MARK SCHEME

PHYSICS

AS-Level

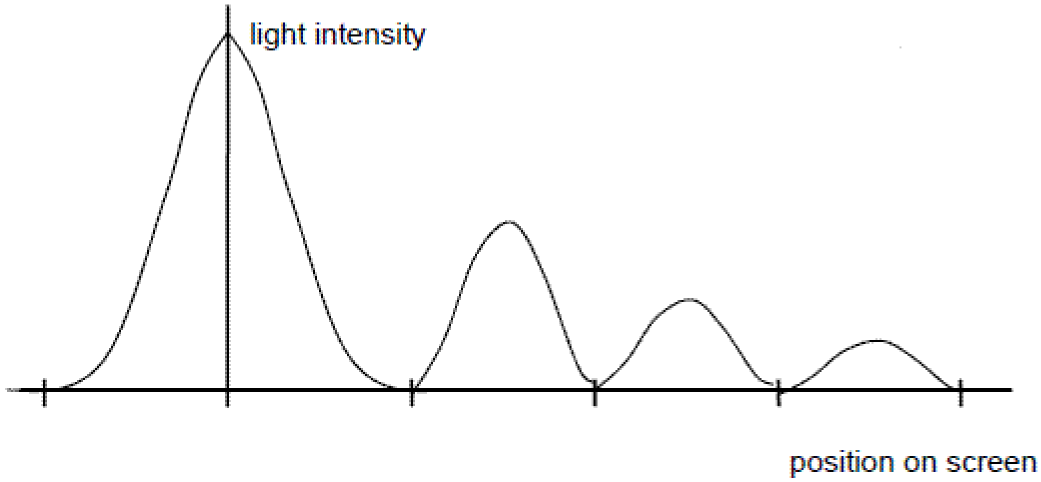
QUANTUM PHYSICS

TEST 2

Mark schemes

1 (a) 3 subsidiary maxima in correct positions **(1)**

intensity decreasing **(1)**



2

(b) a single wavelength **(1)**

constant phase relationship/difference **(1)**

2

(c) maxima further apart/central maximum wider/subsidiary maximum wider/maxima are wider **(1)**

1

(d) wider/increased separation **(1)**

lower intensity **(1)**

2

(e) distinct fringes shown with subsidiary maxima **(1)**

indication that colours are present within each subsidiary maxima **(1)**

blue/violet on the inner edge **or** red outer for at least one subsidiary maximum **(1)**

(middle of) central maximum white **(1)**

3

[10]

2 correct substitution into formula, condone power of ten error

C1

8.7×10^{-10} (m)

A1

[2]

3 (a) release of electrons from (metal) surface when electromagnetic radiation is incident on the surface

B1

1

(b) (i) use of $c = f\lambda$/ or $f = 7.9 \times 10^{14}$ seen (condone power of ten)

C1

correct sub into $E = hf$ (condone power of ten error)

C1

$5.2(3) \times 10^{-19}$ (J)

A1

3

(ii) work function = $2.3 \times 1.6 \times 10^{-19}$ (3.7×10^{-19}) **or** converts 5.2×10^{-19} to 3.27 eV

M1

allow conversion to frequency if comparison made

less than answer to (b) (i) so yes (based on comparison of **cna**) (allow **ecf** from (b) (i))

A1

2

(c) surface attracts negative electron back to positive surface

B1

photons have insufficient energy/energy required increased

B1

2

[8]

4 (a) (i) *hf* is energy available/received **or** same energy from photons **(1)**

energy required to remove the electron varies (hence kinetic energy of electrons will vary) **(1)**

2

(ii) (work function is the) minimum energy needed to release an electron **(1)**
(or not enough energy to release electron)

below a certain frequency energy of **photon** is less than work function **or** energy of **photon** correctly related to *f* **(1)**

2

(iii) joule **(1)** (accept eV)

1

(b) (i) (use of $E = hf$)
energy = $6.63 \times 10^{-34} \times 1.5 \times 10^{15}$ **(1)**
energy = 9.9×10^{-19} (J) **(1)**

