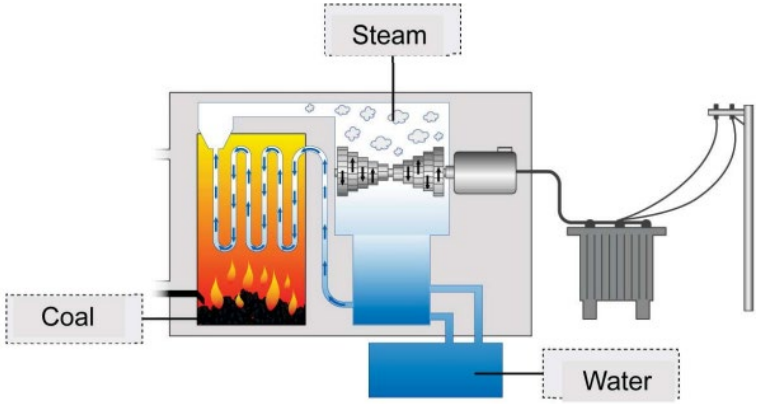
Question		Answers	Notes	Total	
1	a	 All correct		1	A
	b	Molecules move faster	*Accept move more, or vibrate more*	1	A
	c	***Accept any two points from the list [max 2]*** • speed of movement of particles does not increase • energy is being used to break bonds • energy is used to separate molecules/particles • potential energy of particles is increased		2	A
	d	1.125×10^{13} (J) Rounded correctly to 1.1×10^{13} (J)	*Accept 11×10^{12} or 11TJ* *Award 2 marks for a correct answer rounded to 2 sf*	2	A
	e	Recognition/application of efficiency formula 7476 MW or 7.476×10^{9} W	*Seen/implied* *Award 2 marks to correct answers given with units of kW, W or MW to 2 or more significant figures.*	2	A

	f	Heat energy absorbed and re-emitted by greenhouse gases		**1**	**A**
	g	***Relevant concept from thermal physics identified [max 1]*** • melting of ice • convection currents • evaporation • kinetic energy of molecules in atmosphere ***Link between increased temperature/heat and its influence on the process in marking point 1, for example [max 1]*** • increased heat in the atmosphere increases the rate of evaporation of water ***Connection to weather, for example [max 1]*** • movement of air masses across globe • more energy in storms • more water/precipitation to fall from atmosphere • flooding • drought • rising sea levels	*Only award MP3 if MP1 and MP2 have been awarded*	**3**	**A**

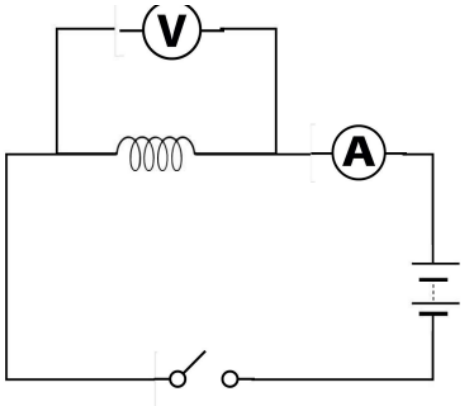
2	**a**	Protons = 92 Neutrons = 143		**2**	A
	b	**Any correct statements from the list [maximum two]** • Protons ***or*** neutrons ***or*** protons and neutrons are divided (between the daughter nuclei) • The total number of protons in the daughter nuclei is the same as in U-235 • Two free neutrons are released • Total number of neutrons and protons is the same after the reaction as before		**2**	A
	c	One reaction causes another reaction to occur The released neutrons cause other reactions	*WTTE*	**2**	A
	d	More reactions mean more energy is released ***or*** each reaction in a chain reaction releases energy ***or*** too much energy is released Results in an atomic explosion **or** a nuclear melt down Emission of radioactive material into the surrounding environment ***or*** Nuclear fallout ***or*** harmful effects of radiation on living things ***or*** effects of fire/explosion on the surrounding environment	*Accept reference to heat in place of energy*	**3**	A
	e	1400-1600 million years or 1.4 - 1.6 billion years		**1**	C
	f	***Comment about the risk of radioactive material [max 1]*** • radiation is harmful to human health/living things/cells • radiation causes environmental damage/problems to agriculture ***Comment about storage concerns [max 1]*** • needs to be stored safely for a long time • needs to be stored securely for a long time • stays radioactive for a long time		**2**	D

