QUANTUM PHYSICS I

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 Which of the following statement on photoelectric effect is **not** an evidence for particulate nature of light?

A Emission of electrons happens as soon as light shines on metal.

B Increasing intensity of light increases rate at which electrons leave metal.

C Maximum speed of emitted electrons is dependent on the frequency of incident light.

D A minimum threshold frequency of light is needed.

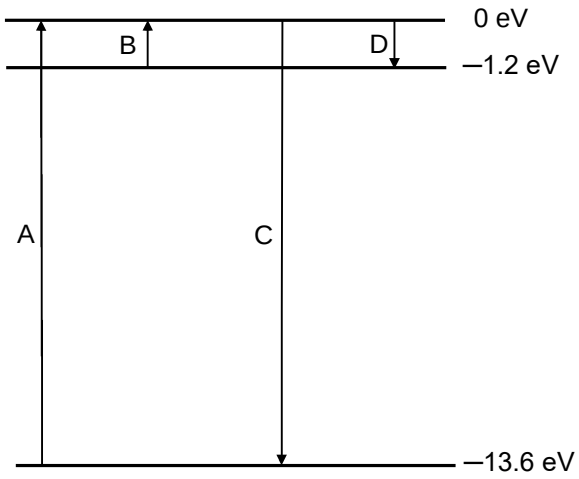
2 In an experiment to investigate the photoelectric effect, monochromatic light is incident on a metal surface. The photoelectric current and the maximum kinetic energy of the photoelectrons are measured.

Which one of the following correctly shows the change, if any, in the photoelectric current and in the maximum kinetic energy of the photoelectrons when light of the same intensity but higher frequency is incident on the same metal surface?

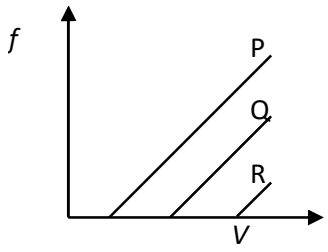
	photoelectric current	maximum kinetic energy
A	decreases	no change
B	decreases	increases
C	no change	decreases
D	no change	increases

3 The diagram below shows some possible electron transitions between three principal energy levels in the hydrogen atom.

Which transition is associated with the absorption of a photon of the longest wavelength?



4 When electromagnetic radiation of frequency *f* falls on a particular metal surface, photoelectrons may be emitted. The graph below shows the variation with *f* of the stopping potential *V* of these electrons for different materials P, Q and R.



Which of the following statement is correct?

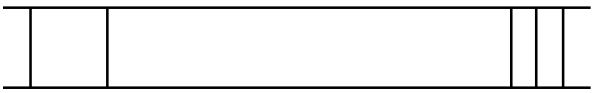
A P has the smallest work function because *f* is higher for the same *V*.

B R has the smallest work function because *V* is higher for the same *f*.

C P emits the most number of photoelectrons because its work function is the smallest.

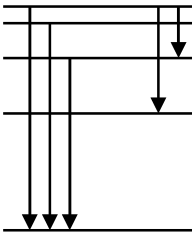
D R emits the most number of photoelectrons because its work function is the smallest.

5 The diagram shows the emission spectrum of a gas. The frequency scale is linear and increases to the right.

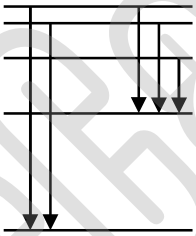


Which diagram best illustrates the transition in energy levels of the gas atoms?

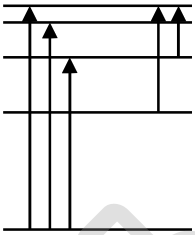
A



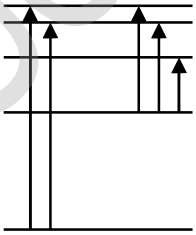
B



C



D



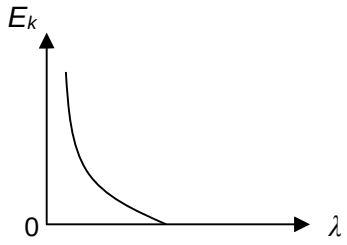
6 An alpha particle is fired at a thin piece of gold foil and passes close to a gold nucleus. As it approaches the gold nucleus which one of the following is true about the electric potential energy and the magnitude of the momentum of the alpha particle?

	potential energy	**magnitude of momentum**
A	decreases	unchanged
B	increases	decreases
C	decreases	decreases
D	increases	unchanged

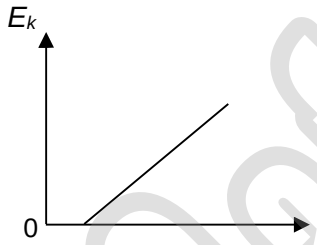
7 The maximum kinetic energy E_k of the electrons, emitted by light of a particular intensity incident on a metal surface, is measured in photoelectric experiments.