2

(ii) number of photons per second = $3.0 \times 10^{-10}/9.9 \times 10^{-19}$ **(1)**

number of photons per second = 3.0×10^{8} **(1)**

2

(c) (i) (time taken = $6.8 \times 10^{-19}/3 \times 10^{-22}$)

time taken = 2.3×10^{3} s **(1)**

1

(ii) light travels as particles/ photons **(1)**
(or has a particle(like) nature)

(which transfer) energy in discrete packets **(1)**
or 1 to 1 interaction
or theory rejected/modified (in light of validated evidence)

2

[12]

5 (a) (electron) diffraction/interference/superposition **(1)**

1

(b) (use of $\lambda = h/mv$)

$\lambda = 6.63 \times 10^{-34}/(9.11 \times 10^{-31} \times 4.50 \times 10^{5})$ **(1)**

$\lambda = 1.6 \times 10^{-9}$ (m) **(1)**

2

(c) $207 \times 9.11 \times 10^{-31}$ **(1)** $\times\, v = 6.63 \times 10^{-34}/1.6 \times 10^{-7}$ **(1)**

$v = 2200\ (2170)\ (\text{m s}^{-1})$ **(1)**

3

[6]

6 (a) (i) an electron/atom is at a higher level than the ground state **(1)**

or electron jumped/moved up to another/higher level

1

(ii) electrons (or electric current) flow through the tube **(1)**

and collide with orbiting/atomic electrons or mercury atoms **(1)**

raising the electrons to a higher level (in the mercury atoms) **(1)**

3

(iii) photons emitted from mercury atoms are in the **ultra violet** (spectrum) **or** high energy photons **(1)**

these photons are absorbed by the powder **or** powder changes frequency/wavelength **(1)**

and the powder emits photons in the visible spectrum **(1)**

incident photons have a variety of different wavelengths **(1)**

max 3

(b) (i) (use of $E = hf$)

$-0.26 \times 10^{-18} - 0.59 \times 10^{-18}$ **(1)** $= 6.63 \times 10^{-34} \times f$ **(1)**

$f = 0.33 \times 10^{-18}/(6.63 \times 10^{-34}) = 5.0 \times 10^{14}$ (Hz) **(1)**

3

(ii) **one** arrow between n = 3 and n = 2 **(1)** in correct direction **(1)**

2

[12]

7 (a) (i) $f = c/\lambda$ seen in this form

C1

4.41×10^{14} seen

A1

2

(ii) $\Phi = hf$

C1

2.917×10^{-19} to 2.93×10^{-19} seen

A1

2

(iii) $h(7.8 \times 10^{14})$ – their (ii)

C1

2.2×10^{-19} (J) to 2.3×10^{-19} (J)

A1

2

(b) no photoemission below threshold frequency (even with bright light)

B1

wave theory would allow gradual accumulation of energy to cause emission

B1

2

[8]

8 **C**

[1]

9 **B**

[1]

10 3rd box

(Electrons produe dark rings in diffraction experiments) ✓

[1]

11 **C**

[1]

Examiner reports

1 Most candidates gained at least one mark in part (a) for showing that the intensity of peaks reduced with distance from the centre. However, many did not recall the key difference between the pattern for single and double slits – the single slit pattern has a central maximum which is double the width of the subsidiary maxima.

There were many correct definitions of monochromatic and coherent in part (b). A few stated 'same colour' for monochromatic and 'in phase' for coherent. Neither of these were accepted.

In part (c), many candidates incorrectly used the equation for two slits to show that the maxima were further apart. This was not penalised since an explanation was not asked for.

Many candidates got part (d) the wrong way around, saying that the fringes would be more closely spaced and more intense. There seemed to be some guess work evident here. Candidates need to be able to describe the appearance of the single slit pattern and be aware of how it will change for different wavelengths, slit widths and for monochromatic and white light. Some teachers introduce the equation for the single slit although it is not in the specification. This is not necessary but can certainly help the more mathematically minded students. To illustrate the change in the pattern, a simple demonstration can be carried out with a red and a green laser shone through the same slit onto a screen.

