Mark scheme for Support Worksheet – Topic 6, Worksheet 3

1 **a** The energy carried by a wave is distributed along wavefronts; if we consider a very low intensity beam of light incident on the metal the energy is being delivered to the metal at a very low rate and so the time required for the electron to accumulate the energy needed to escape would be very large. [2]

b According to the photon theory of light, the energy of light is carried by individual photons; and the entire energy carried by the photon is transferred to the electron at once when the photon is absorbed. [2]

2 **a** (Whereas the energy carried by mechanical waves depends on both frequency and amplitude) the energy carried by electromagnetic waves depends only on the amplitude and not the frequency; hence the energy of the emitted electron cannot have any dependence on frequency. [2]

b According to the photon theory the energy of a photon is given by hf; hence the energy of the emitted electron is $hf - \phi$ and so depends on the light frequency. [2]

3 **a** The intensity has no effect on the energy of the electrons; increased intensity implies more photons not more energetic photons. [2]

b More electrons would be ejected; increased intensity implies more photons and hence greater probability for more electrons to be ejected from the metal. [2]

4 The work function is the minimum energy required to eject an electron from a metal surface. [1]

5 $$E_K = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.2\times10^{-7}} - 2.2\times1.6\times10^{-19}$$
$$= 1.00\times10^{-19}\ \text{J}$$

$$\frac{1}{2}mv^2 = 1.00\times10^{-19}\ \text{J} \Rightarrow v = \sqrt{\frac{2.00\times10^{-19}}{9.1\times10^{-31}}} = 4.7\times10^{5}\ \text{m s}^{-1}$$ [3]

6 **a** Stopping voltage is that voltage between the anode and the cathode in a photoelectric effect experiment for which the photocurrent becomes zero. [1]

b From $eV_S = hf - \phi \Rightarrow V_S = \frac{hf}{e} - \frac{\phi}{e}$ the slope is $\frac{h}{e}$, i.e. Planck's constant divided by the elementary charge. [1]

7 **a** Particles show wavelike behaviour; with a wavelength that equals Plank's constant divided by the particle's momentum. [2]

b See *Physics for the IB Diploma*, pages 394–395. [3]

8 $\frac{p^2}{2m} = 150 \times 1.6 \times 10^{-19} \Rightarrow p = 6.61 \times 10^{-24}$ N s; and so

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{6.61 \times 10^{-24}} = 1.0 \times 10^{-10}$ m [2]

9 **a** The allowed wavelengths are $\lambda = \frac{2L}{n}$ with $n = 1, 2, 3 \ldots$ [1]

b $E = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$; and so $E = \frac{h^2}{2m(\frac{2L}{n})^2} = \frac{h^2 n^2}{8mL^2}$ [2]

10 **a** The product of the uncertainties in momentum and position is never less than Planck's constant divided by 4π. [1]

b Since $\Delta x : 10^{-10}$ m (this is an order of magnitude calculation so you may choose $\Delta x : \frac{1}{2} \times 10^{-10}$ m if you wish);

$\Delta p \approx \frac{h}{4\pi \Delta x} = \frac{6.63 \times 10^{-34}}{4\pi \times 10^{-10}} = 5.3 \times 10^{-25} \approx 10^{-24}$ N s [2]