<table>
<tr><td rowspan="3">3</td><td>a</td><td>How does the length of the wire affect the resistance of the wire?</td><td></td><td>1</td><td>B</td></tr>
<tr><td>b</td><td>If, Then: hypothesis links length and resistance
or
hypothesis links length and brightness of the bulb

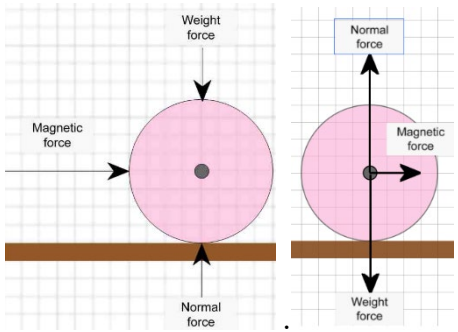
Correctly linked explanatory points, for example [max 2]
• current is a flow of electrons
• electrons have to travel a further distance with more obstacles in the way
• electrons collide with more ions as they pass through a longer wire
• as R=ρL/A, resistance is directly proportional to length</td><td>Does not have to be correct for mp 1</td><td>3</td><td>B</td></tr>
<tr><td>c</td><td>Table Object
<table><tr><th></th><th>Length / cm</th><th>Material</th><th>Cross-sectional area / mm²</th></tr><tr><td>☑</td><td>40</td><td>Silver</td><td>2.5</td></tr><tr><td>☑</td><td>60</td><td>Silver</td><td>2.5</td></tr><tr><td>☑</td><td>80</td><td>Silver</td><td>2.5</td></tr><tr><td>☐</td><td>100</td><td>Copper</td><td>1.0</td></tr><tr><td>☐</td><td>100</td><td>Silver</td><td>1.5</td></tr><tr><td>☐</td><td>100</td><td>Copper</td><td>2.0</td></tr><tr><td>☐</td><td>100</td><td>Aluminium</td><td>2.5</td></tr><tr><td>☐</td><td>100</td><td>Copper</td><td>2.5</td></tr><tr><td>☐</td><td>100</td><td>Gold</td><td>2.5</td></tr><tr><td>☐</td><td>100</td><td>Nichrome</td><td>2.5</td></tr><tr><td>☑</td><td>100</td><td>Silver</td><td>2.5</td></tr><tr><td>☐</td><td>100</td><td>Copper</td><td>3.0</td></tr><tr><td>☑</td><td>120</td><td>Silver</td><td>2.5</td></tr></table>
At least three of one material only, and no other material included

At least three of one cross-sectional area only

5 different lengths of 2.5 mm² cross-sectional area silver only</td><td></td><td>3</td><td>B</td></tr>
</table>

	d	Independent variable is length ***or*** the only variable that should change is length ***or*** Silver is the only material with five different lengths ***or*** Five data points are required for sufficient data Material ***and*** cross-sectional area should be controlled	*WTTE*	**2**	**B**
	e	 All correct	*Switch and ammeter acceptable in either position*	**1**	**B**
	f	Evidence of using R = V/I Correct answer: 6.25 or 6.3 (Ω)	*Seen or implied* *Award 2 marks for a correct result*	**2**	**C**
	g	Data point plotted correctly (100, 6.3) Line of best fit has data points above and below line and correctly models the data	*On 100 on the x axis and between 6.2 and 6.4* *Proportional relationship, judge by eye, intercept at (0,0) not required to be seen*	**2**	**C**

	h	***A suggestion of a reasonable source of error, for example [max 1]*** • wires may heat up which changes the resistance/resistivity of wire. • voltage and current readings may fluctuate • voltmeter or ammeter may be inaccurate • measurement of length was inaccurate • clipping on probes/leads of voltmeter and ammeter may not be at exact length • diameter of wire may not be consistent throughout wire length ***A correctly linked comment about the effect on resistance [max 1]*** • resistance will increase (at increased temperature) • calculated values of resistance will be inaccurate • resistance will not be calculated for correct length • calculated resistance will not be reliable	*Do **not** accept increase the number of trials* *Award second point for a comment correctly linked to MP1*	**2**	**C**

