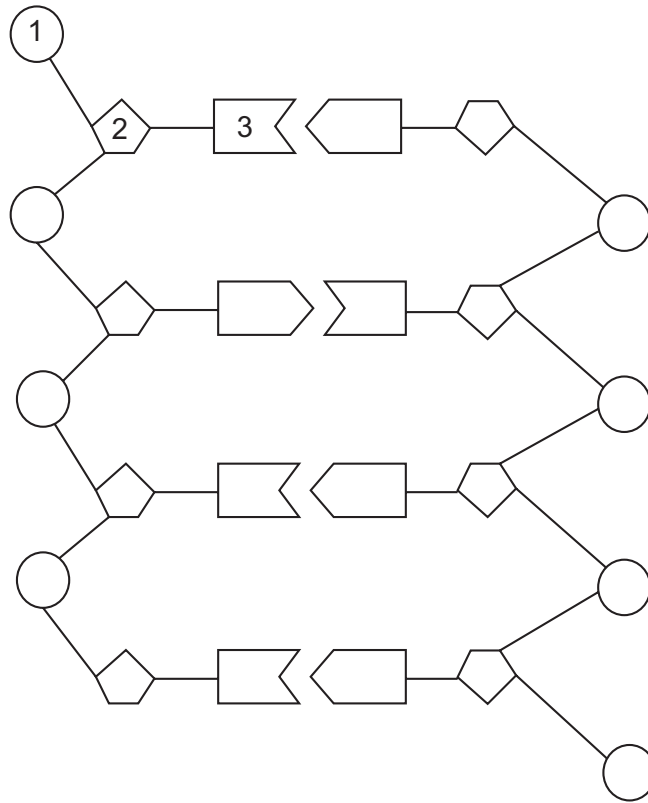
What do the parts labelled 1, 2 and 3 represent?

	1	*2*	*3*	*1 and 2 and 3*
A	base	phosphate	glycerol	gene
B	base	sugar	amino acid	gene
C	phosphate	sugar	base	nucleotide
D	phosphate	sugar	base	DNA strand
E	sugar	phosphate	base	nucleotide
F	sugar	phosphate	fatty acid	DNA strand

58 Using the information in the table, which animal (**A**-**F**) is most at risk of extinction?

animal	geographic range	habitat tolerance	population size
A	restricted	broad	large
B	extensive	broad	large
C	restricted	narrow	small
D	extensive	narrow	small
E	restricted	broad	small
F	extensive	broad	small

59 An ecologist used a 50 cm × 50 cm square quadrat to estimate the number of meadow buttercups present in a field with an area of 50 m². The quadrat was distributed randomly on ten occasions in the field and the number of buttercups counted in each quadrat.

quadrat	number of buttercups
1	3
2	10
3	0
4	4
5	21
6	19
7	6
8	11
9	15
10	3

How many buttercups were there estimated to be in the 50 m² field?

A   368

B   460

C   920

D   1840

E   4600

F   18 400

G   45 000

60 The photomicrograph shows a section through the wall of a human bronchus, one of the tubes which carries air towards the lungs.

A student studying this structure annotated the photomicrograph by describing the cells found in two different layers in the wall of the bronchus.

Two different types of cells are found in this single layer. Goblet cells, which synthesise and secrete the protein in mucus, and cells with cilia, which sweep mucus that has trapped dust and dirt away from the lungs.
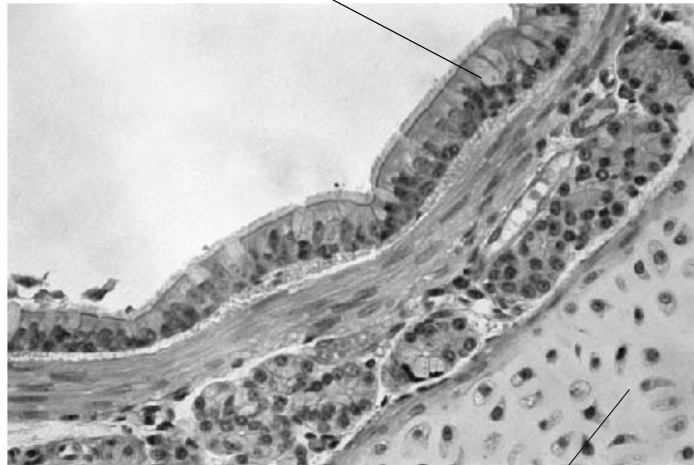
A layer consisting of a group of similar cells. Each cell synthesises and secretes a protein that then surrounds the cells.

The student used these observations to write some conclusions.

Which of the following conclusions is/are correct?

1	The two different layers are both tissues.
2	The bronchus can be described as an organ.
3	Amino acids are found in the cytoplasm of cells in each layer.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 1, 2 and 3

61 A student carried out an investigation using the diffusion of a gas along a tube to model movement of gases in the air space of a leaf. An alkaline gas was released from a solution that evaporated from the cotton wool.

As the gas diffused, it caused damp litmus paper to change colour.

The time was recorded when each piece of litmus paper changed colour.

The apparatus and a graph of the results are shown below.
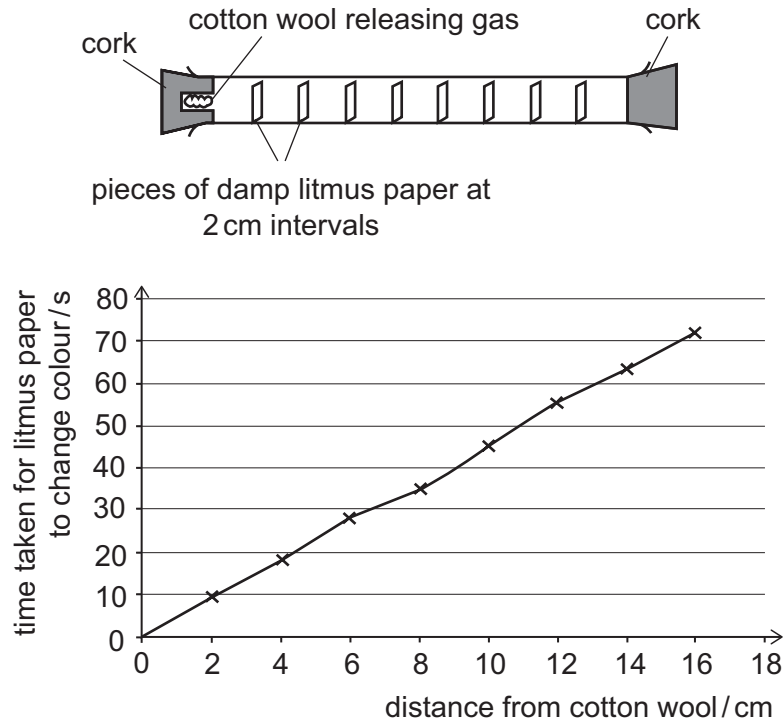
Which of the following statements about the investigation is/are correct?

1 The dependent variable has been plotted on the x-axis.

2 If diffusion of the gas was slower, the graph line would become steeper.

3 If a more concentrated solution was used in an identical set of apparatus, the data collected would result in a line on the graph below the points plotted for the original gas.

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

62 A bacterium was genetically modified by inserting a human gene into a plasmid. A plasmid is a small circle of DNA that can be used to transfer genes into bacterial cells. These modified bacteria then secrete the protein that the human gene codes for. The gene contains a sequence of bases that is not repeated anywhere else in its DNA and is not found in the DNA of other organisms. This sequence of bases is found in every allele of this gene.

Assuming that no mutations occur, how many copies of this base sequence would you expect to find at each of the stages X, Y and Z?

X | one human liver cell containing required gene

↓

one copy of gene removed from human cell

↓

Y | gene inserted into one bacterial plasmid

↓

one modified plasmid moved into bacterial cell and human protein released

↓

Z | purified human protein
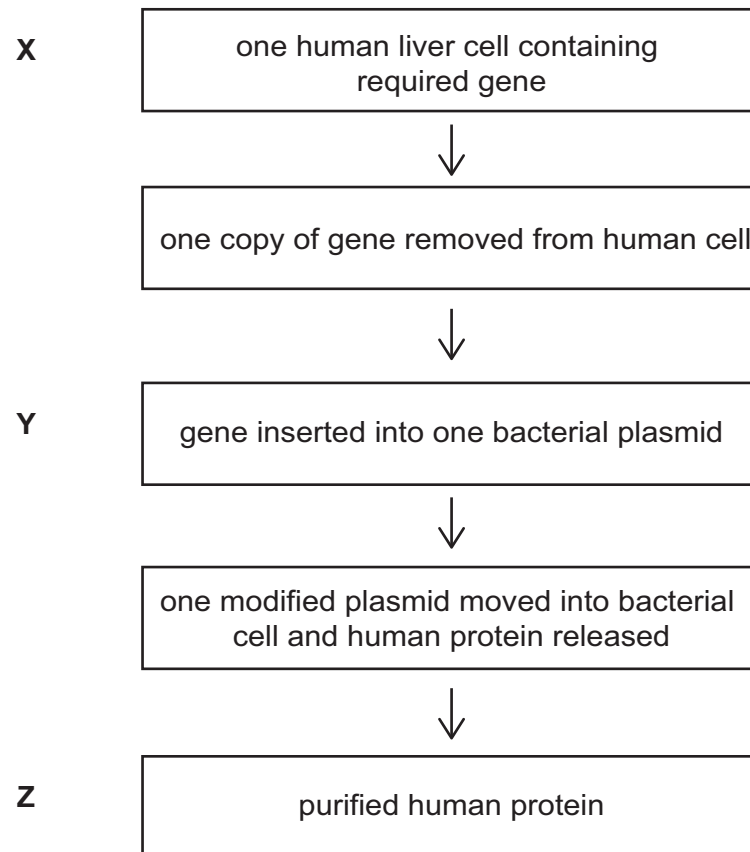
	number of copies of DNA sequence found		
	stage X	stage Y	stage Z
A	1	1	0
B	1	2	1
C	1	1	1
D	2	1	0
E	2	1	1
F	2	2	0

63 A student set up an experiment to measure the rate of photosynthesis, as shown in the diagram.
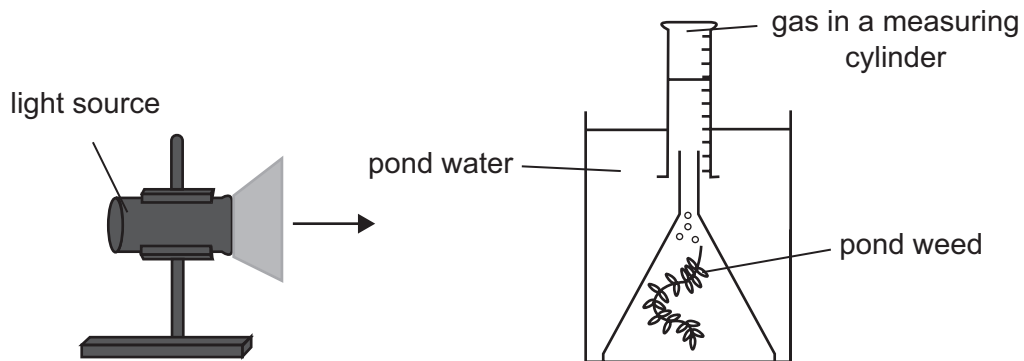
Data was collected and plotted on a graph.

If plotted, which of the following variables would give a gradient that is directly proportional to the rate of photosynthesis?

(All other variables were kept constant.)

	x-axis	y-axis
1	time	volume of CO_2 released
2	time	number of gas bubbles released per minute
3	volume of oxygen released	time

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

64 Bacteria reproduce asexually by dividing into two by binary fission.

Which of the following statements is/are correct about binary fission in bacteria?

1 As it is a form of asexual reproduction, there cannot be any variation in the offspring.

2 It can lead to a repeated doubling in population size if there are no limiting factors.

3 If binary fission occurs every 20 minutes, one bacterium would become 72^2 bacteria in 24 hours.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

65 Which of the following may stay the same when a mutation occurs in a human gene that codes for a protein?

1 the genotype of the organism's offspring

2 the phenotype of the organism

3 the sequence of amino acids in the protein

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 A child is affected by a dominant genetic condition. All of his cells have the same genotype. The allele associated with this condition is not present in either of his parents.

Which of the following statements could explain this?

1 A mutation occurred during meiosis in his father.

2 A random mutation occurred in his DNA after he was born.

3 Both of his grandmothers had the condition.

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   Phosphatase enzymes break the bond between a phosphate group and the rest of a molecule.

Phenolphthalein phosphate (PPP) is colourless and is a substrate for phosphatase enzymes.

- The phosphate group of PPP can be removed by the phosphatase enzyme to produce the indicator phenolphthalein.
- Phenolphthalein goes pink in alkaline conditions.

Five tubes were set up with equal concentrations of PPP and a plant phosphatase enzyme.

Each tube was at a different pH. The tubes were incubated at the same temperature. After 10 minutes Na_2CO_3 was then added to each tube until a pH of 9.5 was reached. The colour was observed immediately and then again after another 5 minutes.

tube	1	2	3	4	5
pH of the initial reaction	3.2	4.2	5.2	8.2	9.2
colour immediately after Na_2CO_3 addition	pale pink	pink	dark pink	colourless	colourless
colour after another 5 minutes	pale pink	pink	dark pink	colourless	colourless

Which of the following statements is/are correct?

1 Na_2CO_3 solution inhibited the activity of the phosphatase enzyme.

2   More substrate was produced in conditions of high acidity compared to low acidity.

3   The optimum pH for this plant phosphatase must be 5.2.

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 gene found on the X chromosome in humans has two alleles, dominant and recessive. Individuals who have only recessive alleles have a condition that affects their eyesight.

