AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.2.2 ELECTROMAGNETIC RADIATION AND QUANTUM PHENOMENA

SCORE	PERCENTAGE
/107	%

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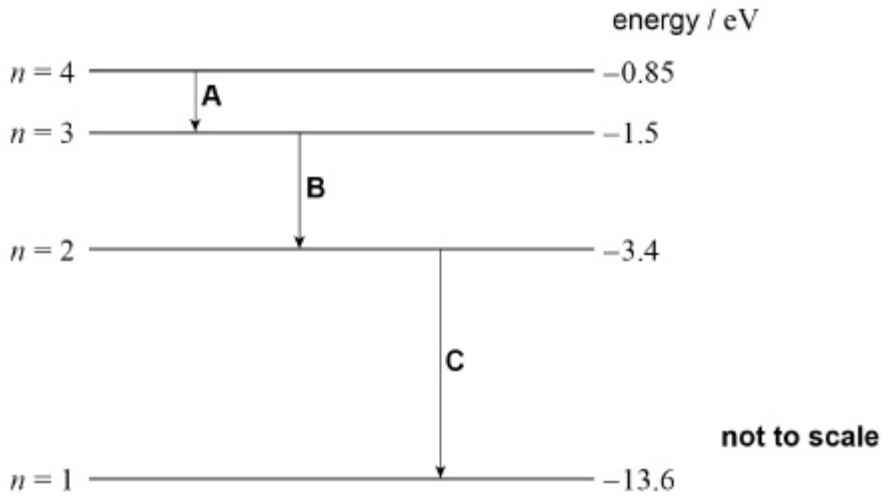
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Q1.

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



An excited hydrogen atom can emit photons of certain discrete frequencies. Three possible transitions are shown in the diagram.

(a) The transitions shown in the diagram result in photons being emitted in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.

To which region of the spectrum do the emitted photons belong?

Tick (✓) the correct box for each transition, **A**, **B** and **C**.

Transition	Ultraviolet	Visible	Infrared
A	☐	☐	☐
B	☐	☐	☐
C	☐	☐	☐

(1)

(b) Two ways to excite a hydrogen atom are by collision with a free electron or by the absorption of a photon.

Explain why, for a particular transition, the photon must have an exact amount of energy whereas the free electron only needs a minimum amount of kinetic energy.

_____

_____

_____

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(3)

(c) The surface of a sample of caesium is exposed to photons emitted in each of the three transitions shown in the diagram.

The threshold frequency of caesium is 5.1×10^{14} Hz

Determine whether any of these transitions would produce photons that would cause electrons to be emitted from the surface of caesium.

(3)

(d) Photons each with energy 12.1 eV are incident on the surface of the caesium sample.

Calculate the maximum speed of electrons emitted from the caesium.

maximum speed = _____ m s^{-1}

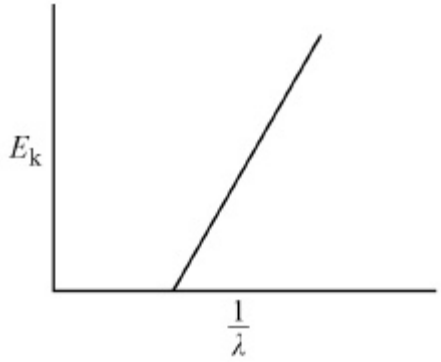
(3)

(Total 10 marks)

Q2.

The graph shows how the maximum kinetic energy E_k of photoelectrons emitted from a metal surface varies with the reciprocal of the wavelength λ of the incident radiation.

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What is the gradient of this graph?

