

APOLLO

Quantum physics

HL

Physics

First assessment 2025

19 questions | questions

34. A photoelectron is emitted when a photon of energy E is incident on a metal surface.

The work function of the surface is Φ .

What is the maximum possible speed of the photoelectron as it leaves the surface?

A. $\sqrt{\frac{2(E - \Phi)}{m_e}}$

B. $\sqrt{\frac{E - \Phi}{m_e}}$

C. $\sqrt{\frac{E - \Phi}{m_e h}}$

D. $\sqrt{\frac{2(E - \Phi)}{m_e h}}$

— 41 —

4425-0101

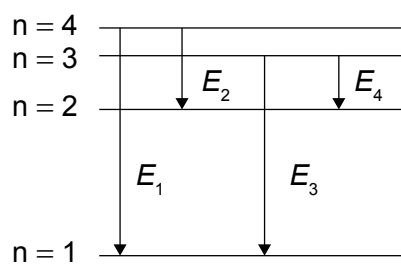
35. In a Compton scattering experiment a photon of wavelength λ_0 and frequency f_0 interacts with an electron.

After the interaction the wavelength and frequency of the photon are λ and f .

What are $\frac{\lambda}{\lambda_0}$ and $\frac{\lambda \times f}{\lambda_0 \times f_0}$?

	$\frac{\lambda}{\lambda_0}$	$\frac{\lambda \times f}{\lambda_0 \times f_0}$
A.	Greater than 1	Equal to 1
B.	Greater than 1	Less than 1
C.	Less than 1	Equal to 1
D.	Less than 1	Less than 1

32. Some transitions between the energy states of an atom are shown.

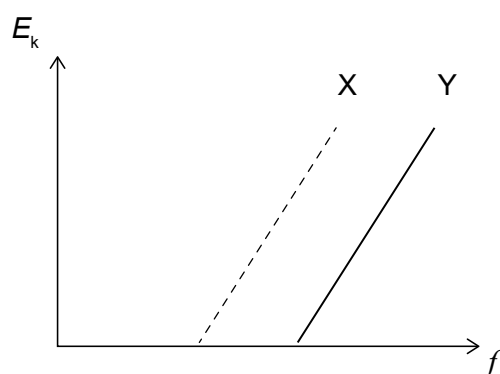


Which transition will emit a photon with the longest wavelength?

- A. E_1
- B. E_2
- C. E_3
- D. E_4

34. In two experiments X and Y measurements were made of the kinetic energies E_k of photoelectrons emitted when light is incident on two different metal surfaces.

The graph shows the variation of E_k with frequency f of the incident photons for both surfaces.



It can be deduced that in experiment Y...

- A. the surface has a smaller work function than the surface in experiment X.
- B. the surface has a larger work function than the surface in experiment X.
- C. the intensity of the incident light is less than in experiment X.
- D. the intensity of the incident light is more than in experiment X.

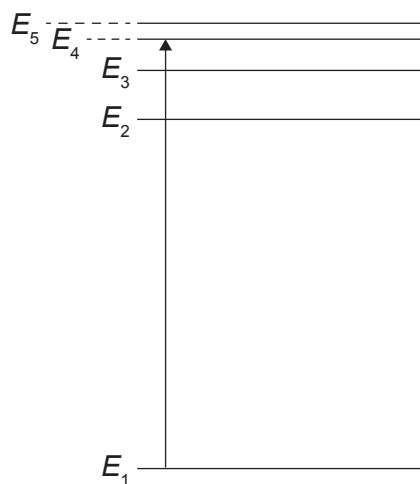
- 35.** The intensity of electromagnetic radiation incident on a surface is I . The wavelength of the radiation is doubled and the number of photons incident per unit time per unit area is doubled.

What is the new intensity of radiation incident on the surface?

- A. $\frac{I}{2}$
- B. I
- C. $2I$
- D. $4I$

32. The energy levels of an atom in which an electron transitions from E_1 to E_4 are shown. E_1 is the ground state.

diagram to scale



How many different wavelengths can be emitted when electrons return to the ground state from E_4 ?

