CHAPTER 11

From photoelectric cells to photo cells

Answers to revision questions

1. The setup of Hertz's experiment can be found in Chapter 11. The other significant observation made in the experiment was the photoelectric effect. Hertz recognised that the UV from the primary coil helped the formation of the sparks in the secondary coil. Although we know now that this is caused by the photoelectric effect, Hertz did not investigate this phenomenon further.
2. See Chapter 11.
3. (a) The black body radiation curve can be obtained by heating a black body and assessing the intensity of the emitted radiation at different wavelengths with a detector.

   (b) The curve will have an overall larger amplitude, and its peak will be shifted to the left.
4. The definition can be found in Chapter 11. The hypothesis was initially made to resolve the left-hand catastrophe and to theoretically derive the black body radiation curve.
5. (a) Using Planck's equation:

$$E = hf = \frac{hc}{\lambda}$$

Known quantities:

$h = 6.626 \times 10^{-34}$

$c = 3 \times 10^{8}\ \text{m s}^{-1}$

$\lambda = 0.5\ \text{m}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{0.5}$$

$$= 4.0 \times 10^{-25}\ \text{J}$$

(b) Using Planck's equation:

$$E = \frac{hc}{\lambda}$$

Known quantities:

$h = 6.626 \times 10^{-34}$

$c = 3 \times 10^{8}\ \text{m s}^{-1}$

$\lambda = 1.1 \times 10^{-10}\ \text{m}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1.1 \times 10^{-10}}$$

$$= 1.8 \times 10^{-15}\ \text{J}$$

6.
$$Power = \frac{Energy}{Time}$$
$$2.23 \times 10^{-16} = \frac{E}{1}$$
$$E = 2.23 \times 10^{-16}\ \text{J}$$

If 270 protons have a total energy of 2.23×10^{-16}J, then one proton will have:

$$\frac{2.23 \times 10^{-16}}{270} = 8.26 \times 10^{-19}\ \text{J}$$

Using Planck's equation:

$$E = hf$$

Known quantities:

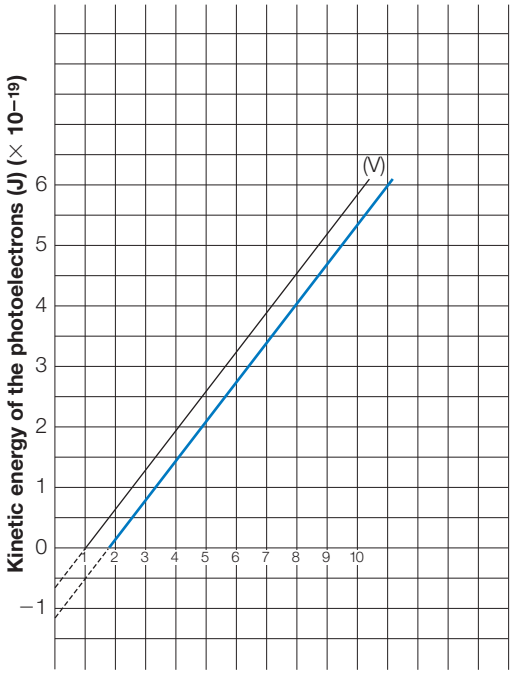
$$h = 6.626 \times 10^{-34}$$
$$E = 8.26 \times 10^{-19}\ \text{J}$$
$$f = \frac{E}{h} = \frac{8.26 \times 10^{-19}}{6.63 \times 10^{-34}}$$
$$= 1.25 \times 10^{15}\ \text{Hz}$$

7. No, insulators have no free electrons; that is, the work function is too high.

8. See Chapter 11.

9. Intensity has no effect on the maximum kinetic energy of the photoelectrons. Intensity is related to the number of photons; however, to increase the maximum kinetic energy of the electrons, the photons need to be more energetic. This can only be done by changing the frequency of the EMR.

10. (a) Refer to graph.



(b) *x*-intercept: the threshold frequency for this particular metal
y-intercept: the absolute value of the *y*-intercept is the work function
Gradient: Planck's constant (6.626×10^{-34})
Work function:
X: the threshold frequency is 1.8×10^{14} Hz (from the graph).
Using the work function equation:

$W = hf$

$W = 6.626 \times 10^{-34} \times 1.8 \times 10^{14}$

$\approx 1.2 \times 10^{-19}$ J

OR

Y: The *y*-intercept is -1.2×10^{-19} (from the graph) which means the work function is 1.2×10^{-19} J.

(c) The graph allows a line of best fit to be drawn, hence it aims to eliminate any errors in any particular set of data.

(d) The voltage source (e.g. a battery) should be placed in the circuit so that its negative terminal is facing the collector.
To calculate the size of this voltage, use the equation:

$E_K = qV$

$\therefore V = \frac{E_K}{q}$

Kinetic energy of the photoelectrons (J)	Stopping voltage (V)
0	0
8.18×10^{-20}	0.51
2.14×10^{-19}	1.34
3.47×10^{-19}	2.17
4.79×10^{-19}	2.99

(e) Refer to graph (a). Note the graph shifts to the left.

11. (a) Using Planck's equation:

$E = \frac{hc}{\lambda}$

Known quantities:

$h = 6.626 \times 10^{-34}$

$c = 3 \times 10^{8}\ \text{m s}^{-1}$

$\lambda = 620\ \text{nm} = 6.2 \times 10^{-7}\ \text{m}$

$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{6.2 \times 10^{-7}}$

$= 3.21 \times 10^{-19}\ \text{J}$

(b) Using Planck's equation:

$E = \frac{hc}{\lambda}$

Known quantities:

$h = 6.626 \times 10^{-34}$

$c = 3 \times 10^{8}\ \text{m s}^{-1}$

$\lambda = 520\ \text{nm} = 5.2 \times 10^{-7}\ \text{m}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{5.2 \times 10^{-7}}$$

$$= 3.82 \times 10^{-19}\ \text{J}$$

(c) The work function will just be a little below the energy of the green photons, which is 3.82×10^{-19} J, and above the energy of the orange photons.

(d) The basic principle of the old-fashioned breathalyser is that when the person has not been drinking, the breath contains no alcohol, hence the solution of the analyser remains orange and no photoelectric effect will take place, and the photocell will not register any current. However, for a person who has been drinking, when they breathe into the machine the alcohol in the breath changes the solution into green, and the green light is able to cause the photoelectric effect. The photoelectric effect causes the electrons to be released from the cathode of the photocell and as a result a current will be flowing inside the photocell. The flow of the current then either triggers off an alarm or a reading that suggests that the driver has been drinking.

12. (a) An induction coil can be used to produce radio waves. One may choose to use metal plates to focus the waves but this is not necessary.

(b) To confirm that the radio waves have been produced, one can use a loop coil to demonstrate the production of a faint spark, as Hertz observed in his experiment. However, this is very difficult to do. A simpler method to detect the radio waves is to use an earpiece made from a piezoelectric material, such as quartz. (These earpieces were once used to actually receive radio waves from radio stations). One should hear a buzzing sound when radio waves are present. Unfortunately no music will be heard!

13. Einstein was a pacifist and was very active in trying to bring science and politics together. Besides his love for physics, Einstein was also very passionate about pacifism – no one should be harmed or killed in any way. Einstein was actively involved in the development of the nuclear bombs that ended World War II.