UNIVERSITY OF
CAMBRIDGE

Natural Sciences Admissions Assessment

Section 2

Specimen Sample Questions: Explained Answers

Updated for 2022

Part X Physics

1 The answer is option **C**.

This problem can be solved by considering the vertical and horizontal motion separately and using the equations of motion, since the acceleration is constant.

Vertically:

$$s = ut + \frac{1}{2}at^2$$

$$4 = \frac{1}{2}gt^2$$

$$t^2 = \frac{4}{5}$$

$$t = \frac{2}{\sqrt{5}}\,\text{s}$$

Horizontally:

$$\text{distance} = \text{speed} \times \text{time}$$

$$\frac{6\sqrt{5}}{5} = \frac{2\sqrt{5}}{5}v$$

$$v = \frac{5 \times 6\sqrt{5}}{5 \times 2\sqrt{5}}$$

$$v = 3\,\text{m}\,\text{s}^{-1}$$

2 The answer is option **A**.

This problem can be solved by using $V = IR$ and

$$\text{resistivity} = \text{resistance} \times \frac{\text{cross-sectional area}}{\text{length}}, \quad \rho = \frac{RA}{l}$$

The current in the resistor is given by:

$$I = \frac{V}{R} = \frac{\text{pd across resistor}}{\text{resistance of resistor}} = \frac{1.0}{1.0 \times 10^{3}} = 1.0 \times 10^{-3}\,\text{A}$$

The wire and the resistor are connected in series so the current is the same in each of them.

The wire and the resistor act as a potential divider. The 1.2 V across the arrangement is shared between the wire and the resistor.

There is 1.0 V across the resistor so the pd across the wire is:

$$(1.2 - 1.0) = 0.20\,\text{V}$$

Therefore the resistance of the wire is given by:

$$R = \frac{V}{I} = \frac{\text{pd across wire}}{\text{current in wire}} = \frac{0.2}{1.0 \times 10^{-3}} = 2.0 \times 10^{2}\,\Omega$$

The resistivity is then:

$$\rho = \frac{RA}{l} = \frac{\left(2.0 \times 10^{2}\right) \times \left(0.020 \times 10^{-6}\right)}{4.0} = 1.0 \times 10^{-6}\,\Omega\,\text{m}$$

3 The answer is option **A**.

This problem can be solved by considering each set of resistors and the internal resistance separately.

The combined resistance of the two $10\,\Omega$ resistors in parallel is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{10\,\Omega} + \frac{1}{10\,\Omega} = \frac{1}{5\,\Omega}$$

$$R_{\text{total}} = \frac{10\,\Omega \times 10\,\Omega}{10\,\Omega + 10\,\Omega}$$

$$R_{\text{total}} = 5.0\,\Omega$$

The total resistance in the circuit, not including the internal resistance of the battery, is:

$$5.0\,\Omega + 3.0\,\Omega = 8.0\,\Omega$$

The total resistance in the circuit including the internal resistance of the battery is:

$$\frac{\text{emf}}{I} = \frac{20\,\text{V}}{2.0\,\text{A}} = 10\,\Omega$$

The internal resistance of the battery is $10\,\Omega - 8.0\,\Omega = 2.0\,\Omega$

4 The answer is option **C**.

This problem can be solved by first considering one cable individually.

Calculate the force applied by one of the cables by combining the equation for Young modulus:

$$E = \frac{\sigma}{\varepsilon}$$

and the equation defining stress:

$$\sigma = \frac{F}{A}$$

to give:

$$\sigma = \varepsilon E = \frac{F}{A}$$

$$F = \varepsilon EA$$

$$F = 0.0025 \times 2.0 \times 10^{11} \times 2.0 \times 10^{-4}$$

$$F = 1.0 \times 10^{5}\,\mathrm{N}$$

The four cables are connected in parallel so the total force on the boulder is

$$4.0 \times 10^{5}\,\mathrm{N} = 400\,\mathrm{kN}$$

The boulder is moving at constant velocity so the resultant force is zero and the frictional force is equal to the total pulling force. Therefore the magnitude of the frictional force is also 400 kN.

Power transfer is given by $P = Fv = 400\,000\,\mathrm{N} \times 0.20\,\mathrm{m\,s^{-1}} = 80\,000\,\mathrm{W} = 80\,\mathrm{kW}$.

5 The answer is option **B**.

This problem can be solved by considering the situation when the object is falling at an acceleration of $0.5g$ with velocity v_0.

Weight of object $= mg$

Drag force acting on object $F = kv_0^n$

Resultant force on object downwards $= mg - kv_0^n = ma = 0.5mg$

Rearranging:

$$\frac{1}{2}mg = kv_0^n$$

$$k = \frac{mg}{2v_0^n}$$

Now consider the object falling at terminal speed v_T:

Drag force = weight, so:

$$kv_T^n = mg$$

$$\frac{mg}{2v_0^n}v_T^n = mg$$

$$2v_0^n = v_T^n$$

Raising both sides to the power $(1/n)$:

$$2^{(1/n)}v_0 = v_T$$

6 The answer is option **E**.

This problem can be solved by considering the ratio of the forces on and extensions of the springs.