4	**a**	(The law of conservation of) <u>energy</u>		**1**	**A**
	b	Magnetic force drawn horizontally to the right (any length) Normal force vertically up and weight force vertically down Normal force and weight force are equal in magnitude ***and*** no additional forces added either horizontally or vertically  	*Arrows must align with the center of the ball to be accepted* *Arrows can be directed into the ball or away from the ball* *Only award MP3 if MP2 has been awarded*	**3**	**A**
	c	Magnetic force increases as the ball approaches the magnet ***or*** magnetic field is stronger closer to the magnet Acceleration increases		**2**	**C**
	d	A		**1**	**A**
	e	A reference to magnetic energy being released ***or*** changes in the magnetic field cause additional kinetic energy		**1**	**C**

4	**f**		**11**	B

	1 mark	**2 marks**	**3 marks**	**4 marks**	***Notes***
1.V	Identifies height as IV ***or*** maximum height as DV	Identifies initial height as IV ***and*** maximum height as DV	Identifies initial height as IV ***and*** maximum height as DV ***and*** one appropriate CV		*Only requirement is to state using the terminology of IV, DV and CV. No need to explain further.* ***Accept*** *h1 and h2 in place of initial height and maximum height for IV and DV, maximum can be implied for the DV* ***Accept*** *for CV – strength of magnet, angle of incline of plane, material/mass/size of balls* ***Do not accept "****keeping equipment the same", "type of balls", "magnet", "temperature", "pressure", "acceleration due to gravity" as a CV.*
2.H	Attempt at a hypothesis linked to height	Testable hypothesis linked to initial height ***and*** maximum height	Testable hypothesis linked to initial height ***and*** maximum height with an attempted explanation	Testable hypothesis linked to initial height ***and*** maximum height and with an explanation linking to the conservation of energy or conversion of kinetic energy or (gravitational) potential energy	***Accept*** *a scientific explanation that correctly uses conservation of momentum to explain the hypothesis* *The hypothesis does not need to be correct to receive credit but full credit can only be awarded to logical answers based on scientific reasoning*
3.M	Attempt at a method linked to the collision between the balls	Method to change initial height and measure final height is outlined but is not detailed enough to be followed by another student	Complete method is described with measurements of initial height and maximum height, detailed enough to be followed by another student		*A method that does not include how to vary the IV is incomplete.* *Details on the number of trials and number of increments is not needed to award full credit*

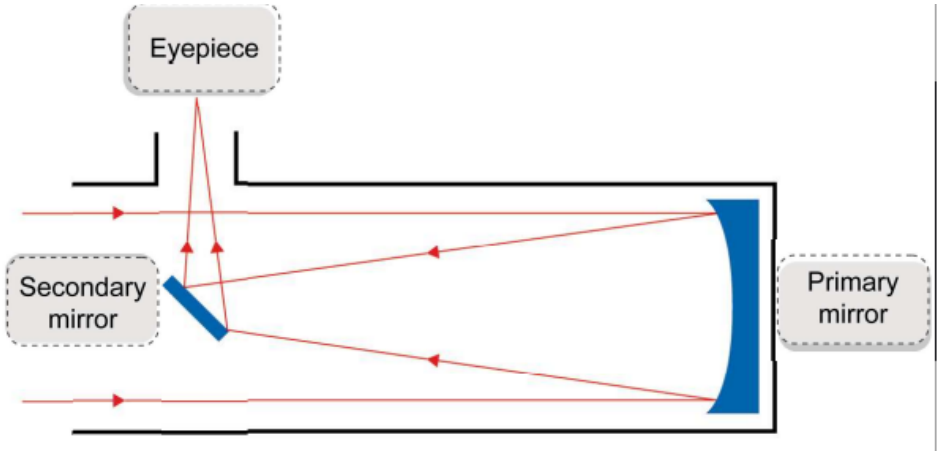
4.S	Mentions a relevant precaution linked to a specific hazard				***Do not accept*** *general considerations not linked to the specific investigation, e.g. wear a mask, tie hair back* ***Do not accept:*** *handle magnets carefully as this is not linked to a hazard, wear gloves unless this is linked to prevention of trapping fingers etc* *Accept: taking care not to trap fingers between the colliding balls/magnets* *Precautions regarding heavy balls rolling off the table onto feet/other objects*