Which of the following is a possible graph showing how the maximum kinetic energy E_k varies with the wavelength λ of the light?

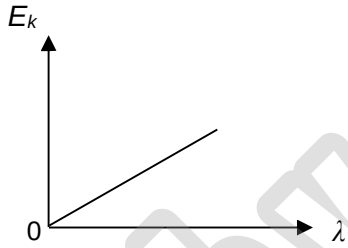
A



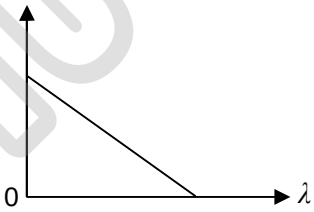
B



C



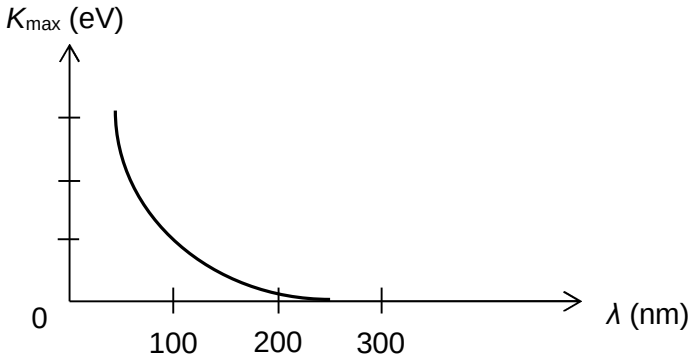
D



8 Transitions between three energy levels in a particular atom give rise to three spectral lines. The shortest and longest wavelengths of these spectral lines are λ_1 and λ_2 respectively. What is the wavelength of the other spectral line?

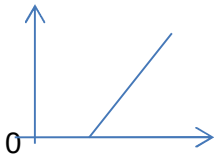
A $\lambda_2 - \lambda_1$ **B** $\frac{\lambda_2 - \lambda_1}{2}$ **C** $\frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$ **D** $\frac{\lambda_1 \lambda_2}{\lambda_2 - \lambda_1}$

9 In a photoelectric experiment, the maximum kinetic energy of the ejected photoelectrons is measured for various wavelength of incident electromagnetic radiation. A graph of this maximum kinetic energy, K_{max}, as a function of the wavelength λ of the incident electromagnetic radiation falling on the surface of a metal is shown below. What is the work function for this metal?



A 4.97 eV **B** 6.22 eV **C** 7.96 eV **D** 24.9 eV

10 The result of an experiment to investigate the energy of photoelectrons emitted from a metallic surface is shown below.



The gradient of the graph depends on the

A intensity of the incident radiation

B wavelength of the incident radiation

C work function of the irradiated surface

D ratio of Planck's constant to the electronic charge

11 Light of wavelength 450 nm is incident on a metal surface. The most energetic electrons ejected from the metal surface are undeflected as they pass through a region of mutually perpendicular magnetic and electric fields of strength 2.0×10^{-3} T and 1400 V m^{-1}, respectively.

What is the work function energy of the metal?

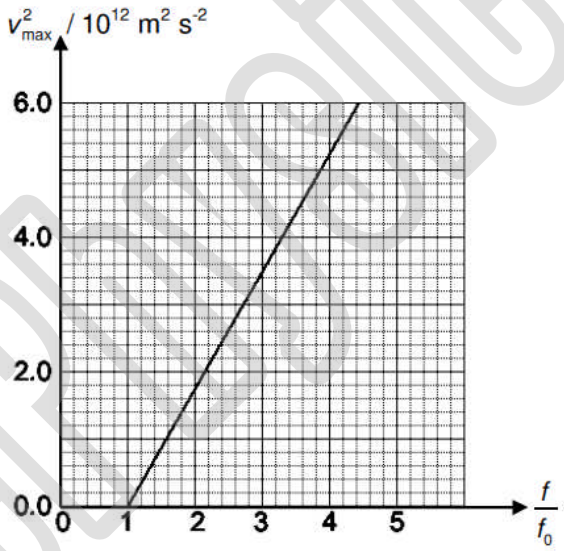
A 2.2×10^{-19} J

B 4.4×10^{-19} J

C 6.6×10^{-19}

D 8.8×10^{-19} J

12 In a series of photoelectric experiments, a metal surface with threshold frequency f_0 is illuminated with electromagnetic radiation of different frequencies f. The square of the maximum speed v_{max}^2 of the photoelectrons is found to vary with $\frac{f}{f_0}$ as shown in the graph.