The inheritance of the condition in one family is shown in the family tree.
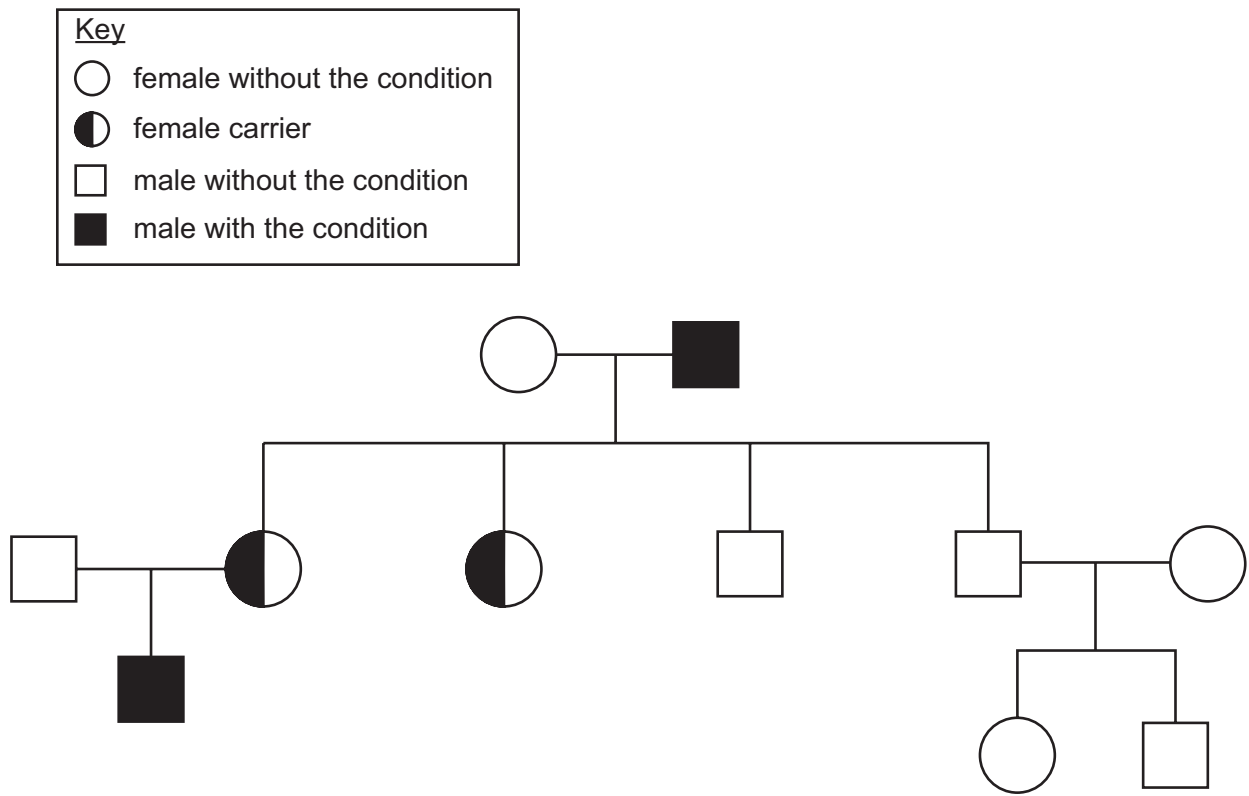
If one living skin cell from each member of this family were analysed, how many of the following alleles would be found?

	number of copies of the recessive allele	*number of copies of the dominant allele*
A	2	7
B	2	12
C	2	14
D	4	7
E	4	12
F	4	14
G	6	7
H	6	12

69 The graphs below show the oxygen uptake before, during and after a period of strenuous physical exercise.

Which shaded area correctly represents the additional oxygen taken in to repay the oxygen debt acquired through anaerobic respiration?
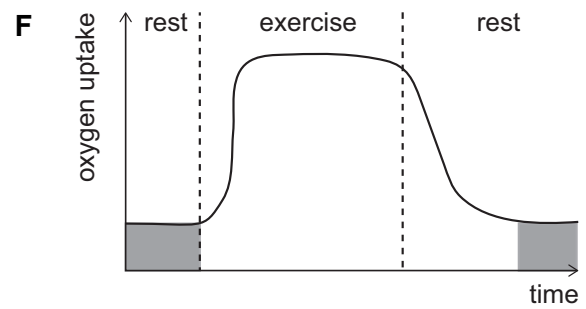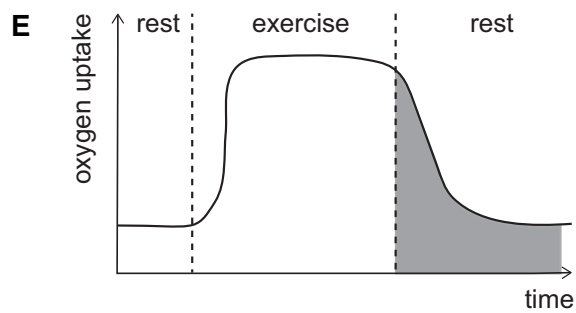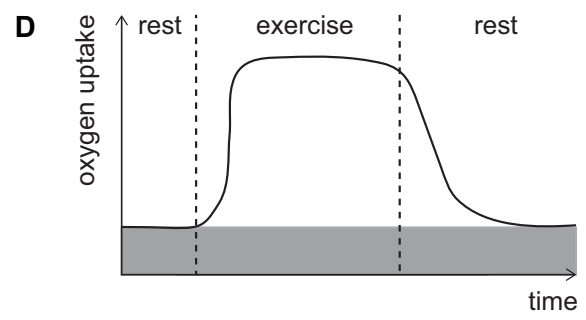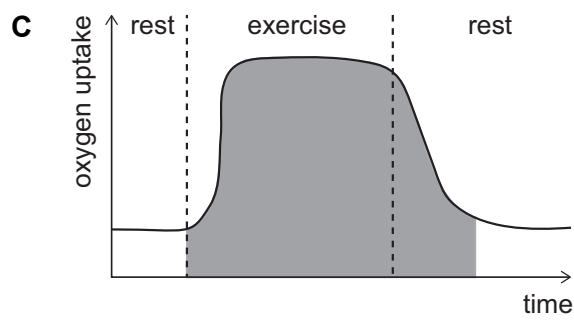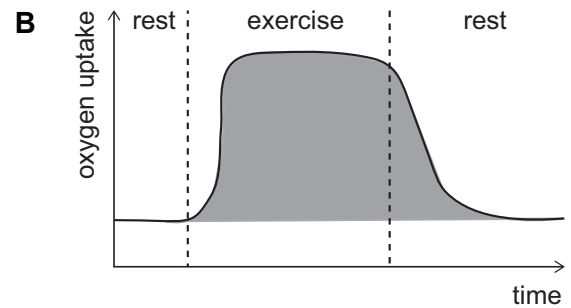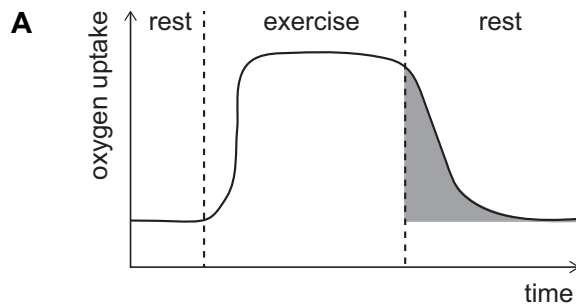
70 An investigation was carried out using clones of one plant.

Twenty plants of the same initial height were selected and divided into four equal groups. Each group was grown for six months and their environments were controlled as follows:

- kept at a different temperature to each other
- grown in a pot with an equal mass of soil with the same nutrients
- watered with an equal volume of water
- kept in the same light intensity

After six months, the height of the plants was measured. The mean height of the plants in each pot was calculated. The results are shown in the chart.
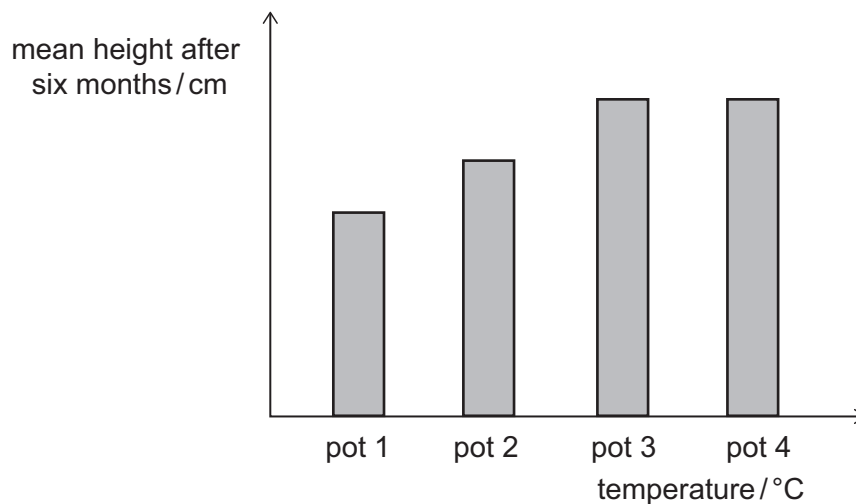
Which of the following statements could explain the results?

1 The difference in mean height between plants in pot 1 and plants in pot 2 could be due to the environment.

2 The mean height of plants in pot 4 equals that of plants in pot 3 because of another environmental factor in addition to temperature.

3 The mean height of plants in pot 3 equals that of plants in pot 4 because of the genotype of the plants.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

71 An investigation was carried out on the effect of substrate concentration on an enzyme-controlled reaction.

Four different concentrations of substrate were tested. In each case, the concentration of product was measured at regular intervals following the introduction of the substrate.

All the other variables were kept constant.

The results obtained are shown on the graph.
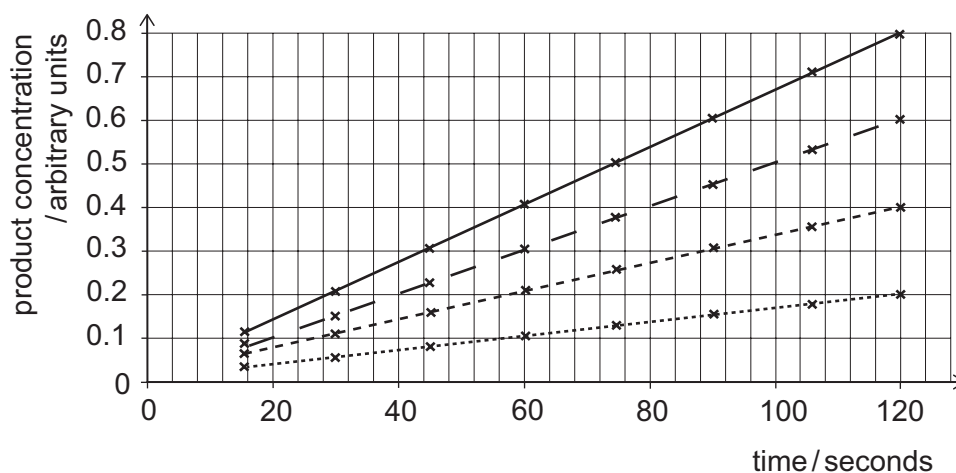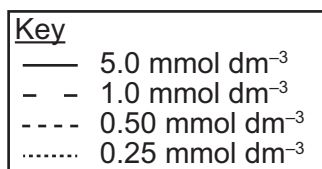
Which of the following statements is/are correct?

1 As substrate concentration increases, the time taken to produce 0.2 arbitrary units of product increases.

2 Doubling the substrate concentration always doubles the rate of the reaction.

3 The average rate of reaction for a substrate concentration of $1.0\,mmol\,dm^{-3}$ is 0.005 arbitrary units per second.

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 sequence of a coding section of DNA is shown below.

CTAGTCTGGTGGCTACGTCCTCCTCTACTATGGCTAGTCGTCTGGTGGCTA

The number of each type of amino acid coded for by this sequence of DNA bases is shown in the table.

amino acid coded for	number of this type of amino acid present
Arg	1
Leu	6
Pro	2
Trp	5
Val	3

What is the correct sequence of amino acids coded for by this sequence of DNA?

A   Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Val-Leu-Val-Val-Trp-Trp-Trp

B   Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Trp-Val-Val-Val-Val

C   Leu-Val-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp

D   Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Val-Leu-Val-Val-Trp-Trp-Trp-Leu

E   Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Trp-Val-Val-Val-Val-Leu

F   Leu-Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Val

G   Leu-Val-Trp-Trp-Leu-Leu-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Leu

H   Leu-Val-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Leu

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PART E Advanced Mathematics and Advanced Physics

73 Find the area of the shape bounded by the four lines:

$$2y + x = 4$$

$$x = -6$$

$$x = 0$$

$$y = 0$$

A 4

B 12

C 21

D 25

E 27

F 30

74 A hydroelectric power station uses the water in a reservoir to power the generators. The water falls through a vertical height of 150 m to the turbines which power the generators.

The efficiency of the power station is 90% and the output power of the power station is 1800 MW.

The gravitational field strength is $10\,\mathrm{N\,kg^{-1}}$ and the density of water is $1000\,\mathrm{kg\,m^{-3}}$.

What volume of water passes through the turbines in one minute?

A $6.48 \times 10^4\,\mathrm{m^3}$

B $7.20 \times 10^4\,\mathrm{m^3}$

C $8.00 \times 10^4\,\mathrm{m^3}$

D $6.48 \times 10^7\,\mathrm{m^3}$

E $7.20 \times 10^7\,\mathrm{m^3}$

F $8.00 \times 10^7\,\mathrm{m^3}$

75 The curve

$$y = x^3 + px^2 + qx + r$$

has a local maximum when $x = -1$ and a local minimum when $x = 3$

What is the value of p?

A −9

B −3

C −1

D 1

E 3

F 9

76 A car P of mass 1000 kg is travelling north at 30 m s^{-1} along a straight, horizontal road when it hits another car Q which is directly ahead of P and travelling in the same direction. Car Q has a mass of 500 kg and is travelling at 20 m s^{-1}.

The collision lasts for 0.20 s and immediately after the collision car Q is moving north at 30 m s^{-1}.

What is the speed of P immediately after the collision and what is the size of the average resultant force that acts on Q during the collision?

(Assume that no external forces act on the cars during the collision.)

	speed of P / m s^{-1}	average force on Q / N
A	20	25 000
B	20	50 000
C	20	100 000
D	20	125 000
E	25	25 000
F	25	50 000
G	25	100 000
H	25	125 000

77 It is given that

$$7\cos x + \tan x \sin x = 5$$

where $0° < x < 90°$

What are the possible values of $\tan x$?

A $\dfrac{1}{2}$ or $\dfrac{1}{3}$

B $\dfrac{1}{\sqrt{3}}$ or $\dfrac{1}{2\sqrt{2}}$

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

D $\sqrt{3}$ or $2\sqrt{2}$

E 3 or 2

78 A metal wire of length 0.50 m has a uniform cross-sectional area of $4.0 \times 10^{-7}\,\text{m}^2$.

There is a current of 4.0 A in the wire.

What is the potential difference across the ends of the wire?

(resistivity of the metal $= 1.6 \times 10^{-7}\,\Omega\,\text{m}$)

A 0.05 V

B 0.20 V

C 0.80 V

D 3.2 V

E 5.0 V

F 20 V

79 An equilateral triangle of side 8 cm is drawn so that its vertices lie on the circumference of a circle, as shown in the diagram.

