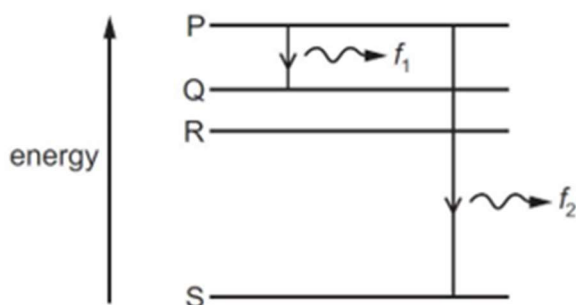


- 1 The energy level diagram shows four energy levels for the electrons.

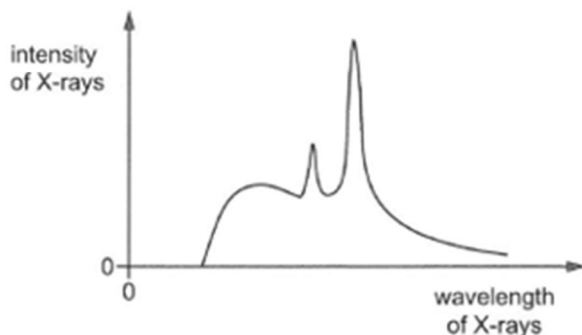


Two electron transitions are also shown together with the frequencies f_1 and f_2 of the emitted photons.

Which statement is **not** correct?

- A All the emitted photons have the same speed.
 - B The frequency of the photon emitted is $f_2 - f_1$ for the transition Q to S.
 - C The longest wavelength is for the transition Q to R.
 - D There are five possible spectral lines for these four energy levels.
- 2 X-rays are produced when high speed electrons collide with a metal target. To attain the high speed, electrons are accelerated over a potential difference.

The graph illustrates how the intensity of X-rays varies with their wavelength when the target is tungsten.



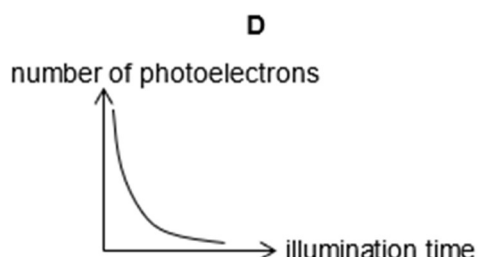
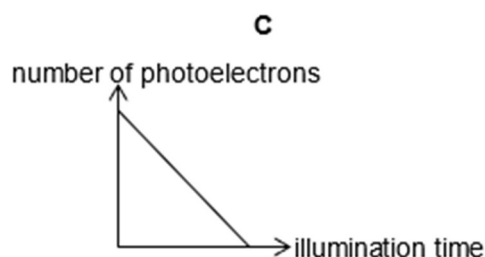
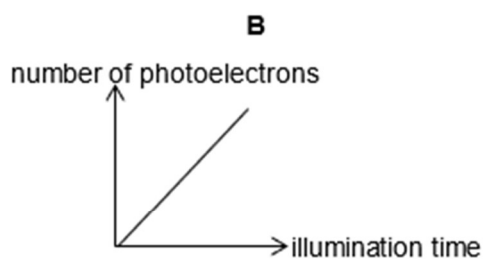
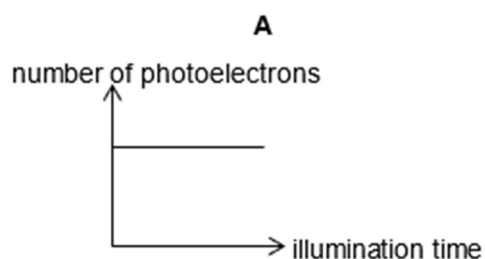
The electrons are subsequently accelerated across a higher potential difference.

Which statement is correct?

- A The minimum wavelength will decrease.
- B The minimum wavelength will increase.
- C The number of peaks will increase.
- D The position of the peaks will move towards shorter wavelengths.

- 3 When electromagnetic radiation of frequency f illuminates on a particular metal surface, photoelectrons are emitted.

Which graph is obtained when the intensity of the electromagnetic radiation is kept constant?



