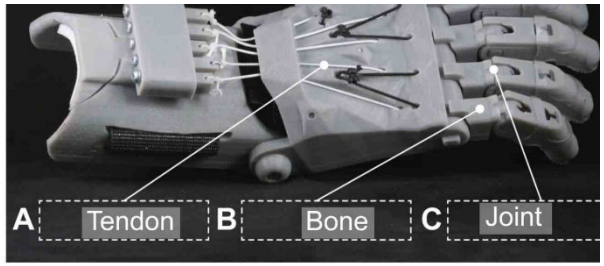
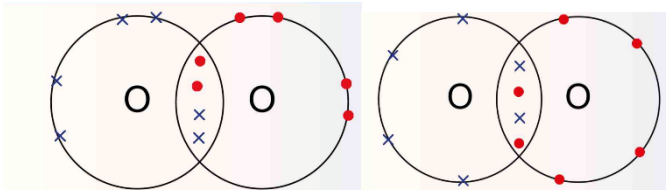
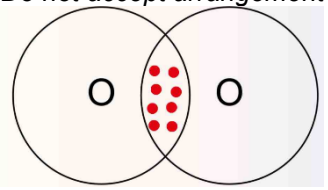
Question		Answers	Notes	Total	
1	a	They grow ***or*** develop	*Do not accept "they are active, and they might break them"*	1	A
	b	Kinetic		1	A
	c	Weight = 45*10 = 450 N	 *Award unit mark separately*	2	A
	d	Carry: (90/20 =) 4.5 times more mass ***or*** 70 (kg) more ***or*** 450% Grip: (130/70 =) 1.8 times stronger ***or*** 60 (N) more ***or*** 180%		2	A
	e	A comparison between human hand and at least one bionic hand A reference to data ***Any advantage or disadvantage, for example: [max 1]*** • A grip force/strength much higher than a human hand could be dangerous as can cause accidents and injury self and other people. • Having a high grip force might break objects accidently or damage them • Having a strength/grip force higher than a human hand could be good for self-esteem • Having a greater strength/grip force could be useful for specified job/tasks • Having a greater strength will allow you to excel in any sports • Having a greater strength will allow to carry objects much easier Conclusion based on the evidence discussed	 *Do **not** accept as an advantage: any bionic hand is stronger or carry a higher mass/weight" as it is related to M1 and M2.* *Do **not** award M4 unless another mark has also been awarded*	4	A

2	**a**	 ***Tendon – Bone – Joint*** All correct		**1**	**A**
	b	When the biceps contracts or shortens The triceps relaxes or lengthen (so) the lower arm moves (upwards as they are connected)	 *WTTE accept any equivalent to relax* *Do **not** award M3 if M1 **and** M2 are not awarded*	**3**	**A**
	c	***Skin (receptor):*** detects heat ***or*** hot surface ***or*** temperature ***Sensory neurones:*** send (electrical) signals ***or*** impulses to motor neurones ***or*** (central) nervous system ***Motor neurones:*** send (electrical) signals or impulses to the effector/muscle ***Muscles (effector):*** contract ***or*** move the hand away	 *Do **not** accept brain in place of (C)NS, accept "messages"*	**4**	**A**
	d	Carbon ***and*** hydrogen ***and*** nitrogen		**1**	**A**
	e	C_8H_8 formula correct Correctly presented with correct subscripts	*Accept H_8C_8*	**2**	**A**
	f	**2** C_4H_6 +**11** $O_2 \rightarrow$ **8** CO_2 + **6** H_2O Reactants correctly balanced Products correctly balanced		**2**	**A**

	g	Two to four electrons are shared (shown in the intersection) 4 electrons are shared – two from each oxygen atom 4 non-shared electrons for each oxygen atom 	*Accept dots or crosses* *Do not accept arrangement below for M1* 	**3**	**A**

3	**a**	Corrosive		**1**	**B**
	b	***If*** acidity of water increases/ more acid is added to water/greater number of drops of acid were added/ pH of water decreases ***Then*** there will be a greater decrease in mass, or the mass of the shell will decrease ***Because*** more calcium carbonate reacts with the (acidic) ocean water ***or*** the rate of reaction between calcium carbonate of the shell and the (acidic) ocean water is greater/faster/increases ***or*** there is a more vigorous reaction	*ORA* Do ***not*** accept change *Check for marks in any box*	**3**	**B**
	c	Bubbles (have formed) ***or*** Measure the pH change		**1**	**C**
	d	***Accept any two reasonable control variables, for example [max 2]*** • volume of water • initial mass of shells • time/duration the shells are in the water • temperature of water • initial temperature of water ***Accept any two correctly linked pieces of equipment, for example [max 2]*** • measuring cylinder • (electric) balance • timer or stopwatch • water bath	*Do not accept "amount" of water or room temperature, or temperature* *Accept same ocean water although not linked with equipment (1 max)* *Do **not** accept measuring beaker or beaker* *Accept thermometer*	**4**	**B**
	e	0.2 (g)	*Accept value seen in either table or response box*	**1**	**C**