8 cm
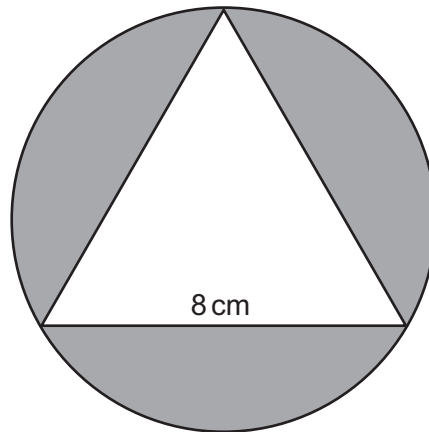
What is the total of the three areas shaded in the diagram, in cm^2?

A $8(2\pi - 3)$

B $24(\pi - \sqrt{3})$

C $48(4\pi - \sqrt{3})$

D $\dfrac{16}{3}(4\pi - 6 - 3\sqrt{3})$

E $\dfrac{16}{3}(4\pi - 3\sqrt{3})$

80 A uniform square trap door of side 0.80 m and mass 14 kg has a smooth hinge at one edge and is held open at an angle of 30° to the horizontal. It is supported by a single rigid rod placed so that it meets the surface of the trap door at 90° at a distance 0.10 m from the top edge of the trap door, as shown.
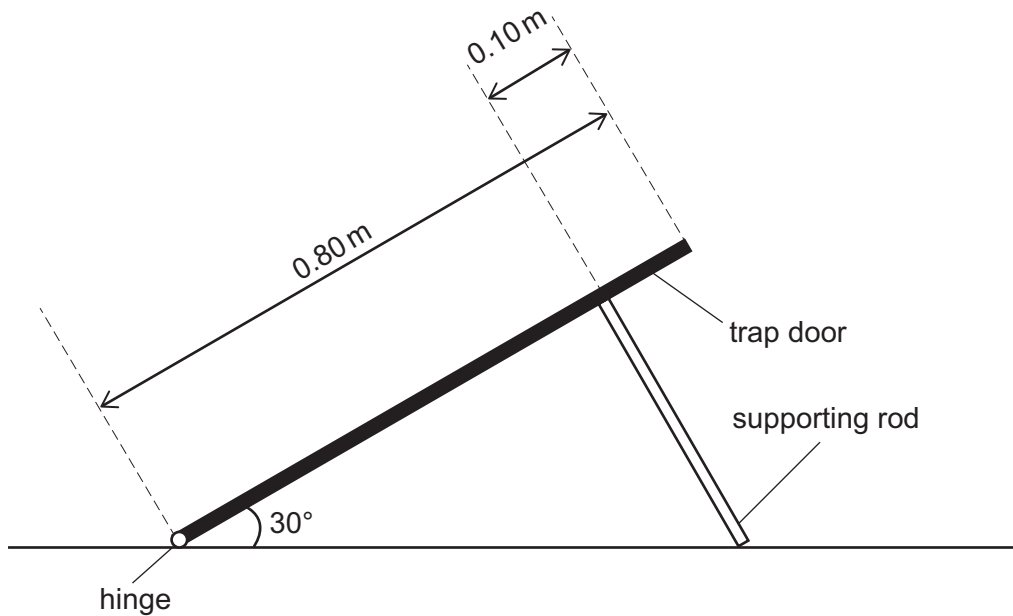
What is the normal contact force exerted on the trap door by the rod?

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

A 40 N

B $35\sqrt{3}$ N

C $40\sqrt{3}$ N

D 80 N

E $80\sqrt{3}$ N

F $280\dfrac{\sqrt{3}}{3}$ N

81   Which one of the following is the real solution of the equation

$$3 \times 5^{2x+1} - 5^x - 2 = 0$$

A $x = \log_5\left(\dfrac{1}{3}\right)$

B $x = \log_5\left(\dfrac{2}{5}\right)$

C $x = \log_5\left(\dfrac{3}{5}\right)$

D $x = \log_5\left(\dfrac{2}{3}\right)$

E $x = \log_5\left(\dfrac{5}{3}\right)$

F $x = \log_5\left(\dfrac{5}{2}\right)$

82 Two small loudspeakers are placed side by side 30 cm apart.

They are connected to the same signal generator so that they emit sound of frequency 400 Hz in phase with one another.

The sounds both reach a microphone placed 40 cm directly in front of one of the two loudspeakers as shown.
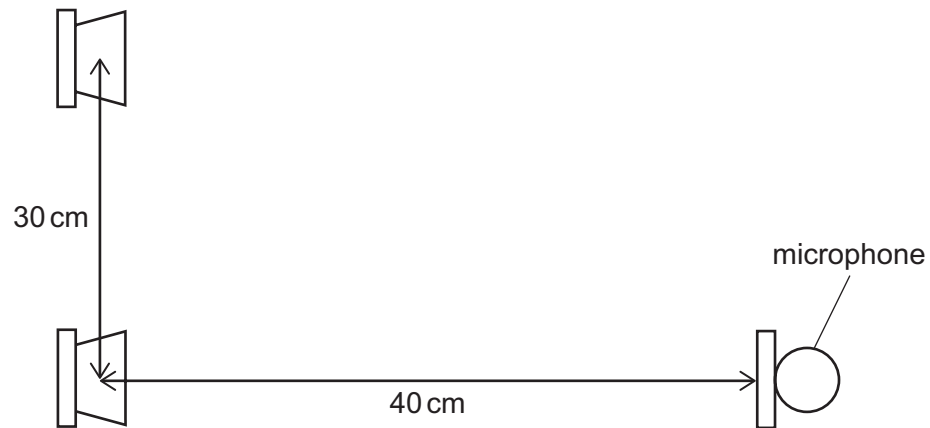
What is the phase difference between waves from the loudspeakers as they arrive at the microphone?

(speed of sound $= 320\,\mathrm{m\,s^{-1}}$)

A 30°

B 36°

C 45°

D 60°

E 72°

F 90°

G 120°

83 For a particular function $f(x)$, it is given that:

$$\int_{-2}^{2} 2f(x)\,dx + \int_{2}^{4} f(x)\,dx = 4$$

and also:

$$\int_{-2}^{2} 5f(x)\,dx - \int_{-2}^{4} f(x)\,dx = 7$$

Find the value of $\int_{2}^{4} f(x)\,dx$

A $\dfrac{1}{3}$

B $\dfrac{11}{7}$

C $\dfrac{11}{6}$

D $\dfrac{13}{6}$

E $\dfrac{13}{3}$

84 An astronaut on the Moon throws a ball vertically upwards. The ball has a mass of 2.0 g and is thrown upwards at $80\,\mathrm{m\,s^{-1}}$.

What is the maximum height gained by the ball?

(gravitational field strength close to the Moon's surface = $1.6\,\mathrm{N\,kg^{-1}}$)

A   25 m

B   50 m

C   320 m

D   2000 m

E   3200 m

F   4000 m

85 Given that

$$f(x) = \int_0^x (3+2t)^7 \, dt$$

what is the coefficient of x^4 in the expansion of $f(x)$ in powers of x?

A 70

B 162

C $\dfrac{2835}{4}$

D 3024

E 5670

F 15 120

G 22 680

86   A student has one $300\,\Omega$ resistor and another resistor of resistance R.

The student plots a graph of current I against potential difference V for the $300\,\Omega$ resistor and then for both resistors connected in parallel.
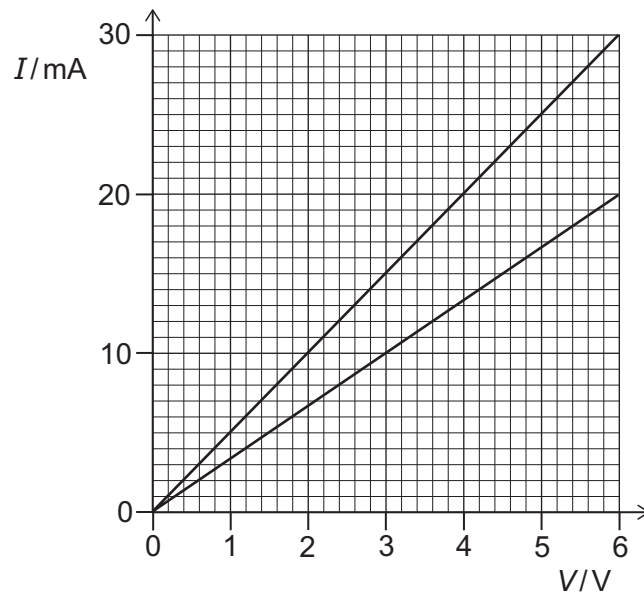
What is the resistance R?

A $3.3\,\Omega$

B $5.0\,\Omega$

C $10\,\Omega$

D $100\,\Omega$

E $200\,\Omega$

F $600\,\Omega$

G $1000\,\Omega$

87 The three internal angles in a triangle are α, β and θ, and

$$3\tan\alpha - 2\sin\beta = 2$$
$$5\tan\alpha + 6\sin\beta = 8$$

What is the value of θ in degrees?

A 15

B 45

C 75

D 105

E 135

88 A light, vertical, copper wire of length 2.4 m and uniform cross-sectional area $2.0 \times 10^{-6}\,\text{m}^2$ supports a load of mass 4.0 kg.

The Young modulus of copper is $1.2 \times 10^{11}\,\text{Pa}$.

What is the strain energy in the wire?

(gravitational field strength = $10\,\text{N}\,\text{kg}^{-1}$; assume that the wire obeys Hooke's law and that the cross-sectional area remains constant)

A $8.0 \times 10^{-5}\,\text{J}$

B $1.7 \times 10^{-4}\,\text{J}$

C $4.0 \times 10^{-4}\,\text{J}$

D $8.0 \times 10^{-3}\,\text{J}$

E $4.0 \times 10^{-2}\,\text{J}$

F $1.6 \times 10^{-2}\,\text{J}$

89 Find the complete set of values of x for which

$$x^3 - 2x^2 - 7x - 4 > 0$$

A $x < -1$

B $x > -1$

C $-1 < x < 4$

D $x < -1$ or $x > 4$

E $x < 4$

F $x > 4$

90 The velocity–time graph is for an 80 kg person in a lift that is moving vertically upwards.
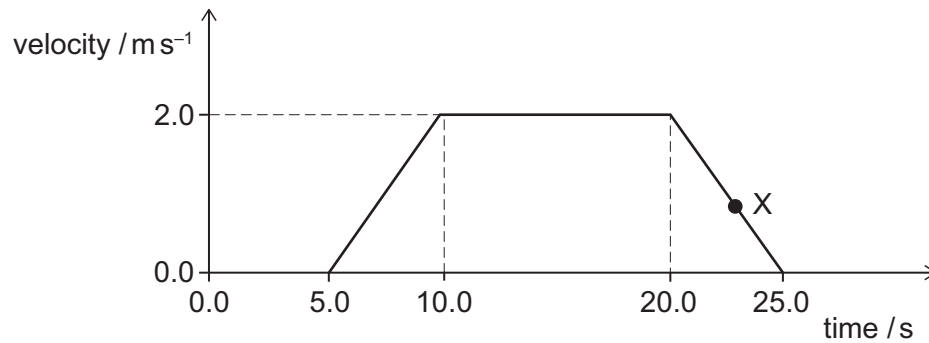
What is the magnitude of the contact force between the person and the lift floor at the time corresponding to X?

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

A 640 N

B 768 N

C 800 N

D 832 N

E 960 N

UNIVERSITY OF CAMBRIDGE

Candidate number

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Centre number

□□□□□

Date of birth (DD MM YYYY)

□□ □□ □□□□

First name(s)

Surname / Family name

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

A B C D E
○ ● ○ ○ ○

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

ALL candidates must complete Part A

Part A: Mathematics

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

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Candidate number

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Attempt any **TWO** of parts B, C, D, E.

Part B: Physics

	A B C D E F G H		A B C D E F G H
19	○○○○○○○○	28	○○○○○○○○
20	A B C D E F G H ○○○○○○○○	29	A B C D E F ○○○○○○
21	A B C D E F G ○○○○○○○	30	A B C D E ○○○○○
22	A B C D E F G H ○○○○○○○○	31	A B C D E F ○○○○○○
23	A B C D E ○○○○○	32	A B C D E F G ○○○○○○○
24	A B C D E F G H ○○○○○○○○	33	A B C D E F G H ○○○○○○○○
25	A B C D E F ○○○○○○	34	A B C D E F ○○○○○○
26	A B C D E F ○○○○○○	35	A B C D E F G H ○○○○○○○○
27	A B C D E F ○○○○○○	36	A B C D E ○○○○○

Part C: Chemistry

	A B C D E F G H		A B C D E
37	○○○○○○○○	46	○○○○○
38	A B C D E F G H ○○○○○○○○	47	A B C D E ○○○○○
39	A B C D E F ○○○○○○	48	A B C D E ○○○○○
40	A B C D E F G ○○○○○○○	49	A B C D E ○○○○○
41	A B C D E F G H ○○○○○○○○	50	A B C D E F ○○○○○○
42	A B C D E F ○○○○○○	51	A B C D E F ○○○○○○
43	A B C D E ○○○○○	52	A B C D E ○○○○○
44	A B C D E F G H ○○○○○○○○	53	A B C D E F ○○○○○○
45	A B C D E F G H ○○○○○○○○	54	A B C D E F G H ○○○○○○○○

Part D: Biology

	A B C D E F G H		A B C D E F G H
55	○○○○○○○○	64	○○○○○○○○
56	A B C D E ○○○○○	65	A B C D E F G H ○○○○○○○○
57	A B C D E F ○○○○○○	66	A B C D E F G H ○○○○○○○○
58	A B C D E F ○○○○○○	67	A B C D E F G H ○○○○○○○○
59	A B C D E F G ○○○○○○○	68	A B C D E F G H ○○○○○○○○
60	A B C D E F G ○○○○○○○	69	A B C D E F ○○○○○○
61	A B C D E F G ○○○○○○○	70	A B C D E F G H ○○○○○○○○
62	A B C D E F ○○○○○○	71	A B C D E F G H ○○○○○○○○
63	A B C D E F G H ○○○○○○○○	72	A B C D E F G H ○○○○○○○○

Part E: Advanced Maths & Physics

	A B C D E F		A B C D E F G
73	○○○○○○	82	○○○○○○○
74	A B C D E F ○○○○○○	83	A B C D E ○○○○○
75	A B C D E F ○○○○○○	84	A B C D E F ○○○○○○
76	A B C D E F G H ○○○○○○○○	85	A B C D E F G ○○○○○○○
77	A B C D E ○○○○○	86	A B C D E F G ○○○○○○○
78	A B C D E F ○○○○○○	87	A B C D E ○○○○○
79	A B C D E ○○○○○	88	A B C D E F ○○○○○○
80	A B C D E F ○○○○○○	89	A B C D E F ○○○○○○
81	A B C D E F ○○○○○○	90	A B C D E ○○○○○

28606

NSAA S1 2019 Answer Key

Question	Key
1	F
2	H
3	E
4	C
5	E
6	D
7	B
8	F
9	A
10	D
11	E
12	G
13	D
14	G
15	C
16	C
17	C
18	E
19	B
20	E
21	F
22	A
23	C
24	D
25	A
26	A
27	E
28	F
29	C
30	C
31	C
32	E
33	F
34	D
35	B
36	B
37	F
38	C
39	E
40	G
41	H
42	F
43	E
44	B
45	H
46	D
47	D

Question	Key
48	A
49	D
50	B
51	D
52	E
53	B
54	E
55	D
56	E
57	C
58	C
59	D
60	G
61	G
62	D
63	A
64	C
65	H
66	B
67	B
68	E
69	A
70	H
71	D
72	H
73	C
74	C
75	B
76	E
77	D
78	C
79	E
80	C
81	B
82	C
83	A
84	D
85	E
86	F
87	D
88	D
89	F
90	B

UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES
ADMISSIONS ASSESSMENT

D568/12

Wednesday 30 October 2019

40 minutes

SECTION 2

Candidate Number	N						Centre Number					

		d	d		m	m		y	y	y	y
Date of birth				–			–				

First name(s)	

Surname / Family name	

INSTRUCTIONS TO CANDIDATES

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

There are six questions in this paper, of which you should answer any **two**.