What is the value of f_0?

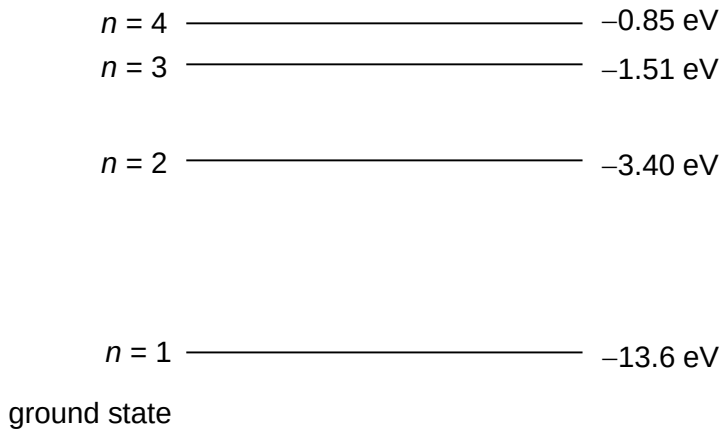
A 1.7×10^{12} Hz **B** 8.9×10^{14} Hz **C** 1.2×10^{15} Hz **D** 2.1×10^{26} Hz

13 An ultraviolet laser beam is incident on a metallic surface, and causes photoelectrons to be ejected from the metal.

How would the rate of ejected photoelectrons n and the maximum kinetic energy E_k of the photoelectrons be affected if the frequency of the laser beam increases while the intensity of the beam decreases?

	E_k	n
A	increase	decrease
B	increase	increase
C	decrease	decrease
D	decrease	no change

14 The diagram represents four discrete energy levels of an atom of a gas. The gas is subjected to electrical excitation and subsequently emits photons of different energies.



Which transition could be associated with the emission of blue light?

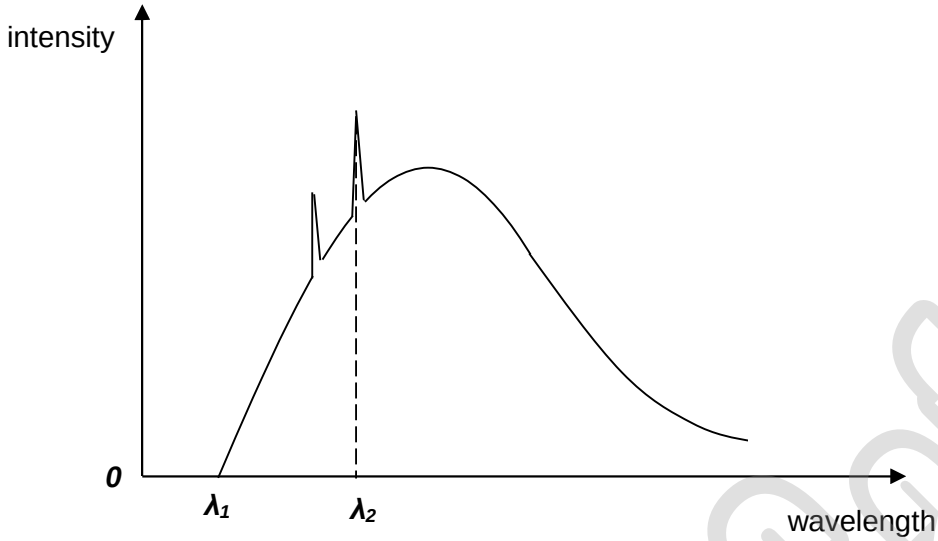
A E_4 to E_2

B E_4 to E_1

C E_4 to E_3

D E_3 to E_2

15 The diagram below shows a typical X-ray spectrum produced by an X-ray tube.



The operating voltage across the X-ray tube is decreased. Which of the following gives the corresponding changes, if any, in λ_1 and λ_2?