	f	x axis scale has numbers at equal increments y axis scale has numbers at equal increments with plotted points taking up at least half of the graph two data points plotted correctly all data plotted correctly Title links pH of water with the change in mass of the shell		**5**	**C**
	g	***Accept any two reasonable points, for example [max 2]*** • Conditions of the model are different to the real ocean conditions • Using real ocean water increase the validity of the model • Adding HCl to increase acidity is not real as HCl is a strong acid or not present in the ocean water • Using real shells increase the validity of the model The model is valid, invalid or partially valid linked to the above discussion	*Do **not** award the final mark unless at least one other mark is awarded*	**3**	**C**
	h	***Improvement:*** Dry the shells before reweighing		**1**	**C**

4	**a**	7.9(0) ± 0.02		**1**	**C**
	b	***Values read correctly from the graph:*** 18.5 or 18.4 or 18.3 and 13 ***Correct calculation:*** • If 18.5 used then percentage CO_2= 42.31% • If 18.4 used then percentage CO_2= 41.54 % • If 18.3 used then percentage CO_2 =40.76 % ***Correct rounding:*** 42% or 41%	*No ECF from M1*	**3**	**C**
	c	How does (increasing) water temperature ***A reference to the time taken for chalk to completely react, for example [max 1]*** • affect the reaction time of chalk • time chalk (completely) reacts • rate of reaction of chalk?	*WTTE*	**2**	**B**

4	**d**		**16**	B

	1 mark	**2 marks**	**3 marks**	**4 marks**	***Notes***
1.V	IV identified as temperature of water ***or*** DV identified as time taken for chalk to react completely	IV identified as temperature of water ***and*** DV identified as time taken for chalk to react completely	IV identified as temperature of water ***and*** DV identified as time taken for chalk to react completely ***and*** one relevant CV identified	IV identified as temperature of water ***and*** DV identified as time taken for chalk to react completely ***and*** two relevant CVs identified	*Only requirement is to state using the terminology of IV, DV and CV. No need to explain further.* ***Examples of CV:*** • *type or size of chalk* • *same (acidified) ocean water* • *volume of ocean water* • *mass of chalk* • *pH of the (acidified) ocean water* ***Do not accept as CV:*** • *concentration of $CaCO_3$* • *atmospheric pressure* • *type of thermometer* • *keeping equipment, the same* ***Do not accept** "amount" of water*
2.E	Equipment to change temperature ***or*** Timer/stopwatch to measure time taken for chalk to react completely	Equipment to change temperature ***and*** Timer/stopwatch to measure time taken for chalk to react completely	Equipment to change temperature ***and*** Timer/stopwatch to measure time taken for chalk to disappear ***and*** equipment to monitor at least one CV	Equipment to change ***and*** monitor temperature ***and*** Timer/stopwatch to measure time taken for chalk to disappear ***and*** equipment to monitor at least one CV	*Equipment needs to be correct for the given situation and stated CVs.* *Do not accept beakers to measure volume* *Accept the following equipment to change temperature: hotplate, heater, Bunsen burner, water bath etc*

3.D	Five different temperatures implied	Five different temperatures specified ***or*** plans for three trials	Five different temperatures specified ***and*** plans for three trials	Five different temperatures specified ***and*** plans for three trials ***and*** plans to calculate the average	
4.M	Attempt at method but detail is insufficient to follow	Method described and could be followed	Complete method is described, fully explained, could easily be followed and would give reliable data		*A method that does not include how to vary the IV is not complete.* *Limited information about CVs mean that data is unlikely to be relevant*
5.S	A safety precaution explicitly linked to use of hot equipment or hot water				*Do not accept general considerations not linked to the specific investigation, e.g. wear a mask, tie hair back*

<table>
<tr><td>5</td><td>a</td><td>
<table>
<tr><td>Mass of coffee (grounds) / g</td><td>Volume (of tomato juice) /cm^3</td></tr>
<tr><td>250</td><td>6</td></tr>
<tr><td>400</td><td>9</td></tr>
<tr><td>500</td><td>12</td></tr>
<tr><td>750</td><td>18</td></tr>
<tr><td>1000</td><td>17.5</td></tr>
</table>
Headers: mass of coffee used and volume

Units g and cm^3 correct and in headers only

five correct volume readings in order, ascending or descending</td><td>Accept reversed columns, accept 18cm^3 as rounded value for 1000cm^3</td><td>3</td><td>C</td></tr>
<tr><td></td><td>b</td><td>As the mass of coffee grounds in soil increases, the volume of juice increases

