7 **(a)** State what is meant by the *photoelectric effect* and describe how it provides evidence for the particulate nature of electromagnetic radiation when it is interacting with matter.

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..... [6]

(b) State an equation to express the principle of energy conservation as applied to the photoelectric effect. Explain the meaning of all the terms that you use.

equation .....

terms used .....

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..... [3]

(c) Light of wavelength 3.82×10^{-7} m is incident on a substance and electrons are emitted with a maximum speed of $6.87 \times 10^{5}\,\text{m s}^{-1}$. Calculate the work function energy of the substance.

work function energy = ... J [3]

(d) A pulse of a radio wave lasts for 1.0×10^{-5} s. A photon of the radio wave may be considered to be at a point anywhere within this pulse, although the location of the point is not known. Calculate

(i) the length of the pulse,

length of pulse = ... m [1]

(ii) the uncertainty in the position of the photon,

uncertainty in position = ... m [1]

(iii) the uncertainty in the momentum of the photon.

uncertainty in momentum = ... [3]

(e) Show, with the aid of a diagram, what is meant by a *potential barrier*. Discuss how the wave nature of particles allows particles to tunnel through such a barrier.

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..... [3]