State Examination Commission – Physics Higher Level, 2011

Question 11

Read the following passage and answer the accompanying questions.

> The government has introduced regulations to phase out the use of incandescent filament lamps in the home. The Sustainable Energy Authority of Ireland promotes theuse of compact fluorescent lamps (CFL) in place of less energy-efficient filament lamps.
> A CFL operates due to the effect of an electric discharge passing through mercury gas at low pressure. Most of the photons that are released from the mercury atoms have a wavelength of 254 nm, which is in the ultraviolet region of the spectrum. These ultraviolet photons are absorbed by electrons in the atoms of the lamp's interior fluorescent coating, causing further photons to be emitted. The photons that are emitted from these interactions have a lower energy than the ones that caused them. The chemicals that make up the fluorescent coating are chosen so that these emitted photons are at wavelengths visible to the human eye.
> Light emitting diode (LED) lighting is also recommended and growing in popularity. An LED is a special type of diode that emits light when in forward bias. LEDs emit strongly coloured light, such as red, green, or blue, depending on the semiconductor material used. As the light output of an individual LED is small compared to filament lamps, multiple diodes are used together to give white light.

(*a*) A 60 W filament lamp provides 8 J of light energy every second, the same as a CFL with a power rating of 11 W. Compare the efficiencies of the two lamps.
(*b*) Most of the energy emitted in a CFL is in the form of ultraviolet radiation.
How is this changed to white light?
(*c*) Calculate the energy of an ultraviolet photon emitted in a CFL.
(*d*) How does an electron in an atom of the fluorescent coating emit a photon?
(*e*) Why does the fluorescent coating in a CFL get warm during use?
(*f*) A light sensor attached to a datalogger indicates that the light emitted from a CFL used in the home is not continuous, but flickers at a frequency that is not detected by the eye. What is the cause of the flickering in the light?
(*g*) Draw a circuit diagram of a diode in forward bias.
(*h*) How can LEDs be used to produce white light? (8 × 7)

(*a*) A 60 W filament lamp provides 8 J of light energy every second, the same as a CFL with a power rating of 11 W. Compare the efficiencies of the two lamps

A 60 W filament lamp, with 8 J light output, has an efficiency of 8/60 x 100/1 = 13.3%
An 11 W CFL, with 8 J light output, has an efficiency of 8/11 x 100/1 = 72.7% (5½ times more efficient than the incandescent bulb)

(*b*) Most of the energy emitted in a CFL is in the form of ultraviolet radiation. How is this changed to white light?

The CFL interior coating absorbs this radiation, and re-radiates it in the visible region of the spectrum

(*c*) Calculate the energy of an ultraviolet photon emitted in a CFL.

$$E = hf = hc/\lambda = 6.6 \times 10^{-34} \times (3.0 \times 10^{8})/2.54 \times 10^{-7} = 7.8 \times 10^{-19} \text{ J}$$

(*d*) How does an electron in an atom of the fluorescent coating emit a photon?

By dropping to a lower energy level and emitting the difference in energy between the two levels as a photon

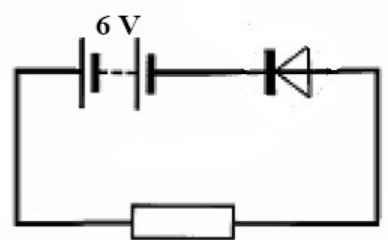
(*e*) Why does the fluorescent coating in a CFL get warm during use?

It gets warm because the difference in energy between the absorbed ultra-violet photon and the lower energy emitted visible light photon goes toward heating up the fluorescent coating.

(*f*) A light sensor attached to a datalogger indicates that the light emitted from a CFL used in the home is not continuous, but flickers at a frequency that is not detected by the eye. What is the cause of the flickering in the light?

CFL's operating on a.c produce light flickering at a frequency of 100 Hz, twice the mains supply frequency of 50 Hz . The voltage varies from +240 volts to -240 volts, 50 times a second and is at zero volts twice in each cycle - essentially, the power is turning on and off 100 times a second .

(*g*) Draw a circuit diagram of a diode in forward bias.



(*h*) How can LEDs be used to produce white light?

One way is by combining light from red, green, and blue colored LEDs. If you get the right mix, the primary colours give the effect of white light.