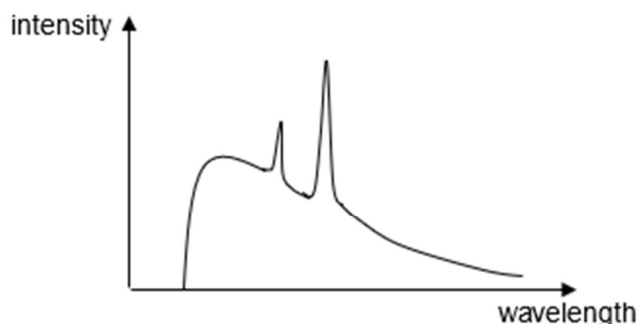
- 4

The accelerating potential difference in an X-ray tube is 20 kV.

What is the shortest wavelength of the X-ray photon emitted from the X-ray tube?

- A** $1.6 \times 10^{-11} \text{ m}$
- B** $6.2 \times 10^{-11} \text{ m}$
- C** $1.6 \times 10^{-10} \text{ m}$
- D** $6.2 \times 10^{-10} \text{ m}$

- 5 The following graph shows the spectrum of X-rays emitted from an X-ray tube.



If the potential difference between the target and cathode is increased, which one of the following combinations represents a possible change in wavelength and intensity of the peaks?

	wavelength	intensity
A	remain the same	increase
B	decrease	remain the same
C	remain the same	remain the same
D	decrease	increase

- 6 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 $2.0 \times 10^{-3} \text{ T}$ and 1400 V m^{-1} , respectively.

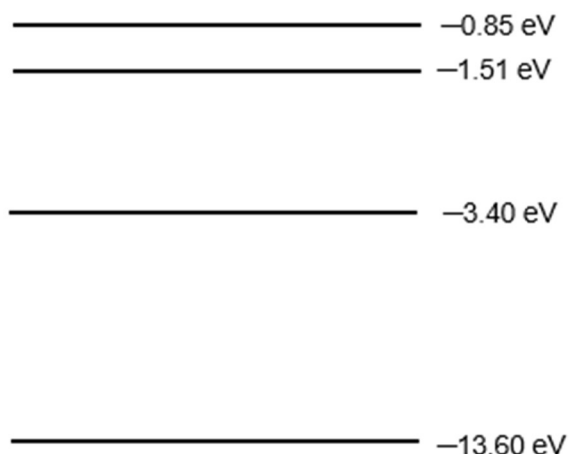
What is the work function energy of the metal?

- A** $2.2 \times 10^{-19} \text{ J}$ **B** $4.4 \times 10^{-19} \text{ J}$ **C** $6.6 \times 10^{-19} \text{ J}$ **D** $8.8 \times 10^{-19} \text{ J}$

7

The diagram below shows some of the lowest energy levels for the hydrogen atom.

The atom is at its ground state.

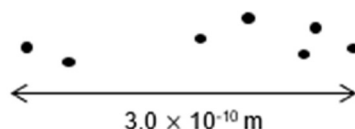


Which of the following will result in excitation to the highest possible energy level?

- A** A photon of energy 10.20 eV incident on the atom.
- B** An electron of energy 11.50 eV colliding with the atom.
- C** An electron with de Broglie wavelength of 3.50×10^{-10} m colliding with the atom.
- D** A photon of wavelength 9.95×10^{-8} m incident on the atom.

8

The dots in the diagram below show location of an electron detected at several intervals of time.



What is the order of magnitude of the minimum uncertainty in the determination of its momentum?

- A** 10^{-12} kg m s⁻¹
- B** 10^{-24} kg m s⁻¹
- C** 10^6 kg m s⁻¹
- D** 10^{10} kg m s⁻¹

- 9 Electrons gain kinetic energy by accelerating through a large potential difference before striking the target metal to produce X-ray.

What is the percentage change to the minimum wavelength of the X-ray spectrum produced if the potential difference is reduced by half?

- A decrease by 25 %
B decrease by 50 %
C increase by 50 %
D increase by 100 %

- 10 A moving electron of mass m and a photon have the same energy E .

The ratio of the wavelengths associated with them, $\frac{\lambda_{\text{electron}}}{\lambda_{\text{photon}}}$ is

- A $\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ B $c(2mE)^{\frac{1}{2}}$ C $\frac{1}{c}\left(\frac{2m}{E}\right)^{\frac{1}{2}}$ D $\frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$

- 11 Two beams, P and Q, of light of the same wavelength fall upon the same metal surface causing photoemission of electrons. The photoelectric current produced by P is nine times that produced by Q.

