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|  | |  |  | | --- | --- | | **Physics A**  **High Challenge practice questions mix** |  | | This pack contains **200** marks of random high level of challenge questions. The first half is based on Modelling Physics, the second half is based on Exploring Physics  **OCR supplied materials:** Additional resources may be supplied with this paper.  **Other materials required:** •   Pencil •   Ruler (cm/mm) |  | |  | | |  |

## INSTRUCTIONS TO CANDIDATES

•   Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.  
•   Use black ink. HB pencil may be used for graphs and diagrams only.  
•   Answer **all** the questions, unless your teacher tells you otherwise.  
•   Read each question carefully. Make sure you know what you have to do before starting your answer.  
•   Where space is provided below the question, please write your answer there.  
•   You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number  
    and question number(s).

## INFORMATION FOR CANDIDATES

•   The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography   
    a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and  
    grammar and the use of specialist terminology* is assessed.  
•   The number of marks is given in brackets **[ ]** at the end of each question or part question.  
•   The total number of marks for this paper is **200**.  
•   The total number of marks may take into account some 'either/or' question choices.

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|  | |  |  | | --- | --- | |  |  | | **1.** | \* A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is M. A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is m.  The arrangement of the pendulums is shown below.     The bob of mass M is pulled back to a vertical height of H from its rest position. It is released and collides with the bob of mass m. The two bobs then stick together and reach a maximum vertical height h from the rest position.  The height h is given by the equation .     |  | | --- | | Describe how to perform an experiment to test the validity of this equation and how the data can be analysed. |                                                 **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **2.** | \* In 2017, an ultra-cool star TRAPPIST-1 was discovered with at least five of its own orbiting planets. Astronomers are interested about the possibility of finding life on some of the planets orbiting TRAPPIST-1.  The table below shows some data.     |  |  |  | | --- | --- | --- | |  | **TRAPPIST-1** | **Sun** | | **Luminosity L / W** | 2.0 × 1023 | 3.8 × 1026 | | **Surface temperature T / K** | 2500 | 5800 | | **Radius of star / m** | R | 7.0 × 108 | | **Distance between Earth and Sun / m** |  | 1.5 × 1011 | | **Distance between planets and TRAPPIST-1 / m** | 1.6 × 109 to 9.0 × 109 |  |   The temperature T in kelvin of a planet, its distance d from the star and the luminosity L of the star are related by the expression   constant.     |  |  | | --- | --- | | • | The average temperature of the Earth is about 290 K. Explain how life may be possible on some of the planets orbiting TRAPPIST-1. | | • | Use your knowledge of luminosity to show that the radius R of TRAPPIST-1 is smaller than the Sun. | | • | Support your answers by calculations. |                                                       **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **3.** | Antares is a red giant and one of the brightest stars in the night sky. The parallax angle for this star is 0.0059 arc seconds.  Sirius-B is a white dwarf. In comparison with Sirius-B, Antares has 12 times greater mass and has 1.1 × 105 times greater radius. The surface temperatures of Sirius-B and Antares are 25000 K and 4300 K respectively.  The intensity I of electromagnetic radiation emitted from the surface of a star is related to its temperature T in kelvin as follows:  I ∝ T4.   1. Explain what is meant by intensity.     **[1]**   1. Calculate the ratio        |  | | --- | | ratio = ........................................................... **[2]** |        |  | | --- | | ratio = ........................................................... **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **4.** | A gas is at a temperature of 20°C. The mass of each molecule is 4.7 × 10−26 kg.   1. Show that the root mean square (r.m.s.) speed the gas molecules is about 500 m s−1.   **[3]**   1. A gas molecule makes a head-on collision with a **stationary** smoke particle. Fig. 20 shows the gas molecule and the smoke particle before and after the collision. The final speed of the smoke particle is 23 m s−1.      1. State and explain the **total** momentum of the molecule and smoke particle after the collision in a direction perpendicular to initial velocity of the gas molecule.       **[2]**   1. Calculate the speed v of the gas molecule after the collision.   v = ............................................m s−1 **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **5(a).** | This question is about a simple pendulum made from a length of string attached to a mass (bob). For oscillations of small amplitude, the acceleration a of the pendulum bob is related to its displacement x by the expression    where g is the acceleration of free fall and L is the length of the pendulum. The pendulum bob oscillates with simple harmonic motion.   1. Show that the period T of the oscillations is given by the expression          |  |  | | --- | --- | |  | **[3]** |  1. A student notices that the amplitude of each oscillation decreases over time. Explain this observation and state what effect this may have on T.           **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Describe with the aid of a labelled diagram how an experiment can be conducted and how the data can be analysed to test the validity of the equation for oscillations of small amplitude.                                          **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | Another student conducts a similar experiment in the laboratory to investigate the small amplitude oscillations of a pendulum of a mechanical clock. Each ‘tick’ of the clock corresponds to **half** a period.   1. Show that the length of the pendulum required for a tick of 1.0 s is about 1 m.      |  |  | | --- | --- | |  | **[2]** |  1. If the pendulum clock were to be used on the Moon, explain whether this clock would run on time compared with an identical clock on the Earth.           **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **6.** | **Fig. 2.1** shows the path of a golf ball which is struck at point **F** on the fairway landing at point **G** on the green. The effect of air resistance is negligible.    The ball leaves the club at 17 m s−1 at an angle of 60° to the horizontal at time t = 0.  Show that the speed of the ball at the highest point **H** of the trajectory is between 8 and 9 m s−1.  speed = .......................................... m s−1  **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **7.** | A plastic kettle is filled with 0.60 kg of water at a temperature of 20°C. A 2.2 kW electric heater is used to heat the water for a time of 4.0 minutes.  The specific heat capacity of water is 4200 J kg−1 K−1 and the specific latent heat of vaporisation of water is 2.3 × 106 J kg−1. The boiling point of water is 100°C.  Calculate the mass of water **remaining** in the kettle after 4.0 minutes. Assume that all the thermal energy from the heater is transferred to the water.     |  |  | | --- | --- | |  | mass of water remaining = ......................................... kg **[4]** | | |

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|  | |  |  | | --- | --- | |  |  | | **8(a).** | Lasers are often used to form precision-welded joints in titanium. To form one such joint it is first necessary to increase the temperature of the titanium to its melting point. Fig. 5.1 shows the joint and the volume of titanium to be heated.    The photon beam from the laser is focused onto the shaded volume of the joint and is converted into thermal energy in the titanium.  The wavelength of the photons is 1.1 × 10−6 m.  Show that the energy of a photon in the beam is 1.8 × 10−19 J.     |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Photons are emitted from the laser at a constant rate of 6.3 × 1019 s−1.  Estimate the time taken to raise the temperature of the shaded volume of titanium shown in Fig. 5.1 to melting point. Use the data below for your calculations.  initial temperature = 20 °C melting point of titanium = 1700 °C density of titanium = 4.5 × 103 kg m−3 specific heat capacity of titanium = 520 J kg−1 K−1 shaded volume of titanium being heated = 8.1 × 10−12 m3.     |  | | --- | | time = ........................................................... s **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | In practice it takes a longer time to reach the melting point. State and explain **two** factors that will increase the time taken.        **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | To complete the weld more photons must be focused onto the joint. During this final stage the temperature remains constant. Explain why this is to be expected.      **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **9.** | Fig. 23.1 shows a metal cylinder of diameter of about 5 cm placed on a horizontal table.    **Fig. 23.1**   1. State Archimedes' principle.       **[1]**   1. Fig. 23.2 shows the metal cylinder hung from a newtonmeter.     **Fig. 23.2**  The reading on the newtonmeter is 9.0 N. The cylinder is slowly lowered into water in a beaker until it is completely submerged. The cylinder does not touch the side or the bottom of the beaker. The newtonmeter reading now is 7.8 N. The density of water is 1000 kg m−3. Calculate the density ρ of the metal of the cylinder.  ρ = ........................................................... kg m−3 **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **10.** | Fig. 3.1 shows a simple representation of a hydrogen iodide molecule. It consists of two ions , held together by electric forces.    **Fig. 3.1**  Fig. 3.2 shows a simple mechanical model of the molecule consisting of two unequal masses connected by a spring of force constant k and negligible mass. The ions oscillate in simple harmonic motion when disturbed.     1. The approximate acceleration a of the hydrogen ion, mass mH, is given by the equation     where k is the force constant of the spring and x is the displacement of the ion. The ions oscillate with a frequency of 6.6 × 1013 Hz. The mass mH is 1.7 × 10−27 kg. Show that the value of k is about 300 N m−1.  **[3]**   1. Use Newton's laws of motion and a requirement for simple harmonic motion to explain why the amplitude of oscillation of the iodine ion, mass mI, is about 0.08 pm when the amplitude of oscillation of the hydrogen ion is about 10 pm.                   **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **11(a).** | Civil engineers are designing a floating platform to be used at sea. **Fig. 4.1** shows a model for one section of this platform, a sealed metal tube of uniform cross-sectional area, loaded with small pieces of lead, floating upright in equilibrium in water.    The tube has length 300 mm and diameter 50 mm. The total mass of the lead and tube is 0.50 kg. Show that the length l of tube above the surface is more than 40 mm.        density of water = 1000 kg m−3  **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | When the tube is pushed down a small amount into the water and released it moves vertically up and down with simple harmonic motion. The period of these oscillations which quickly die away is about one second.  The oscillations of the tube can be maintained over a range of low frequencies by using a flexible link to a simple harmonic oscillator.  **Fig. 4.2** shows a graph of amplitude of vertical oscillations of the tube against frequency obtained from this experiment.     1. Use information from **Fig. 4.2** to state the amplitude of the motion of the oscillator.   amplitude = .......................................... mm **[1]**   1. Add a suitable scale to the frequency axis of **Fig. 4.2**.   **[1]**   1. The experiment is repeated in a much more viscous liquid such as motor oil. On **Fig. 4.2** sketch the graph that you would predict from this experiment.   **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **12.** | \* A supply rocket, with its engines shut down, is trying to dock with the International Space Station. Initially it is moving in the same circular orbit above the Earth and at the same speed as the ISS. The two craft are separated by a distance of a few kilometres. The rocket is behind the ISS. It can move closer to the ISS using the following procedure.  The rocket engines are fired in reverse for a few seconds to slow the rocket down. This action causes the rocket to fall into an orbit nearer to the Earth.  After an appropriate time, the rocket engines are fired forwards for a few seconds to move the rocket back into the original orbit closer to the ISS.  Use your knowledge of gravitational forces and uniform motion in a circular orbit to explain the physics of this procedure.                        **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **13.** | A flat, circular disc moves across a horizontal table with negligible friction. **Fig. 19.1** shows the disc **X** of mass 50 g subject to a force F. **Fig. 19.2** shows the variation of the force F with time t.    The disc is initially at rest. Calculate the change in velocity of the disc caused by F.  change in velocity = ............................. ms−1   **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **14(a).** | **Fig. 2.1** shows the path of a golf ball which is struck at point **F** on the fairway landing at point **G** on the green. The effect of air resistance is negligible.    The ball leaves the club at 17 m s−1 at an angle of 60° to the horizontal at time t = 0.  At t = 1.5 s the ball reaches point **H**. Calculate   1. the maximum height h of the ball   h = .......................................... m **[3]**   1. the distance between the points **F** and **G**.   distance **FG** = .......................................... m **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Suppose the same golfer standing at **F** had hit the ball with the same speed but at an angle of 30° to the horizontal. See **Fig. 2.2**.    Show that the ball would still land at **G**.  **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | Compare the magnitude and direction of the two velocities as the ball lands at G and using this information suggest, with a reason, which trajectory you would choose to travel a longer distance after hitting the green at G.                **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **15(a).** | A cyclist moves along a horizontal road. She pushes on the pedals with a constant power of 250 W. The mass of the cyclist and bicycle is 85 kg. The total drag force is 0.4v2, where v is the speed of the cyclist.  The cyclist now moves up a slope at a constant speed of 6.0 ms−1 and continues to exert a power of 250 W on the pedals.  **Fig. 17.1** represents the cyclist and bicycle as a single point **P** on the slope.     1. Draw arrows on **Fig. 17.1** to represent the forces acting on **P**. Label each arrow with the force it represents.   **[1]**   1. Calculate the angle θ of the slope to the horizontal.   θ = ............................. °   **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | The cyclist continues to move up the slope at 6.0 ms−1 and approaches a gap of width 2.5 m as shown in **Fig. 17.2**.    A student has calculated that the cyclist will be able to clear the gap and land on the other side. Another student suggests that this calculation has assumed there is **no** drag and has not accounted for the effect caused by the front wheel losing contact with the slope before the rear wheel.  Without calculation, discuss how drag and the front wheel losing contact with the slope will affect the motion and explain how these might affect the size of the gap that can be crossed successfully.                **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **16.** | A high energy gamma photon passing through a scintillator crystal converts some of its energy into visible light photons of mean wavelength 450 nm.   Show that the energy of a single photon of wavelength 450 nm is less than 3 eV.     |  | | --- | | **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **17.** | A researcher is investigating the de Broglie wavelength of charged particles.  The charged particles are accelerated through a potential difference *V*. The de Broglie wavelength *λ* of these particles is then determined by the researcher.  Each particle has mass *m* and charge *q*.   1. Show that the de Broglie wavelength *λ* is given by the expression .      |  | | --- | | **[2]** |  1. The researcher plots data points on a *λ*2 against grid, as shown below.      |  | | --- | |  |      |  |  |  |  | | --- | --- | --- | --- | |  | **1** | Calculate the percentage uncertainty in *λ* for the data point circled on the grid. | | |  |  | percentage uncertainty = ..................................................... % **[2]** | | |  | **2** | Draw a straight line of best fit through the data points. | **[1]** | |  | **3** | The charge *q* on the particle is 2*e*, where *e* is the elementary charge.  Use your best fit straight line to show that the mass *m* of the particle is about 10−26 kg. | | |  |  | **[4]** | | | |

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|  | |  |  | | --- | --- | |  |  | | **18.** | \* A resistance wire is coiled around a thermistor. The coil of wire will warm the thermistor.  It is suggested that the relationship between the power *P* dissipated in the coiled wire and the stable resistance *R* of the thermistor is given by the expression *P* = *kRn*, where *k* and *n* are constants.  Describe how an experiment can be conducted to assess the validity of this expression and how the data collected can be analysed to determine *k* and *n*.  Use the space below for a circuit diagram.                                              **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **19.** | \* A student is investigating electron diffraction. A beam of electrons is directed towards a thin slice of graphite in an evacuated tube. The electrons are accelerated by a potential difference of 2000 V. The diagram below shows the pattern formed on the fluorescent screen of the evacuated tube.     |  | | --- | |  |      |  | | --- | | Describe and explain how the pattern changes as the potential difference is increased. Include how the de Broglie wavelength λ of the electron is related to the potential difference V. |                                             **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **20.** | Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.     |  | | --- | | **Fig. 20** |   A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.  A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.  Each rubidium ion has charge +1.6 × 10–19 C and speed 4.8 × 104 m s–1. The radius of the semi-circular path of the ions is 0.18 m. The mass of a rubidium ion is 1.4 × 10–25 kg.  Calculate the magnitude of the magnetic flux density B of the magnetic field.     |  | | --- | | B = ......................................................T **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **21.** | \* Fig. 22.4 shows an arrangement used by a student to investigate the forces experienced by a small length of charged gold foil placed in a uniform electric field.     |  | | --- | | **Fig. 22.4** |   The two vertical metal plates are connected to a high-voltage supply.  The foil is given a positive charge by briefly touching it to the positive plate. The angle θ made with the vertical by the foil in the electric field is given by the expression   where q is the charge on the foil, E is the electric field strength between the plates and W is the weight of the foil.  The angle θ can be determined by taking photographs with the camera of a mobile phone.  