The weight of each mass is $0.10\,\text{kg} \times 10\,\text{N}\,\text{kg}^{-1} = 1.0\,\text{N}$

The weight of the springs can be ignored because their masses are negligible.

The force on the upper spring is 2.0 N, and the force on the lower spring is 1.0 N.

As they are subjected to different forces, the two springs will have different extensions.

Force, F, and extension, x, are related by $F = kx$ and the spring constant, k, is the same for both springs.

Therefore, since the ratio of the forces on the upper and lower springs is 2 **:** 1, their extensions must also be in the ratio 2 **:** 1

The sum of the extensions of the two springs is $30.0\,\text{cm} - (2 \times 12.0\,\text{cm}) = 6.0\,\text{cm}$.

Splitting this in the ratio 2 **:** 1 gives 4.0 cm **:** 2.0 cm for the extensions of the upper and lower springs respectively.

The spring constant k can be calculated by considering either of the springs:

Upper spring:

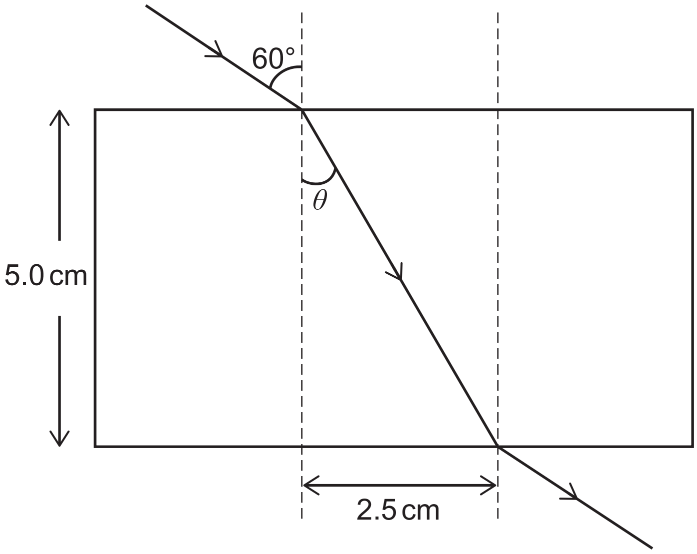
$$k = \frac{F}{x} = \frac{2.0\,\text{N}}{4.0\,\text{cm}} = 0.50\,\text{N}\,\text{cm}^{-1}$$

Lower spring:

$$k = \frac{F}{x} = \frac{1.0\,\text{N}}{2.0\,\text{cm}} = 0.50\,\text{N}\,\text{cm}^{-1}$$

7 The answer is option **H**.

This problem can be solved by using trigonometry to find the angle θ (shown in the diagram) and then using the law of refraction to find the refractive index n of the block.



Using Pythagoras, $\sin\theta = \dfrac{2.5}{\sqrt{2.5^2+5.0^2}} = \dfrac{2.5}{\sqrt{\dfrac{25}{4}+25}} = \dfrac{2.5}{\sqrt{\dfrac{125}{4}}} = \dfrac{2.5}{\sqrt{\dfrac{5\times5\times5}{4}}} = \dfrac{2.5}{2.5\sqrt{5}} = \dfrac{1}{\sqrt{5}}$

Since $\sin 60° = \dfrac{\sqrt{3}}{2}$

$$n = \frac{\sin 60°}{\sin\theta} = \frac{\left(\dfrac{\sqrt{3}}{2}\right)}{\left(\dfrac{1}{\sqrt{5}}\right)} = \frac{\sqrt{3}\sqrt{5}}{2} = \frac{\sqrt{15}}{2}$$

8 The answer is option **B**.

This problem can be solved by considering the displacements of point mass.

Assume that positive vector quantities are in the direction from P towards Q time $t = 0$.

The point of zero displacement is taken to be the position of P at time $t = 0$.

At time t, mass P has displacement

$$s = \frac{1}{2}at^2$$

$$= \frac{1}{2} \times 6 \times t^2$$

$$= 3t^2$$

The initial displacement of Q is +60 m.