There are 20 marks for each question. In total 40 marks are available.

You should write your answers in the spaces provided in this question paper. Please complete this section in **black pen**. Pencil may be used for graphs and diagrams only.

You can use the blank pages inside this booklet for rough working or notes, but **no extra paper** is allowed. Only answers in the spaces indicated in the paper will be marked.

Calculators may be used in this section. Please record your calculator model in the box below:

Calculator model	

Write the numbers of the questions you answer in the order attempted in the boxes below:

Question number

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

This question paper consists of 30 printed pages and 10 blank pages.

PV3

This page is intentionally left blank for your rough working or notes.

Physics

Question P1

a) Four sheets of transparent material are placed on top of each other. A ray of light propagates through medium 1 and is incident at the boundary between medium 1 and medium 2 at an angle θ_1 to the normal. The refractive index of medium 1 is $n_1 = 1.50$.

(i) Given that $n_1 > n_2 > n_3 > n_4$ and n_4 is such that the ray of light **does not** enter medium 4, complete the diagram to show the path of a ray of light through the different mediums. Label the angles to the normal at the boundaries between medium 1 and 2, medium 2 and 3, and medium 3 and 4.

[2 marks]

Answer:

$n_1 = 1.50$ medium 1

n_2 medium 2

n_3 medium 3

n_4 medium 4

(ii) If the angle at which the light meets the normal to the boundary between medium 3 and medium 4 is the critical angle, find an expression for θ_1 in terms of n_1 and n_4.

[3 marks]

Answer: ………………………………………………………………………………………………....

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(iii) If the refractive index of each medium is given by $n_m = 1.50 \times (0.99)^{m-1}$, where m has values 1, 2, 3, and 4, find the minimum value of θ_1 for total internal reflection to occur at the boundary between medium 3 and medium 4.

[2 marks]

Answer: ………………………………………………………………………………………………....

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[Turn over

b) A meerkat is in a desert on a hot day with a clear blue sky above the sand. A thin layer of air, of thickness t, above the sand is so hot that it has a lower refractive index, n, than the cold air directly above it. The cold air has a refractive index, $n_c = 1.004$. The meerkat has height h where $h \gg t$. The meerkat believes that he is standing on an "island" of sand of radius r, with what appears to be water all around him. He thinks that there is water because at distances greater than r away from him he sees a reflection of the blue sky when he is looking below the horizon towards the ground.

(i) On the diagram, draw rays to show how light reaches the meerkat's eyes from the sky, by reflection, and from the sand, by refraction.

[2 marks]
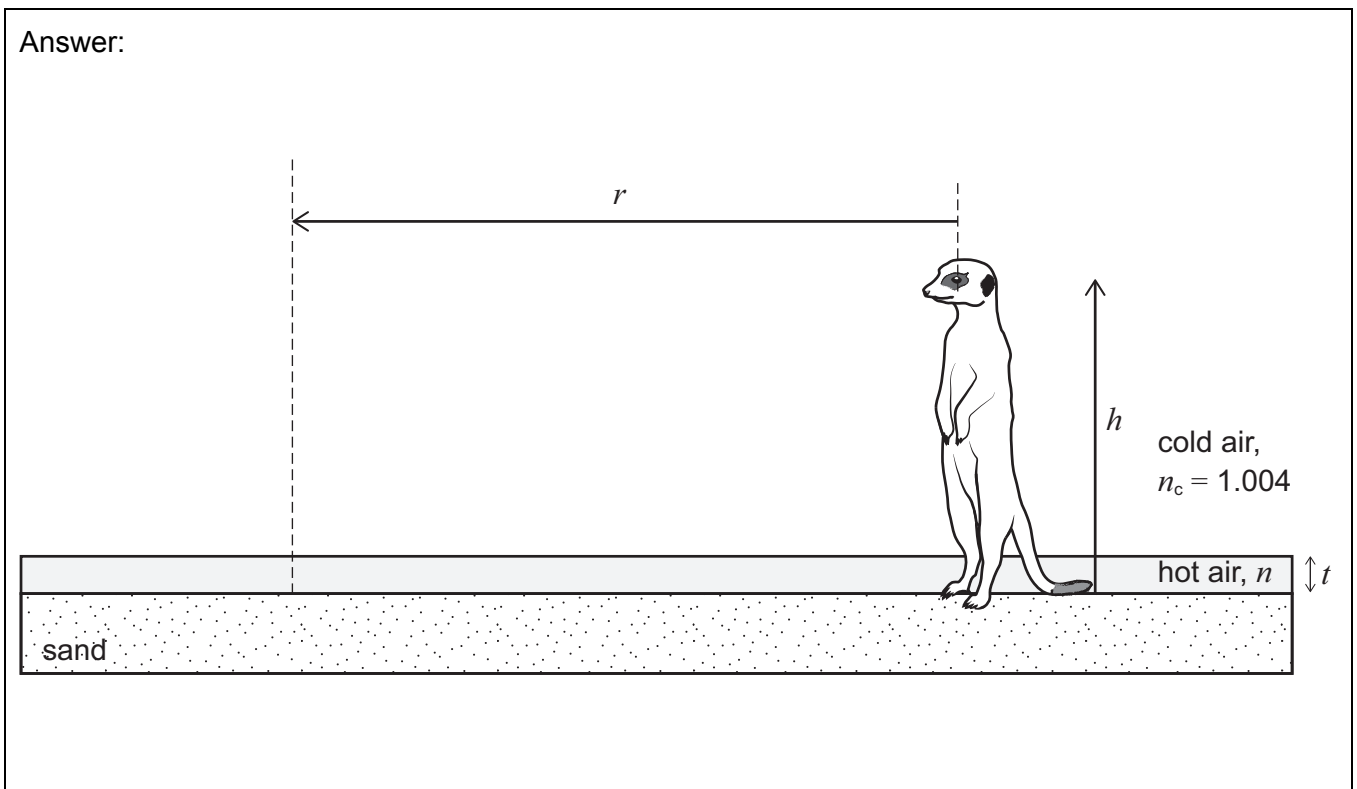
Answer:

(ii) Add to the diagram a critical ray showing the path of the light reaching the meerkat's eye from the edge of the "island".

Find an expression for the angle this ray makes with the normal in terms of n_c and n.

[3 marks]

Answer: …………………………………………………………………………………………….....
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(iii) A giraffe stands at the same position as the meerkat. The giraffe has height H, where $H \gg h \gg t$. The giraffe thinks the edge of the "island" is at a distance R.

Find an expression for $\dfrac{R}{r}$ in terms of H and h.

[1 mark]

Answer: ………………………………………………………………………………………...…

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(iv) Using your result from **(ii)**, show that the radius of the meerkat's "island" is given by

$r = \dfrac{anh}{\sqrt{bn_c^2 + kn^2}}$ and find the integer values of a, b and k.

[3 marks]

Answer: ………………………………………………………………………………………...…

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(v) As the day progresses the hot air warms up and its refractive index n reduces, but the cold air remains at the same temperature and with the same refractive index, n_c. By considering the expression for r from **(iv)**, explain what happens to r as the hot air warms up. Does the meerkat think that the water is **getting closer, staying the same, or getting further away**?

[2 marks]

Answer: ………………………………………………………………………………………...…

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[Turn over

c) The camera that took this photograph was placed at the bottom of a swimming pool. The area labelled A is a window above the pool. The area labelled B is the top surface of a step.

Describe the path that the light has taken to reach the camera from A and from B.

[2 marks]
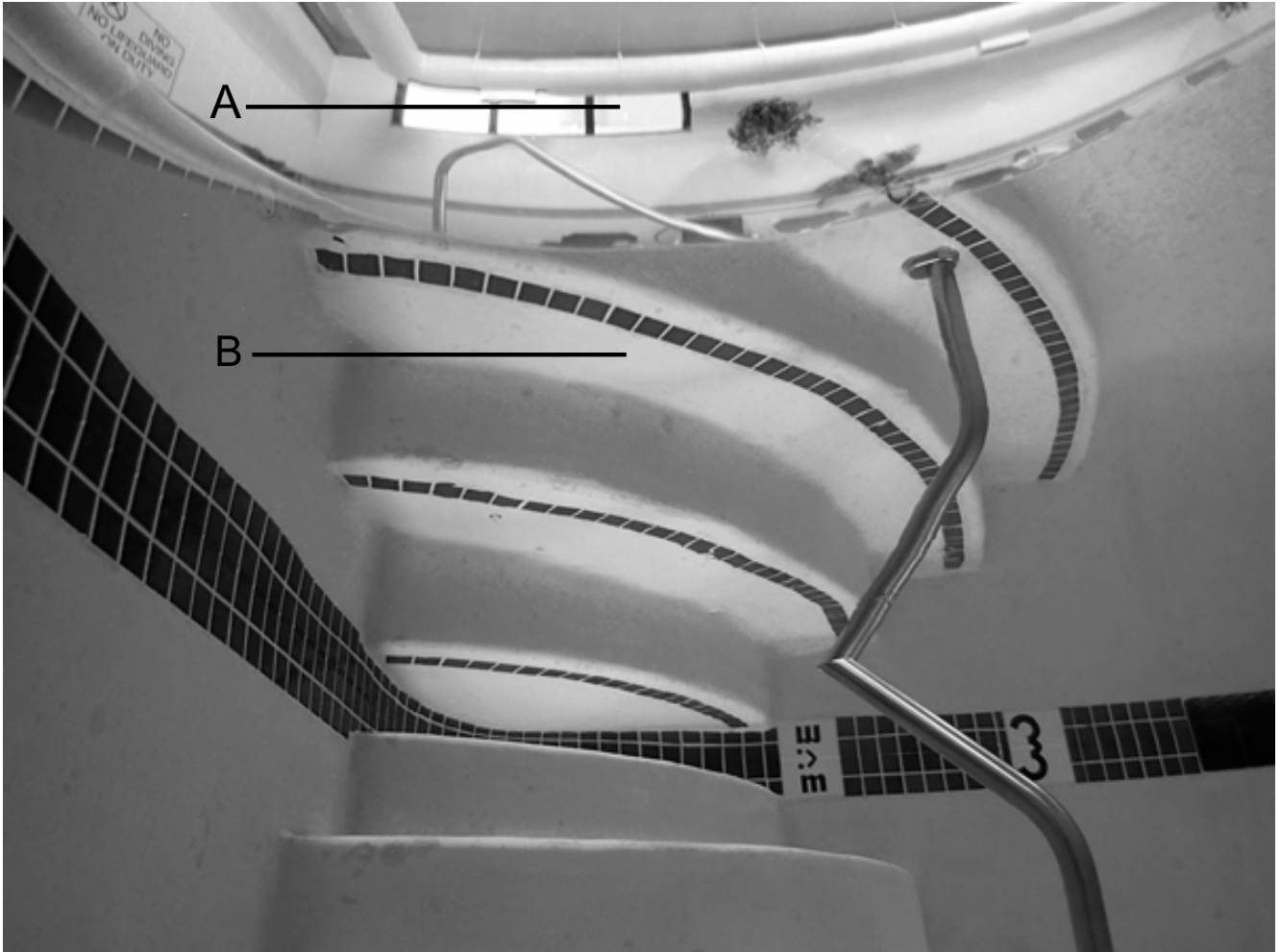
Image used with permission of the High School Physics Photo Contest © 2019 American Association of Physics Teachers

Answer: …………………………………………………………………………………………......

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Question P2

A mass m is placed on a frictionless horizontal surface and attached to the end of a light spring of spring constant k, and the spring is attached to a wall as shown in the diagram.
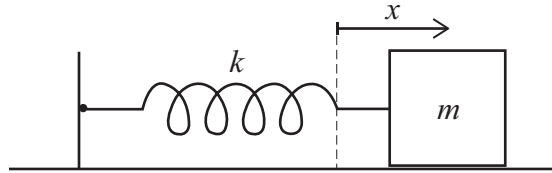
When displaced from equilibrium the mass oscillates with a frequency f. At time t the mass is at a displacement, x, from equilibrium and is moving with velocity, v.

a) Write down an expression for the elastic potential energy, E_p, stored in the spring at time t.

[1 mark]

Answer: ………………………………………………………………………………………….....

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b) Write down an expression for the kinetic energy, E_k, of the mass-spring system.

[1 mark]

Answer: ………………………………………………………………………………………….....

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[Turn over

c) The rate of change of displacement, $\frac{dx}{dt} = v$ and the rate of change of velocity, $\frac{dv}{dt} = a$.

Using the formula $\frac{dE_p}{dt} = \frac{dE_p}{dx} \times \frac{dx}{dt}$ show that $\frac{dE_p}{dt} = kxv$.

Using a similar method, find an expression for $\frac{dE_k}{dt}$ in terms of m, v and a.

Show all of your working.

[3 marks]

Answer: ………………………………………………………………………………………………….....

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d) Give the physical reason in words why $\frac{d(E_k + E_p)}{dt} = 0$

[1 mark]

Answer: ………………………………………………………………………………………………….....

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e) A formula for the acceleration of the mass is $a = -(2\pi f)^2 x$. Using your answers from part **c)**, the expression given in part **d)** and this formula, find an expression for the frequency of the oscillation, f, in terms of m and k.

Show all of your working.

[3 marks]

Answer: …………………………………………………………………………………………………....

