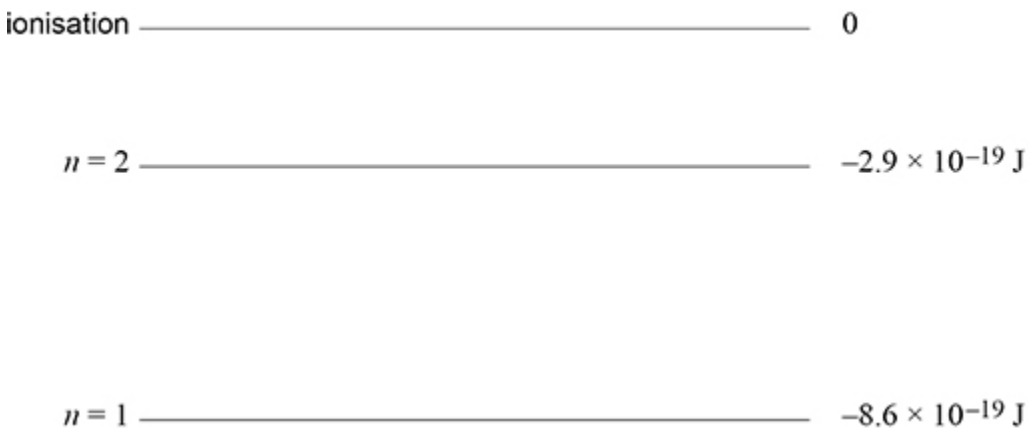
2. Some energy levels of a lithium atom are shown below.



A free electron with kinetic energy 6.0×10^{-19} J collides with a stationary lithium atom in its $n = 1$ energy level. The lithium atom is excited to the $n = 2$ energy level.

What is the kinetic energy of the free electron after the collision?

A 0.3×10^{-19} J ⬭

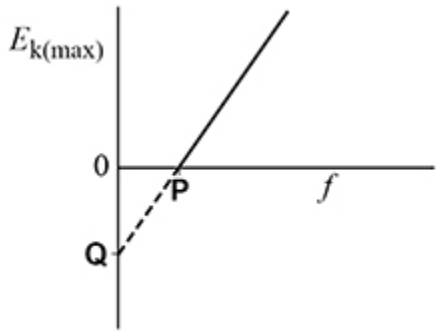
B 2.6×10^{-19} J ⬭

C 3.1×10^{-19} J ⬭

D 5.7×10^{-19} J ⬭

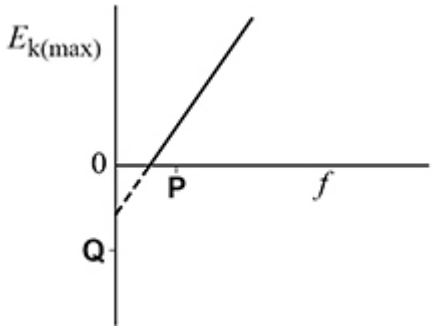
(Total 1 mark)

3. The graph shows how the maximum kinetic energy $Ek_{(max)}$ of photoelectrons emitted from a metal surface varies with the frequency f of the incident radiation.
P is the intercept on the f axis. **Q** is the intercept on the $Ek_{(max)}$ axis.

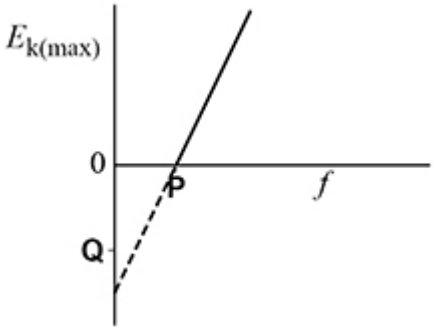


Which graph shows the variation of $Ek_{(max)}$ with f for a metal with a greater work function?