Describe how the student can safely conduct an experiment to investigate the relationship between θ and E. Identify any variables that must be controlled.                                                  **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **22.** | A narrow beam of unpolarised light is incident at the boundary between air and glass.  Fig. 18 shows the incident ray, the reflected ray and the refracted ray at the air-glass boundary.  **Fig. 18 (not to scale)**  The refractive index of air is 1.00 and the refractive index of the glass is 1.50. The angle of incidence of the light is 56.3°.  Calculate the time t taken for the refracted light to travel a **depth** of 6.0 cm of glass.     |  |  |  | | --- | --- | --- | | t = |  | s **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **23.** | A metal circular plate is rotated at a constant frequency by an electric motor. The plate has a small hole close to its rim. Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.  **Fig. 17.1**  A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.  Fig. 17.2 shows the variation of V with time t.  **Fig. 17.2**  Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR. Describe how the student can determine the frequency of the rotating plate.                                        **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **24.** | Fig. 6.1 shows a single photomultiplier tube and its internal components. The tube can detect gamma photons in high-energy physics experiments. A single gamma photon incident on the scintillator crystal generates many photons of blue light. These visible light photons travel to the photocathode where they are converted into photoelectrons. The number of electrons is then multiplied in the photomultiplier tube with the help of electrodes called dynodes. A short pulse of electric current is produced at the output end of the photomultiplier tube.  **Fig. 6.1**  The photocathode is coated with potassium which has a work function of 2.3 eV. Each emitted photoelectron is accelerated by a potential difference of 100 V between the photocathode and a metal plate, called the first dynode.   1. Show that the maximum kinetic energy of an emitted electron at the photocathode is very small compared to its kinetic energy of 100 eV at the first dynode.      |  | | --- | | **[1]** |  1. 2000 photoelectrons are released from the photocathode. Each photoelectron has enough energy to release four electrons from the first dynode at the collision. These four electrons are then accelerated to the next dynode where the process is repeated. There are 9 dynodes in the photomultiplier tube. The total number of electrons collected at the anode for each photoelectron is 49.  The pulse of electrons at the anode lasts for a time of 2.5 × 10−9 s.  Calculate the average current due to this pulse.      |  |  |  | | --- | --- | --- | | average current = |  | A **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **25(a).** | Fig. 18.1 shows a circuit.  **Fig. 18.1**  The cell has e.m.f. 1.5 V. The cell and the variable power supply both have negligible internal resistance.   1. The e.m.f. of the power supply is set at 4.2 V. Calculate the current I in the 33 Ω resistor.   I = ......................................... A **[3]**   1. The e.m.f. of the variable supply is now slowly decreased from 4.2 V to 0 V. Describe the effect on the current I in the 33 Ω resistor.         **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | A group of students are investigating the power dissipated in a variable resistor connected across the terminals of a cell. The cell has e.m.f. 1.5 V. The students determine the power P dissipated in the variable resistor of resistance R.  Fig. 18.2 shows the data points plotted by the students on a graph of P (y-axis) against  **Fig. 18.2**  The group of students know that **maximum power** is dissipated in the variable resistor when R is equal to the internal resistance r of the cell.  Describe, with the help of a suitable circuit diagram, how the students may have determined P and R. Use Fig. 18.2 to estimate the internal resistance r of the cell and discuss any limitations of the data plotted by the group.                                    **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **26(a).** | Fig. 19 shows a photocell.    When the metal **M** is exposed to electromagnetic radiation, photoelectrons are ejected from the surface of the metal. These photoelectrons are collected at the electrode **C** and the sensitive ammeter indicates the presence of a tiny current. The work function of the metal **M** is 2.3 eV. The incident electromagnetic radiation has wavelength 5.1 × 10−7 m. The ammeter reading is 0.24 μA.  Calculate the maximum kinetic energy of the ejected photoelectrons.  maximum kinetic energy = .......................................... J **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | The wavelength of the incident radiation is kept constant but the intensity of the radiation is doubled.  State and explain the effect, if any, on the current in the photocell.        **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **27(a).** | Calculate the maximum wavelength of the X-rays for the pair production process.  maximum wavelength = .......................................... m **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | An X-ray image of a patient’s arm is required. Fig. 23.1 shows a parallel beam of X-rays is incident on a cross-section of the patient’s arm.    Fig. 23.2 shows the variation of the intensity of the X-rays with distance x from the point **A**.    Explain the shape of the graph shown in Fig. 23.2.                      **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **28.** | A possible fission reaction is    where k is the number of neutrons released in the reaction. The    nucleus is very unstable.   1. State the number k of neutrons released in this reaction.   k = ................................. **[1]**   1. State the binding energy of the released neutrons.   **[1]**   1. A nuclear reactor uses uranium-235 as fuel. The output power from the reactor is 1.0 GW. The mass of the nucleus is 236.053 u. The total mass of the fission products is 235.840 u.  Calculate the number of fission reactions per second.   number of reactions per second = .......................................... s−1 **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **29(a).** | A radioactive substance has 2000 nuclei. The decay constant of the isotope of the substance is 0.10 s−1.  Use the equation and Δt = 1.0 s to estimate the number of nuclei left after time t = 2.0 s.  number of nuclei left = .......................................... **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | \* A group of students are investigating the decay of protactinium. A fresh sample of protactinium is prepared. The activity of the sample was measured at intervals of 1.0 minutes for 6.0 minutes. The table shows the activity corrected for background radiation.     |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | time t / min | 0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | | activity A / Bq | 943 | 523 | 287 | 161 | 79 | 61 | 20 |   Fig. 20 shows the variation of ln(A) with time t.    Explain how the graph in Fig. 20 can be used to determine the half-life of protactinium. Determine the half-life of protactinium. Include an uncertainty in your value.                              **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **30(a).** | **Fig. 22.1** shows the circular track of a positron moving in a uniform magnetic field.    The magnetic field is perpendicular to the plane of **Fig. 22.1**. The speed of the positron is 5.0 × 107 m s−1 and the radius of the track is 0.018 m.  At point **B** the positron interacts with a stationary electron and they annihilate each other. The annihilation process produces two identical gamma photons travelling in opposite directions.  Calculate the wavelength of the gamma photons. Assume the kinetic energy of the positron is negligible.  wavelength = .......................................... m **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Calculate the magnitude of the magnetic flux density of the magnetic field.  magnetic flux density = .......................................... T **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **31.** | The speed *v* of the transverse waves on the string is directly proportional to √*T*, where *T* is the tension in the string. The tension *T* in the string is increased by 14 %. The frequency *f* of the oscillator is adjusted to get the same stationary wave pattern as **Fig. 18.1**.  Calculate the percentage increase in the frequency *f*.  increase = .......................................... % **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **32.** | This question is about the use of a thermistor fitted inside a domestic oven as a temperature sensor in a potential divider circuit.  Fig. 2.1 shows the potential divider circuit in which the component **R2** is connected in parallel to the input of an electronic circuit that switches the mains supply to the heating element in the oven on or off.    It is required that the p.d. across the thermistor **R2** is 7.0 V when at a temperature of 180 °C. The variation of resistance with temperature for **R2** is shown in Fig. 2.2.    The thermistor **R2** is fitted inside the oven. When the p.d. across **R2** falls to 5.0 V the oven heater switches off. The oven cools until the p.d. across **R2** rises to 7.0 V when the heater switches on again.  **R1** is adjusted to 250 Ω. Calculate the temperatures at which the oven heater is switched on and off.     |  | | --- | | temperature on ........................................................... °C |      |  | | --- | | temperature off ........................................................... °C **[4]** | | |