A pleasing number of candidates produced very detailed and high quality answers to part (e), with many gaining all three marks. Some drew a graph of intensity, which did not gain a mark on its own.

2 Many candidates were able to obtain full marks for this calculation. The two most common errors made were the lack of substitution for the mass of the electron and a calculator error involving the order in which the calculation was performed. This calculation error meant that candidates performed (h ÷ m) × *v*.

3 Many candidates were unable to answer part (a) with sufficient detail. Often these candidates did not include that this is a surface phenomenon and were penalised.

The calculation in part (b) (i) was performed well with most candidates achieving full credit. The most common error made by those who attempted the calculation was an incorrect conversion of the wavelength for nm to m.

In part (b) (ii), many candidates were unable to correctly convert 2.3 eV into joules or made no attempt to convert the work function but then compared $5.2(3) \times 10^{-19}$ J with 2.3 eV.

Part (c) was answered poorly, with many candidates stating that there were no electrons left or that the photoelectric effect can only occur when the emitting surface is negative. Very few candidates were able to explain the lack of photoelectrons from an energy perspective.

4 The initial parts of this question caused considerable problems to candidates. They found it very difficult to explain why the kinetic energy of the emitted electrons had a maximum value and also fully explain the link between photon energy, work function and maximum kinetic energy. The idea that some electrons require more energy to be emitted than others did appear to be well understood. Candidates also had a tendency to confuse the photoelectric effect with excitation and ionisation. Evidence from this and previous papers suggests that this is a topic candidates find very difficult and this is particularly true when they are required to explain aspects of the phenomena.

Parts (b) and (c) proved much more accessible and candidates used the various relevant equations confidently. Full marks for calculations were quite common. Part (c) (ii), which assessed *How Science Works*, did confuse some candidates. When this happened, candidates tended to explain the significance of validated evidence in general terms, rather than how it was used to develop the particle model of light.

5 This question was well answered and the majority of candidates appreciated that diffraction is a wavelike property that electrons exhibit. The calculation in part (b) proved to be quite straightforward and full marks were obtained by a pleasing number of candidates.

6 Part (a) proved to be quite discriminating and less able candidates found it hard to explain the process by which mercury atoms become excited in a fluorescent tube. There was also evidence to suggest that some candidates think that excitation only occurs due to the absorption of photons and seemed unaware that it can also happen by electron collision. Most candidates seemed to appreciate that the mercury atoms emitted photons that were in the ultraviolet part of the spectrum and that the coating changed the frequency of these although there was a tendency to describe these photons as photons of light or coloured light rather than visible light.

Part (b) was answered well and the only common error was a failure to appreciate that the energy levels were in Joules and that the value adjacent to each level needed to be multiplied by 10^{-18}. A minority of candidates either emitted this factor or assumed that the energies were in electron volts and multiplied them by 1.6×10^{-19}.

7 Many candidates found the calculations in part (a) to be accessible. However, candidates should be aware that simply getting the correct answer in not sufficient when they have been asked to 'show that'. In these cases they must be clear with their selection of equations, manipulation, substitution and in dealing with powers of ten. They should also quote their answer to a greater degree of provision than number mentioned in the question in order to demonstrate that they have performed the calculation completely. There were a surprising number of candidates that did not attempt this part of the question.

Answers to part (b) were poor. It seems that candidates were familiar with the effect but they were not able to articulate the logic of why it demonstrates that light, in this case, is not acting as a wave.

8 Most students selected A as their answer, this being *d* rather than the number of lines per mm as requested. Only 25.5% of students were able to select the correct answer.

9 68.6% correct

10 Students should be reminded to make it clear which answer they have chosen, and to avoid putting marks in more than one box. It was very accessible, with over 70% obtaining the mark.

11 The most frequently selected distractor was B, accounting for 30% of the responses. It would benefit students to emphasise that the maximum kinetic energy depends only on the frequency of the incident radiation and the work function of the metal surface. Increasing the power, without changing the frequency, will only increase the number of photons incident on the surface every second, and will not increase the energy each photon carries. It would have had to have been clearly stated that the frequency had been doubled as a means of doubling the power for distractor B to have been the answer.