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The mass is now placed on a frictionless surface between two walls. It is attached to the left wall by **two** identical, light springs in **parallel**, each of spring constant k and to the right wall by **two** identical springs in **series**, each of spring constant k.
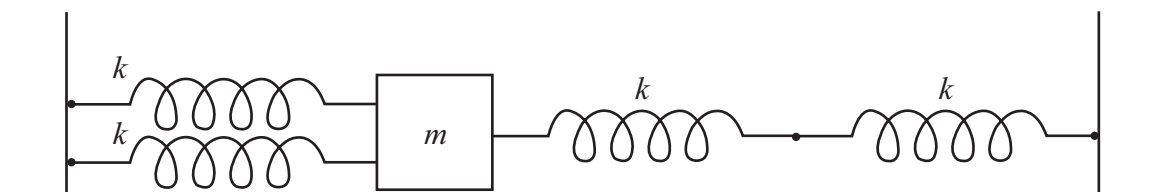
f) What is the new oscillation frequency, f_{new}, of this new system?

[2 marks]

Answer: …………………………………………………………………………………………………....

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A carbon monoxide molecule can be modelled as two different masses, m and M, each on one end of a light spring of spring constant, k.

When the molecule vibrates it does so such that the centre of mass of the molecule does not move. At time t the spring is extended and the masses are displaced from their equilibrium positions as shown in the diagram. The carbon atom, mass m, has moved a distance x to the left and is moving with a speed u to the left. The oxygen atom, mass M, has moved a distance X to the right and is moving with a speed v to the right.
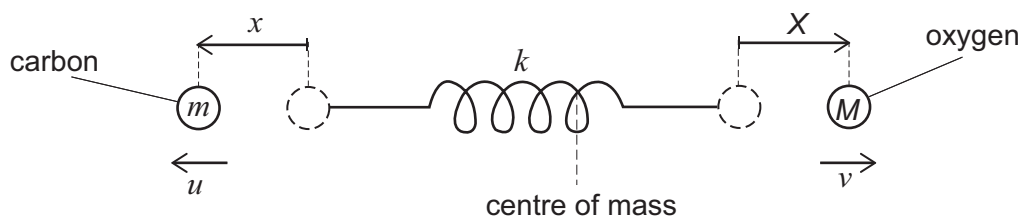
g) What is the total elastic potential energy stored in the spring in terms of k, x and X?

[1 mark]

Answer: ……………………………………………………………………………………........

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h) What is the total kinetic energy of the whole system in terms of m, u, M and v?

[1 mark]

Answer: ……………………………………………………………………………………........

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i) Explain in words why $MX = mx$. Hence deduce an expression for the acceleration, a_M, of mass M, in terms of the acceleration, a_m, of mass m.

[2 marks]

Answer: ……………………………………………………………………………………........

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j) Given that the total energy of the carbon monoxide molecule is constant, find an expression for the acceleration, a_m, of mass m, in terms of k, m, M and x.

Hence deduce the frequency of the oscillation, f.

[3 marks]

Answer: ....

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k) Calculate the frequency f of the vibration of the carbon monoxide molecule if the mass of the carbon atom is $12\,m_u$, the mass of the oxygen atom is $16\,m_u$ and $k = 2.0 \times 10^3\,\mathrm{N\,m^{-1}}$.

If this vibration was caused by an electromagnetic wave incident on the molecule, which part of the electromagnetic spectrum would this wave correspond to?

($m_u = 1.66 \times 10^{-27}$ kg. The wavelength of visible light ranges from 400 nm to 700 nm.)

[2 marks]

Answer: ....

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The Periodic Table of the Elements

Group																		He 2 4.003
H 1 1.008																		
Li 3 6.941	Be 4 9.012											B 5 10.81	C 6 12.01	N 7 14.01	O 8 16.00	F 9 19.00	Ne 10 20.18	
Na 11 22.99	Mg 12 24.31											Al 13 26.98	Si 14 28.09	P 15 30.97	S 16 32.06	Cl 17 35.45	Ar 18 39.95	
K 19 39.10	Ca 20 40.08	Sc 21 44.96	Ti 22 47.87	V 23 50.94	Cr 24 52.00	Mn 25 54.94	Fe 26 55.85	Co 27 58.93	Ni 28 58.69	Cu 29 63.55	Zn 30 65.38	Ga 31 69.72	Ge 32 72.63	As 33 74.92	Se 34 78.97	Br 35 79.90	Kr 36 83.80	
Rb 37 85.47	Sr 38 87.62	Y 39 88.91	Zr 40 91.22	Nb 41 92.91	Mo 42 95.95	Tc 43	Ru 44 101.1	Rh 45 102.9	Pd 46 106.4	Ag 47 107.9	Cd 48 112.4	In 49 114.8	Sn 50 118.7	Sb 51 121.8	Te 52 127.6	I 53 126.9	Xe 54 131.3	
Cs 55 132.9	Ba 56 137.3	La* 57 138.9	Hf 72 178.5	Ta 73 180.9	W 74 183.8	Re 75 186.2	Os 76 190.2	Ir 77 192.2	Pt 78 195.1	Au 79 197.0	Hg 80 200.6	Tl 81 204.4	Pb 82 207.2	Bi 83 209.0	Po 84	At 85	Rn 86	
Fr 87	Ra 88	Ac† 89																

Key

symbol
atomic number
relative atomic mass (A_r)

*Lanthanides	Ce 58 140.1	Pr 59 140.9	Nd 60 144.2	Pm 61	Sm 62 150.4	Eu 63 152.0	Gd 64 157.3	Tb 65 158.9	Dy 66 162.5	Ho 67 164.9	Er 68 167.3	Tm 69 168.9	Yb 70 173.0	Lu 71 175.0
†Actinides	Th 90 232.0	Pa 91 231.0	U 92 238.0	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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Chemistry

Question C1

Data: Assume that the molar gas volume = $24.0\,dm^3\,mol^{-1}$ at room temperature and pressure (rtp).

This question concerns the chemistry of tellurium, an element in Group 16 of the Periodic Table.

a) What do you expect will be the maximum and minimum oxidation states of tellurium? Briefly explain your answer.

[3 marks]

Answer: ……………………………………………………………………………………….....

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b) How do the electronegativities of the elements vary on descending Group 16?

[1 mark]

Answer: ……………………………………………………………………………………….....

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c) Which hydride, H_2O or H_2Te, has the higher boiling point? Briefly explain your answer.

[2 marks]

Answer: ……………………………………………………………………………………….....

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Tellurium reacts directly with fluorine gas to form a dense gas, **A**, in which each molecule contains a single tellurium atom bonded to several fluorine atoms. In an experiment, $50\,cm^3$ of gas **A** is formed from $150\,cm^3$ of fluorine and a certain mass of tellurium, with all measurements made at room temperature and pressure.

d) Calculate the formula of the gas **A**.

[2 marks]

Answer: …………………………………………………………………………………………........

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e) Predict the value(s) of the F−Te−F bond angles in **A**.

[1 mark]

Answer: …………………………………………………………………………………………........

f) Calculate the minimum mass of tellurium needed to produce $50\,cm^3$ of **A**.

[2 marks]

Answer: …………………………………………………………………………………………........

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g) Calculate the density of gas **A** in $g\,cm^{-3}$ at room temperature and pressure.

[2 marks]

Answer: …………………………………………………………………………………………........

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h) Calculate how many times denser gas **A** is than oxygen gas at room temperature and pressure.

[1 mark]

Answer: …………………………………………………………………………………………........

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In another experiment, 5.0 g of tellurium is oxidised and dissolved in water to form 9.0 g of an acid with general formula H_mTeO_n. On neutralisation with aqueous KOH, 18 g of a salt is formed with general formula K_mTeO_n.

i) Give an expression, in terms of m and n, for the oxidation state of the tellurium in the acid H_mTeO_n.

[1 mark]

Answer: ………………………………………………………………………………………......

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j) Calculate the relative molecular mass of the acid H_mTeO_n.

[1 mark]

Answer: ………………………………………………………………………………………......

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k) Calculate the values of m and n, and hence the formulae of the acid H_mTeO_n and the salt formed on neutralisation.

[2 marks]

Answer: ………………………………………………………………………………………......

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l) Calculate the volume of a $2.0\,mol\,dm^{-3}$ aqueous solution of KOH that would be needed to neutralise the 9.0 g of acid formed from 5.0 g of tellurium.

[2 marks]

Answer: ………………………………………………………………………………………......

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Question C2

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is $1.489\,g\,cm^{-3}$.

a) Draw the structure for trifluoroethanoic acid (TFEA). Indicate on your structure the approximate bond angles around each carbon.

[2 marks]

Answer:

An aqueous solution of TFEA is made up by mixing $0.0700\,mol$ of the pure acid with water and making the solution up to $100.0\,cm^3$.

b) Calculate the volume of pure TFEA needed to make the solution.

[3 marks]

Answer: …………………………………………………………………………………………………..
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c) Give an equation for the ionisation of TFEA in water.

[1 mark]

Answer: …………………………………………………………………………………………………..
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d) Give an expression for the equilibrium constant for the ionisation of TFEA in water.

[2 marks]

Answer: …………………………………………………………………………………………………

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e) Given that the measured concentration of H^+ ions is $0.4119\,mol\,dm^{-3}$, calculate the value of the equilibrium constant. You may ignore the self-dissociation of water.

[3 marks]

Answer: …………………………………………………………………………………………………

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A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:

A   + H_2O $\xrightarrow{\text{H}^+ \text{ catalyst}}$ **B**
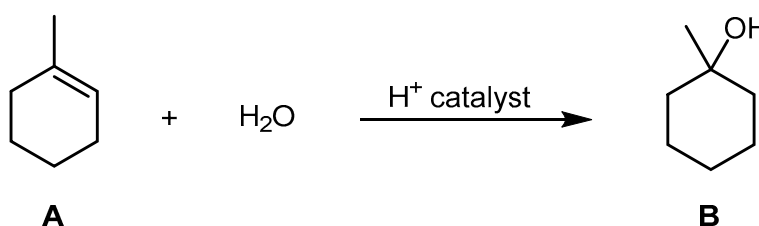
f) How may this reaction be classified? Choose from: *addition*, *elimination*, *substitution*, *oxidation*, *addition polymerisation*.

[1 mark]

Answer: …………………………………………………………………………………………………

g) Draw the structure of the intermediate initially formed when the H⁺ catalyst reacts with alkene **A**.

[1 mark]

Answer:

h) The same product **B** is formed when an alkene isomer of **A** is treated under identical conditions. Suggest a structure for this isomer.

[1 mark]

Answer:

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is $-98.3\,kJ\,mol^{-1}$.
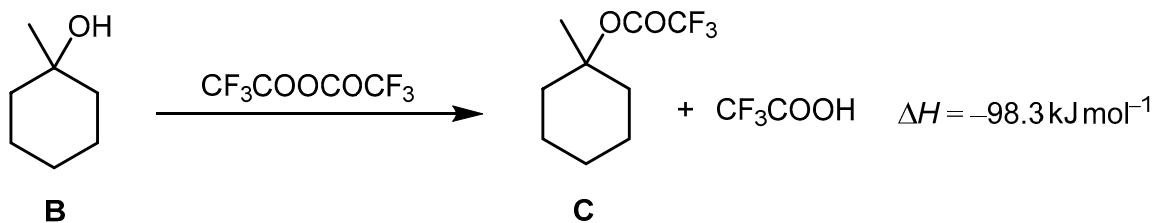
Compound **C** may also be formed in the same mixture of TFEA and trifluoroethanoic anhydride from the reaction between 1-methylcyclohexene and TFEA. The standard enthalpy change for this reaction is $-36.7\,kJ\,mol^{-1}$.
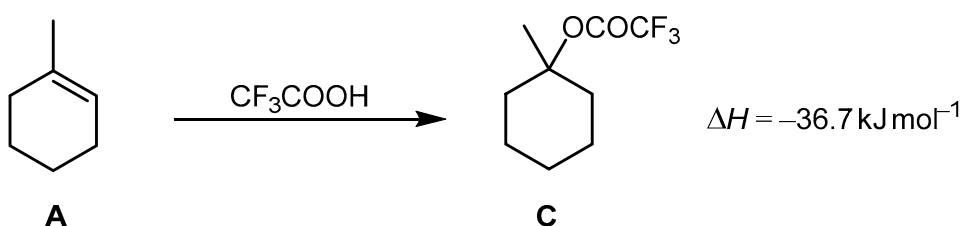
The standard enthalpy change for the reaction between one mole of water and one mole of trifluoroethanoic anhydride is $-75.6\,kJ\,mol^{-1}$.

i) Draw the structure of trifluoroethanoic anhydride.

[1 mark]

Answer:

j) Give the equation for the reaction between one mole of water and one mole of trifluoroethanoic anhydride.

[1 mark]

Answer: ……………………………………………………………………………………........

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k) By constructing an appropriate energy cycle, calculate the standard enthalpy change for the hydration of alkene **A**.

[4 marks]

Answer: ……………………………………………………………………………………........

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Biology

Question B1

The diagram shows an evolutionary tree for a kingdom of organisms. This tree was constructed over 20 years ago using shared observable features to group these organisms into smaller groups. The time at which three of these shared features first appeared is shown on the evolutionary tree. Each branching point in the tree indicates the time at which groups of organisms diverged from a common ancestor.
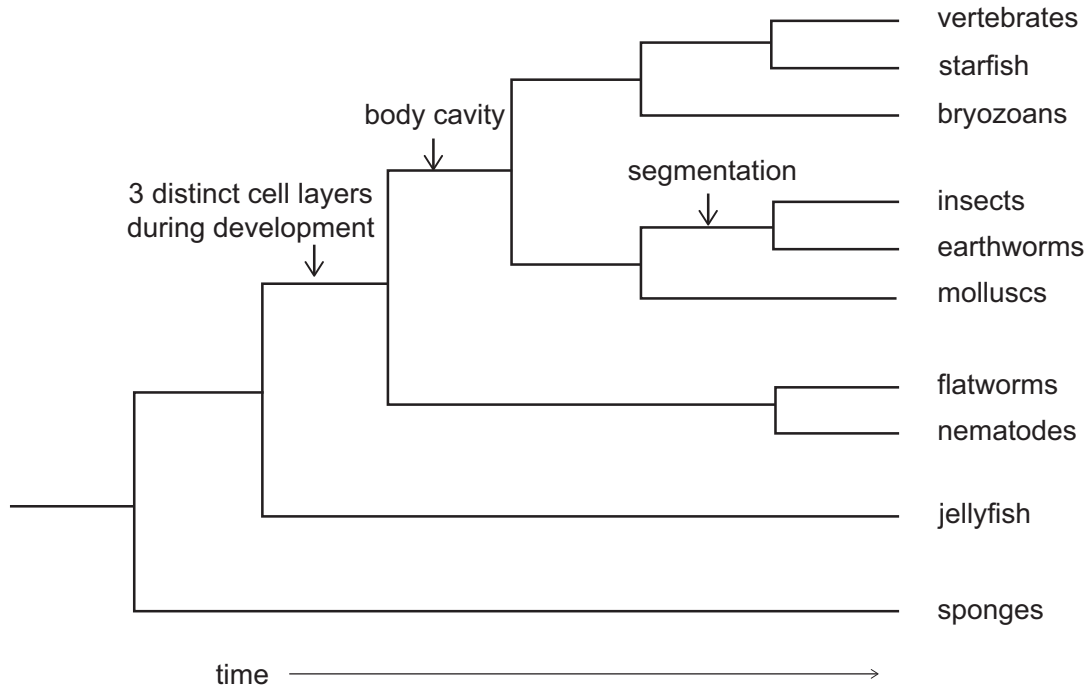
a) Identify the kingdom represented in this evolutionary tree.