4	**g**	Column headers for initial height and maximum exiting height including units Values for five increments of initial height shown Spaces for at least three trials of maximum height Column for average or mean maximum height	*Award marks for arrangement in columns or rows* *Values should be realistic, do not award MP2 if units in the column are repeated*	**4**	C

Initial Height of Ball / cm	Trial One Max Height / cm	Trial Two Max Height / cm	Trial Three Max Height / cm	Average Max Height of exiting ball / cm
5				
10				
15				
20				
25				

5	**a**	1.87 (s)		**1**	**C**
	b	$s = \frac{1}{2}at^2$ seen or implied 0.11(07266436) m s^{-2} ***or*** m/s^2 ***or*** 11(.07266436) cm s^{-2} ***or*** cm/s^2		**3**	**C** **D**
	c	Mass	*Do **not** accept weight*	**1**	**C**
	d	D		**1**	**B**
	e	***Accept any 2 statements from the list [max 2]*** • The line of best fit does not go through the origin • The line of best fit intercepts the x axis at 4A or there is no force when the current is 4A • The line of best fit intercepts the y axis at –2.7mN • Force is negative and positive ***or*** candidate uses 2 specific data points (to show that) doubling the current does not double the force ***or*** candidate uses 2 specific data points (to show that) F divided by I is not constant		**2**	**C**

	f	The rod will not move ***or*** The rod will not accelerate (because) there is no (net) force ***or*** (because) the force is not strong enough (to overcome friction)		**2**	**C**
	g	2.6 - 2.8 (mN)	*Accept a negative value for friction*	**1**	**C**

6	**a**	(White light is) made up of different frequencies ***or*** (White light is) made up of different wavelengths (different frequencies/wavelengths) <u>refract</u> by different amounts ***or*** (different frequencies/wavelengths) have different <u>refractive indices</u> ***or*** (white light is) <u>dispersed</u>		**2**	**D**
	b	 All labels in correct location		**1**	**D**
	c	3		**1**	**D**
	d	Galaxies moving away **or** A reference to red shift ***or*** Increased wavelength/decreased frequency of light emitted from galaxies	*Accept reference to stars instead of galaxies*	**1**	**D**

	e	A reference to the atmosphere or air on Earth ***or*** In space the telescope is in vacuum ***A specific effect caused by the atmosphere, for example [max 1]*** • scattering • refraction • light pollution • weather conditions • absorption	*Do **not** accept references to being closer to space*	**2**	**D**