Which of the following gives the ratio

$$\frac{\text{wave amplitude of beam P}}{\text{wave amplitude of beam Q}}?$$

- A 0.11 B 0.33 C 3.0 D 9.0

- 12 Electron diffraction from a crystal occurs when the wavelength of the electrons is comparable to the atomic spacing of the atoms in the crystal. Atomic spacing is about 10^{-10} m.

Free electrons are accelerated from rest by a potential difference V in a vacuum before being incident onto the crystal.

What would be a suitable value for V ?

- A 1 mV B 1 V C 1 kV D 1 MV

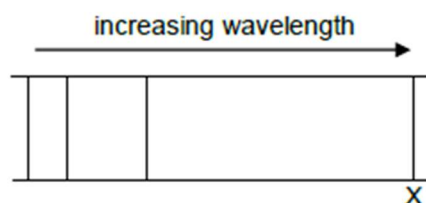
- 13 A metal surface is illuminated with a beam of monochromatic electromagnetic radiation. By the photoelectric effect, photoelectrons may be emitted from the metal surface.

Which statement about the photoelectrons is correct?

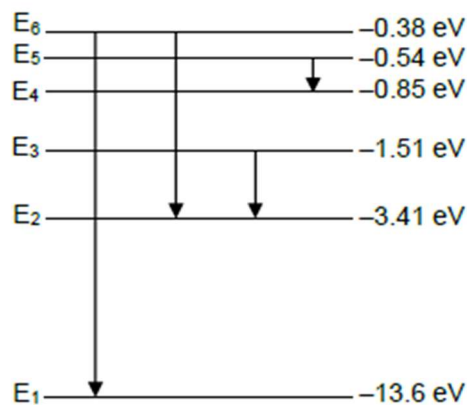
- A No emission of photoelectrons occurs if the radiation is of a very low intensity.
- B Photoelectrons are emitted only if the wavelength of the radiation is greater than a minimum value.
- C The maximum speed of the photoelectrons emitted increases when the intensity of the radiation increases at constant frequency.
- D The rate of emission of photoelectrons decreases when the frequency of the radiation increases at constant intensity.

- 14 The line emission spectrum of a hydrogen discharge tube when viewed through a diffraction grating consists of coloured lines on a dark background. One of the coloured lines is marked X, as shown.

The wavelength scale is linear and increases to the right.



The diagram below represents some of the electron energy levels in a hydrogen atom.



Which transition best corresponds to the emission of line X?

15

A proton travelling in a straight line with momentum p has an uncertainty of 0.10% in its kinetic energy.

What is the minimum uncertainty in its position, in terms of p and the Planck constant h ?

- A** $0.0005 \frac{h}{p}$ **B** $0.001 \frac{h}{p}$ **C** $1000 \frac{h}{p}$ **D** $2000 \frac{h}{p}$

16

In a photoelectric effect experiment, white light shone on a piece of metal causes the emission of photoelectrons. The threshold wavelength for this metal is 580 nm (yellow light).

Which statement is correct?

- A** If a violet filter is placed in front of the light source, the rate of emission of photoelectrons will increase.
- B** If a red filter is placed in front of the light source, the rate of emission of photoelectrons will decrease to zero.
- C** If the light source is focused onto a smaller surface area of the metal, photoelectrons will be emitted with greater maximum kinetic energy.
- D** If another metal of twice the work function of the original metal is used, there will still be photoemission.

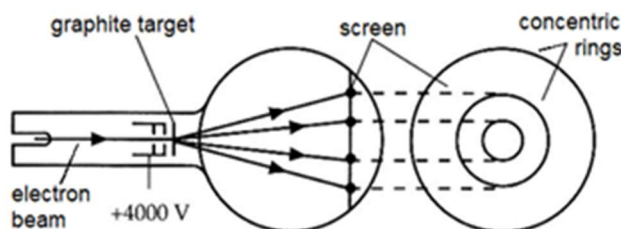
17

Which option shows the change in velocity, frequency and wavelength of an electromagnetic wave as it travels from an optically less dense to an optically denser medium?

	velocity	frequency	wavelength
A	decreases	unchanged	decreases
B	increases	unchanged	increases
C	decreases	decreases	unchanged
D	increases	increases	unchanged

18

In an experimental setup, a beam of accelerated electrons strikes an extremely thin layer of polycrystalline graphite target and concentric rings are seen on the tube face as shown.