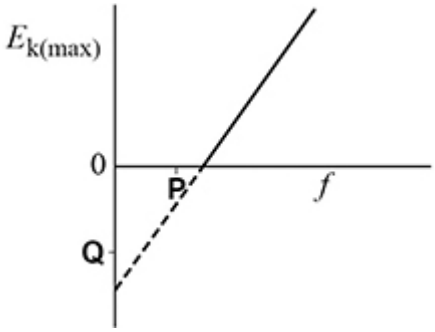
A



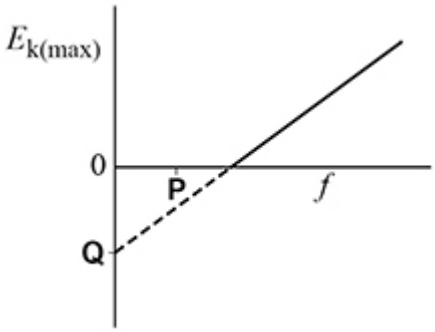
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

8. Scintillation counters are used to detect beta particles. A scintillation counter consists of a scintillation material and a photomultiplier tube (PMT).

(a) Beta particles collide with atoms in the scintillation material, which emits photons of light as a result.

Explain how photons are produced by collisions between beta particles and atoms.

_____

_____

_____

_____

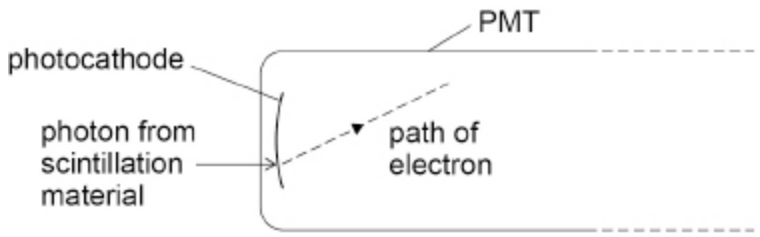
_____

_____

(2)

(b) A photon of light from the scintillation material enters the PMT, as shown in **Figure 1**. The front of the PMT contains a thin photocathode. The photon strikes the photocathode to release an electron.

Figure 1



The longest wavelength of light that releases an electron from this photocathode is 630 nm.

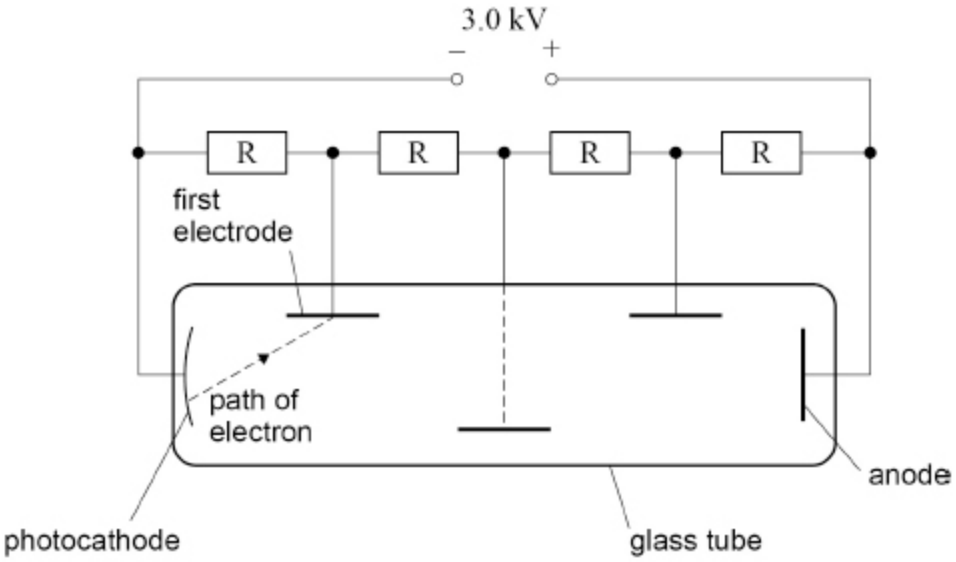
Calculate the minimum photon energy required to remove an electron from the photocathode.

minimum photon energy = _____ J

(2)

(c) The PMT consists of an evacuated glass tube containing the photocathode, an anode and three metal electrodes, as shown in **Figure 2**.

Figure 2



The electrodes, anode and photocathode are connected to a potential divider consisting of four identical resistors R. The emf of the electrical supply is 3.0 kV.

The potential difference between the photocathode and the first electrode accelerates the electron along the path shown in **Figure 2**.