- A. 1
- B. 3
- C. 6
- D. 8

- 34.** Which of the following expressions gives the de Broglie wavelength, in metres, of a tennis ball of mass 0.06 kg and kinetic energy 3 J?

- A. $\frac{h}{3}$
- B. $\frac{h}{0.6}$
- C. $\frac{h}{(0.6)^2}$
- D. $\frac{h}{0.06}$

5. (a) Outline why Compton scattering offers better evidence for the particle nature of light than the photoelectric effect. [2]

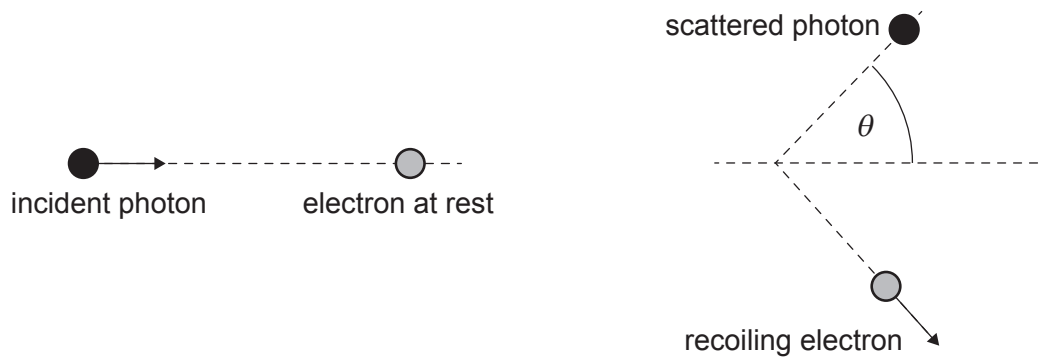
.....

.....

.....

.....

A photon of wavelength $6.40 \times 10^{-12} \text{ m}$ and energy 0.194 MeV is incident on an electron at rest. The photon scatters at an angle θ with wavelength $7.47 \times 10^{-12} \text{ m}$. The electron recoils.



- (b) Outline why the wavelength of the scattered photon is longer than that of the incident photon. [2]

.....

.....

.....

.....

- (c) (i) Show that the energy of the scattered photon is about 0.17 MeV . [1]

.....

.....

(This question continues on the following page)



(Question 5 continued)

(ii) Calculate the kinetic energy of the recoiling electron. [1]

.....

.....

(iii) For an electron, $\frac{h}{m_e c} = 2.43 \times 10^{-12}$ m. Determine θ . [2]

.....

.....

.....

.....



