1 Give a clear piece of experimental evidence for the particle nature of light. Describe the way in which the behaviour of light is like a particle in this instance and why it can not be thought of as wave-like in this experiment.

2 Describe an experiment in which light is clearly behaving as a wave. Show how only wave behaviour can explain this phenomenon and how we explain lights wave like properties.

3 Describe an experimental situation in which light appears to be at first wave-like and then particle-like in its behaviour. Why is this a problem for physics?

4 In 1924 Louis de Broglie showed that Einstein's and Planck's ideas could be combined to show an equivalence between light's wave and particle properties. He made the brave step of asserting that all matter particles could have wave-like properties. What is de Broglie's postulate relating the momentum of a particle to its apparent wavelength?

5 Given light of wavelength 650nm, what would its apparent momentum be according to de Broglie?

6 Given an electron of velocity 2×10^{5} ms^{-1} and mass 9.11×10^{-31} kg,
a What is the momentum of the electron?
b What is electron's apparent wavelength?

7 When a wave passes through a gap,
a Maximum diffraction will occur under what condition?
b What will the diffraction pattern be under this condition?
c If the gap is slightly larger than this condition how will the diffraction pattern change?

8 Given an electron of energy 150 eV,
a Find the momentum of the electron
b Find the wavelength of the electron
c Under what conditions would you expect to observe the wave-like property of this electron?

9 If a beam of electrons accelerated by a potential difference of 150V is fired at a crystal lattice of graphite with atoms spaced about 1×10^{-10} m apart, what would you expect to observe when the electrons pass through the crystal - electrons can be visualised using a phosphor screen that glows when electrons impact the screen.

10 **Extension:** Max Planck originated his idea about the quantum nature of light based on observations of black-body radiation. All objects when heated emit light of a certain wavelength directly linked to the temperature of the body. As the body is heated the mode of the wavelengths of light emitted gets shorter and shorter leading to the characteristic patter of red hot leading to yellow leading white and eventually blue hot if the temperature can increase higher enough.
Why does this fit the quantum theory of light and cause big problems for a wave theory of light?

11 Take the mass of student to be 60 kg. She wants to walk through a door of width 0.8 m. If she walks at 1.5 ms-1,

a What is her momentum?

b What would be her de Broglie wavelength?

c Would she diffract noticeably as she went through the door?

d If she were to diffract what should wavelength be?

e At what velocity should she walk through the door to notice an appreciable amount of diffraction?

f Why is it very unlikely we will see her diffract when she walks through doors at school?

12 Given the Sun's spectrum peaks at around 450nm,

a Find the momentum of a single photon of this wavelength

The light shines onto the black surface of a satellite in space. Given the power incident from the Sun when the light reaches the satellite is $15W/m^2$ and the satellite has a surface area of 4 m^2,

b What is the radiation power absorbed by the surface of the satellite?

c How many photons are being absorbed per second?

d What is the total momentum of light hitting the satellite in one second?

e What is the force exerted by radiation on the satellite in space due to the Sun's light?