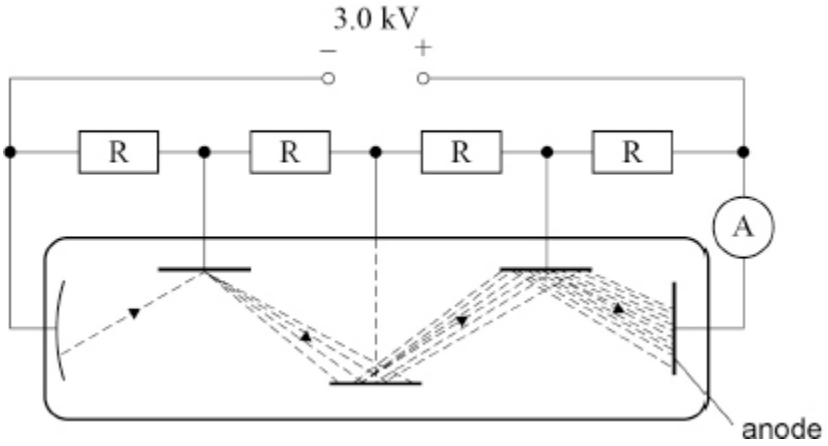
Calculate, in J, the maximum kinetic energy transferred to the electron when it accelerates from the photocathode to the first electrode.

maximum kinetic energy = _____ J

(2)

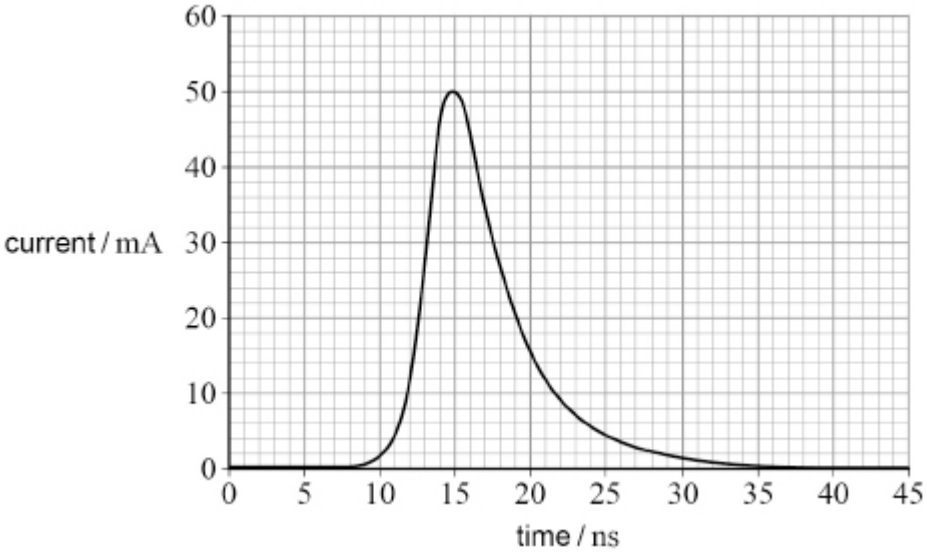
(d) The electron hits the first electrode and causes the release of several electrons. **Figure 3** shows how a series of accelerations and collisions produces a large number of electrons. These electrons hit the anode and produce a pulse of current in an ammeter.

Figure 3



The **Figure 4** shows the variation of current in the ammeter with time due to this pulse.

Figure 4



Determine the number of electrons that flow through the ammeter.

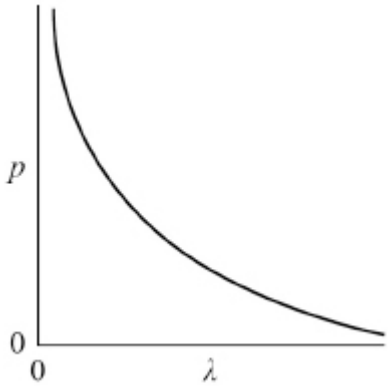
number of electrons = _____

(4)

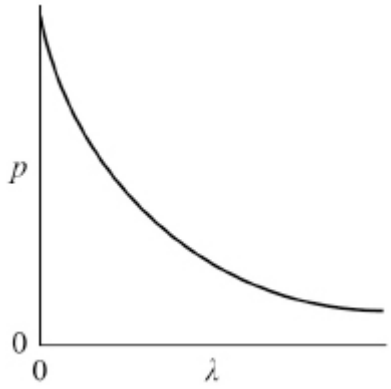
(Total 10 marks)