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|  | |  |  | | --- | --- | |  |  | | **33.** | An X-ray tube operates using a 150 kV supply. X-ray photons are produced inside the tube when a beam of high-speed electrons accelerated from the cathode collide with the metal anode. About 99% of the total kinetic energy of the electrons at the anode is converted into heat energy which heats the anode. The remaining energy is transformed into the energy of the X-ray photons.  The current in the electron beam between the cathode and the anode is 4.8 mA.   1. Show that the number of electrons incident at the anode per second is 3.0 × 1016 s−1.      |  | | --- | | **[1]** |  1. The anode is made from metal of specific heat capacity 140J kg−1 K−1. It has a mass of 8.6 g. The X-ray tube is switched on. Calculate the initial rate of increase of temperature of the anode.      |  | | --- | | rate of temperature increase = ........................................................... °C s−1 **[3]** |  1. A single electron is responsible for producing an X-ray photon. Calculate the shortest wavelength of the X-rays produced from the X-ray tube.      |  | | --- | | wavelength = ........................................................... m **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **34.** | A charged particle enters a region of uniform magnetic field. Fig. 2.2 shows the path of this particle.    The direction of the field is perpendicular to the plane of the paper. The magnetic field has flux density B. The particle has mass m, charge Q and speed v. The particle travels in a circular arc of radius r in the magnetic field.   1. Derive an equation for the radius r in terms of B, m, Q and v.      |  | | --- | | **[2]** |  1. A thin aluminium plate is now placed in the magnetic field. Fig. 2.3 shows the path of an unknown charged particle.     The particle loses some of its kinetic energy as it travels through the plate. The initial radius of the path of the particle before it enters the plate is 4.8 cm. After leaving the plate the final radius of the path of the particle is 1.2 cm.  Calculate the ratio         |  | | --- | | ratio = ........................................................... **[2]** | | |

**END OF QUESTION PAPER**

# Mark scheme

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| --- | --- | --- | --- | --- | --- |
| **Question** | | | **Answer/Indicative content** | **Marks** | **Guidance** |
| 1 |  |  | **Level 3 (5–6 marks)**  Clear description of experiment **and** measurements **and** clear analysis.  *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*   **Level 2 (3–4 marks)**  Some description of experiment **and** some measurements **and** some analysis.  *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*   **Level 1 (1–2 marks)**  Limited description of experiment **or**  Limited measurements **or**  Limited analysis  *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.*    **0 marks** No response or no response worthy of credit. | B1×6 | **Indicative scientific points may include:**    **Description**   * Release method * Ensure bob is not pushed * Repeat experiment for same *H* * Repeat for different H * Centre of mass of single bob and joined bob considered * Keep bob string taught   **Measurements**   * Measure heights *h* and *H* with ruler * Use centre of mass of bob or another suitable method * Use video camera to record motion * Use of datalogger and appropriate sensor to measure *H* and *h* * Measure mass with (top pan) **balance**   **Analysis**   * Construct a table of *h* and *H* * Plot graph of *h* against *H* * LoBF should pass through origin. * Determine gradient or calculate *h*/*H* ***repeatedly*** * gradient (gradient must be consistent with the plot) * Masses substituted into above expression and checked against experimental gradient |
|  |  |  | **Total** | **6** |  |
| 2 |  |  | **Level 3 (5−6 marks)** Correct calculations for radius and temperature range or distance or intensity for Earth-like temperature within given distance range, with clear explanation.  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3−4 marks)** Radius calculated or at least one temperature of planet calculated and some explanation.  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1−2 marks)** Some explanation and an attempt at least one calculation.  There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.  **0 marks** No response or no response worthy of credit. | B1x6 | Use level of response annotation in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks etc.  **Indicative scientific points may include:**  **Explanation**   * TRAPPIST-1 is cooler than the Sun * The planets are closer to TRAPPIST-1 * Possible for temperature on planets to be like Earth * For life to exist, temperature is not the only factor * L = 4πr2σT4 (Any subject)   **Calculations**   * Calculation of ’constant’ for Earth: 4(.19) x 105 * For inner-most planet, T = 430 K * For outer-most planet, T = 180 K * Calculation of distance for T = 290 K, i.e. 3.4 x 109 (m) * There must therefore be a planet with temperature similar to that of the Earth * L = 4πr2σT4 used to calculate radius of TRAPPIST-1 * Radius of TRAPPIST-1 is 8.5 x 107 (m) **or** L/T4 is smaller for TRAPPIST-1 * Comparison of calculated intensities at extreme distances around TRAPPIST-1 to intensity at Earth   **Examiner’s Comments**  This level of response question was very well answered, largely due to the highly mathematical content. Higher level responses showed clarity of method as well as one of a range of ways of supporting the idea that life may be possible on the planets of TRAPPIST-1.  Many candidates opted to show that that the temperature of the nearest planet was approximately 430 K while that at the furthest planet was approximately 180 K. The argument went that there must be a distance at which the temperature was approximately 290 K. Other methods found the distance from TRAPPIST-1 that would give a surface temperature of 290 K and showed that lay within the range of distances given in the table. |
|  |  |  | **Total** | **6** |  |
| 3 |  | i | power per (unit) area or power/area | B1 | **Allow** ‘energy per (unit) area per unit time’ **Not**: power per m2  **Examiner's Comments**  Most candidates correctly defined intensity as power divided by area. A small number of candidates defined intensity incorrectly as *‘energy divided by area’*. |
|  |  | ii | **1** |  |  |
|  |  | ii | ratio = | C1 |  |
|  |  | ii | ratio = 9.0 × 10−15 | A1 | **Allow**: 9.0 × 10−15 : 1**Allow**: 1 sf answer of 9 × 10−15 |
|  |  | ii | **2** (power = intensity × surface area) |  |  |
|  |  | ii | power ∞ *T*4*r*2 | C1 |  |
|  |  | ii | ratio = | C1 |  |
|  |  | ii | ratio = 1.1 × 107 | B1 | **Note**: Answer to 3 sf is 1.06 × 107 **Allow**: 1.1 × 107 : 1  **Examiner's Comments**  This was a good discriminating question that required careful execution. Most candidates in the upper quartile scored four or more marks. Their answers showed good development and errors were minimised. Most candidates in the lower quartile managed to get at least one mark. Candidates at this end struggled with writing the correct expressions for surface area and volume of the star. Sadly, for a significant number of candidates, the volume V of a star was given by the expression *V = 4π****r2****/3*. A significant number of candidates confused the terms ‘power’ and ‘intensity’ and ended up calculating the ratio of intensities instead. |
|  |  |  | **Total** | **6** |  |
| 4 |  | i | T = 293 K | M1 |  |
|  |  | i | 3/2 kT = ½ mv2 | C1 |  |
|  |  | i | 3/2 × 1.38 × 10−23 × 293 = ½ × 4.7 × 10−26 × v2 | M1 |  |
|  |  | i | v = 510 (m s−1) | A0 | Note answer is 509.8 m s−1 to 4 s.f. |
|  |  | ii | **1.**Total vertical momentum after = 0 Total vertical momentum before = 0 (momentum is conserved) | B1 B1 |  |
|  |  | ii | **2.**4.7 × 10−26 × v × sin 88° = 1.4 × 10−24 × 23 × sin 45° | C1 |  |
|  |  | ii | v = 480 (m s−1) | A1 | **Allow** other correct methods. |
|  |  |  | **Total** | **7** |  |
| 5 | a | i | Correct substitution and  rearranging to give correct expression | **M1    M1    A1** | **Note:** Both M1 marks are required to score this A1 mark  **Examiner’s Comments** Most students had considerable success in deriving the required expression. |
|  |  | ii | Transfer of **energy** to air / retort stand (because of air resistance / friction)    No effect on T (as T is independent of amplitude in SHM for small amplitude oscillations of pendulum) | **B1     B1** | **Allow** ‘loss of energy from pendulum (due to friction)’ **Allow** ‘work done’ for ‘energy’  **Allow** ‘isochronous’  **Examiner’s Comments** A pleasingly large proportion of students remembered that specification point 5.3.1 (f) states that the period of a simple harmonic oscillator is independent of its amplitude.  A similarly large proportion referred to damping or action of the drag force but fell slightly short of the idea that the effect of that force is to reduce the energy stored in the pendulum. |