The increase (at the start) is linear or there is a positive correlation

The line then starts to level off /drop between 750g and 1000g
or
the data recorded at 1000 g is an outlier/human error

A statement about validity correctly linked to previous evidence</td><td>Accept directly proportional

WTTE

Do not award the final mark unless at least one other mark is awarded</td><td>4</td><td>C</td></tr>
<tr><td></td><td>c</td><td>Repeat for additional trials</td><td>Do not accept “add extra values of the IV”</td><td>1</td><td>C</td></tr>
</table>

6	**a**	***Accept any reasonable suggestion, for example [max 1]*** • Determining a specific location • Finding a route to travel from point A to point B • Monitoring/track objects/pet or personal movement • Creating digital maps • Can give estimated delivery time		**1**	**D**
	b	d=3x10^8 m/s x 0.09 s **or** 27000000 **or** 2.7x10^7 (m) **or** 27x 10^6 (m) d=2.7x10^4 (km) ***or*** 27000 (km)	*Seen or implied*	**2**	**D**
	c	***Accept any two reasonable advantages, for example [max 2]*** • Provide specific details such as traffic, delays due to traffic, • Easy to access • Constant system update • Crowdsources information from many users • Different routes can be compared ***Accept any two reasonable disadvantages, for example [max 2]*** • Requires internet connection • Driving distraction • Loss of Signal due to weather conditions/others • Not everyone able to use digital mapping • GPS consumes a lot of energy/battery • Roadworks may not be updated	*Do not accept reference to searching locations, show distances and arrival times as in the question.* *Do not accept routes alone, routes should be linked to foreign countries or unknown cities to award the mark*	**4**	**D**
	d	A simple statement linked to knowledge of a person's location ***Two justifications of why knowledge of a person's location is a concern, for example [max 2]*** • Different people you give access could know your routines • Stalkers, thieves • Could be used without consent • Could be sold		**3**	**D**

	e	***Accept any reasonable answer, for example [max 2]*** • location ***or*** size of hunting grounds • if species are coming close to human settlements • can see how different species are interacting • can give information about overlapping hunting grounds • can see if an animal has been injured or has died • track poaching	*Do not accept movement, behaviour or migratory patterns **alone** as this information is given in the question*	2	D

7			**13**	D

A discussion of the impacts on the ecosystem		
Mark	**Descriptor**	**Notes**
1	A statement	***Examples of statements*** • overfishing/decreasing number of species/food chain • bycatch and habitat destruction • unsustainable practices: short and long term • fuel consumption and carbon emissions • tracking fish can help conserve the ecosystem ***Examples of support*** • discussion on the impact to the food chain • extinction • new species introduced
2	A statement with further support ***or*** Two statements	
3	Two statements with further support for one	

<table>
<tr><th colspan="3">Positive economic impacts</th></tr>
<tr><th>Mark</th><th>Descriptor</th><th>Notes</th></tr>
<tr><td>1</td><td>A statement</td><td rowspan="4">Examples of statements
increase fish market/decrease prices
increase profit/low consumption of fuel/less personal
more jobs for people
more sophisticated fishing and less risk for fishermen so less expenses (health issues)
Examples of support
decrease prices of fish/affordable for many people.
quality is good and cheaper</td></tr>
<tr><td>2</td><td>A statement with further support
or
Two statements</td></tr>
<tr><td>3</td><td>Two statements with further support for one</td></tr>
<tr><td>4</td><td>Two statements with further support for both</td></tr>
</table>

<table>
<tr><th colspan="3">Negative economic impacts</th></tr>
<tr><th>Mark</th><th>Descriptor</th><th>Notes</th></tr>
<tr><td>1</td><td>A statement</td><td rowspan="4">Examples of statements
reduce trading for traditional fishing
with over-fishing, availability of fish drops so does profit.
GPS technology is expensive
more fishing boats in an area
Examples of support
more traditional fishermen will get less money and decrease life quality
not all fishermen can afford GPS
tourism will be affected</td></tr>
<tr><td>2</td><td>A statement with further support
or
Two statements</td></tr>
<tr><td>3</td><td>Two statements with further support for one</td></tr>
<tr><td>4</td><td>Two statements with further support for both</td></tr>
</table>

An outline of how GPS technology can be used responsibly		
Mark	**Descriptor**	**Notes**
1	A suggestion of how GPS could be used responsibly	***Examples of responsible use*** • fish stocking monitoring by local authorities/government • community could set rules to fish during certain seasons ***Examples of enforcement/monitoring*** • could introduce fines or legal action for overfishing • could increase taxes for overfishing • could give licenses or permits
2	Two suggestions of how GPS could be used responsibly ***or*** One suggestion of how GPs could be used responsibly ***and*** one further point	