7	a		**13**	D

The scientific challenges of launching a telescope into space		
Mark	**Descriptor**	**Notes**
1	A statement	***The main themes to explore are:*** 1. Requires great technological innovations, extensive testing to ensure it can work remotely 2. Issues due to location / distance from Earth, including communication issues and the danger of impact with other objects in space 3. Thermal issues 4. Deployment issues, including coordinating the launching process and navigating to the required location ***Examples of statements*** • repair of space telescopes is challenging • a large diameter mirror requires advanced scientific innovation • harsh conditions in space. Nothing to protect the telescope from extreme high and low temperatures • once in deep space, the telescope must operate autonomously for long periods • the launching process is complex and requires precise calculations and coordination ***Examples of scientific support*** • the JWST's remote location at L2 (from video) could not be physically repaired (maintenance) • folding and unfolding mechanisms for 18 hexagonal mirrors would need to be created to fit into the rocket. (OR reference to precision alignment of mirror segments) • metal parts of the telescope can fuse together due to temperatures causing cracks and damage to the telescope • during testing, simulated conditions must include complexities such as vacuums, intense vibrations, extremely loud sounds, dense dust, extreme temperatures • autonomous communication links with earth are difficult to establish since ... the position of the satellite relative to the earth will be changing ... obstacles may block communication lines, time lags of signals due to long distances.
2	A statement with further support ***or*** Two statements	
3	Two statements with further support for one	
4	Two statements with further support for both	

<table>
<tr><th colspan="3">The social or cultural implications of observations made with telescopes</th></tr>
<tr><th>Mark</th><th>Descriptor</th><th>Notes</th></tr>
<tr><td>1</td><td>A statement</td><td rowspan="3">The main themes to explore are
1. Expanding human knowledge
2. Religion / philosophical
3. Artistic / literary creativity
4. Collaboration internationally

Examples of social or cultural implications
• it can expand our understanding of the universe
• it can improve international collaboration
• images observed will contribute to humanity’s collective cultural heritage...
• artists can draw inspiration from these images to create pieces that depict the mystery and beauty of the universe
• observations may go against or support certain religious beliefs or conspiracy theories.
• it can stimulate interest in science amongst a new generation of young people

Examples of support
• by observing the formation of stars and galaxies in closer detail (with infrared sensors), we will be able expand our knowledge of cosmic evolution
• space telescopes can involve collaboration between countries (as with the JWST), which would lead to greater unity amongst nations
• deep space images have been incorporated in artwork displayed in museums, clothing designs and tattoos
• images from space telescopes can be used in church or religious groups to portray the wonders of God or support beliefs that there is extra – terrestrial life</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>
</table>

<table>
<tr><th colspan="3">The economic implications of spending government funds on a space telescope</th></tr>
<tr><th>Mark</th><th>Descriptor</th><th>Notes</th></tr>
<tr><td>1</td><td>A statement</td><td rowspan="4">The main themes to explore are
1. High costs / budget
2. Economic growth due to tech advancement, industry innovation, or scientific discoveries

Examples of economic implication
• a large government investment for a space telescope
• the development of a space telescope would lead to new tech or industrial innovations helping society

Examples of support (do not need to be linked to the JWST directly)
• space telescopes require nations to budget carefully. These funds could be used for other services such as healthcare and education
• advancement in materials, optics, and other engineering solutions (such as folding mirrors) could lead to other innovations and applications enhancing the economy
• the budget of the JWST does not seem high when it is placed alongside the annual budget of the US military (750 billion) and this money was spent over the many years of the project
• countries that develop space telescopes can attract the best and brightest scientists to work for them, some of these scientists will relocate from overseas</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>

A concluding appraisal giving your opinion on the impact of the JWST		
Mark	**Descriptor**	**Notes**
1	A simple conclusion	***Characteristics of a simple conclusion*** • the candidate writes a statement saying they are in support/against JWST in simple terms without an attempt to balance the positive and negative aspects which are evident ***Characteristics of an appraisal*** • the candidate recognises the fact that there are positive and negative aspects to the impact of the JWST but makes a case for why they are in support/against the development by weighing up both sides
2	A concluding appraisal with reference to issues raised	

7	b	***Accept any two reasonable benefits, for example [max 2]*** • planetary data that was not available previously • picks up wavelengths specific to biomolecules ***Accept any two reasonable limitations, for example [max 2]*** • technique is limited in scope – can only be used for planets around small number of stars • no direct evidence of existence of alien life • cannot be sure if molecules were formed biologically or geologically A simple conclusion Conclusion is linked to benefits and limitations	*WTTE*	**6**	**D**