|  | b |  | **Level 3 (5–6 marks)** Clear description including steps to obtain high quality data **and** analysis  There is a well-developed line of reasoning which is clear and logically structured.The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Clear description **and** some analysis  There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Limited description **and** analysis **Or** limited description  The information is basic and communicated in an unstructured way.The information is supported by limited evidence and the relationship to the evidence may not be clear.  **0 marks** No response or no response worthy of credit. | **B1 × 6** | **Indicative scientific points may include:** **Experiment  Description**   * Pendulum string clamped / fixed (can be shown on diagram) * Use a stopwatch to determine time period T * Time multiple oscillations to determine T * Use a ruler to measure L * Vary length L and determine T   **Quality of Data**   * Method used to ensure small oscillations * Small angles i.e. <10 degrees * Idea of fiducial mark * Start / stop timing at the centre of the oscillation * Measure from the fixed point to the centre of the bob   **Analysis**   * Correct plotting of graph, e.g. T2 against L or T against √L or lg T against lgL * Analysis of data table showing T2/L = constant * Expect a straight line through the origin * Correct gradient of the line e.g. 4π2/g   Use only L1, L2 and L3 in RM Assessor.  **Examiner’s Comments** While a small number of candidates described the incorrect experiment (such as masses on a spring or circular motion) most candidates made excellent attempts to describe the experiment and the ensuing analysis.  References to even the most basic equipment are essential, such as measuring lengths with a ruler and periods of time with a stopwatch or other suitable timer. Candidates that did neither could not score higher than Level 1.  Level 3 responses included ideas about achieving high quality data, such as use of a fiducial mark, starting the oscillation count (and hence the timer) at the midpoint where the pendulum bob is fastest, stating a suitable small angle of ten degrees or less and how to achieve that consistently with a protractor and by measuring the length of the string from the suspension point to the centre of the bob.  By far the preferred method of analysis leading to verification of the relationship was plotting a graph of T2 against L and expecting the trend to be not only straight but also through the origin with a gradient of (4π2/g). An acceptable alternative was to suggest calculating several values of (T2/L) and demonstrating that ratio to be constant and equal to (4π2/g). Note that writing ‘Plot a graph of T2/L’ is not an acceptable short hand for ‘plot T2 on the y-axis and L on the x-axis. |
|  | c | i | Correct substitution of T= 2(.0 s) into   length = 0.99 (m) | **C1     A1** | **Note:** 1 (m) here cannot score this A1 mark  **Examiner’s Comments** A large majority of candidates successfully showed that the pendulum length should be 0.99m for a ‘tick’ length of 1.0 seconds.  Candidates that attempted the reverse argument, by assuming a length of 1 m and then calculating the corresponding length, were usually unable to show the period of the resulting pendulum was 2.01s. Candidates that showed how to arrive at this period gained full credit. |
|  |  | ii | Lower g / gravitational field strength / acceleration (of free fall) on Moon.  T is longer (on Moon) **and** justified by   or is larger | **B1     B1** | **Accept** ‘g is a sixth of g on Earth’ AW **Not** gravity (is less)    **Examiner’s Comments** Many candidates suggested that g is less on the Moon than it is on the Earth, gaining one mark of credit. Most candidates suggested that would mean the period of the pendulum would be larger, but did so without justification from the formula in the question or contradicted themselves by stating that would make the pendulum ‘run faster’. |
|  |  |  | **Total** | **15** |  |
| 6 |  |  | horizontal component = 17 sin 30 or 17 cos 60 = 8.5 (m s–1) | B1 |  |
|  |  |  | at highest point vertical component of velocity is zero. | B1 |  |
|  |  |  | **Total** | **2** |  |
| 7 |  |  | Energy used to heat water to 100 °C = 0.60 × 4200 × 80 (= 201.6 kJ)  Energy remaining to vaporise water = 528 (kJ) − 201.6 (kJ) (= 326.4 (kJ)  mass vaporised = 326.4 × 103 / 2.3 × 106 = 0.1419 (kg)  mass of water left = 0.60 − 0.1419  mass of water left = 0.46 (kg) | **C1   C1   C1     A1** | Possible ecf from **(a)**          **Examiner’s Comments** This was a challenging multi-step calculation that differentiated between the candidates well.  A method employed by many high-scoring candidates began with a word equation "Total energy transferred = energy required to heat water to boiling point + energy required to vaporize water”. This made it clear to award the mark for substituting into the specific heat capacity equation and clear to the candidate how to find the mass of vaporized water.  A minority of candidates forgot to subtract the mass of vaporized water from the initial mass. |
|  |  |  | **Total** | **4** |  |
| 8 | a |  |  | B1 | Values must be substituted |
|  |  |  | *E* = 1.8 × 10−19 (J) | A0 | Answer to 3sf is 1.81 × 10−19 (J)  **Examiner's Comments**  This question was specifically included to give a hint as to the method to be used in (b). The question was written in a ‘show’ format to enable candidates to answer (b) even if they could not recall this area of synoptic work. However this did mean that all working, including substitution, had to be shown and this did result in a small number losing the mark. |
|  | b |  | *m* = *pV* = 8.1 × 10−12 × 4.5 × 103 = (3.645 × 108) | C1 |  |
|  |  |  | Thermal energy gained = *(mc Δθ)* = 3.645 × 10−8 × 520 × [1700 − 20] (= 0.0318) 1.81 × 10−19 × 6.3 × 1019 × *t* = 0.0318 | C1 | **Allow:** ecf from (a) and mass of titanium |
|  |  |  | *t* = 2.8 × 10−3 (s) | A1 | **Examiner's Comments**  Again this question had three distinct strands to the physics. The vast majority of candidates were capable of determining the correct mass and thermal energy required to raise the temperature of the titanium. A small number of errors were seen in these two strands however: mainly in transposition of the density formula and converting temperature changes incorrectly to kelvin scale. The final stage to determine the time was less confidently handled with transposition errors and some strange manipulation of the equations which usually resulted in the reciprocal of the correct answer. Perhaps the very small time involved in this form of welding surprised a few candidates. |
|  | c |  | Thermal energy is conducted / transferred to the rest of titanium / metal | B1 | **Not:** heat lost to surroundings |
|  |  |  | Photons are reflected / scattered from / not absorbed the titanium surface | B1 | **Examiner's Comments**  The answers given for this question were disappointing. All too often the only factor quoted was the vague ‘*heat lost to the surroundings’.* A significant number of candidates scored one mark by identifying the loss of thermal energy to the non-shaded volume of titanium. Only a tiny minority realised that some photons would be reflected from the metal surface. Other suggestions such as *‘photons are absorbed in the air’, ‘photons would miss the target’, ‘not all photons have the same energy’, ‘the laser needs to heat up as well’* were not given any credit. Marks for this discriminating question were mostly awarded only to the more able candidates. |
|  | d |  | (Photon) energy is converted into potential energy (rather than kinetic energy) OR Energy is used to change solid to liquid / phase (rather than increase kinetic energy) OR Energy provides (specific) latent heat of fusion (rather than increase kinetic energy) | B1 | **Allow:** energy is used to overcome the forces between atoms / breakdown the crystal structure of titanium (rather than increase kinetic energy)  **Examiner's Comments**  This question discriminated across the entire spectrum of ability, largely as a result of candidates writing about the lack of a temperature change rather than focusing on what actually happened to the energy supplied at this stage. Many answers were merely statements lacking in the vital explanation. It was, however, encouraging to see that the physics involved in this unfamiliar situation was broadly understood by the candidates. |
|  |  |  | **Total** | **7** |  |
| 9 |  | i | The upthrust is equal to the weight of the fluid / liquid / water / air displaced | B1 | **Examiner's Comments**  About one in every seven candidates omitted this question and only about a third of the candidates gave an acceptable statement of Archimedes' principle. It was clear from the answers that most candidates had not revised this topic. There were countless guesses, with many famous laws incorrectly linked to this principle. |
|  |  | ii | (upthrust =) 9.0 − 7.8 (N) or (mass =) 9.0/9.8(1) | C1 | **Note**: This C1 mark for determining the upthrust (1.2 N) or the mass (0.92 kg) of the cylinder |
|  |  | ii |  | C1 |  |
|  |  | ii | ρ = 7.5 × 103 (kg m−3) | A1 | **Allow** full credit for alternative methods, e.g:    **Examiner's Comments**  This proved to be a discriminating question that favoured those candidates who could apply, rather than just rote learn, Archimedes‘ principle. About a third of the candidates scored nothing in this question but many candidates did score one mark for determining the upthrust of 1.2 N. Most candidates stopped at this point. The top-end candidates correctly determined the volume of the displaced water and then went on to successfully calculate the density of the metal. |
|  |  |  | **Total** | **4** |  |
| 10 |  | i | a = 4п2f2 × | C1 | condition for SHM |
|  |  | i | so k = (m4п2f2) = 1.7 × 10−27 × 4 × 9.87 × 43.7 × 1026 | B1 | substitution |
|  |  | i | k = 292 (N m−1) | A1 | **ecf** if incorrect mass used |
|  |  | ii | (N2 gives) FH = mHaH and FI = mIaI | B1 | **allow** total momentum = 0 at all times |
|  |  | ii | (N3 gives) FH = FI   *can be implicit* | B1 | SHM gives v = 2пfxmax |
|  |  | ii | SHM gives a α (−)x | B1 | so mHXH = mIxI |
|  |  | ii | hence xH/xI = aH/aI = mI/mH = 127 | B1 | **accept** 127 = xH/xI ≈ 10/0.08 = 125 |
|  |  |  | **Total** | **7** |  |
| 11 | a |  | W of tube = upthrust (caused by submerged length) = A(0.30 − l) ρg | B1 | Archimedes principle expressed in some form. |
|  |  |  | W = 0.5 × 9.8 = 4.9 = π(2.5 × 10−2)2 × (0.3 − l) × 1.0 × 103 × 9.8 = 19.2 (0.30 − l) | C1 |  |
|  |  |  | 0.30 – l = 0.255 giving l = 0.045 m = 45 (mm). | A1 |  |
|  | b | i | 5 (mm). | A1 |  |
|  |  | ii | 1.0 mark on scale at peak of curve. | B1 | minimum requirement for mark: 0 to 3 Hz marked at 1 Hz intervals along axis. |
|  |  | iii | approx. same (or slightly lower) resonance frequency. | B1 |  |
|  |  | iii | smaller amplitude/broader peak *but curves must not cross* and passes through (0, 5 mm). | B1 |  |
|  |  |  | **Total** | **7** |  |