At time t, mass Q has displacement

$$s = 60 + ut + \frac{1}{2}at^2$$

$$= 60 + (-14t) + \frac{1}{2} \times 2t^2$$

$$= 60 - 14t + t^2$$

Masses P and Q meet when they have the same displacement at the same time, so

$$3t^2 = 60 - 14t + t^2$$

$$2t^2 + 14t - 60 = 0$$

$$t^2 + 7t - 30 = 0$$

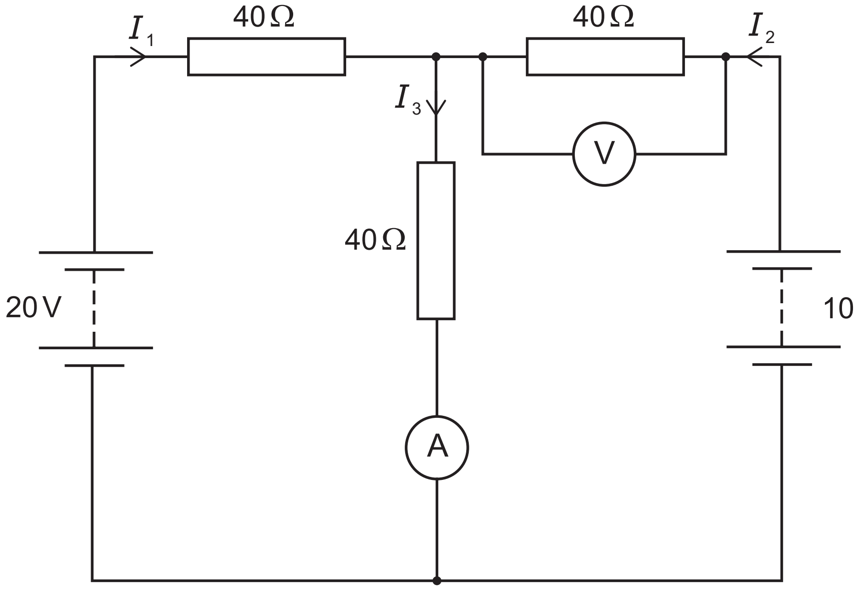
$$(t - 3)(t + 10) = 0$$

Therefore P and Q will meet when $t - 3 = 0$, so $t = 3.0$ s.

9 The answer is option **A**.

This problem can be solved using Kirchhoff's laws and solving the resulting simultaneous equations.

Label currents I_1, I_2 and I_3 as shown in the diagram.



Using Kirchhoff's laws:

$$I_3 = I_1 + I_2 \qquad (1)$$

$$20 = 40I_1 + 40I_3 \qquad (2)$$

$$10 = 40I_2 + 40I_3 \qquad (3)$$

From (1) $I_1 = I_3 - I_2$, so substitute for I_1 into (2):

$$20 = 80I_3 - 40I_2$$

Add this to (3):

$$30 = 120I_3$$

giving the ammeter reading I_3:

$$I_3 = \frac{30}{120} = 0.25\,\text{A}$$

Substitute for I_3 into (3):

$$10 = 40I_2 + 10$$

$$I_2 = 0\,\text{A}$$

The voltmeter is therefore connected across a resistor that has no current, so the voltage across it is zero, and the voltmeter reading is 0 V.

10 The answer is option **E**.

This problem can be solved by considering both the hydrostatic pressure and the pressure due to the force of the water falling.

The water falls 45 m. Its velocity just before hitting the rock can be calculated from conservation of energy:

change in kinetic energy = change in gravitational potential energy

$$\frac{1}{2}mv^2 = mgh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \times 10 \times 45}$$

$$= \sqrt{900}$$

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

The pressure on the rock surface arises from two things. Firstly, the hydrostatic pressure from water resting on the surface, and secondly the pressure exerted on the surface as the water stops, equal to its rate of change of momentum divided by the area of the rock.

hydrostatic pressure $P_1 = \rho gh = 1000 \times 10 \times 0.050 = 500\,\mathrm{Pa}$

pressure $P_2 = \frac{F}{A} = \frac{\Delta(mv)}{A\Delta t} = \frac{40 \times 30}{2.0} = 600\,\mathrm{Pa}$

Total pressure exerted on the rock is $P = P_1 + P_2 = 500 + 600 = 1100\,\mathrm{Pa}$.

Part Y Chemistry

11 The answer is option **D**.

The heat required to warm the copper container and that required to warm the water are calculated separately using the expression $Q = mc\Delta T$

Copper: $Q_1 = 500 \times 0.4 \times 60 = 12\,000\,\text{J} = 12\,\text{kJ}$

Water: $Q_2 = 400 \times 4 \times 60 = 96\,000\,\text{J} = 96\,\text{kJ}$

Total heat transfer $= Q_1 + Q_2 = 12 + 96 = 108\,\text{kJ}$

This is only 20% of the heat released by burning the methane.

So, total heat released from burning $= 108 \times \dfrac{100}{20} = 540\,\text{kJ}$

Number of moles of methane burned to release this amount of heat $= \dfrac{540}{900} = 0.6\,\text{mol}$

Mass of methane $= 0.6 \times 16 = 9.60\,\text{g}$

12 The answer is option **A**.

$\Delta_r H$ is the enthalpy of reaction and $\Delta_f H$ is the enthalpy of formation.