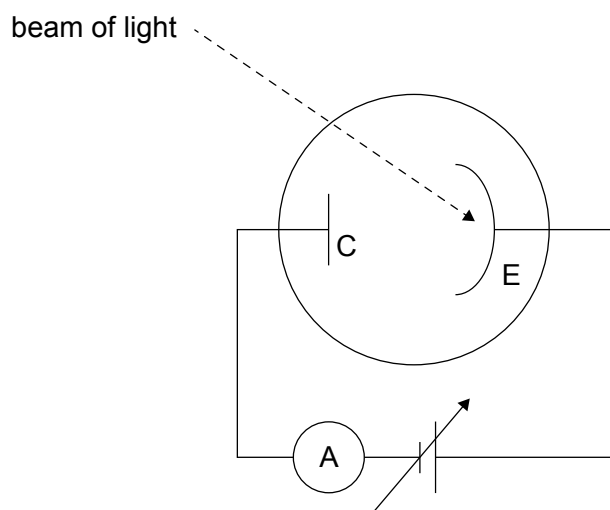
— 17 —

4425-0113

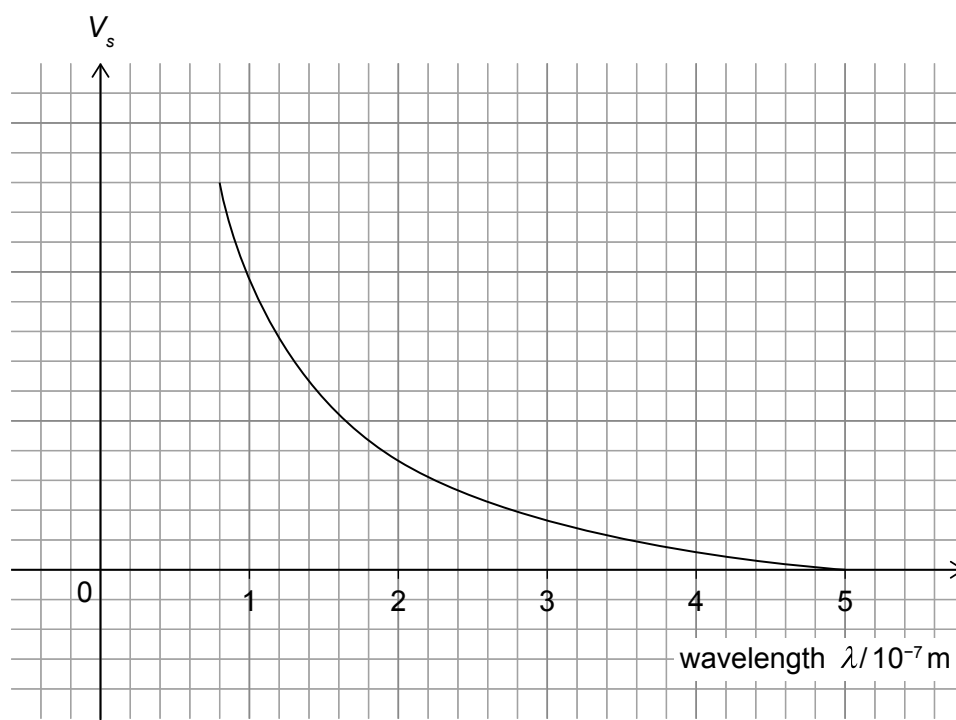
6. An electric circuit is used to investigate the photoelectric effect.

A beam of light from a laser of variable wavelength λ and constant intensity I is used to illuminate a curved metallic electrode E. Another electrode, C, is near E. Both electrodes are in vacuum. For each λ tuned in the laser, the voltage across CE is raised. The minimum voltage V_s that shows no current in the ammeter is recorded.

diagram not to scale



The graph shows the variation of V_s with λ .



(This question continues on the following page)



(Question 6 continued)

(a) Show that the work function of the metal used in C is about 2.5 eV. [2]

.....

.....

.....

.....

(b) Calculate V_s when λ is 4.0×10^{-7} m. [2]

.....

.....

.....

.....

The laser is now replaced by a monochromatic laser of red light and variable intensity.

Although the intensity of the laser is increased significantly, no current is read in the ammeter.

(c) Explain how this observation is consistent with the particle nature of light. [2]

.....

.....

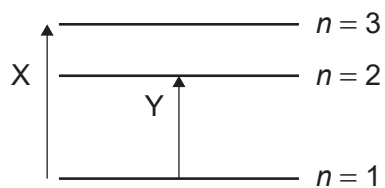
.....

.....



33. Some energy levels for a hydrogen atom are shown.

diagram not to scale



What is $\frac{\text{energy absorbed in transition X}}{\text{energy absorbed in transition Y}}$?

- A. $\frac{32}{27}$
- B. $\frac{3}{2}$
- C. 2
- D. $\frac{9}{4}$

34. Monochromatic electromagnetic radiation is incident on a metal surface. Three observations about the electrons emitted from the surface are:

- I. The maximum energy of the electrons does not depend on radiation intensity.
- II. The number of electrons emitted in a unit time increases with radiation intensity.
- III. No electrons are emitted when the frequency of radiation is less than a threshold value.

Which observations are inconsistent with the wave model of electromagnetic radiation?

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

— 41 —

0020-0107

- 35.** A photon of wavelength λ_0 scatters off an electron at rest. The shift in photon wavelength is $\Delta\lambda$. What is the kinetic energy of the scattered electron?