| 12 |  |  | **Level 3 (5–6 marks)** a structured combination of at least 6 statements taken from A, B and C or A and D a combination of at least 5 statements; script of a lower quality **N.B.** bonus given for any of E at any level *The ideas are well structured providing significant clarity in* *the communication of the science.*  **Level 2 (3–4 marks)** a good combination of at least 4 statements taken from A and B or A and C or B and C or A and D a combination of at least 3 statements taken from two sections which are relevant together. *There is partial structuring of the ideas with communication of the science generally clear.*  **Level 1 (1–2 marks)** at least 2 statements from A, B, C or D which are relevant together some attempt which is related to the question *The ideas are poorly structured and impede the communication of the science.*  **Level 0 (0 marks)** Insufficient or relevant science. | B1 | **A initial scenario**   * for circular orbit a centripetal force (of magnitude mv2 / r) is required or AW in terms of accelerations * this is provided by the gravitational force GMm/r2 **or** G force just pulls radially inwards sufficiently to maintain orbit * the speed in orbit v = (GM/r)1/2   **B reverse thrust**   * G force causes rocket to spiral towards Earth when rocket slowed; * rocket speeds up in process * v in orbit is larger when radius r is smaller; condition for faster lower orbit can be achieved **or** T smaller because either v is larger or r / circumference is smaller or both or 2πr/v is smaller   **C forward thrust**   * when rocket speeds up with engines fired forwards G force insufficient to hold orbit so spirals to larger orbit * slowing as it does so   **D energy approach**   * some p.e. goes to k.e. when rocket is slowed as it moves towards Earth * so v increases * vice versa when rocket is accelerated   **E further comments**   * extra corrections needed to obtain circular orbit after manoeuvre (not mentioned in passage) * any other relevant statement not included above |
|  |  |  | **Total** | **6** |  |
| 13 |  |  | Area under graph = 0.5 × 0.06 × 1.8 = 0.054 (Ns) | C1 |  |
|  |  |  | 0.05 × v = 0.054, therefore v = 1.1 (ms−1) | A1 |  |
|  |  |  | **Total** | **2** |  |
| 14 | a | i | u = 17 cos 30 = 14.7 (m s–1) | C1 |  |
|  |  | i | h = ut − ½gt2; = 14.7 × 1.5 − ½ × 9.81 × 1.52 | C1 | **or** use v2 = u2 – 2gs **or** s = (u + v)t/2 |
|  |  | i | h = 11 (m) | A1 | **note**: if g = 10 is used, then maximum score is 2/3 |
|  |  | ii | s = 2 × 8.5 × 1.5 | C1 | **ecf 2a** |
|  |  | ii | s = 26 (m) | A1 | allow 25.5 m |
|  | b |  | 0 = 17 sin 30 t - ½ × 9.81 × t2 | C1 |  |
|  |  |  | so t = 0 or 17/9.81 = 1.73 | C1 |  |
|  |  |  | s = 14.7 × 1.73 = 25.4 (m) | A1 | allow s = 15 × 1.7 = 25.5 (accept 25 or 26 to 2 sf) |
|  | c |  | the ball has the same speed (of 17 m s–1) but is at different (either at 60o or 30o) angle to the horizontal. | B1 |  |
|  |  |  | larger horizontal velocity (second trajectory) so travels further or higher bounce (first trajectory) so less drag from grass so travels further. | B1 | accept any sensible answer, e.g. steeper bounce loses more energy in impact so slows more. |
|  |  |  | **Total** | **10** |  |
| 15 | a | i | weight; (tractive) force up slope; drag; (normal) reaction |  |  |
|  |  | i |  | B1 |  |
|  |  | i | All forces in correct direction and correctly labelled. |  |  |
|  |  | ii | 14.4 + (85 × 9.81 × sin *θ*) = 41.7 | C1 | **ecf** from **(a)(ii)** |
|  |  | ii | *θ* = 1.9 ° | A1 |  |
|  | b |  | any three from:   * drag reduces velocity **or** increases time to cross **or** some kinetic energy of cyclist goes to heat. * longer crossing time results in cyclist at lower point on other side of gap. * moment on bicycle * rotation lowers height of front wheel. | B1 × 3 | Allow argument based on:   * very short crossing time (< 0.43s at speed of 6 ms−1 up slope). * energy changed to heat insignificant compared to KE * amount of rotation very small in short time. |
|  |  |  |  |  | conclusion based on argument(s). So no change in maximum gap width. |
|  |  |  | Conclusion based on argument(s). The maximum gap width is smaller. | B1 |  |
|  |  |  | **Total** | **7** |  |
| 16 |  |  | E = (hc/λ =) 6.63 × 10−34 × 3.0 × 108/450 × 10−9  E = 4.42 × 10−19 (J)  energy = 2.76 (eV) | C1   C1  A1 | **N.B.** the answer here must be 2 SF or more |
|  |  |  | **Total** | **3** |  |
| 17 |  | i | |  |  | | --- | --- | | Vq = ½ mv2 **and** |  |   Clear algebra leading to | M1    A1 | **Allow** p for mv  **Allow** e for q in **(b)(i)** – this is to be treated as a ‘slip’ |
|  |  | ii | |  |  | | --- | --- | | **1** | (% uncertainty in λ2 =) 10%  (% uncertainty in λ =) 5% | | **2** | Straight line of best fit passes through all error bars | | **3** | gradient = 1.0 (× 10−22)     gradient     gradient   m = 6.9 × 10 −27 (kg) (hence about 10−26 kg) | | C1  A1   B1    C1    C1   C1   A1 | **Note** 10 (%) on answer line will score the C1 mark      **Ignore** POT for this mark; **Allow** ± 0.20 (× 10−22)      Possible ECF for incorrect value of gradient  **Note check for AE** (condone rounding error here) **and** answer must be about 10−26 (kg) for any incorrect gradient value for this A1 mark  **Special case**: 1.37 × 10−26 kg scores 3 marks for q = 1.6 × 10−19 C because answer is about 10−26 kg |
|  |  |  | **Total** | **9** |  |
| 18 |  |  | **Level 3 (5–6 marks)** Clear description **and** clear analysis of data  *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*   **Level 2 (3–4 marks)**  Some description **and** some analysis of data **OR**  Clear description **OR**  Clear analysis of data  *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*   **Level 1 (1–2 marks)**  Limited description **and** limited analysis **OR**  Some description **OR**  Some analysis of data  *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant*.  **0 marks** No response or no response worthy of credit | B1×6 | **Indicative scientific points may include:**   **Description**   * Circuit showing supply, ammeter, voltmeter and resistance wire / coil * Measure *I* (in coil) with ammeter * Measure *V* (across coil) with voltmeter * Power (for coil) calculated: *P* = *VI* * Resistance of thermistor either calculated using *R* = *V*/*I* **or** measured with ohmmeter * Change *P* / change *V* / use variable power supply / use variable resistor (to change *I*) * Keep the number of turns of coil constant throughout / no draughts / wait until the resistance stabilises   **Analysis**   * lg*P* = lg*k* +*n*lg*R* (or natural logs ln) * Plot a graph of lg*P* against lg*R* * If expression is correct, then a straight line with non-zero intercept * gradient = *n* * intercept = lg*k* * *k* = 10intercept (or *k* = eintercept for natural logs) |
|  |  |  | **Total** | **6** |  |
| 19 |  |  | **Level 3 (5–6 marks)** Description and explanation of pattern changes **and** quantitatively explains link between de Broglie wavelength and potential difference.  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.   **Level 2 (3–4 marks)** Clear description of how pattern changes and explanation of pattern changes and qualitatively explains link between de Broglie wavelength and potential difference **or**   limited description of how pattern changes and quantitatively explains link between de Broglie wavelength and potential difference.  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.   **Level 1 (1–2 marks)** Limited description of how pattern changes and limited attempts to explain qualitatively the link between de Broglie wavelength and potential difference **or**   qualitatively explains link between de Broglie wavelength and potential difference.  The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.   **0 marks** No response or no response worthy of credit. | B1 ×6 | ***Indicative scientific points may include:***    ***Description of pattern changes***  • Rings become closer (not just smaller) • Rings become brighter   ***Qualititative explanation of pattern changes in terms of de Broglie wavelength and potential difference***     |  |  | | --- | --- | | • | Electrons gain greater energy | | • | Electrons have a greater speed | | • | Electrons have a greater momentum | | • | Implies smaller wavelength | | • | Smaller wavelength means less diffraction | | • | Shorter wavelength gives shorter path differences between areas of constructive and destructive interference |   ***Quantitative explanation of pattern changes in terms of de Broglie wavelength and potential difference***  •    •   p = mv •   v2 α V or p2 α V     |  |  |  |  | | --- | --- | --- | --- | | • |  | or |  |      |  |  |  |  | | --- | --- | --- | --- | | • |  | or |  |   **Examiner’s Comments** This question tested an understanding of electron diffraction. Many candidates gave a good qualitative explanation of how the pattern would change. High achieving candidates clearly demonstrated how the de Broglie wavelength λ was related to the potential difference V by equating the energy eV to kinetic energy, then using the definition of momentum and the de Broglie wavelength. Some candidates confused speed v with potential difference V. Many candidates gave a good qualitative explanation. Many candidates did not state that the rings would become brighter.     |  |  | | --- | --- | |  | **AfL** |   Candidates should be able to describe how to use light gates. In particular, candidates should be able to indicate the measurements that are needed to determine speed and acceleration. Candidates should state that the light gates should be connected to a timer or data-logger.     |  |  | | --- | --- | |  | **AfL** |   When analysing experimental data, candidates should be able to determine appropriate graphs to plot which will give a straight line (if the given relationship is true). Candidates should also be able to describe how unknown quantities may be determined using the gradient and / or y-intercept.     |  |  | | --- | --- | |  | **Misconception** |   There is some confusion between the equations to use for photoelectric effect and the equations to use when considering the de Broglie wavelength. For the de Broglie wavelength, a common misconception is to relate the energy to wavelength by the equation for the energy of a photon, |
|  |  |  | **Total** | **6** |  |