[1 mark]

Answer: ………………………………………………………………………………………....

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b) Recently, molecular evidence has changed our understanding of these relationships. Based upon each of the three findings below, what conclusions about evolution can you draw?

(i) Insects and earthworms are not closely related to each other.

[1 mark]

Answer: ……………………………………………………………………………………………......

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(ii) Nematodes and insects, both of which undergo moulting, are very closely related.

[2 marks]

Answer: ……………………………………………………………………………………………......

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(iii) Flatworms, which all lack a true body cavity, are not actually a single group. Some diverged at the base of the tree, some are related to the molluscs, and some are related to starfish and vertebrates.

[2 marks]

Answer: ……………………………………………………………………………………………......

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c) Briefly describe two benefits of using molecular evidence, rather than visible characteristics, to construct trees.

[2 marks]

Answer: ………………………………………………………………………………………………....

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d) The following three tree diagrams show **all** of the possible relationships between 3 different organisms.

How many possible tree diagrams are there with 4 organisms?

[2 marks]

Answer:

e) Using examples, discuss the different ways by which we can measure biodiversity.

[10 marks]

Answer: ………………………………………………………………………………………...

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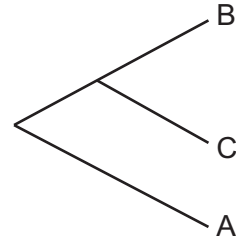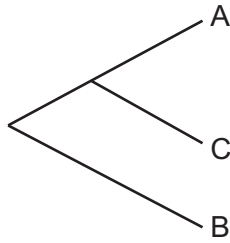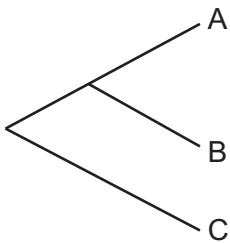
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Question B2

The graph shows net CO_2 uptake of two different plants, A and B, when exposed to increasing light levels.
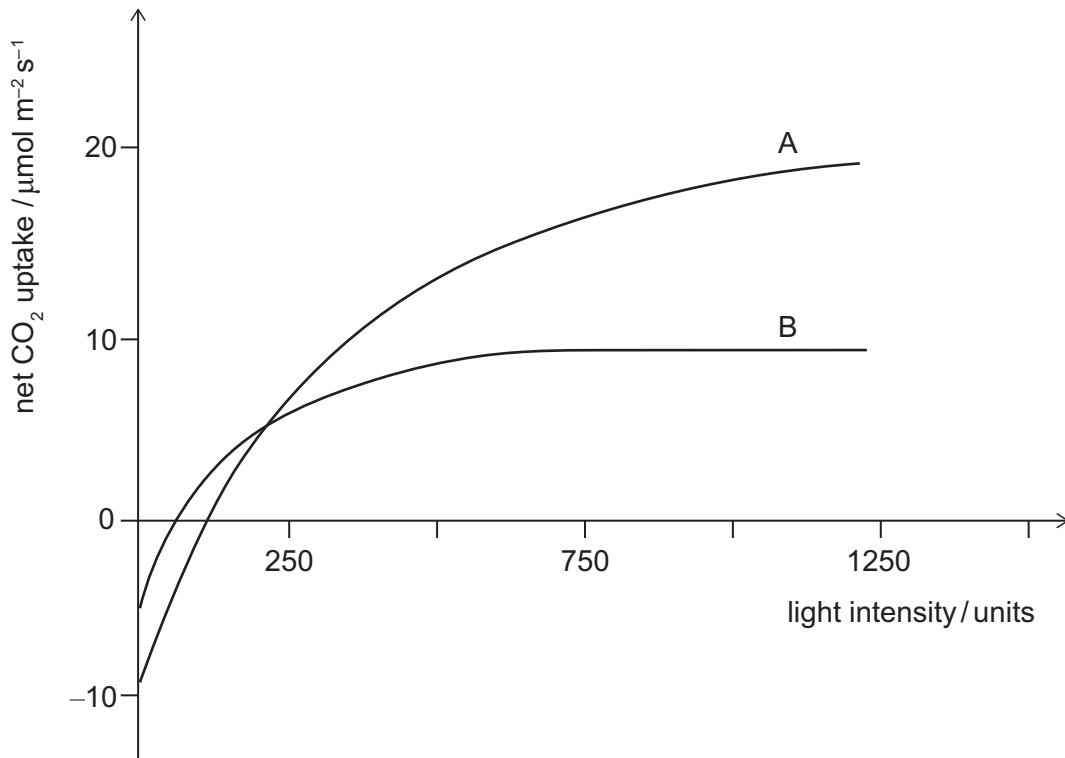
a) Name two physiological processes that affect the net CO_2 uptake in plants.

[1 mark]

Answer: ……………………………………………………………………………………………….....

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b) State what can be concluded when the net CO_2 uptake in each plant is zero.

[1 mark]

Answer: ……………………………………………………………………………………………….....

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c) For plant B, estimate the value at which increasing light intensity no longer affects CO_2 uptake.

[1 mark]

Answer: ………………………………………………………………………………………………......

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d) Estimate the number of micromoles of CO_2 that would be taken up by a 50 cm^2 leaf of plant B in one minute at light intensity of 750 units.

[2 marks]

Answer: ………………………………………………………………………………………………......

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e) Propose two explanations for the existence of a plateau in the curve for plant B.

[2 marks]

Answer: ………………………………………………………………………………………………......

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f) Describe the differences in the curves for plants A and B and suggest why these differences might occur.

[3 marks]

Answer: ………………………………………………………………………………………………......

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g) Discuss how temperature might affect net CO_2 uptake in plants, with reference to the effects of temperature on enzymatic activity. Use graphs to illustrate your answer.

[10 marks]

Answer:

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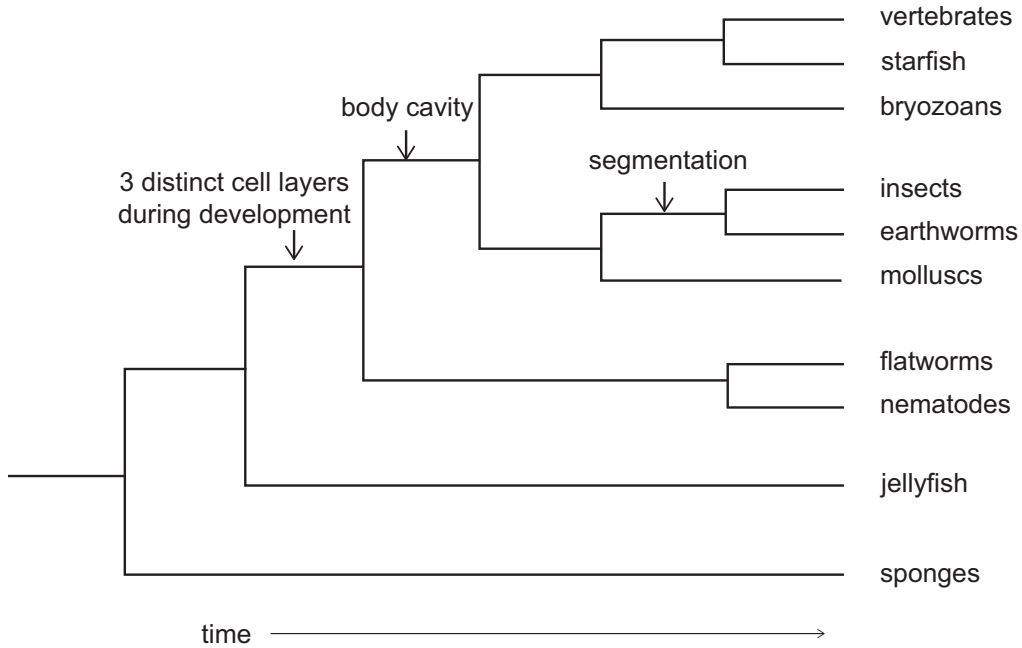This page is intentionally left blank for your rough working or notes.

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Biology

Question B1

The diagram shows an evolutionary tree for a kingdom of organisms. This tree was constructed over 20 years ago using shared observable features to group these organisms into smaller groups. The time at which three of these shared features first appeared is shown on the evolutionary tree. Each branching point in the tree indicates the time at which groups of organisms diverged from a common ancestor.

a) Identify the kingdom represented in this evolutionary tree.

[1 mark]

Answer: ...**ANIMALIA**..

………

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b) Recently, molecular evidence has changed our understanding of these relationships. Based upon each of the three findings below, what conclusions about evolution can you draw?

(i) Insects and earthworms are not closely related to each other.

[1 mark]

Answer: ………………………………………………………………………………………....
Segmentation is not a good indicator of relatedness/ it must have evolved independently (or ancestrally)
………………………………………………………………………………………………………

(ii) Nematodes and insects, both of which undergo moulting, are very closely related.

[2 marks]

Answer: ………………………………………………………………………………………....
Moulting arose in their common ancestor and is a good indicator of relatedness (1 Mark).
The above tree is incorrect (1 mark).
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(iii) Flatworms, which all lack a true body cavity, are not actually a single group. Some diverged at the base of the tree, some are related to the molluscs, and some are related to starfish and vertebrates.

[2 marks]

Answer: ………………………………………………………………………………………....
Absence of body cavity is not a good indicator of relatedness (1 mark).
………………………………………………………………………………………………………
It must have been lost independently, or the body cavity arose on many separate occasions (1 mark).
………………………………………………………………………………………………………
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c) Briefly describe two benefits of using molecular evidence to construct trees, rather than visible characteristics.

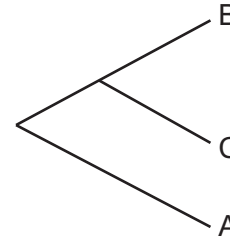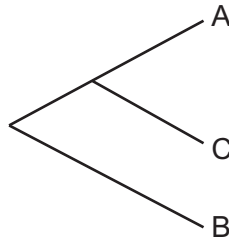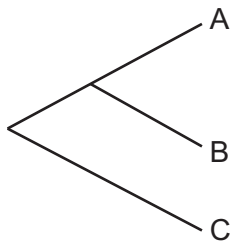**[2 marks]**

Answer: ……………………………………………………………………………………………......
Genetics provides a huge amount of data that can be used to construct trees (1 mark).
There is less convergence at the molecular level (1 mark)
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d) The following three tree diagrams show **all** of the possible relationships between 3 different organisms.
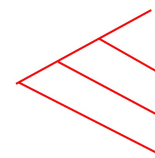

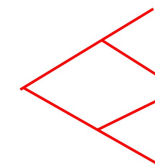How many possible tree diagrams are there with 4 organisms?   **[2 marks]**

Answer:

There are 15 trees, 12 with branching patterns of:

….and a further 3 with a different branching pattern:.

1 Mark should be awarded for an answer of 12, and 2 Marks for an answer of 15.

e) Using examples, discuss the different ways by which we can measure biodiversity.

[10 marks]

Answer: …………………………………………………………………………………………………..

There are basic points that should be made, but beyond this additional marks may be accrued for further insights

Basic points:

1. **Definition: the variety and complexity of life**
2. **Can be measured at a Genetic level**
3. **Can be measured at a Population level**
4. **Can be measured at a Habitat level (i.e. no species)**

Advanced points:

1. **Description of genetic variation**
2. **Mention of the importance of mutation in causing genetic differences**
3. **Discussion of the quantification of genetic differences (within + between species)**
4. **Discussion of classificatory systems**
5. **Discussion of the concept of a species**
6. **Mention that new new classificatory systems move beyond observable features**
7. **Mention of the role of Natural selection in causing diversity**
8. **Discussion of behavioural, physiological and anatomical adaptations**
9. **Mention of how quadrats and belt transects are used to investigate the distribution and abundance of organisms in a habitat.**
10. **Explanation of how to determine the number of organisms in a given area.**
11. **2 bonus points may be added for particularly in-depth descriptions of advanced conserations**

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Question B2

The graph shows net CO_2 uptake of two different plants, A and B, when exposed to increasing light levels.
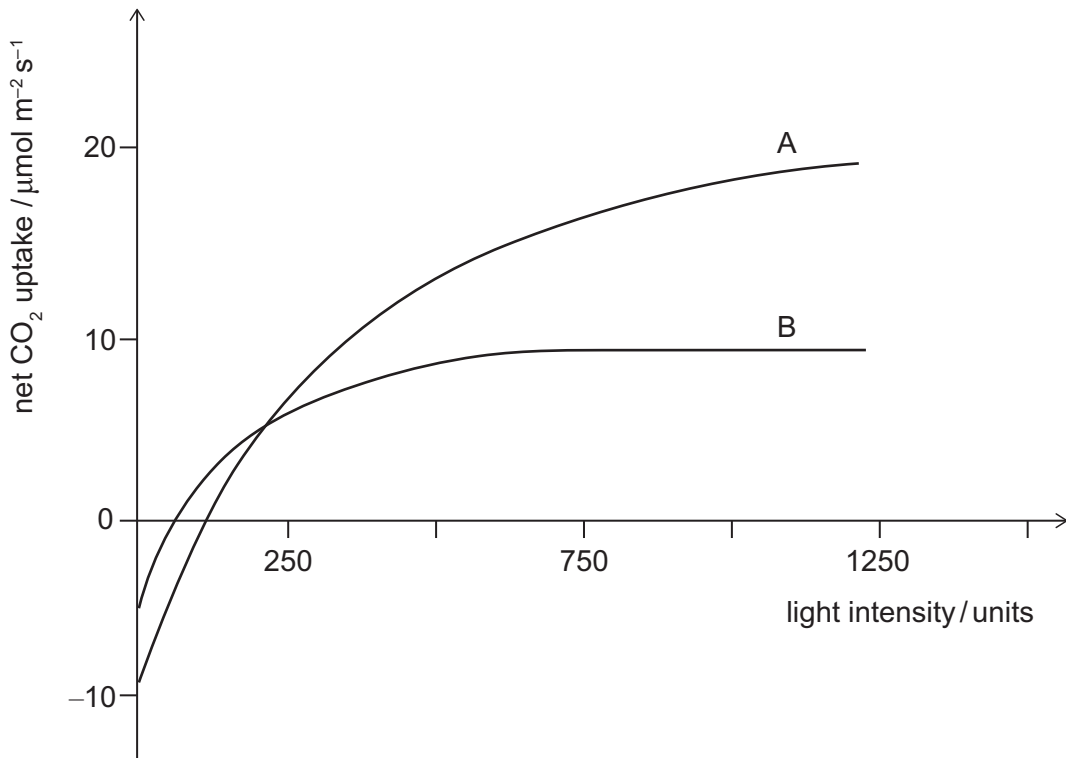
a) Name two physiological processes that affect the net CO_2 uptake in plants.