If the setup is modified such that instead of electron beam, a beam of protons strike the graphite target with the same speed, the radii of the concentric rings will

- A decrease.
- B increase.
- C stay the same.
- D not be seen. (No rings appear.)

19

The energy levels in a hydrogen atom are shown.

energy level n	energy / eV
1	-13.6
2	-3.4
3	-1.5
4	-0.9
5	-0.5

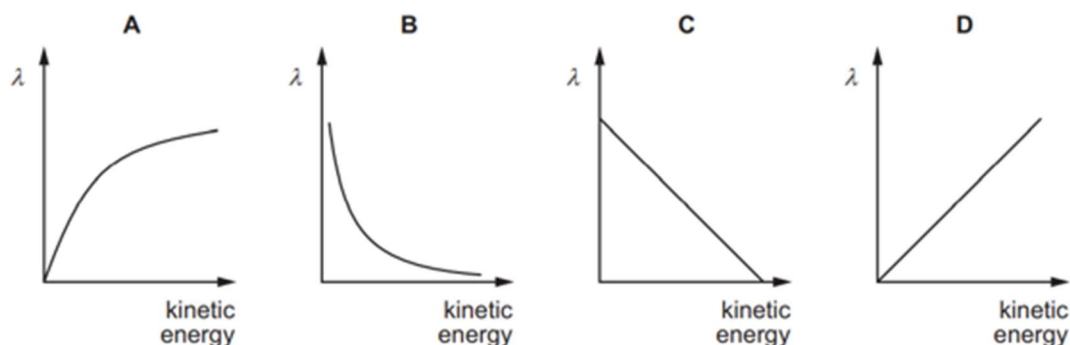
A red spectral line known as the hydrogen alpha line has been of great value to astronomers. Its wavelength is 656.28 nm.

Which level change gives rise to the hydrogen alpha line?

- A 2 to 1
- B 3 to 1
- C 3 to 2
- D 5 to 2

20

For velocities much less than the speed of light, which graph shows how the de Broglie wavelength of an electron and its kinetic energy are related?



21

In 2010, the Japanese launched the world's first interplanetary solar sail spacecraft, called IKAROS. This works because photons reflected from the sail of area A exerts a forward force on the sail.

A beam of light of intensity I and frequency f is reflected at right angles to a solar sail.

What is the force exerted on the sail?

A $\frac{IA}{hf}$

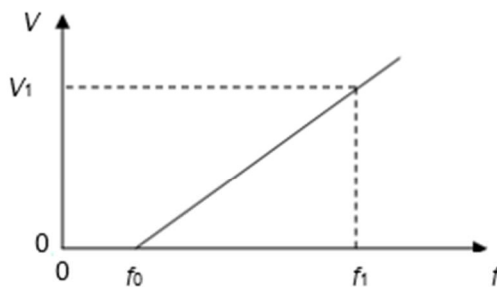
B $\frac{2hf}{c}$

C $\frac{I}{c}$

D $\frac{2IA}{c}$

22

In a photoelectric experiment, the potential difference V that must be maintained between the illuminated surface and the collector so as to just prevent any electrons from reaching the collector is determined for different frequencies f of the incident light. The graph below is obtained.



What is the maximum kinetic energy of the electron emitted at frequency f_1 ?

A hf_1

B $h(f_1 - f_0)$

C $eV_1 - hf_0$

D $\frac{V_1}{f_1 - f_0}$

23

The figure shows the four lowest energy levels of a hydrogen atom. It is known that the wavelength of visible light ranges from 400 nm to 700 nm.

$$n = 4 \quad \text{_____} \quad -0.85 \text{ eV}$$

$$n = 3 \quad \text{_____} \quad -1.53 \text{ eV}$$

$$n = 2 \quad \text{_____} \quad -3.40 \text{ eV}$$

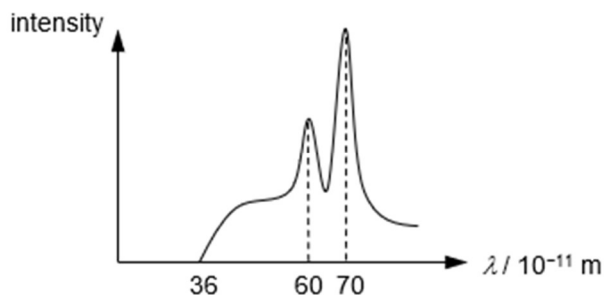
$$n = 1 \quad \text{_____} \quad -13.6 \text{ eV}$$

If electrons having kinetic energy of 12.5 eV are used to bombard a large number of hydrogen atoms at room temperature, how many spectral lines in the visible region can be obtained subsequently?