| 20 |  |  | F = BQv **and** F =mv2/r **or** B = mv/Qr (Any subject)     |  |  | | --- | --- | | (B =) |  |   B = 0.23 (T) | C1   C1    A1 | **Allow** e   **Examiner’s Comments**  This question on the circular motion of charged particles in a uniform magnetic field was answered with confidence and flair. Most candidates got the correct answer of 0.23 T for the magnetic flux density. A small number of candidates, mainly at the low-end, were using incorrect equation for the magnetic force experienced by the ions. Some of these equations were hybrids of the **electric** force experienced by charged particles. |
|  |  |  | **Total** | **3** |  |
| 21 |  |  | **Level 3 (5–6 marks)** Clear description **and** at least two from control of variables  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Some description **and** at least one from control of variables  There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Any description but no control of variables **or** Limited mention of control of variable(s)  There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.  **0 marks** No response or no response worthy of credit. | B1× 6 | Use level of response annotations in RM Assessor **Indicative scientific points may include:**  **Description**   * E = V/d * Voltmeter used to measure p.d. * Ruler used to measure separation d plates * Plastic rod held in a stand * Safety: Do not touch the terminals of high-voltage supply / (positive) plate * Vary d or V to change E * θ determined for each value of E * Experiment repeated for several values of E * Sensible techniques used to determine θ, e.g. use a protractor * Plot tanθ against E **or** tanθ against 1/d graph * Straight line through origin (expected)   **Control of variables**   * Charge q kept constant (ignore method) * Method for keeping q constant (e.g. same V for the (positive) plate, use separate constant voltage supply, etc) * Use the same foil / keep W the same * Keep d or V constant * Foil in between plates (where the field is uniform) * Draught-free room * Do the experiment quickly to avoid leakage of charge   **Examiner’s Comments** This was the second level of response (LoR) question in this paper. This too was designed to assess practical skills of planning, implementation, analysis and evaluation. The context of the question was force experienced by a charged gold foil in the uniform electric field provided by two parallel plates. Candidates were not expected to have seen such an experiment, but they were expected to use their knowledge of electric field strength and practical skills to present plausible approaches. On occasions, the experimental methods showed poor appreciation of some basic ideas. Some candidates were charging the foil using large current that allegedly would cause heating issues for the foil, while others decided to use Q = It, ammeter and a stopwatch to determine the charge on the foil – failing to appreciate that the time constant will be too small for such a technique. However, on this occasion, such over ambitious techniques were generally overlooked by examiners.  As with **16d**, a holistic approach to marking was used, with marks given according answers matching the descriptors for the various levels. There is no one perfect answer for this question, examiners were expecting an eclectic approach. The key things examiners were looking for were:  - Methods for determining electric field strength E.  - Using the right instruments for the measurements.  - Plotting the correct graph to show the relationship given in the question was valid.  - Correctly identifying the variables that were being controlled (kept constant).  Access to higher level marks dependent on fully answering the question – and this included the last statement about control of variables. A significant number of candidates focused on the description and analysis of the data, without ever addressing the last sentence of the question. This question did discriminate well, with L1, L2 and L3 marks roughly distributed in the ratio 1:3:4. |
|  |  |  | **Total** | **6** |  |
| 22 |  |  | distance = 6.0/cos 33.7 **or** 7.2 (cm)  **OR**  *v* = 3.00 × 108 / 1.50 **or** 2.00 × 108 (m s−1)  *t* = 7.2 × 10−2/ 2.00 × 108  *t* = 3.6 × 10−10 (s) | C1 A1 | **Allow** 34°    **Allow** 2 × 108 |
|  |  |  | **Total** | **2** |  |
| 23 |  |  | **Level 3 (5–6 marks)** Clear explanation, some description **and** both resistance values correct  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Some explanation, limited or no description **and** both resistance values correct **OR** Clear explanation, limited or no description **and** calculations mostly correct / one correct calculation **OR** Clear explanation, some description **and** no calculations  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Some explanation **OR** Some description **OR** Some calculation  There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.  **0 marks** No response or no response worthy of credit | **B1 × 6** | **Indicative scientific points may include:**  **Explanation of trace**   * The ‘trace’ is because of light reaching and not reaching LDR * Resistance of LDR varies with (intensity) of light * In light   + resistance of LDR is low   + p.d. across LDR is low   + p.d across resistor (or V) is high   + current in circuit is large * In darkness   + resistance of LDR is high   + p.d. across LDR is high   + p.d across resistor (or V) is low   + current in circuit is small * Vmax = 4.0 V; Vmin = 2.0 V * Potential divider equation quoted * Substitution into potential divider equation   **Description of determining frequency**   * Time between pulses is constant because of constant speed * Time between pulses = 0.4 (s) * f = 1/T * frequency = 2.5 (Hz)   **Calculations**   * Resistance of LDR is 150 (Ω) in light * Resistance of LDR is 1500 (Ω) in darkness   **Examiner’s Comments**  This was one of the two LoR questions. It required understanding of potential dividers, light-dependent resistor and rotation frequency of a spinning plate.  Examiners expect varied responses, and two very dissimilar answers can score comparable marks as long as the criteria set out in the answers’ section of the marking scheme are met. Level 3 answers had the correct maximum and minimum resistance values of the LDR, a decent description and explanation of the trace shown in Fig. 17.2, and an outline of how the frequency of the spinning plate was determined. As mentioned earlier, eclectic answers are inevitable – verbose and concise answers can be at Level 3.  In Level 2 answers there were generally missed opportunities. Half-done calculation and descriptions either with some errors or lacking in depth. Level 1 answers had some elements of calculations or descriptions.  The two exemplars below, illustrate a Level 3 response and a Level 1 response.  **Exemplar 7**    This is a Level 3 response from a top-end candidate who scored 6 marks.  The description of the variation of the resistance of the LDR, the circuit current and the potential difference across the fixed resistor is perfect. The calculations of the LDR resistances are nicely embedded into the general explanation. The calculation of the frequency is all correct. This is a model answer for 6 marks.  Compare and contrast this with the Level 1 response below.  **Exemplar 8**    This is a Level 1 response from an E-grade candidate.  The description of the variation of the resistance of the LDR is correct. However, there are no calculations of the resistance of the LDR, as required in the question. Hence, a significant part of the question has been omitted. According to the marking criteria, this could only score Level 1. The examiner credited 2 marks for this response. |
|  |  |  | **Total** | **6** |  |
| 24 |  | i | 2.76 − 2.3 = 0.46 eV (so only 0.5% of energy/AW) | B1 | **allow** 2.8 − 2.3 = 0.5 eV and 3.0 − 2.3 = 0.7 eV possible **ecf** from **(b)** |
|  |  | ii | n = 2000 × 49 (= 5.24 × 108)  Q = ne = 8.4 × 10−11 (C)  I = 8.4 × 10−11 / 2.5 × 10−9  average current = 0.034 (A) | C1  C1    A1 | **allow ecf** for wrong n      **allow** 34 m(A); answer is 1.7 × 10−5 A if 2000 omitted (2/3)  **Examiner’s Comments**  Almost all of the candidates attempted this last section of the paper with some success. In part (i) most candidates showed that they understood the theory behind the question and subtracted the appropriate two numbers from part (b) to gain the mark. Part (ii) was done well with a significant number obtaining the correct answer. Another large group forgot that 2000 electrons were released and performed the calculation for only a single electron being multiplied up and so forfeited the final mark. |
|  |  |  | **Total** | **4** |  |
| 25 | a | i | Resistance of parallel combination = 40 (Ω)    I = 0.037 (A) | **C1    C1   A1** | **Allow** (1/60 + 1/120)-1       **Allow** 2 marks for    **Examiner’s Comment** The success in this question hinged on understanding the effect of two opposing e.m.f.s in a circuit and determining the total resistance of the circuit. About a third of the candidates produced well-structured and reasoned answer leading to the correct current of 0.037 A. Most candidates picked up a mark for determining the total resistance of the two parallel resistors (40 Ω). The total e.m.f. in the circuit is  2.7 V and the total resistance is 73 Ω. Those using a total e.m.f. of 5.7 V ended up with the incorrect current of 0.078 A; two marks were awarded for this answer. A small number of candidates tried to calculate the current using either using 1.5 V or 4.2 V or 33 Ω. |
|  |  | ii | Any two from:  The current decreases up to 1.5 V The current is zero at 1.5 V The current changes direction / is negative when < 1.5 V The current increases below 1.5 V | **B1×2** | **Allow** ‘current is zero when the e.m.f.s are the same’  **Examiner’s Comment** Most of the answers here showed poor understanding of the circuit in Fig. 18.1. Nothing could be awarded for vague answers such as ‘current decreases because I ∝ V or ‘e.m.f. decreases so current decreases’. The current decreases as the e.m.f. of the supply approaches 1.5 V, at 1.5 V the current is zero, the direction of the current reverses and its magnitude increases when the e.m.f. of the supply gets below 1.5 V. About a quarter of the candidates gave credible answers. |