Deduce reaction equation: $HgC_2N_2O_2 \rightarrow Hg + N_2 + 2CO \qquad \Delta_r H = -606\,\mathrm{kJ\,mol^{-1}}$

Deduce equation for enthalpy of formation of mercury(II) fulminate:

$$Hg(l) + 2C(s) + N_2(g) + O_2(g) \rightarrow HgC_2N_2O_2(s) \qquad \Delta_f H = +386\,\mathrm{kJ\,mol^{-1}}$$

Deduce equation for enthalpy of formation of carbon monoxide:

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta_f H = x\ \mathrm{kJ\,mol^{-1}}$$

Construct a Hess cycle:

$$\begin{tikzcd}
HgC_2N_2O_2(s) \arrow[r, "-606"] & Hg(l) + N_2(g) + 2CO(g) \\
 & Hg(l) + N_2(g) + 2C(s) + 2O_2(g) \arrow[ul, "+386"] \arrow[u, "2x"']
\end{tikzcd}$$

$2x = (+386) + (-606) = -220$

$x = -110\,\mathrm{kJ\,mol^{-1}}$

13 The answer is option **B**.

The hydrocarbon contains 14.3% by mass of H, so must contain 85.7% by mass of C.

The empirical formula of X is found by considering the ratio C **:** H which is $\frac{85.7}{12} : \frac{14.3}{1}$, cancelling to 2 **:** 1 by approximation.

Therefore the empirical formula is CH_2.

The mass spectrum shows the molecular ion peak at $m/z = 84$, so $M_r = 84$.

The molecular mass of cyclobutane (C_4H_8) is 56. This corresponds to the highest intensity peak, but that does not correspond to the molecular ion.

Molecular formula of X is therefore: C_6H_{12}

X does not react with bromine, so it is not an alkene. X cannot be hex-2-ene.

X must be a cycloalkane with 6 C atoms, such as cyclohexane.

14 The answer is option **E**.

From the information provided in the question the formulae in the chemical equation can be deduced to be:

$$?SO_3 + ?Cl_2 + ?SCl_2 \rightarrow ?SOCl_2$$

Balancing: $SO_3 + Cl_2 + 2SCl_2 \rightarrow 3SOCl_2$

Number of moles Cl_2 gas $= \frac{2}{24} = \frac{1}{12}$

Mole ratio $Cl_2 : SOCl_2$ $= 1:3$

Number of moles of $SOCl_2$ $= \frac{1}{12} \times 3 = 0.25\,\text{mol}$

$SOCl_2$ is collected in water, where it reacts. It produces HCl, which will dissolve to form hydrochloric acid, and another gaseous product, which can be deduced to be sulfur dioxide:

$$SOCl_2 + H_2O \rightarrow 2HCl + SO_2$$

Mole ratio $SOCl_2 : HCl$ $= 1:2$

Number of moles of HCl $= 0.25 \times 2 = 0.50\,\text{mol}$

Concentration of HCl $= \frac{\text{number of moles}}{\text{volume}} = \frac{0.50}{\left(\frac{200}{1000}\right)} = 2.50\,\text{mol}\,\text{dm}^{-3}$

15 The answer is option **A**.

The oxidation state of silver in Tollens' reagent is +1, as NH_3 is a neutral species and the nitrate anion has a charge of –1.

It acts as a reducing agent as shown by the half-equation: $Ag^+(aq) + e^- \rightarrow Ag(s)$

Combining this with the organic oxidation half-equation shows that the overall reaction has the stoichiometry:

$$2Ag^+(aq) + RCHO + H_2O \rightarrow 2Ag(s) + RCOOH + 2H^+$$

The internal surface area of the beaker is the area of the circular base added to the curved sides.

Surface area to be coated $= \pi r^2 + 2\pi rh = 25\pi + 100\pi = 125\pi\,\text{cm}^2$

Volume of silver required $=$ surface area × thickness $= 125\pi\,\text{cm}^2 \times 0.01\,\text{cm} = 1.25\pi\,\text{cm}^3$

Mass of silver required in g $=$ volume × density $= 1.25\pi\,\text{cm}^3 \times 10.5\,\text{g cm}^{-3}$

Number of moles of Ag(s) required $= \dfrac{\text{mass in g}}{A_r\,(\text{Ag})} = \dfrac{10.5 \times 1.25 \times \pi}{108}$

So, the number of moles of aldehyde required $= \dfrac{1}{2} \times \dfrac{10.5 \times 1.25 \times \pi}{108}$

16 The answer is option **B**.

Hess's Law can be used to solve this by creating a Hess Cycle.

The equation for the enthalpy change of formation of ethanol can be set up at the top of the cycle. This enthalpy change is known.

The enthalpy change of vaporisation of ethanol should be included, as by definition the bond enthalpy data is for gaseous covalent bonds.

The gaseous atoms are included such that bond enthalpy (BE) data and atomisation of carbon data can be utilised and the cycle completed:

$$\begin{tikzcd}
2C(s) + 3H_2(g) + \tfrac{1}{2}O_2(g) \arrow[r, "\Delta_f H^\circ(CH_3CH_2OH)"] \arrow[d, "\substack{2 \times \Delta_{at}H^\circ(C(s)) \\ + 3 \times BE(H{-}H) \\ + \frac{1}{2} \times BE(O{=}O)}"'] & CH_3CH_2OH(l) \arrow[d, "\Delta_{vap}H^\circ(CH_3CH_2OH)"] \\
2C(g) + 6H(g) + O(g) & CH_3CH_2OH(g) \arrow[l, "\substack{5 \times BE(C{-}H) \\ + 1 \times BE(C{-}C) \\ + 1 \times BE(C{-}O) \\ + 1 \times BE(O{-}H)}"']
\end{tikzcd}$$