14. Which graph shows the variation of momentum p with wavelength λ of a photon?

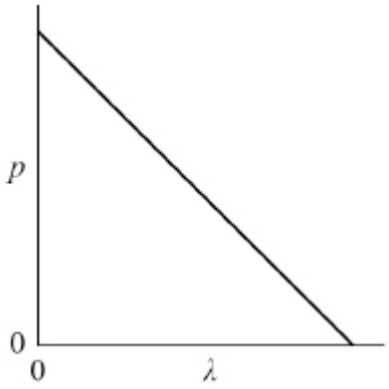
A



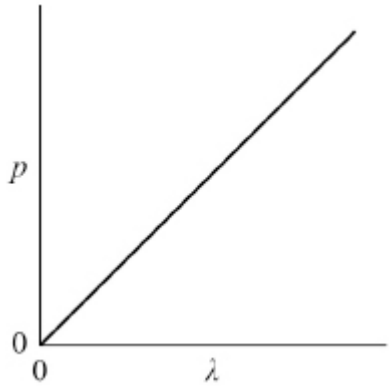
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

15. Scientists at CERN have produced atoms of antihydrogen.
An atom of antihydrogen contains the antiparticle of the proton and the antiparticle of the electron.

(a) State what is meant by an antiparticle.

_____

_____

_____

(2)

(b) Complete the table with the names of the antiparticles in an atom of antihydrogen.

Name of particle	Name of antiparticle
proton	
electron	

(2)

(c) The particles in antihydrogen can be made by pair production.

Calculate the total minimum energy, in J, needed to produce the particles in one atom of antihydrogen.

energy = _____ J

(3)

(d) Line emission spectra of hydrogen and antihydrogen have been compared.

Explain in terms of energy changes how line emission spectra are produced.

(3)

(Total 10 marks)

16. Photons of energy 1.0×10^{-18} J are incident on a metal surface and cause the emission of electrons from the metal surface.

Which statement about the emitted electrons is correct?

A They each have a kinetic energy of 1.0×10^{-18} J. ⬭

B They each have a kinetic energy that is a multiple of 1.0×10^{-18} J. ⬭

C Their mean kinetic energy is 1.0×10^{-18} J. ⬭

D The kinetic energy of each must be less than 1.0×10^{-18} J. ⬭

(Total 1 mark)

17. Evidence of the wave-like properties of electrons is

A the emission of electrons when short-wavelength light falls on a metal surface. ⬭

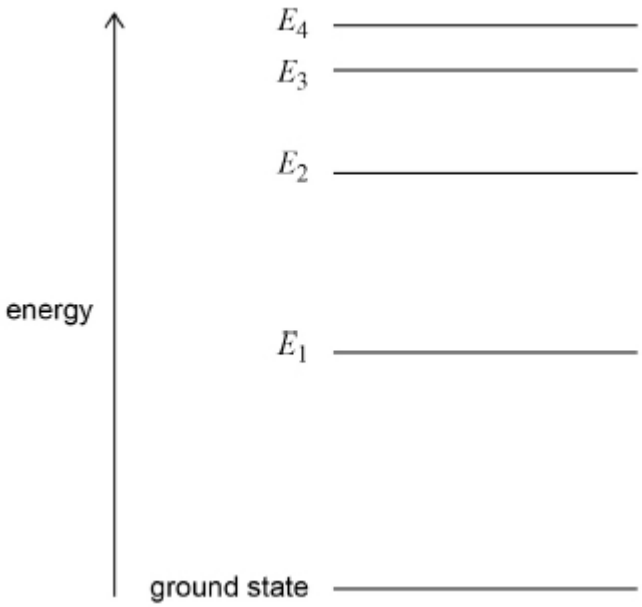
B the movement of electrons in an electric current. ⬭

C the diffraction of electrons by a metal crystal. ⬭

D the annihilation of an electron with a positron. ⬭

(Total 1 mark)

18. The diagram shows the energy levels in an atom drawn to scale. A transition from E_4 to E_2 causes the emission of a photon of green light.



Which transition could cause the emission of a photon of red light?

A E_2 to E_1 ⬭

B E_3 to E_1 ⬭

C E_3 to E_2 ⬭

D E_4 to E_1 ⬭

(Total 1 mark)