|  | b |  | **Level 3 (5-6 marks)** Clear description including a reasonable estimate of r **and** clear limitations  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3-4 marks)** Some description with an attempt to estimate r **and** some limitations  There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.  **Level 1 (1 -2 marks)** Limited description  There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.  **0 marks** No response or no response worthy of credit. | **B1×6** | Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2ˆ for 3 marks, etc. **Indicative scientific points may include:**  **Description and estimation**   * Correct circuit with (variable) resistor, ammeter and voltmeter * Correct symbols used for all the components * R changed to get different values for P * R = V / I (using ammeter and voltmeter readings) or R measured directly using an ohmmeter with the variable resistor isolated from the circuit or R read directly from a resistance box * Power calculated using P = V2/R or P = VI or P =I2R * The value of r is between 1.0 to 3.0 Ω * A smooth curve drawn on Fig. 18.2 (to determine r) * A better approximation from sketched graph or r is between 1.5 and 2.7 Ω * Any attempt at using E = V +Ir, with or without the power equation(s) to determine r - even if the value is incorrect   **Limitations**   * ‘More data’ required * Data point necessary at R = 2.0 Ω / More data (points) needed between 1 to 3 Ω * No evidence of averaging / Error bars necessary (for both P and R values)   **Examiner’s Comment** This was a level of response (LoR) question had three ingredients - drawing a viable circuit diagram that would enable the data shown in Fig.18.2 to be reproduced, using the figure to estimate the internal resistance of the cell and finally outlining any limitations of the data displayed in the figure. There is no one perfect model answer for a level of response question. A variety of good answers did score top marks. Most circuit diagrams were correct and well-drawn. There was the occasional mistake with the circuit symbol for a variable resistor; the thermistor symbol was a regular substitute. Most candidates drew a smooth curve on Fig. 18.2 and used this to estimate the internal resistance of the cell. Many also realised that the data points showed no evidence of averaging or error bars and that there were missing data points between 1.0 Ω and 3.0 Ω. Some candidates wanted ‘more data points spaced regularly at interval of0.5 Ω’, which was a sensible suggestion. Some weaker candidates attempted to draw a straight line of best-fit through the data points and then tried to determine the internal resistance from the gradient. There was a good spread of marks amongst the three levels. |
|  |  |  | **Total** | **11** |  |
| 26 | a |  |  | C1 |  |
|  |  |  |  | C1 |  |
|  |  |  | *KE*max = 2.2 × 10−20 (J) | A1 | **Allow** 3 marks for an answer of 2.0 × 10−20 J; value of *h* to 2 s.f. is used. |
|  | b |  | The rate of photons incident on **M** is doubled. | B1 |  |
|  |  |  | The rate of emission of photoelectrons / current is doubled. | B1 |  |
|  |  |  | **Total** | **5** |  |
| 27 | a |  |  | C1 |  |
|  |  |  |  | C1 |  |
|  |  |  | λ = 1.2 × 10−12 (m) | A1 | **Allow** 2 marks for 2.4 × 10−12 (m); factor of 2 omitted in the first line. |
|  | b |  | The intensity decreases with thickness of muscle / bone. | B1 |  |
|  |  |  | The decrease is exponential. | B1 |  |
|  |  |  | The attenuation (absorption) coefficient *μ* of bone must be greater than the *μ* of muscle | B1 |  |
|  |  |  | because there is a significant decrease in the intensity from *x* = 3.0 cm to 4.0 cm. | B1 |  |
|  |  |  | **Total** | **7** |  |
| 28 |  | i | 2 | B1 |  |
|  |  | ii | Zero | B1 |  |
|  |  | iii | Δ*m* = 236.053 − 235.840 = 0.213 u | C1 |  |
|  |  | iii | Δ*E* = [0.213 × 1.661 × 10−27] × (3.0 × 108)2 = 3.184 × 10−11 (J) | C1 |  |
|  |  | iii | number of reactions per second = 109/3.184 × 10−11 | C1 |  |
|  |  | iii | number of reactions per second = 3.1 × 1019 (s−1) | A1 |  |
|  |  |  | **Total** | **6** |  |
| 29 | a |  | number decaying in 1st second = 2000 × 0.10 = 200 | C1 |  |
|  |  |  | number decaying in the 2nd second = 1800 × 0.10 = 180 number left = 1800 – 180 = 1620 | A1 |  |
|  | b |  | **Level 3 (5–6 marks)** Correct explanation Correct determination of λ and half-life Correct determination of uncertainty (Maximum 6 marks) Any point omitted or incorrect (5 marks). There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Mostly correct explanation Mostly correct determination of λ and half-life Some attempt of determining uncertainty (Maximum 4 marks) Any point omitted or incorrect (3 marks). There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Basic explanation Some attempt to determine λ or half-life No attempt at uncertainty. (Maximum 2 marks) The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.  **0 marks** No response or no response worthy of credit. | B1 x 6 | **Explanation**  1. A = A0e−λt  2. lnA = lnA0 − λt  3. A graph of lnA against t will be a straight line with gradient (−) λ  4. half-life = ln2/λ  **Determination**  1. Line of best fit drawn  2. Gradient determined using a large triangle  3. decay constant in the range 0.5 to 0.7 min−1  4. half-life in the range 1.0 to 1.4 min  **Uncertainty**  1. Worst line of fit drawn  2. Correct attempt to determine uncertainty |
|  |  |  | **Total** | **8** |  |
| 30 | a |  |  | C1 |  |
|  |  |  |  | C1 |  |
|  |  |  | wavelength = 2.4 × 10−12 (m) | A1 |  |
|  | b |  | centripetal force provided by *BQv*; hence | C1 |  |
|  |  |  |  | C1 |  |
|  |  |  | *B* = 1.6 × 10−2(T) | A1 |  |
|  |  |  | **Total** | **6** |  |
| 31 |  |  | *v* ∝ *f* and since *v* ∝ ✓*T*, therefore *f* ∝ ✓*T* | C1 |  |
|  |  |  | frequency will increase by a factor of ✓1.14 = 1.068, therefore increase = 6.8% | A1 |  |
|  |  |  | **Total** | **2** |  |
| 32 |  |  | **switch on** 5.0 = 12 × 250/(250 + R) or 7.0 = 12 × R/(250 + R) | M1 | **accept** solution in 2 stages first calculating currents |
|  |  |  | giving R = 350 Ω which is 190°C | A1 | on I = 0.02 and R = 7/0.02 |
|  |  |  | **switch off** 7.0 = 12 × 250/(250 + R) or 5.0 = 12 × R/(250 + R) | M1 | off I = 0.028 and R = 5/0.028 |
|  |  |  | giving R = 180 Ω which is 210°C **or** Switch on, R2 / R1 = 7/5 giving R2 - 250 × 7/5 = 350 ohm Switch off, R2 / R1 = 5/7 giving R2 = 250 × 5/7 = 179 ohm | A1 | **allow** ± 5°C in reading from graph **N.B.** zero marks for correct temperatures quoted without some correct working / justification   **Examiner's Comments**  This question discriminated well with the top third scoring full marks; a few candidates failed to indicate which was the ON and which the OFF position reversing their answers. About half had failed to grasp the clues from the earlier parts and tried to include the value of current from b(ii); hence failing to score any marks. |
|  |  |  | **Total** | **4** |  |
| 33 |  | i | number per second = 4.8 × 10−3/1.6 × 10−19 | M1 | **Note**: This must be seen to gain a mark  **Examiner's Comments**  Most candidates scored a mark for dividing 4.8 × 10−3 by 1.6 × 10−19. A small number used a slightly longer route to show that the number of electrons incident at the anode was 3.0 × 1016 s−1. They calculated the total power dissipated using the potential difference and current and then divided the power by the energy gained by each electron (2.4 × 10−14 J). |
|  |  | i | number per second = 3.0 × 1016 s−1 |  |  |
|  |  | ii | (incident power =) 150 × 103 × 4.8 × 10−3 or (incident power =) 3.0 × 1016 × 150 × 103 × 1.6 × 10−19 | C1 | **Note** an incident power of 720 (W) scores this C1 mark |
|  |  | ii | *(P = mc*[Δθ/Δ*t])* 0.99 × 720 = 0.0086 × 140 × [Δθ/Δ*t]* | C1 |  |
|  |  | ii | rate of temperature increase = 590 (°C s−1) | A1 | **Note**: Answer to 3 sf is 592 (°C s−1) **Allow**: 2 marks for 598 (°C s−1) or 600 (°C s−1); 99% omitted **Allow**: 2 marks for 1.97 × 10−14 (°C s−1); 3.0 × 1016 omitted  **Examiner's Comments**  The answers were generally easy to follow. The modal range for this question was two to three marks. The best candidates gave brief and flawless answers. Some candidates lost a mark for   * premature rounding of numbers within the calculation; * failing to convert the mass into kg; * subtracting 273 K from the correct answer. |
|  |  | iii | (photon energy = maximum KE of electron) |  |  |
|  |  | iii | *E* = 150 × 103 × 1.6 × 10−19 or *E* = 2.4 × 10−14 (J) | C1 | **Allow**: *E* = 720/3.0 × 1016 |
|  |  | iii | (Allow any subject) |  |  |
|  |  | iii | wavelength = 8.3 × 10−12 (m) | A1 | **Allow**: 1 mark 8.3 × 10−10 (m); *E* = 2.4 × 10−16 (J) used  **Examiner's Comments**  The more able candidates performed well in this question. The energy of a single photon was equal to the maximum kinetic energy of a single electron. The omission rate was noticeably high for candidates in the lower quartile. The most common errors made were using mc2, 1.6 × 10−19 J and 720 J as the energy of the photon. A small number of candidates tried to use the de Broglie equation to determine the shortest wavelength of the X-rays. |
|  |  |  | **Total** | **6** |  |
| 34 |  | i | BQv = mv2/r | M1 | **Allow** e, q instead of Q |
|  |  | i |  | A1 | **Note**: r must be the subject of this equation   **Examiner's Comments**  The majority of the candidates did extremely well in this question. The physics was clear and the manipulation of the equations was easy to follow. It was rare to see an incorrect answer. Examiners did not award any marks for just quoting the final equation r = mv/BQ without any working. |
|  |  | ii | (p = mv = BQr; ) |  |  |
|  |  | ii | KE α r2 | C1 | **Allow** full credit for correct alternative approaches |
|  |  | ii |  |  |  |
|  |  | ii | ratio = 16 | A1 | **Allow** 16: 1   **Examiner's Comments**  This was a discriminating question, with many best candidates gaining full marks. The answers showed careful reasoning and good algebraic skills. The crucial step towards the correct answer was realising that v ∝ r and hence kinetic energy ∝ r2. About half of the candidates did not make good use of their equation from **(b)(i)** and incorrectly arrived at answers such as 0.0625, √2, 2 and 4. |
|  |  |  | **Total** | **4** |  |