$$\begin{aligned}
\Delta_f H^\circ(CH_3CH_2OH(l)) &= [2(\Delta_{at}H^\circ(C(s)) + 3(BE(H{-}H)) + 0.5(BE(O{=}O))] \\
&\quad - [5(BE(C{-}H)) + BE(C{-}C) + BE(C{-}O) + BE(O{-}H)] \\
&\quad - [\Delta_{vap}H^\circ(CH_3CH_2OH(l))] \\
-277 &= [2987] - [5(BE(C{-}H)) + 1167] - [39] \\
5(BE(C{-}H)) &= +277 + 2987 - 1167 - 39 \\
&= +2058 \\
BE(C{-}H) &= +\frac{2058}{5} \\
&= +412\ \text{kJ mol}^{-1}
\end{aligned}$$

17 The answer is option **E**.

Putting the known coefficients into the equation:

$$As_2O_3(s) + 6Zn(s) + H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2X(g) + H_2O(l)$$

Six zinc atoms each increase their oxidation state by 2 in being oxidised to zinc ions. This gives a total increase in oxidation state of 12.

To balance this, the two arsenics in As_2O_3 must collectively reduce their oxidation states by 12 (i.e. each arsenic in As_2O_3 must reduce its oxidation state by 6).

The oxidation state of arsenic in As_2O_3 is $+3$ (because the oxidation state of the oxygen is -2). Hence each of the two arsenics in X must have an oxidation state of -3.

The only possible arsenic-containing product in this reaction that gives arsenic an oxidation state of -3 is AsH_3.

The balanced equation for the reaction is therefore:

$$As_2O_3(s) + 6Zn(s) + 12H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2AsH_3(g) + 3H_2O(l)$$

The M_r of As_2O_3 is 198 and the M_r of AsH_3 is 78.

From the stoichiometry of the reaction, 198 g of As_2O_3 would produce 156 g of AsH_3.

Hence, 1.98 g of As_2O_3 would produce 1.56 g of AsH_3.

18 The answer is option **E**.

Compound P must have a C=C bond somewhere in its structure, and Q is a bromoalkane.

Alcohols are formed when bromoalkanes undergo substitution reactions with aqueous sodium hydroxide.

When completely oxidised by acidified potassium dichromate(VI), primary alcohols form carboxylic acids which do react with aqueous sodium carbonate.

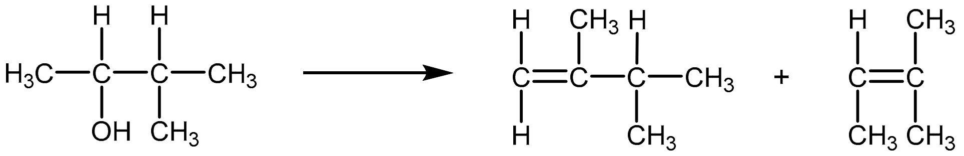
Secondary alcohols are oxidised to ketones which do not react with aqueous sodium carbonate and tertiary alcohols cannot be oxidised by acidified potassium dichromate(VI). Therefore R must be a secondary alcohol.

Pent-1-ene is incorrect as it would form 2-bromopentane as the only major product with HBr, which would then form pentan-2-ol. This would be dehydrated to form pent-2-ene as the other alkene, S. This does have stereoisomers.

Pent-2-ene is incorrect as there would be two products in significant quantity formed in the reaction with HBr: 2-bromopentane and 3-bromopentane (both formed from secondary carbocations).

The correct answer must therefore be one of the branched alkenes. If P were either 2-methylbut-1-ene or 2-methylbut-2-ene, because the double bond is adjacent to the branch in the chain, a tertiary bromoalkane would be formed as the major product. After the substitution reaction, this bromoalkane would become a tertiary alcohol, which cannot be oxidised by acidified potassium dichromate(VI).

3-methylbut-1-ene must therefore be the correct answer. This alkene would firstly form 2-bromo-3-methylbutane as the only major product with HBr and then 2-methylbutan-2-ol. This alcohol would be dehydrated to form 2-methylbut-2-ene as alkene S, which has two methyl groups attached to one end of the carbon double bond, and therefore does not have stereoisomers.



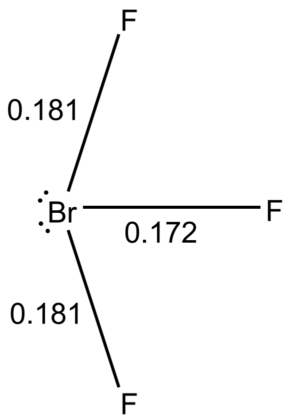
P S

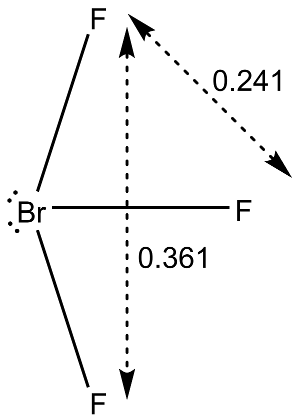
19 The answer is option **G**.