[1 mark]

Answer: ....**Photosynthesis + respiration**...

....

....

b) State what can be concluded when the net CO_2 uptake in each plant is zero.

[1 mark]

Answer: .....**The rate of photosynthesis is equal to the rate of respiration**..................................

....

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c) For plant B, estimate the value at which increasing light intensity no longer affects CO_2 uptake.

[1 mark]

Answer: **650-700** (some 1/2 marks were given if the student was close)
....

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d) Estimate the number of micromoles of CO_2 that would be taken up by a $50\,cm^2$ leaf of plant B in one minute at light intensity of 750 units.

[2 marks]

9 x 0.005m² x 60 =2.7µmol (2.4 -2.9 accepted)

Answer: ....

(1 mark lost for each unit not adjusted)

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e) Propose two explanations for the existence of a plateau in the curve for plant B.

[2 marks]

Answer: ....

Factors other than incident light limit photosynthesis (1 mark).

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These may include temperature, CO_2 levels, or enzymatic activity of the enzymes involved in the process (1 mark each, including if 1st mark not awarded).

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f) Describe the differences in the curves for plants A and B and suggest why these differences might occur.

[3 marks]

Answer: ....

Plant B has a higher CO2 uptake in low light intensities (1 mark)

Plant B reaches a lower plateau (light saturation point) (1 mark)

It would be found in plants that are adapted to living in low light conditions (1 mark)

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g) Discuss how temperature might affect net CO_2 uptake in plants, with reference to the effects of temperature on enzymatic activity. Use graphs to illustrate your answer.

[10 marks]

Answer:

Students should discuss both photosynthesis and respiration, using reaction curves. There are basic points that should be made, but beyond this additional marks may be accrued for further insights

Basic points (1 mark each):

1. **Depends upon relative rates of photosynthesis and respiration**
2. **Balance largely mediated through relative effects on enzyme activity**
3. **At low temperatures, rates are limited by molecular collisions between enzymes and substrates**
4. **A high temperatures, effects caused by denaturation of enzymes**
5. **Reaction curve for photosynthesis**
6. **Reaction curve for respiration (this may be generic)**
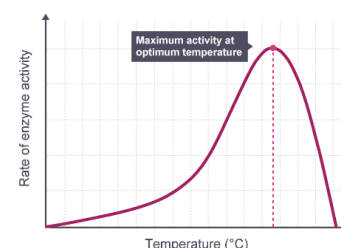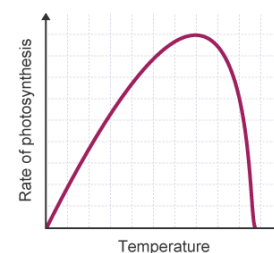
Advanced points (1 mark each):

1. **Mention of range of temperatures at which photosynthesis functions (0-50 degrees C) (or generic respiration)**
2. **Mention of optimum temperatures for photosynthesis (15-40 degrees C) (or generic respiration)**
3. **Comparisons of different types of plant**
4. **Mention of interactions with other limiting factors**
5. **Mention of anaerobic/aerobic effects**
6. **Mention of specific molecules involved in photosynthetic and respiratory reactions.**
7. **Attempt to super-impose and compare curves**
8. **Mention of temperature effects on diffusion of gases**
9. **Specific details on denaturation processes in enzyme**
10. **Anything else that is relevent.**
11. **2 bonus points may be added for particularly in-depth descriptions of advanced conserations**

Question 1

Data: Assume that the molar gas volume = 24.0 dm^3 mol^{-1} at room temperature and pressure (rtp).

This question concerns the chemistry of tellurium, an element in Group 16 of the periodic table.

a) What do you expect will be the maximum and minimum oxidation states of tellurium? Briefly explain your answer. [3 marks]

b) How do you expect the electronegativity of the elements to vary on descending Group 16? [1 mark]

c) Which of the hydrides H_2O and H_2Te do you expect will have the higher boiling point? Briefly explain your answer. [2 marks]

Tellurium reacts directly with fluorine gas to form a dense gas, **A**, in which each molecule contains a single tellurium atom bonded to several fluorine atoms. In an experiment, 50 cm^3 of gas **A** is formed from 150 cm^3 of fluorine and a certain mass of tellurium, all measurements made at room temperature and pressure.

d) Calculate the formula of the gas **A**. [2 marks]

e) Predict the value(s) of the F—Te—F bond angles in **A**. [1 mark]

f) Calculate the minimum mass of tellurium needed to produce 50 cm^3 of **A**. [2 marks]

g) Calculate the density of gas **A** in g cm^{-3} at room temperature and pressure. [2 marks]

h) Calculate how many times denser gas **A** is than oxygen gas. [1 mark]

In another experiment, 5.0 g of tellurium is oxidised and dissolved in water to form 9.0 g of an acid with general formula H_mTeO_n. On neutralisation with aqueous KOH, 18 g of a salt is formed with general formula K_mTeO_n.

i) Give an expression, in terms of m and n, for the oxidation state of the tellurium in the acid H_mTeO_n. [1 mark]

j) Calculate the relative molecular mass of the acid H_mTeO_n. [1 mark]

k) Calculate the values of m and n and hence the formulae of the acid H_mTeO_n and the salt formed on neutralisation. [2 marks]

l) Calculate the volume of a 2.0 mol dm^{-3} aqueous solution of KOH that would be needed to neutralise the 9.0 g of acid formed from 5.0 g of tellurium. [2 marks]

Answers for Question 1

a) Minimum oxidation state = -2 (Te needs 2 electrons for noble gas configuration)
   Maximum oxidation state = +6 (all six of its valence electrons being used in bond
   formation). **[3]**

b) Electronegativity decreases on moving down a group. **[1]**

c) (Generally boiling points for analogous hydrides in a group would increase with the
   mass of the molecule), but due to hydrogen bonding. H_2O would have the higher
   boiling point. **[2]**

d) Since only one Te atom present molecule, 3 moles of F2 form 1 mol of gas A. So 1
   mol of A must containt 6 mols of F, i.e. A is TeF_6. **[2]**

e) Octahedral stucture, so F—Te—F must be 90°. **[1]**

f) Moles of A = 50/24000. Mass of Te = 127.6 x 50/24000 = 0.266 g **[2]**

g) Density = [127.6+(6x19)]/24000 = 0.01007 g cm^{-3}. **[2]**

h) Ratio of densities = ratio of molar masses = [(6x19)+127.6]/32 = 7.55 **[1]**

i) $2n - m$ **[1]**

j) 9.0 g of acid contains 5.0 g of Te. So one mole of Te (127.6 g) would be in 127.6 x 9.0
   / 5.0 = 230 g. **[1]**

k) RMM of salt = 127.6 x 18 / 5.0 = 459.

   459 – 230 = 39m – m
   so m = 6.0
   n = [230 -127.6 – 6]/16 = 6
   Formulae are H_6TeO_6 and K_6TeO_6. **[2]**

l) moles of acid = 5 / 127.6
   moles of KOH needed = 6 x 5 / 127.6
   volume needed = 6 x 5 x 1000 / (127.6 x 2) = 117 cm^3. **[2]**

Question 2

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is 1.489 g cm^{-3}.

a) Draw the structure for trifluoroethanoic acid (TFEA). Indicate on your structure the approximate bond angles around each carbon. [2 marks]

An aqueous solution of TFEA is made up by mixing 0.0700 mol of the pure acid with water and making the solution up to 100.0 cm^3.

b) Calculate the volume of pure TFEA needed to make the solution. [3 marks]

c) Give an equation for the ionization of the TFEA in water. [1 mark]

d) Give an expression for the equilibrium constant for the ionization of TFEA in water. [2 marks]

e) Given that the measured concentration of H$^+$ ions is 0.4119 mol dm^{-3}, calculate the value of the equilibrium constant. You may ignore the self-dissociation of water. [3 marks]

A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:
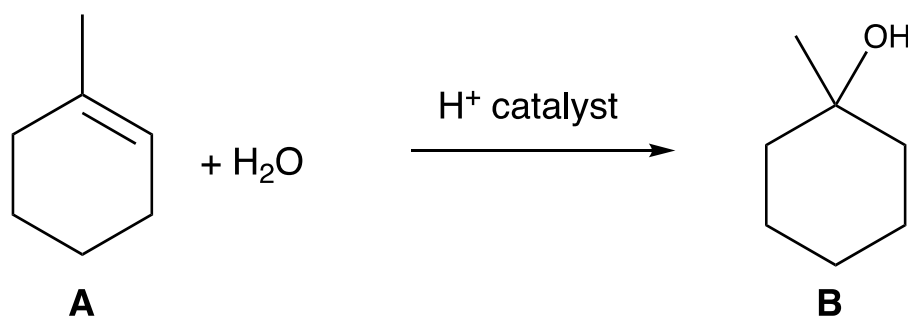
f) How may this reaction be classified? Choose from addition, elimination, substitution, oxidation, addition polymerisation. [1 mark]

g) Draw the structure of the species initially formed when the H$^+$ catalyst reacts with alkene **A**. [1 mark]

h) The same product **B** is formed when an alkene isomer of **A** is treated under identical conditions. Suggest a structure for this isomer. [1 mark]

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is −98.3 kJ mol^{-1}.
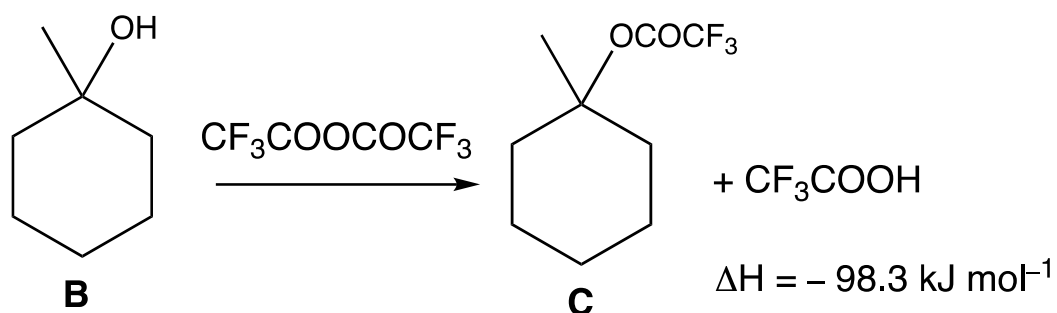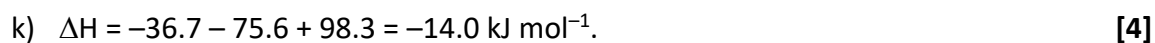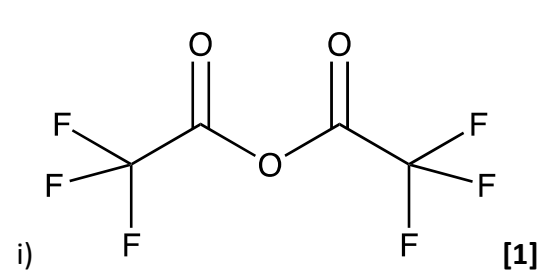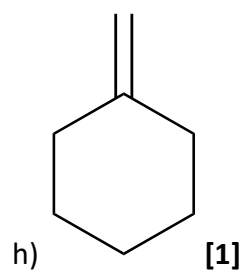

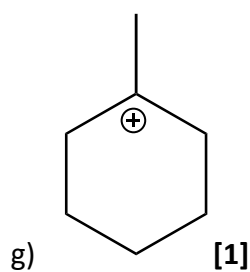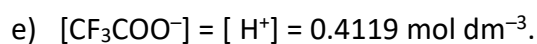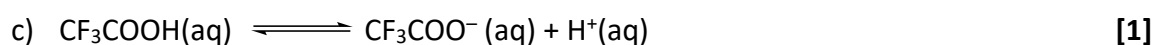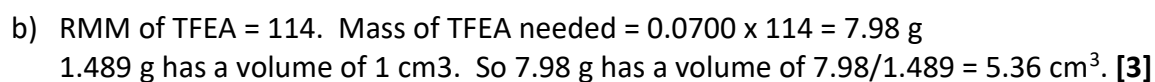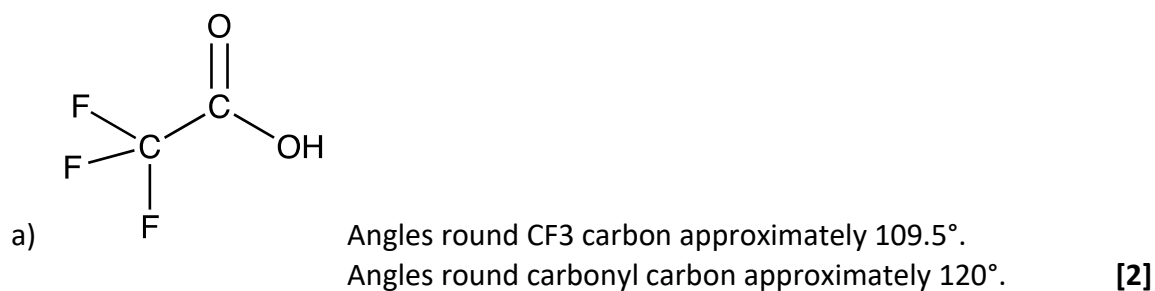Compound **C** may also be formed in the same mixture of TFEA and trifluoroethanoic anhydride from the reaction between 1-methylcyclohexene and trifluoroethanoic acid. The standard enthalpy change for this reaction is −36.7 kJ mol^{-1}.
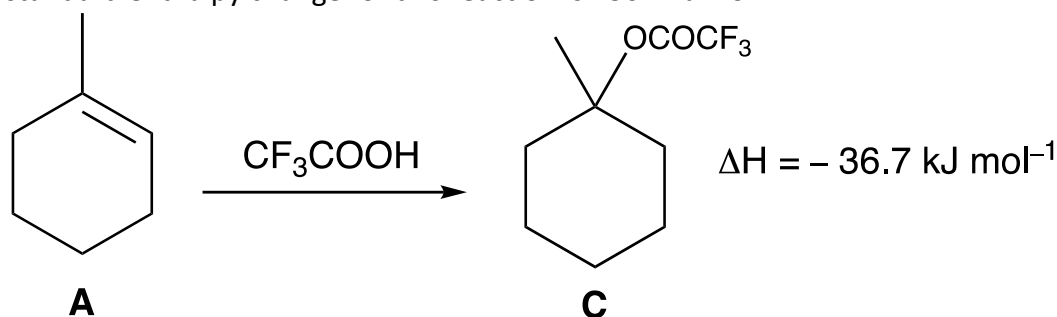
The standard enthalpy change for the reaction between one mole of water and one mole of trifluoroethanoic anhydride is −75.6 kJ mol^{-1}.