A. $\frac{hc}{\Delta\lambda}$

B. $\frac{hc}{\lambda_0 + \Delta\lambda}$

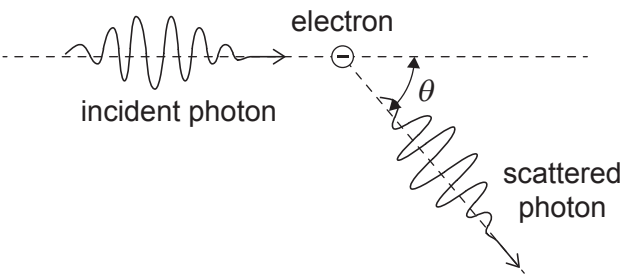
C. $\frac{hc}{\lambda_0} - \frac{hc}{\Delta\lambda}$

D. $\frac{hc}{\lambda_0} - \frac{hc}{\lambda_0 + \Delta\lambda}$

36. Two particles are accelerated from rest through the same electric potential difference. The particles have the same charge and different masses. Which row correctly compares the kinetic energy and the de Broglie wavelength of the particles after the acceleration?

	Kinetic energy	De Broglie wavelength
A.	same	same
B.	different	same
C.	same	different
D.	different	different

35. A photon scatters off an electron at an angle θ , as shown. The shift in the photon wavelength after scattering is $\frac{h}{2m_e c}$.



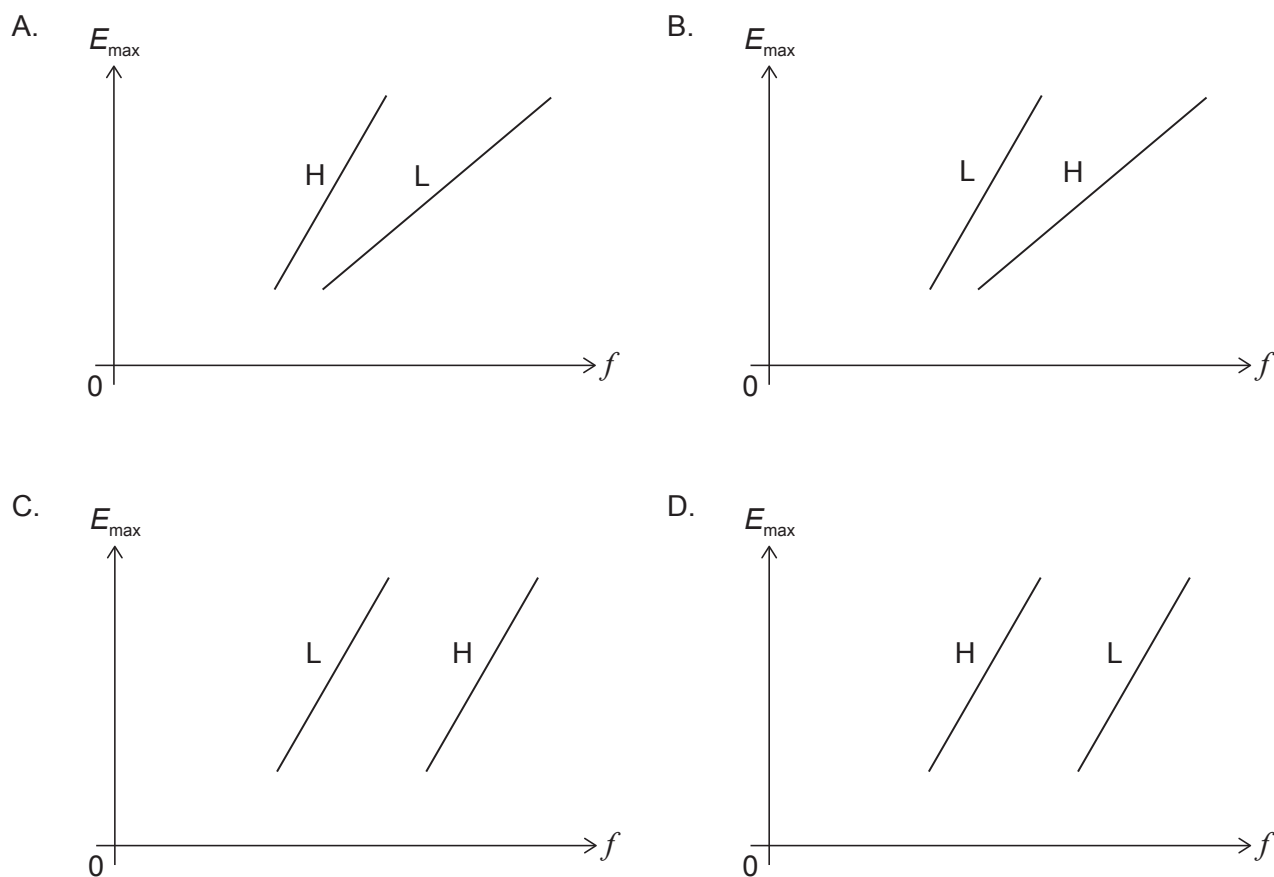
What is correct about the frequency of the photon after scattering and θ ?

