Name: _____

Photoelectric Effect

Mark Scheme

Date:

Time:

Total marks available:

Total marks achieved: _____

Mark Scheme

Q1.

Question Number	Answer	Mark
	B	1

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
(a)	Lowest / minimum frequency (of light / photons incident on a metal) that will cause electrons to be emitted (from surface) **Or** the frequency of (light / photons) that will cause electrons to be emitted (from the surface of a metal) with zero kinetic energy **(1)** (accept only just emitted)	1
(b)	Conversion of eV to J **(1)** Use of $E = hf$ **(1)** $f = 5.5 \times 10^{14}$ Hz **(1)** Example of calculation $\varphi = (2.28 \text{ eV} \times 1.6 \times 10^{-19} \text{ C})$ $= 3.65 \times 10^{-19}$ J $f = 3.65 \times 10^{-19}$ J / 6.63×10^{-34} J s = 5.50×10^{14} Hz	3
	Total for Question	**4**

Q4.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td></td><td>
This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative points seen in answer</td><td>Number of marks awarded for indicative points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content

photon energy $E = hf$
photon energy must be greater than work function (of metal) for photon to provide enough energy for photoemission
UV photons have sufficient energy for photoemission but lab light photons do not
one photon interacts with one electron
with larger area more photons are absorbed/incident in a given time
more electrons are emitted in a given time (so the charge is lost more quickly)

</td><td>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure and lines of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
IC2 accept answers in terms of threshold frequency
IC5 & 6 there must be the idea of 'rate' once
<table>
<tr><th>Number of IC points awarded</th><th>Possible linkage marks</th></tr>
<tr><td>0,1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
</td><td>6</td></tr>
</table>

Q5.

Question Number	Answer		Mark
(a)	max kinetic energy **Or** ke_{max}	(1)	
	joule/J **Or** electronvolt/eV	(1)	
	Or	(1)	
	stopping potential **Or** V_s volt/V	(1)	**2**
	(Unit mark can be scored if no quantity given. If incorrect quantity given no marks awarded but KE/energy in joules/eV scores MP2)		
(b)	Idea that one photon is absorbed by one electron	(1)	
	Photon energy given by $E = hf$ **Or** photon energy increases with frequency	(1)	
	The idea that there is a minimum energy needed for emission of a (photo)electron	(1)	
	(So) emission of electrons only occurs if frequency of light greater than the threshold frequency **Or** threshold frequency is the minimum frequency for the emission of (photo)electrons	(1)	**4**
	Total for question		**6**

Q6.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
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<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Particle model

One photon interacts with one electron
And each photon has energy proportional to the frequency, Or reference to $E=hf$
The electron is emitted (instantly) only if the energy of the photon is greater than the work function (of the metal)
Or The electron is emitted (instantly) only if the energy of the photon is greater than the energy needed for an electron to break free (from metal surface)
Any photon energy over and above the work function is gained by the electron as kinetic energy

Wave model

It would be expected that the energy of the electron would build up and eventually be emitted.
The (kinetic) energy of the (emitted) electrons would depend on the intensity of the wave (and not the frequency)

</td>
<td>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
Linkage marks
<table>
<tr><th>Indicative content points</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6 with points from both models</td><td>2</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

Q7.

Question Number	Answer		Mark
	electron emitted by absorption of light/UV/photon	(1)	
	one photon absorbed by one electron	(1)	
	if frequency above threshold frequency then electron emitted **Or** if photon energy above work function energy then electron emitted	(1)	
	Use of $hf = \varphi$ (using work function to find corresponding frequency or wavelength) **Or** Use photon energy = hf (using any identified frequency or wavelength of visible light or UV to find corresponding photon energy)	(1)	
	Threshold frequency = 1.0×10^{15} Hz **Or** wavelength = 2.9×10^{-7} m **Or** Photon energy for light = a value between 2.9×10^{-19} J and 5.1×10^{-19} J **Or** photon energy for UV = a value between 5.1×10^{-19} J and 1.99×10^{-17} J	(1)	
	State visible light frequency too low / wavelength too long **Or** compare photon energy to work function	(1)	6
	Example of calculation $f = 6.88 \times 10^{-19}$ J ÷ 6.33×10^{-34} J s $= 1.0 \times 10^{15}$ Hz		
	Total for question		6

Q8.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)	• As graphene is only 1 atom thick so the CSA/thickness is far smaller than for a sample of steel **Or** most applications need a thickness greater than one atom **Or** if more than one layer of graphene is used it will be weaker or the bonds between the layers will not be strong **Or** Graphene is difficult to manufacture because it has only one atomic layer	(1)	MP1: accept graphene can only be 1 atom thick but steel can be any thickness (MP1, treat references to cost/energy as neutral)	2
	• Although graphene has a greater breaking stress it will break at a lower force	(1)		

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)	• Use of depth of graphite = 100 × diameter of 1 carbon atom	(1)	Example of calculation Depth of graphite = $100 \times 1.4 \times 10^{-10}$ m = 1.4×10^{-8} m	
	• Use of cross-sectional area = depth × (0.5×10^{-3} m)	(1)	CSA = 1.4×10^{-8} m × 0.50×10^{-3} m = 7.0×10^{-12} m^2	
	• Use of $\rho = \frac{RA}{l}$	(1)	$\rho = \frac{1.029 \times 10^{6}\,\Omega \times 7.0 \times 10^{-12}\,\text{m}^2}{0.200\,\text{m}} =$	
	• $\rho = 3.6 \times 10^{-5}\ \Omega$ m **Or** 36 μΩ m		$3.6 \times 10^{-5}\ \Omega$ m	**4**

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	**Max 3**			
	• Silicon will only release a (photo) electron for a limited range of frequencies/wavelengths	(1)	MP1: accept single frequency for limited range	
	• Silicon releases only one (photo) electron per incident photon	(1)		
	• Greater current (for the same illumination) in graphene	(1)		
	• Graphene (cells are) more efficient **Or** graphene cells could be smaller / cheaper / thinner			**3**

Q9.