Both bromine and fluorine are in Group 17. F is more electronegative than Br and can form multiple bonds.

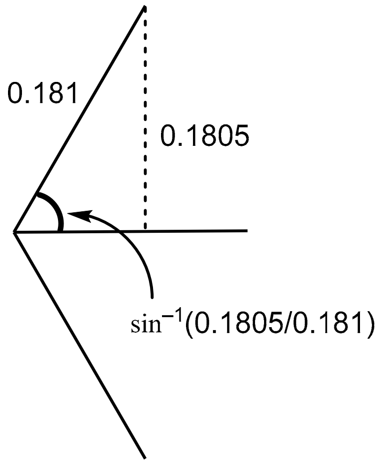
Bromine contributes 7 outer electrons to bonding, and the three F atoms contribute one further electron each. So there are 10 outer electrons around the Br centre, i.e. 5 pairs of electron density.

The structure is therefore based on a trigonal bipyramid. As there are only three bonds, two of these regions of electron density are lone pairs. There are several possible shapes that could form according to VSEPR, but only T-shaped would be faithful to the symmetry if only two bond lengths are equal and the third is not.





Finding a right-angled triangle using appropriate distances, and using the inverse sine function ($\sin^{-1}$), gives the bond angle as $\sin^{-1}\left(\frac{0.1805}{0.181}\right)$ (= 86°)



20 The answer is option **C**.

	CH_3COOH +	CH_3CH_2OH ⇌	$CH_3COOCH_2CH_3$ +	H_2O
mass at the start	120	92	0	18
M_r	60	46	88	18
number of moles at the start	2	2	0	1
number of moles at equilibrium	$2 - x$	$2 - x$	x	$1 + x$

The equilibrium constant is: $K_c = \dfrac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2OH]}$

Substituting in the number of moles: $K_c = \dfrac{(x)(1+x)}{(2-x)(2-x)} = 2$

Rearranging:

$$x^2 + x = 2(x^2 - 4x + 4)$$

$$x^2 + x = 2x^2 - 8x + 8$$

$$x^2 - 9x + 8 = 0$$

Using the quadratic formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \dfrac{-9 \pm \sqrt{9^2 - 32}}{2}$

or by factorising: $(x - 8)(x - 1) = 0$

$$x = 8 \text{ or } 1$$

A value of 8 is impossible because that would require '–6 mol' of reactants.

At equilibrium there would be just one mole of ester, which has a mass of 88 g.

Party Z Biology

21 The answer is option **E**.

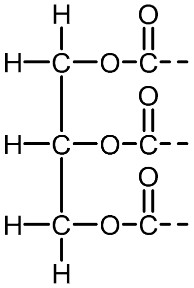
In the notation of a fatty acid, given in the question, the second value refers to the number of carbon–carbon double bonds. If a fatty acid has any of these bonds in the hydrocarbon chain it is unsaturated. The question shows that linoleic acid has two carbon–carbon double bonds and is therefore the most unsaturated fatty acid. Statement A is incorrect.

In the formation of a triglyceride, an atom of hydrogen is lost in the condensation reaction that forms the ester bond which attaches each fatty acid to the glycerol. This will leave 35 hydrogen atoms in the stearic acid component. Statement B is incorrect.

All fatty acids have a carboxyl group but in the formation of a triglyceride part of the group is lost in the condensation reaction that forms the ester bond. Statement C is incorrect.

The carbon–carbon double bonds in unsaturated fatty acids cause the chains to be kinked and not straight. As oleic and linoleic acids are both unsaturated, the hydrocarbon chains will not be in parallel. Statement D is incorrect.

In a triglyceride, there will be one oxygen atom in each ester bond plus 3 oxygen atoms attached by a double bond to the first carbon in each of the hydrocarbon chains as shown in the diagram:



This will give a total of 6 oxygen atoms in the triglyceride. The formula for a molecule of glucose is $C_6H_{12}O_6$. Statement E is correct.

22 The answer is option **C**.

Cardiac output is calculated by the equation:

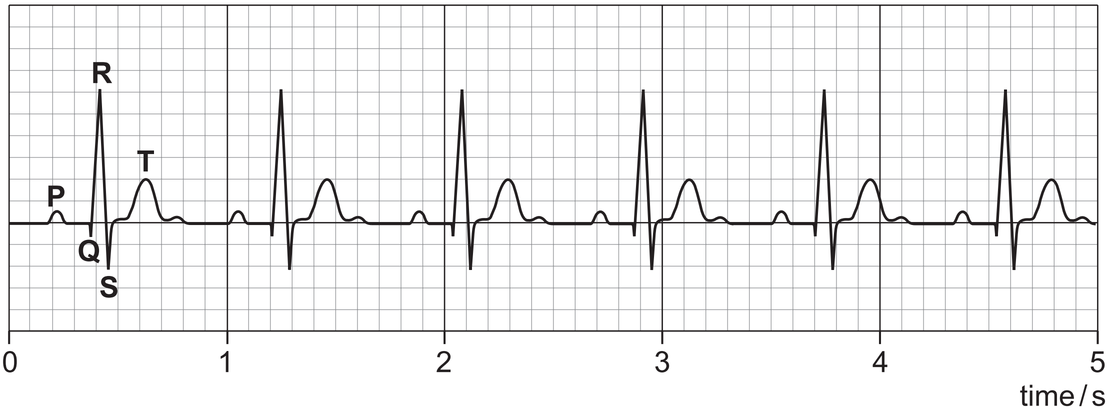
cardiac output = heart rate × stroke volume

