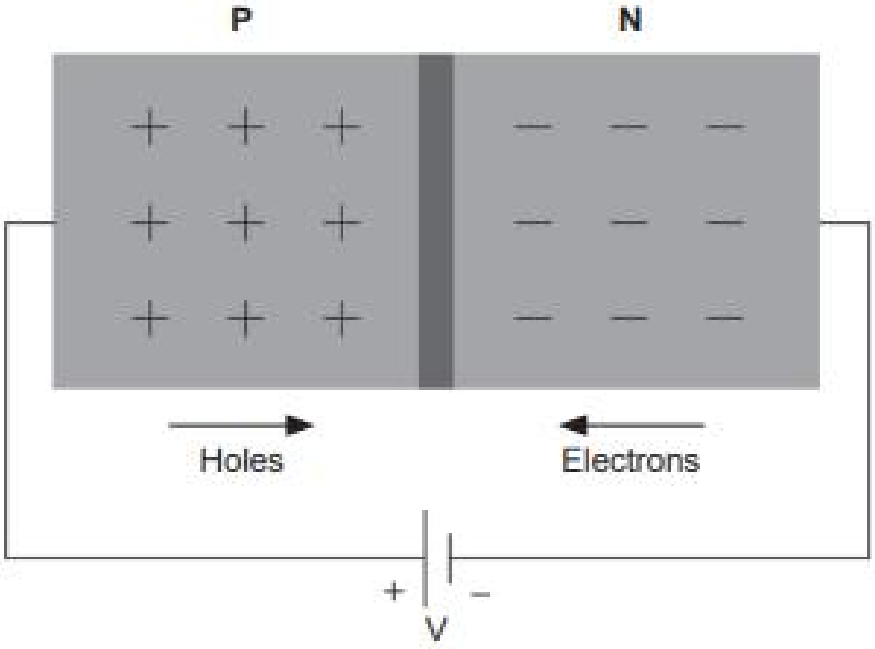
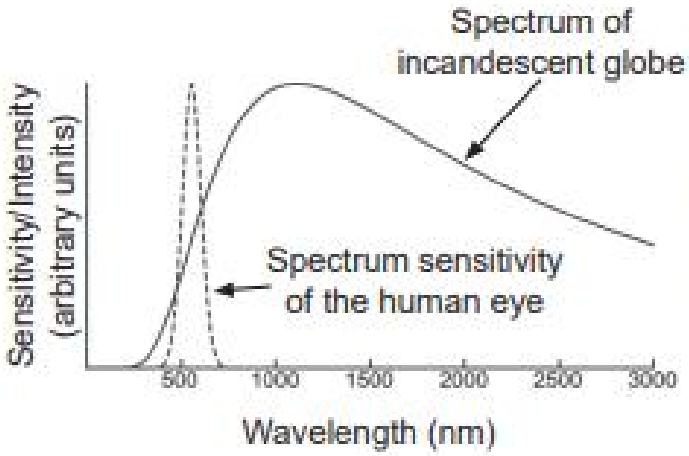
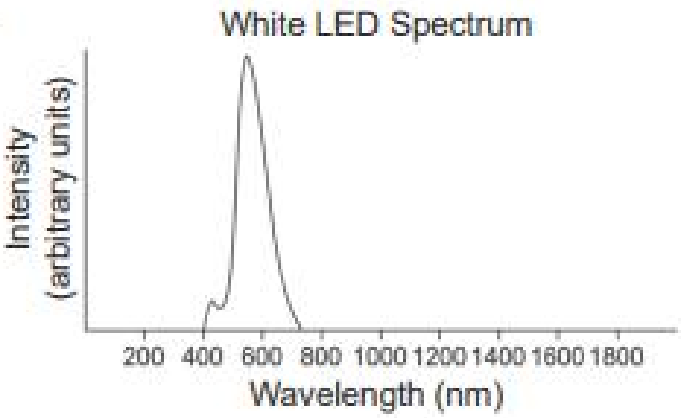
Question 18 **(21 marks)**

Light-emitting diodes (LEDs)



Efficiency





Efficacy

LEDs are also known for having the best 'efficacy' of all light sources. Efficacy is the measure of how well a light source produces visible light. It is measured in lumens per watt, or how much light is provided for every watt of power consumed. The power is calculated by multiplying the forward voltage (the lowest voltage at which current starts to flow in the normal conducting direction, V_F) by the operating current measured in amperes. In order to make sure that the correct voltage gets dropped across the LED, a voltage greater than the minimum required to produce the desired wavelength is used. A table of specific crystals, their forward voltages and the wavelengths they produce is given below. To increase brightness, the current is increased.

Typical LED characteristics			
Semiconductor material	**Wavelength (nm)**	**Colour**	**V_F**
GaAs	850–940	Infra-red	1.20 V
GaAsP	630–660	Red	1.80 V
GaAsP	605–620	Amber	2.00 V
GaAsP:N	585–595	Yellow	2.20 V
AlGaP	550–570	Green	3.50 V
SiC	430–505	Blue	3.60 V
GaInN	450–650	White	4.00 V

(a) Explain how a PN junction produces visible light. (4 marks)

The Law of Conservation of Energy states: 'Energy is neither created nor destroyed; it only moves from one place to another - from one type of energy to another.'

(b) LEDs and incandescent light bulbs are equally efficient at converting energy drawn from the mains into different types of energy. Why then does the passage on page 33 state that LEDs are far more efficient than incandescent light bulbs? Reference must be made to the graphs of intensity versus wavelength. (4 marks)

(c) The efficacy of a particular LED is 120 lumens W^{-1}. Using information in the passage and table on page 33, calculate how much current would need to run through a blue SiC LED light bulb operating at minimum V_F to produce 840 lumens. (4 marks)

Answer: _____ A

(d) With the use of a calculation and data from the table on page 33, show how the minimum V_F for SiC crystals is large enough to produce photons with the lowest energy required for blue light. (4 marks)

(e) Lighting accounts for 15% of yearly global electricity consumption (194 EJ or 194×10^{18} J). Roughly 40% of this is supplied by LEDs. Each tonne of coal produces, on average, 21 GJ of energy. Eighty per cent of world energy consumption is derived from fossil fuels. Using the efficiencies stated in the passage, estimate the mass of coal the world could save per year if 100% of lighting was provided by LEDs. (5 marks)

Answer: _____ Tonnes