	Frequency	θ
A.	increases	30°
B.	increases	60°
C.	decreases	30°
D.	decreases	60°

Turn over
 0020-0719

36. Light is incident on two different metal surfaces L and H. The minimum photon energy required to emit electrons from surface H is less than that from surface L.

Which graph shows the variation with light frequency f of the maximum kinetic energy $E_{\max}$ of photoelectrons emitted from both surfaces?



1. The diagram shows the three lowest energy levels of the hydrogen atom. The energy of each level is indicated.

diagram not to scale

-1.51 eV _____

-3.40 eV _____

-13.6 eV _____

- (a) State the number of transitions between these levels that result in the emission of photons.

[1]

.....

.....

- (b) Calculate the largest photon wavelength for these transitions.

[3]

.....

.....

.....

.....

.....

.....



— T —

Turn over
0020-0721

10. (a) Outline **one** experimental piece of evidence that shows that photons have momentum. [2]

.....

.....

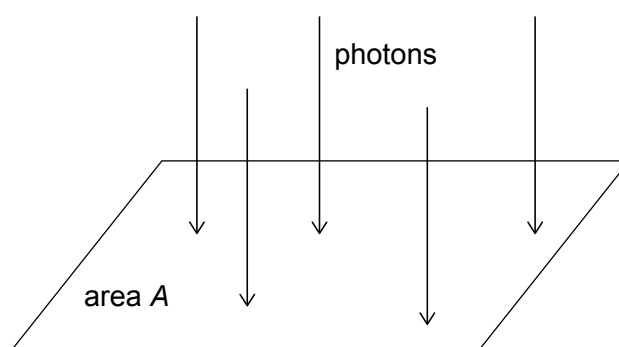
.....

.....

.....

.....

- (b) Photons of wavelength λ are incident normally on a flat surface of area A .
The photons are reflected without change in wavelength.



There are N photons incident per second.

- (i) Show that the intensity I that is incident on the surface is given by $I = \frac{N}{A} \frac{hc}{\lambda}$. [2]

.....

.....

.....

.....

(This question continues on the following page)



(Question 10 continued)

(ii) Deduce that the pressure P exerted on the surface is given by $P = \frac{2I}{c}$. [3]

(This question continues on the following page)



(Question 10 continued)

- (c) It is proposed to send a spacecraft to Jupiter. The spacecraft would be launched to a point Q far from Earth and would then be accelerated by the pressure of the Sun’s radiation on a sail attached to the spacecraft. The following data are available:

$$\begin{aligned} \text{total mass of spacecraft} &= 1400 \text{ kg} \\ \text{sail area} &= 1600 \text{ m}^2 \\ \text{solar radiation intensity at Q} &= 420 \text{ W m}^{-2} \end{aligned}$$

- (i) Show that the acceleration of the spacecraft at Q due to solar radiation alone is about $3 \times 10^{-6} \text{ m s}^{-2}$. [2]

.....

.....

.....

.....

- (ii) The distance between Q and Jupiter is $6.1 \times 10^{11} \text{ m}$. Estimate the time, in years, it would take the spacecraft to reach Jupiter, assuming that the spacecraft moves with the acceleration in (i). [2]

.....