The stroke volume is given in the stem of the question, 70 cm^3. There are 6 beats in 5 seconds shown on the ECG which needs to be multiplied by 12 to give the heart rate per minute. Cardiac output is:

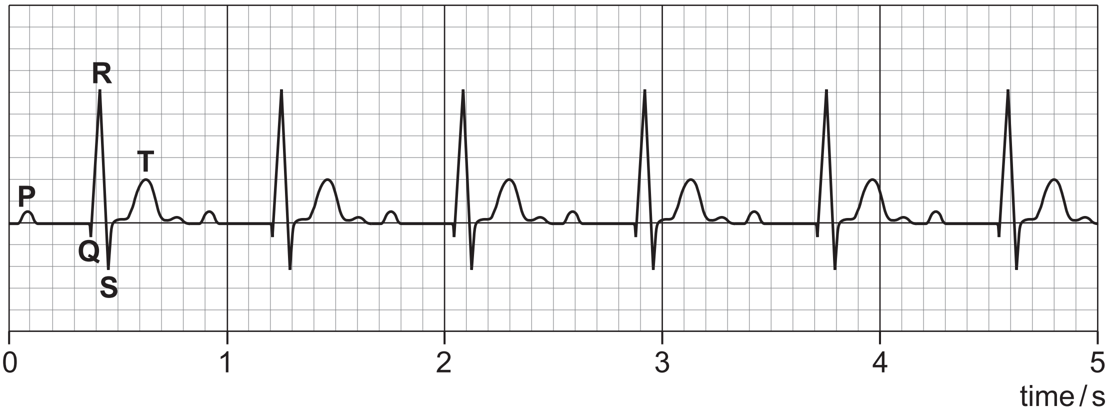
$72 \times 70 = 5040\,cm^3$ per minute

Therefore, statement 1 is not correct.

A normal ECG:



Abnormal ECG from person with known cardiac condition:



In the normal ECG the P wave is next to the QRS complex. In the abnormal ECG there is a short gap between the P wave and the QRS complex. The P wave represents atrial systole as the electrical activity spreads over the atria. The QRS complex represents ventricular systole as the electrical activity spreads over the ventricles. In the normal cardiac cycle ventricular systole follows immediately after atrial systole, as seen in the normal ECG. In the abnormal ECG the gap between P and QRS indicates that electrical conduction does not follow as quickly as it should. Statement 2 is correct.

P represents atrial systole, not atrial diastole. Statement 3 is not correct.

23 The answer is option **F**.

When the water potential of the cell sap and solution surrounding it are equal, the length of the plant tissue should remain the same. The initial length of plant tissue divided by the final length of plant tissue should be equal to 1. The cell sap and the salt solution have the same water potential at a salt solution concentration of 0.4 mol dm^{-3}.

At a salt solution concentration of 0.1 mol dm^{-3} the length of the plant tissue can be calculated:

$$5 \div 0.97 = \frac{5 \times 100}{97} = 5.15$$

Therefore the plant tissue increased by 0.15 cm which is equal to 1.5 mm.

24 The answer is option **E**.

Using data from the bar chart, there are 42 mammals in the owl's diet of which 6 are mice:

$$\frac{6}{42} \times 100 = 14.3\%$$

The change in the population (r) can be calculated by adding together the births (b) and immigration (i), adding together the deaths (d) and emigration (e), then subtracting the second figure from the first, as in the equation:

$$r = (b + i) - (d + e)$$
$$(242 + 11) - (207 + 21) = 25$$

However, this figure is for 2 weeks. The mean change per week is $25 \div 2 = 12.5$

Although this figure shows there is an increase in the mouse population, it is not possible to make a judgement on whether the owl's diet would be likely or unlikely to show an increase in mice, because there is no data available about what is happening to the populations of the other organisms in the owl's diet. The only sound conclusion is that there is insufficient evidence to know the effect on the owl's diet.

25 The answer is option **A**.

Cell X is a haploid cell with 7 chromosomes in prophase II of meiosis. This means the cell has already been through prophase I, metaphase I, anaphase I and telophase I since the end of interphase. Statement 1 is not correct.

All of the cells contain a similar total mass of DNA. Cell X and Cell Z both have a chromosome number of 7, which means that meiosis I has happened. In these cells, each chromosome has two chromatids so there is a total of 14 chromatids in each cell. Cell Y has 14 chromosomes, but these have not duplicated yet so there are also 14 chromatids present in this cell. Statement 2 is not correct.