Question Number	Answer		Mark
(a)	Quantum of … **Or** (discrete) packet of … **Or** discrete quantity of … (To score the mark must refer to something relevant e.g. light / energy) Of <u>electromagnetic</u> radiation/energy	**(1)** **(1)**	**2**
*** (b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) describe relevant interaction between single photon and single electron photon energy depends on frequency **Or** reference to $E = hf$ (must be link to photons/light) if photon energy greater than work function, electron emitted (immediately) whereas for waves energy could build up **Or** with waves that the electron can absorb energy continuously or over time so any frequency should work **Or** but this build up doesn't happen	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
(c)(i)	Use of $4.3 \times 1.6 \times 10^{-19}$ Use of $E = hf$ $f = 1.0 \times 10^{15}$ Hz <u>Example of calculation</u> $E = 4.3\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}$ $= 6.9 \times 10^{-19}\ \text{J}$ $6.9 \times 10^{-19}\ \text{J} = 6.63 \times 10^{-34}\ \text{Js} \times f$ $f = 1.0 \times 10^{15}$ Hz	**(1)** **(1)** **(1)**	**3**
(c)(ii)	Ultraviolet Accept ultraviolet even if frequency in c(i) is incorrect, but allow ecf from candidate's value of frequency to appropriate part of electromagnetic spectrum	**(1)**	**1**
	Total for question		**11**

Q10.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• (UV radiation consists of) photons • One photon interacts with one electron **Or** energy of photon depends on frequency • Electrons released if energy (of photon) greater than work function **Or** frequency is greater than threshold frequency **Or** <u>energy</u> supplied is sufficient to remove electron	**(1)** **(1)** **(1)**	Accept quanta/packets of energy	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• when slider at the bottom - reading on voltmeter is zero **Or** minimum resistance - reading on voltmeter is zero	(1)		
	• When slider at the top – reading on voltmeter is 1.5 V **Or** maximum resistance - reading on voltmeter is 1.5 V	(1)		
	• Potential difference split between top and bottom part of resistor (either side of slider) **Or** reading on voltmeter depends on the ratio of resistances (either side of slider) **Or** moving the slider changes the resistance that the voltmeter is across	(1)		3

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	Maximum Kinetic Energy of electron = 0.6 (eV)	(1)		1

Question Number	Acceptable answers		Additional guidance	Mark
(c)	**Max 4**		Full marks can only be scored if a correct link is made between at least one physics point and the demonstration being valid or not valid	
	Valid because:			
	• Moon and photocell both have vacuum	(1)		
	• Both demonstration and theory use photoelectric effect	(1)	Accept the same concept for photoelectric effect	
	Not valid because:			
	• Different wavelengths in each case	(1)	Accept one uses light the other UV	
	• On the moon there is dust not metal	(1)	Accept different materials for MP4	
	• Dust is free to move but the metal plate is fixed	(1)		
	• On the moon UV removes electrons from (individual) <u>atoms</u> **and** in the demo light removes electrons from metal <u>surface</u>	(1)		
	• Demonstration is based on photoelectric effect but effect on moon could be ionisation	(1)		4

Q11.

Question Number	Answer	Mark
(a)	**When illuminated:** Use of the word photon (1) photons/light cause emission of (photo)electrons (1) Idea that (photo) electrons form a current (1) photon energy greater than or equal to work function. (1) **In darkness:** No photons so no photoelectrons released (1)	**5**
(b)	Use of $E = hf$ (1) Conversion of eV to J (1) One of the 4 values below correct $f = 5.2 \times 10^{14}$ Hz or $\lambda = 5.8 \times 10^{-7}$ m for caesium $f = 8.8 \times 10^{14}$ Hz or $\lambda = 3.4 \times 10^{-7}$ m for zinc (1) Comment that Cs is in the visible range or Zn is ultraviolet – allow even without supporting calculation (1) **Alternative method** Allow assumed max freq/min wavelength for visible light then, calculation of work function, quoted in eV, comparison with given work functions, conclusion: Use of (1); work fn (1), in eV (1), comparison (1) Example of calculation $f = \varphi \div h = (2.14 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 5.2 \times 10^{14}$ Hz for caesium $f = \varphi \div h = (3.63 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 8.8 \times 10^{14}$ Hz for zinc	**4**
(ci)	Maximum displacement of the wave **Or** maximum displacement from the mean **Or** maximum displacement from equilibrium (1)	**1**
(cii)	**Max 3** Size of the gap (in the soundtrack) determines the amount of light (1) Amount of light determines number of photons (1) Number of photons determines number of (photo) electrons (released by phototube) (1) Number of electrons determines size of current (in the circuit) (1) (Combining MP 1 and 2 by writing "size of the gap determines number of photons" scores 1 mark. Combining MP 2 and 3 by writing "the amount of light determines number of (photo) electrons" also scores 1 mark)	**3**
	Total for question	**13**