.....

.....

.....

- (iii) State **one** reason why the acceleration of the spacecraft will **not** be constant. [1]

.....

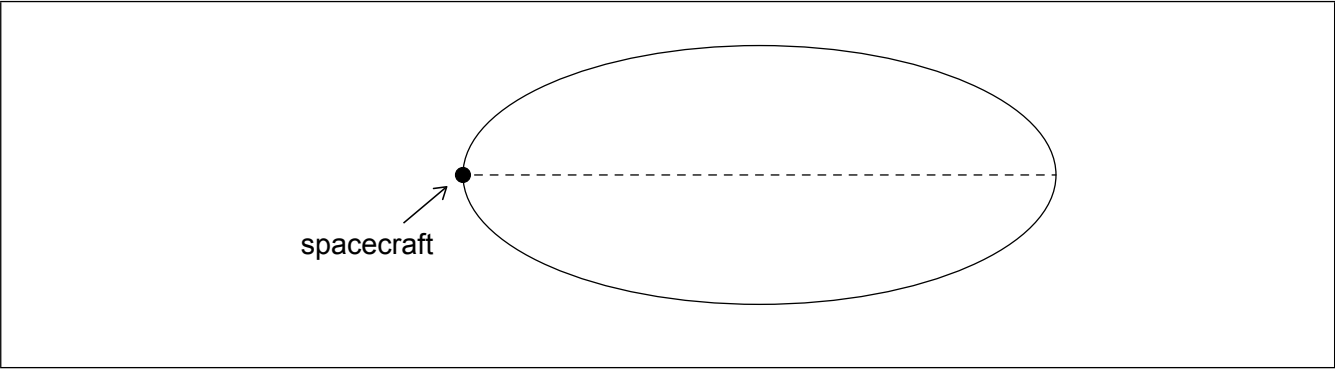
.....

(This question continues on the following page)



(Question 10 continued)

(d) The spacecraft enters an elliptical orbit around Jupiter.



At the position shown, the spacecraft has its maximum orbital speed.

- (i) Draw, on the diagram, a possible position of Jupiter.
 [1]
- (ii) Explain your answer to (d)(i).
 [2]

.....

.....

.....

.....

(This question continues on the following page)

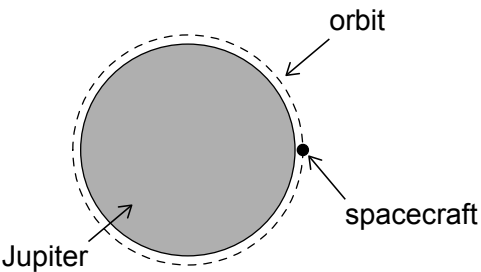


Turn over

(Question 10 continued)

- (e) The spacecraft changes its orbit into a circular orbit just above the surface of Jupiter, so that the orbit radius is essentially equal to the radius of Jupiter.

diagram not to scale



- (i) Show that the orbital period, T , of the spacecraft is given by $T = \sqrt{\frac{3\pi}{G\rho}}$, where ρ is the density of Jupiter. [3]

- (ii) The orbital period is 2.9 hours. Estimate the density of Jupiter. [2]



- 35.** A photon of wavelength λ scatters off an electron at rest. The scattered photon has wavelength λ' .

What is the fraction of the incident photon energy that gets transferred to the electron?

- A. $\frac{\lambda}{\lambda'}$
- B. $\frac{\lambda'}{\lambda}$
- C. $\frac{\lambda' - \lambda}{\lambda}$
- D. $\frac{\lambda' - \lambda}{\lambda'}$

— 28 —

Turn over
0000-0000

- 39.** Monochromatic light of frequency f_1 is incident on the surface of a metal. The stopping voltage for this light is V_1 . When the frequency of the radiation is changed to f_2 , the stopping voltage is V_2 .

What is the quantity $\frac{V_2 - V_1}{f_2 - f_1}$ equal to?

- A. h
- B. $\frac{h}{e}$
- C. $\frac{h}{c}$
- D. $\frac{hc}{e}$