	λ_1	λ_2
A	Increase	No change
B	No change	Decrease
C	Decrease	No change
D	Decrease	Decrease

QUANTUM PHYSICS I WORKED SOLUTIONS

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1 Ans: **B**

2 Ans: **B**

From photoelectric effect equation: $\mathrm{KE}_{\max}$ of electrons$= hf - \phi$, using a light of higher frequency, maximum energy of ejected electrons increases.

As intensity of light = $n_p \times \frac{hf}{Area}$, with a higher frequency, the rate of number of incoming photons decreases. Hence, the photoelectric current decreases.

3 Ans: **B**

For absorption of a photon to take place, the energy transition is from a lower energy level to a higher energy level. For absorption of a photon with highest wavelength, the difference between the 2 energy levels is the smallest. i.e. $\Delta E = \frac{hc}{\lambda}$

4 Ans: **B**

5 Ans: **A**

6 Ans: **B**

7 Ans: **A**

$E_{photon} = \Phi + E_k$

$\frac{hc}{\lambda_1} = \phi + E_k$

$E_k = \frac{hc}{\lambda_1} - \phi$

Plotting E_k against λ will give a (hyperbolic) curve.

8 Ans: **D**

For the shortest wavelength, the energy transition has to be the greatest (from the highest to the lowest, i.e. E_3 to E_1)

$E_3 - E_1 = \frac{hc}{\lambda_1}$

For the longest wavelength, the energy transition has to be the lowest (from the highest to the second highest, i.e. E_3 to E_2)

$E_3 - E_2 = \frac{hc}{\lambda_2}$

Let λ be wavelength of the other spectral line.

The last photon is emitted when the atom makes a transition from E_2 to E_1.

$E_2 - E_1 = (E_3 - E_1) - (E_3 - E_2)$

$\frac{hc}{\lambda} = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$

$\frac{1}{\lambda} = \frac{1}{\lambda_1} - \frac{1}{\lambda_2}$

$\lambda = \frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2}$

9 Ans: **A**

K_{max} = 0 eV occurs when λ = 250 nm. Therefore, the threshold wavelength is 250 nm.

By photoelectric equation, $\frac{hc}{\lambda} = \Phi + K_{max}$

Hence,

$$\Phi = \frac{hc}{\lambda} - K_{max} = \frac{6.63\times10^{-34}(3.0\times10^{8})}{250\times10^{-9}} - 0$$

$$\Phi = 7.956\times10^{-19}\ \text{J} = 4.97\ \text{eV}$$

10 Ans: **D**

11 Ans: **A**

Since electrons pass through undeflected,

$$F_E = F_B$$

$$qE = Bqv$$

$$v = \frac{E}{B} = \frac{1400}{2.0\times10^{-3}} = 700000\ \text{m s}^{-1}$$

By Einstein's Photoelectric Equation,

$$\frac{hc}{\lambda} = \phi + KE_{Max}$$

$$\phi = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(450\times10^{-9})} - [\frac{1}{2}\times(9.11\times10^{-31})\times(700000)^2]$$

$$\therefore \phi = 2.2\times10^{-19}\ \text{J}$$

12 Ans: **C**

$$hf = hf_0 + \frac{1}{2}mv_{max}^2$$

$$\frac{f}{f_0} = 1 + \frac{m}{2hf_0}v_{max}^2$$

$$v_{max}^2 = \left(\frac{f}{f_0} - 1\right)\frac{2hf_0}{m} = \frac{2hf_0}{m}\left(\frac{f}{f_0}\right) - \frac{2hf_0}{m}$$

$$\text{gradient} = \frac{2hf_0}{m} = \left(\frac{5.2\times10^{12} - 0.0\times10^{12}}{4.0 - 1.0}\right) = 1.73\times10^{12}$$

$$f_0 = \frac{5.2\times10^{12}}{3.0}\left(\frac{9.11\times10^{-31}}{2(6.63\times10^{-34})}\right) = 1.19\times10^{15} = 1.2\times10^{15}\ \text{Hz}$$

13 Ans: **A**

Using $hf = \phi + E_k$, increasing frequency will increase E_k.

Using $I = \frac{Power}{Area} = (\frac{N}{t})(\frac{hf}{A})$, decreasing intensity of laser beam would mean decreasing the number photons reaching the metallic surface. This will decrease the number of photoelectrons to be ejected from the metal.

14 Ans: **A**

Considering the emission of photons for atoms transiting from E_4 to E_2, and using $E = \frac{hc}{\lambda}$,

$$\lambda = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(3.40 - 0.85) \times 1.6 \times 10^{-19}} = 488\ nm$$

15 Ans: **A**