   i)   Give the structure of trifluoroethanoic anhydride.   [1 mark]

   j)   Give the equation for the reaction between one mole of water and one mole of trifluoroethanoic anhydride.   [1 mark]

   k)   By constructing an appropriate energy cycle, calculate the standard enthalpy changes for the hydration of alkene **A**.   [4 marks]
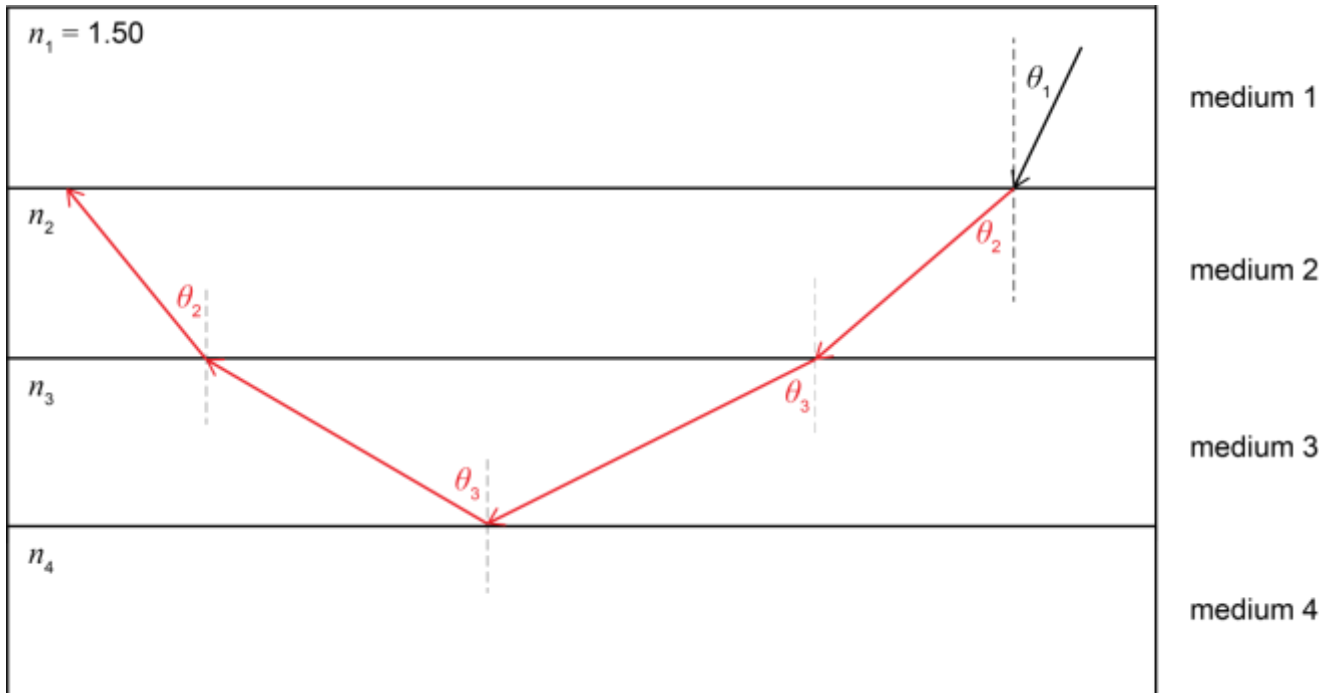
Answers for Question 2

a) Angles round CF3 carbon approximately 109.5°.
Angles round carbonyl carbon approximately 120°. **[2]**

b) RMM of TFEA = 114. Mass of TFEA needed = 0.0700 x 114 = 7.98 g
1.489 g has a volume of 1 cm3. So 7.98 g has a volume of 7.98/1.489 = 5.36 cm^3. **[3]**

c) $CF_3COOH(aq) \rightleftharpoons CF_3COO^-(aq) + H^+(aq)$ **[1]**

d) $K_{eq} = [CF_3COO^-][H^+] / [CF_3COOH]$ **[2]**

e) $[CF_3COO^-] = [H^+] = 0.4119$ mol dm^{-3}.

$[CF_3COOH] = 0.700 - 0.4119 = 0.2881$ mol dm^{-3}.

$K_{eq} = 0.4119\textasciicircum2 / 0.2881 = 0.589$ **[3]**

f) addition **[1]**

g) **[1]** h) **[1]** i) **[1]**

j) $CF_3COOCOCF_3 + H_2O \longrightarrow 2\ CF_3COOH$ **[1]**

k) $\Delta H = -36.7 - 75.6 + 98.3 = -14.0$ kJ mol^{-1}. **[4]**
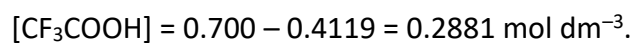
Answers for Question P1

a) [TOTAL = 7 marks]

i)

[1 mark] for correctly showing each ray bending away from the normal.
[1 mark] for showing reflection or critical condition at n_3, n_4 boundary.

ii) [1 mark] Snell's Law $n_1 \sin \theta_1 = n_2 \sin \theta_2$
$n_2 \sin \theta_2 = n_3 \sin \theta_3$
$n_3 \sin \theta_3 = n_4 \sin 90$

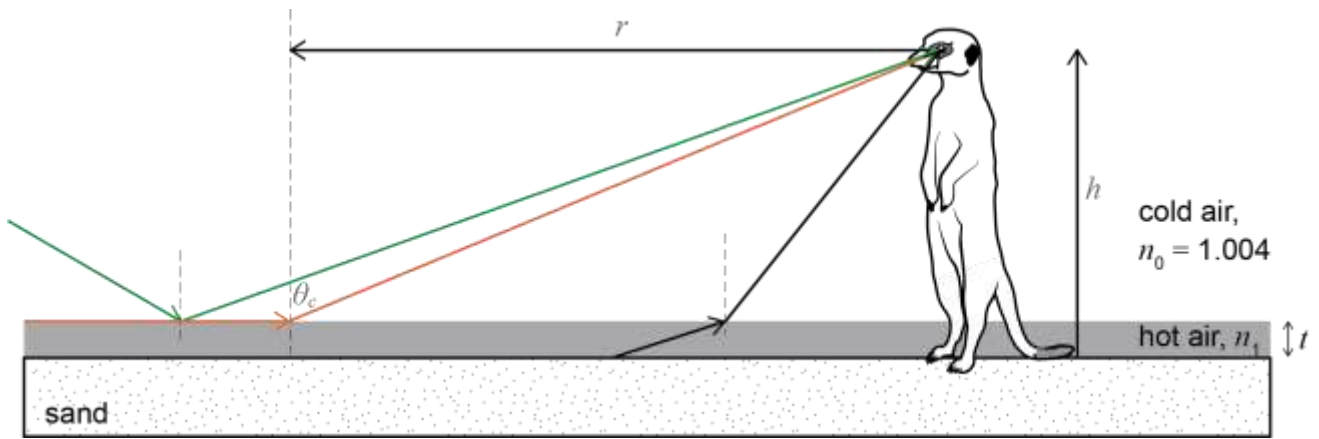[1 mark] Realising that $\theta_4 = 90°$ (or in form $\sin C = \frac{1}{n}$)
[1 mark] answer,
$$\sin \theta_1 = \frac{n_4}{n_1}$$
$$\theta_1 = \arcsin \frac{n_4}{n_1}$$

iii) [1 mark] $n_4 = 1.50 \times 0.99^3 \approx 1.46 \ (1.4554)$,
[1 mark] $\theta_1 = \arcsin (0.99^3) \approx 76° \ (76.001° = 1.326 \text{ rad})$,

b) [TOTAL = 8 marks]

i)

Green ray.   [**1 mark**]
Black ray.   [**1 mark**]

ii) Orange ray   [**1 mark**]

$n_1 \sin 90 = n_0 \sin \theta_c$ [**1 mark**]
$\sin \theta_c = n_1 / n_0$ [**1 mark**]

iii) $\dfrac{r}{\sqrt{(r^2 + h^2)}} = \dfrac{R}{\sqrt{(R^2 + H^2)}}$ (from Snell's Law and sine of the angle)

Equally $\tan \theta_c$ has to be the same for both animals therefore

$\dfrac{R}{r} = \dfrac{H}{h}$ [**1 mark**] **Note:** 0.5 mark for $\dfrac{R}{r} = \dfrac{H\text{-}t}{h\text{-}t}$ as $t \ll h \ll H$ has not been considered

iv) $n = n_c \sin \theta_c$ [**1 mark**]

$n = \dfrac{n_c\, r}{\sqrt{h^2 + r^2}}$ [**1 mark**] this mark is for correctly expressing $\sin \theta_c$ in terms of r and h

$r^2(n_c^2 - n^2) = h^2 n^2$

$r = \dfrac{hn}{\sqrt{n_c^2 - n^2}}$ therefore $a=1$, $b=1$, $k= -1$ [**1 mark in total for the 3 coefficients any coefficient**

wrong = 0]

v) as the hot air gets hotter n decreases therefore the denominator gets bigger and the numerator gets smaller so r must get smaller (h and n are constant). Need numerator and denominator   [**1 mark**]

r gets smaller   [**1 mark**]

note: that although the question says "using the expression" we would also give **1 mark** for the explanation that if the hot air cooled to the temperature of the cold air you would "see" no water therefore if the air got hotter the island must shrink and r get smaller.

note: students will give the incorrect answer gets "bigger" if they have not taken the critical angle from the normal but to the horizontal by mistake

c) A = refraction   [**1 mark**]
B = total internal reflection   [**1 mark**]

Answers for Question P2

a) $E_p = \frac{1}{2}kx^2$ **[1 mark,** if students went on to write something that was incorrect then **1/2]**

b) $E_k = \frac{1}{2}mv^2$ **[1 mark,** if students went on to write something that was incorrect then **1/2]**

c) $\frac{dE_p}{dt} = kxv$ **[1 mark if clearly shown that** $\frac{dE_p}{dx} = kx$ **and that** $\frac{dx}{dt} = v$**]**

$\frac{dE_k}{dt} = \frac{dE_k}{dv}\frac{dv}{dt}$ **[1 mark for correct chain rule]**

$\frac{dE_k}{dt} = mva$ **[1 mark]**

d) **The total energy of the system must remain constant** therefore the rate of change of the total energy = 0; (note: stating energy is conserved is sufficient for the mark)   **[1 mark]**

e) $\frac{dE_T}{dt} = kxv + mva = 0$ **[1 mark]**

$kx = -ma$

$a = -\frac{k}{m}x$ **[1 mark]**

$\therefore f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ **[1 mark]**

note: the question explicitly asks students to show all of their working so if they just write down the answer they only achieve 1 mark. It also asks that they use part c) and d). If they use forces rather than parts c) & d) only 1 mark given.

note: if students gave a physical incorrect answer (i.e. $f = \frac{-1}{2\pi}\sqrt{\frac{k}{m}}$ or $f = \frac{1}{2\pi}\sqrt{-\frac{k}{m}}$ then the mark was not given. Benefit was given if students wrote $f = \pm\frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

f) $k_{eff} = 2k + \frac{k}{2} = \frac{5k}{2}$ **[1 mark, each spring ½ mark – if the student indicated the incorrect result for series or parallel then 0 mark** (e.g. parallel = $\frac{k}{2}$) **]**

$\therefore f_{new} = \frac{1}{2\pi}\sqrt{\frac{5k}{2m}}$ **[1 mark]**

g) $E_p = \frac{1}{2}k(x + X)^2$ **[1 mark]**

$E_p = \frac{1}{2}k(x - X)^2$ gets 0 marks as the spring is extended by $(x + X)$ (if students indicated vectors the negative permitted)

h) $E_k = \frac{1}{2}(mu^2 + Mv^2)$ **[1 mark]**

i) Ideal answer is to state that the momenta of each particle must be equal and opposite for the centre of mass to remain stationary, therefore $mu = Mv$ and integrating gives $mx = MX$.   **[1 mark]**

Note: COM stationary is stated in the questions but benefit [1 mark] was given for stating this as the reason as long as students did not them go on to give further incorrect discussion. Students often referred to moments for the reason $mx = MX$ [0 mark]. If the answer was ambiguous or imprecise then 0 mark was given. Conservation of momentum without further information = 0, Newton's third law without detail of relevance = 0). In summary, the examiners gave the mark for an explanation **in words** that was precise and demonstrated a thorough understanding of the system.

$a_M = \frac{ma_m}{M}$ **[1 mark]** can be positive or negative.

Note: Credit was given for $a_M = \frac{Xa_m}{x}$, although xa_M is not a useful physical quantity, as long as the reasoning for the expression was correct and clear.

j) $E_T = \frac{1}{2}kx^2\left(1 + \frac{m}{M}\right)^2 + \frac{1}{2}\left(mu^2 + \frac{Mm^2}{M^2}u^2\right)$ **[1 mark]** this mark is for correctly substituting for X and v in terms of x and u. This may be done at this stage by the student or after the next step – the mark should be given irrespective of when the substitution happens.

$\frac{dE_T}{dt} = kxu\left(1 + \frac{m}{M}\right)^2 + mua_m + \frac{m^2}{M}ua_m = 0$ **[1 mark]**

Note: if students solve this question by analogy then **[1 mark]** for the correct coefficient of kxu and **[1 mark]** for the correct coefficient of mua.

$kxu\left(1 + \frac{m}{M}\right)^2 + mua_m\left(1 + \frac{m}{M}\right) = 0$

$\frac{k}{m}x\left(1 + \frac{m}{M}\right) + a_m = 0$

$a_m = -k\left(\frac{1}{m} + \frac{1}{M}\right)x$

$\therefore f = \frac{1}{2\pi}\sqrt{k\left(\frac{1}{m} + \frac{1}{M}\right)}$ or $\frac{1}{2\pi}\sqrt{k\left(\frac{M+m}{mM}\right)}$ **[1 mark]**

k) $f = 6.65 \times 10^{13}\,\text{Hz}$ **[1 mark,** if previous frequency expression wrong but numbers applied correctly 1 ecf given**]**

$\lambda = \frac{3 \times 10^8}{6.65 \times 10^{13}} = 4.5(1)\,\mu\text{m} \approx 4500\,\text{nm}$ therefore **Infra-red** **[1 mark]**

Note: Students were given the mark for just stating (knowing) infra-red.