There are only 7 chromosomes in Cell Z, therefore it is a haploid cell and not in mitosis. Statement 3 is not correct.

26 The answer is option **B**.

A mature sieve tube element is made up of many adjacent cells fusing together with holes appearing in adjacent cell walls. These cell walls contain the structural polysaccharide cellulose. The mature element also has cytoplasm which contains mitochondria.

One way to work out the diameter of the cross-sectional area is:

$$\frac{54\pi}{6} = 9\pi$$

$$9\pi = \pi r^2$$

$$\frac{9\pi}{\pi} = r^2$$

$$r^2 = 9$$

$$r = \sqrt{9} = 3$$

$$d = 2r = 6$$

27 The answer is option **F**.

In order to calculate the volume of water lost, we use the volume of the tubing, which is a cylinder:

$$\text{volume of cylinder} = \pi r^2 h$$

For P, this is $\pi \times 0.3^2 \times 90 = \pi \times 0.09 \times 90 = 8.10\pi$

For Q, this is $\pi \times 0.5^2 \times 33 = \pi \times 0.25 \times 33 = 8.25\pi$

For R, this is $\pi \times 0.6^2 \times 25 = \pi \times 0.36 \times 25 = 9.00\pi$

Therefore, the order from most to least is: R, Q, P.

The information provided does not specify anything about controlling variables, so it is possible that R was in a humid environment. However, the loss of water (transpiration) under these conditions is expected to be very low, not the most water lost.

There is also no indication that the leaf area was the same in all three experiments, nor that other variables were controlled.

Therefore, it is only possible to say there is insufficient data to explain the results.

28 The answer is option **G**.

The process of increasing the variation between the two groups of maize grains is not a natural one, but carried out in an experiment artificially. Statement 1 is not correct.

The graph shows that the percentage oil content in the high oil content grains was 5% at the start of the experiment. This increased to 14% after 50 generations.

Percentage change is:

$$\frac{\text{change in percentage oil content}}{\text{oil content at start}} \times 100\%$$

$$= \frac{(14-5)}{5} \times 100\%$$

$$= 180\%$$

Statement 2 is correct.

The maize grains had a mean mass of 0.4 g. At the start of the experiment for the high oil content grains, 5% of this mass was oil:

$$\frac{5}{100} \times 0.4 = 0.02\,\text{g}$$

After fifty generations, 14% of each grain was oil:

$$\frac{14}{100} \times 0.4 = 0.056\,\text{g}$$

The difference is $0.056 - 0.02 = 0.036\,\text{g}$

Statement 3 is correct.

29 The answer is option **C**.

The gaseous product of photosynthesis is oxygen. Statement 1 is not correct.

Any of the points where the distance doubles can be used to test Statement 2. Several intervals should be checked to confirm the relationship.

Between 10 cm and 50 cm, the relationship between the rate of gas production (photosynthesis) and distance from the light source matches the inverse square relationship between distance from the light source and light intensity, e.g. as the distance doubles (from 10 cm to 20 cm) the light intensity will decrease to:

$$\left(\frac{1}{d^2}\right)=\left(\frac{1}{2^2}\right)=\frac{1}{4} \text{ of the original value}$$

This matches the decrease in photosynthesis, which decreases by a factor of 4, from 80 to 20 bubbles.

Similarly, as the distance goes up from 10 cm to 40 cm the light intensity will decrease to $\left(\frac{1}{4^2}\right)=\frac{1}{16}$ of the original value, again matching the decrease in photosynthesis, from 80 to 5 bubbles.

Therefore, statement 2 is correct.

As the pondweed is moved closer than 10 cm to the light source, light intensity will be increasing but the rate of photosynthesis does not increase. Therefore, some factor other than light intensity must be rate limiting at 5 cm. Statement 3 is not correct.

30 The answer is option **E**.

Statement 1 is correct.

$\frac{3}{4}$ of the alleles are the dominant B allele, so the probabilities of each genotype are

	B ¾	b ¼
B ¾	$\frac{9}{16}$	$\frac{3}{16}$
b ¼	$\frac{3}{16}$	$\frac{1}{16}$

Flour beetles with genotypes BB and Bb will have black eyes.

The proportion of black eye beetles will be: $\frac{9}{16}+\frac{3}{16}+\frac{3}{16}=\frac{15}{16}$

Therefore the number of beetles with black eyes in the population is: $\frac{15}{16} \times 1600 = 1500$

Statement 2 is correct. The body cells each have two copies of chromosome 5, and this means they are diploid.

Statement 3 is not correct.

For this population of beetles, using the probabilities in the table for Statement 1:

homozygous black eye (BB) = $\frac{9}{16}$

heterozygous black eye (Bb) = $\frac{3}{16}+\frac{3}{16}$

red eye (bb) = $\frac{1}{16}$

Therefore the ratio of homozygous black eye beetles to heterozygous black eye beetles to red eye beetles is 9 : 6 : 1