A 0**B** 1**C** 2**D** 3

24

X-ray tubes generate X-rays by accelerating electrons across a vacuum and bombarding them into a metal target. The X-ray spectrum of a metal target is shown in the figure below.



Which of the following statements is incorrect?

- A** The smallest wavelength detected, $36 \times 10^{-11} \text{ m}$, is dependent on the maximum kinetic energy of the electrons.
- B** The wavelength detected at $50 \times 10^{-11} \text{ m}$ is due to photon emitted as a result of energy loss when an electron passes near the atom and its path is deflected.
- C** The locations of the peaks can be used to identify the element that the target material is made of.
- D** The positions of the peaks allow us to calculate the energy of the electrons used to bombard the target.

25

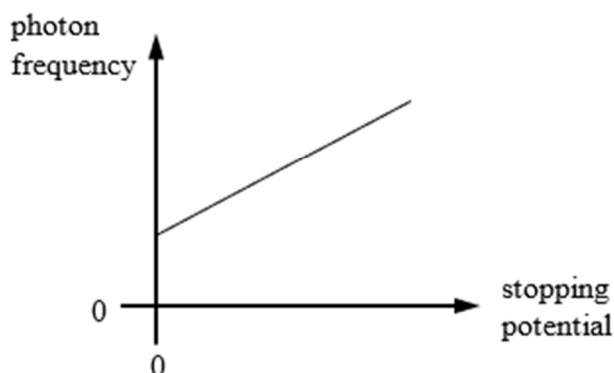
An electromagnetic radiation of constant frequency is incident on a metal surface.

Which statement explains why the photoelectric current from the metal surface is proportional to the intensity of the incident electromagnetic radiation?

- A Radiation of greater intensity overcomes the metal's work function energy allowing more electrons to escape.
- B Radiation of greater intensity causes the metal surface to get warm and so emit more electrons.
- C Radiation of greater intensity means more photons per second strike the metal surface.
- D Radiation of greater intensity consists of photons of greater energy.

26

A photoelectric experiment is conducted by shining electromagnetic radiation of various frequencies on a metal surface. The graph shows the variation of incoming photon frequency with stopping potential of the photoelectrons for the metal surface.



What changes, if any, would occur in the graph for a metal of lower work function?

- | | gradient | y-intercept |
|---|----------|-------------|
| A | lower | lower |
| B | higher | higher |
| C | same | lower |
| D | same | higher |

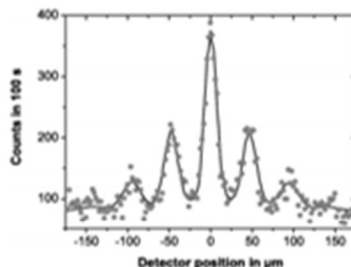
27

In order to produce X-rays of wavelength 0.20 nm, what is the minimum potential difference through which an electron in an X-ray tube must be accelerated to impinge upon the target metal?

- A. 3.22 kV B. 4.22 kV C. 5.22 kV D. 6.22 kV

28

The figure below shows the experimental results of a double-slit experiment performed using buckminsterfullerenes or buckyballs for short, which are actually spherically arranged molecules of carbon 60 (C_{60}).



If neutrons, each of mass 720 times less than a buckyball with the same kinetic energies as the buckyballs are used to do the experiment, the fringe spacing will

- A increase by 720 times
B increase by $\sqrt{720}$ times
C decrease by 720 times
D decrease by $\sqrt{720}$ times

29

A SARS-CoV-2 virus of mass 8.0×10^{-16} kg is moving with a speed of $(3.0 \pm 0.2) \mu\text{m s}^{-1}$. What is the minimum uncertainty in the measurement of the position of the virus?

- A 2×10^{-9} m B 4×10^{-12} m C 5×10^{-27} m D 10×10^{-53} m