

Name of the Student: \_\_\_\_\_

Max. Marks : 26 Marks

Time : 26 Minutes

Mark Schemes

**Q1.**

- (a) One which moves at constant velocity

*Allow: a reference frame in which Newton's laws / Newton's first law holds.*

1

- (b) In frame of particle beam

$$\text{Distance between detectors} = 45 \sqrt{1 - \frac{(0.97c)^2}{c^2}} = 10.9 \text{ m } \checkmark$$

$$\text{Time} = 10.9 / 0.97c = 3.8 \times 10^{-8} \text{ s } \checkmark$$

$$\text{Half-life} = \text{time}/3 \checkmark = 1.3 \times 10^{-8} \text{ s } \checkmark$$

*MP1 is for determination of distance between detectors in ref frame of particles*

*MP2 is for determining the time between detectors in the ref frame of particles*

*MP3 is for use of reduction to 12.5% is equivalent to 3 half-lives*

*MP4 is for correct final answer*

*Allow alternative route from ref frame of detectors*

4

- (c) The time taken for particle beam to travel between detectors 'measured' in the reference frame of particle beam ✓

*Accept: shortest observable time for a particle passing between detectors.*

*Accept  $3.8 \times 10^{-8} \text{ s}$*

1

**[6]****Q2**

- (a) Electrons (in surface) have to overcome the potential/coulomb barrier ✓

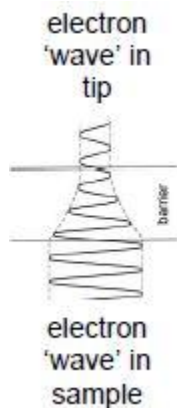
Electrons have insufficient energy so (due to wave properties of electrons) there is a probability of electrons crossing from sample to tip

OR

a fraction of electrons will move from sample to tip. ✓

*Credit diagram of high amplitude wave, barrier and lower amplitude transmitted wave for second mark*

*Eg*



2

- (b) Tip of probe maintained a certain distance (about 1nm) above surface. ✓

(Current from surface into probe due to tunnelling)

When probe moves over higher layer of electrons, current increases ✓

(Through a feedback process) Tip is moved higher to reduce current to original value.  
(Distance moved by tip = distance new surface above/below original surface) ✓

(Hence surface mapped by position of tip.)

*Allow reverse argument*

3

- (c) Attempt to apply  $\frac{1}{2}mv^2 = eV$   
 $\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 2.4 \times 10^{-19}$  ✓  
 If correct  $v = 7.26 \times 10^5$  (m s<sup>-1</sup>)

*Allow if no or incorrect conversion of eV to J*

Attempt to apply  $\lambda = h/mv$   
 $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 7.26 \times 10^5)$  ✓

*Allow for use of their v in substitution*

$1.0 \times 10^{-9}$  m (cao) with conclusion ✓

*Condone 1sf answer, but must have unit*

Alternative one step route:

Attempt to put data in  $\lambda = \frac{h}{\sqrt{2mE}}$  with no conversion to J ✓

Substitution of data with conversion to J ✓

Answer correct with conclusion ✓

*Example conclusion*

*No - less energy (electron) would have longer wavelength and would be too long to map atom/wavelength should be smaller than 1nm*

3

[8]

### Q3.

- (a) Electromagnetic/EM radiation ✓

Spectrum with peak depending on temperature (of emitter alone). ✓

*If no other mark awarded, allow 1 mark for (EM) radiation given off by*

perfect absorber /emitter.  
 Condone light for radiation

2

(b) (Description of ultraviolet catastrophe)

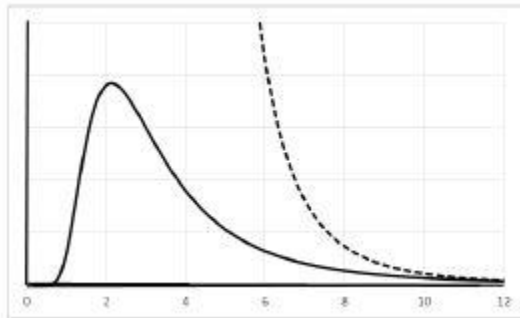
*If no other mark awarded, 1 mark can be given for idea that there is 'no peak'.*

1

Intensity similar at long wavelengths, ✓

(But rather than peak) theory predicts intensity increases at shorter wavelengths/infinite at very short wavelengths ✓

*Allow correct line on graph for either for 1 mark  
 But some correct description needed for both*



*Condone any line that goes to infinity at short wavelengths for MP2.*

1

(c) EM radiation emitted in quanta ✓

Energy of quantum is related to a single frequency **OR**

$E = hf$ , where  $h$  is Planck's constant. ✓

*Do not condone photon or packet for quanta in MP1*

2

(d) The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	All 3 areas covered with at least two aspects of photoelectric effect covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all 3 areas. If there are several errors or missing parts then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed, or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

The following statements are likely to be present.

### **A main outcomes of experiments.**

No photoelectric emission if incident light below threshold frequency

Photoelectric emission is instantaneous/occurs as soon as light is incident on metal surface

(Photoelectrons have a range of KE from zero to max value, depending on type of metal and frequency of incident light.

Number of photoelectrons per second is proportional to intensity of incident radiation)

### **B problems of classical wave theory**

Intensity of wave (brightness of light) should determine whether photoelectron emitted/KE of photoelectron OR light of any frequency should cause emission.

Wave energy spread over surface should mean time needed to for electrons to accumulate enough energy to be emitted/lower intensity the longer the time.

### **C Aspects of Einstein's theory**

Light is made of photons

Photoelectrons due to one photon interacting with one electron in surface of metal.

Minimum energy (work function of metal) needed for electron to be emitted related to a threshold frequency by  $\phi = hf_0$

Remaining energy of photon ( $hf - hf_0$ ) becomes (max) KE of photoelectron.

Brighter source means more photons (per second) and therefore more photoelectrons (per second).