A c ⬭

B h ⬭

C hc ⬭

D $\frac{h}{c}$ ⬭

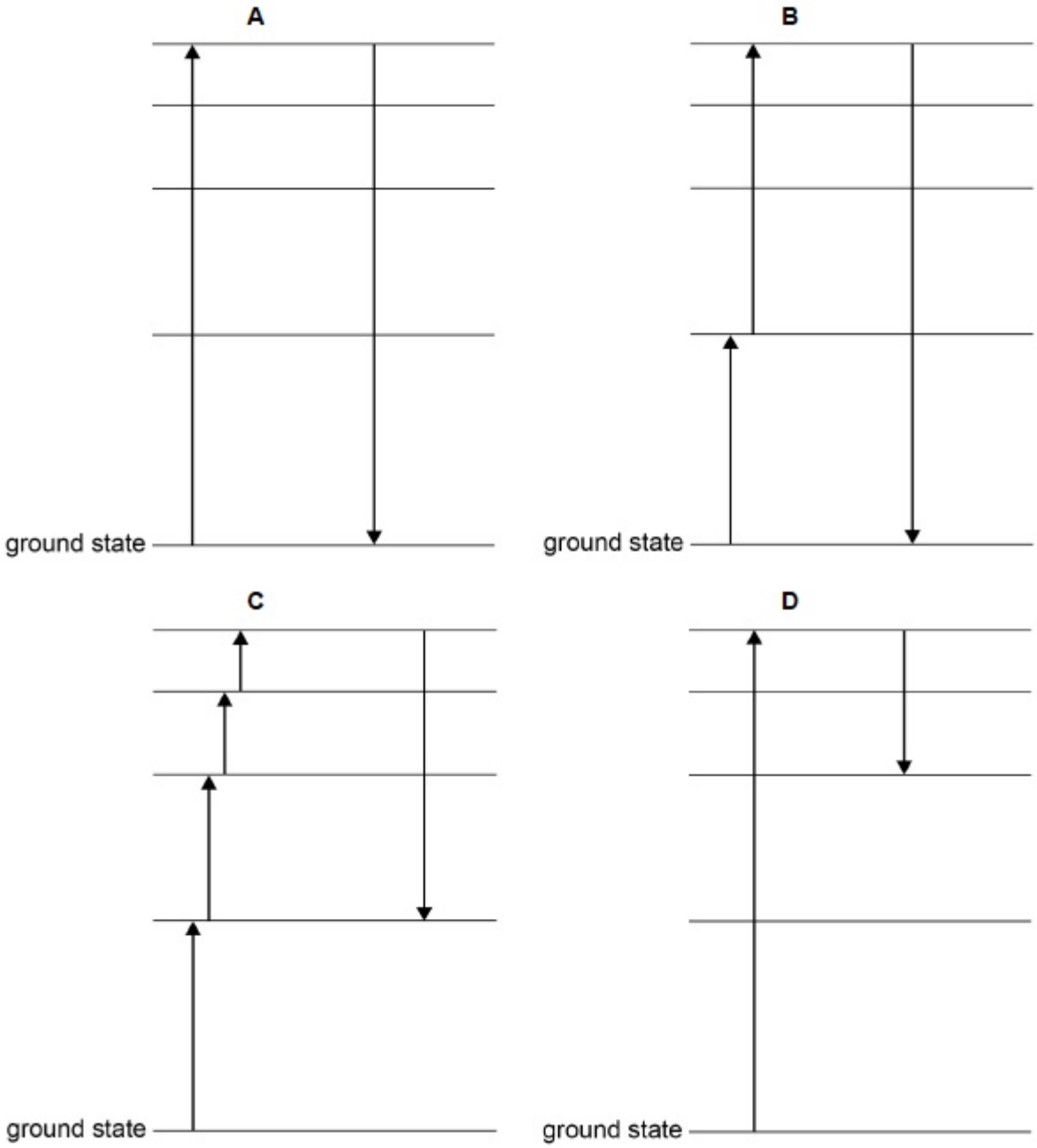
(Total 1 mark)

Q3.

An atom in the inner coating of a fluorescent tube absorbs a photon of ultraviolet radiation. This causes excitation of the atom from its ground state. A photon of visible light is then emitted.

Which energy level diagram represents this process?

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A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q4.

A particle of mass m has a kinetic energy of E.

What is the de Broglie wavelength of this particle?

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A $\frac{h}{\sqrt{(2Em^2)}}$ ⬭

B $\frac{h}{\sqrt{2E}}$ ⬭

C $\frac{h}{\sqrt{\left(\frac{2E}{m^2}\right)}}$ ⬭

D $\frac{h}{\sqrt{2Em}}$ ⬭

(Total 1 mark)

Q5.

Which row links both the photoelectric effect and electron diffraction to the properties of waves and particles?

	Photoelectric effect	Electron diffraction	
A	Particle property	Particle property	⬭
B	Wave property	Wave property	⬭
C	Particle property	Wave property	⬭
D	Wave property	Particle property	⬭

(Total 1 mark)

Q6.

The table shows results of an experiment to investigate how the de Broglie wavelength λ of an electron varies with its velocity v.

v / 10^7 m s^{-1}	λ / 10^{-11} m
1.5	4.9
2.5	2.9
3.5	2.1

(a) Show that the data in the table are consistent with the relationship $\lambda \propto \frac{1}{v}$

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(2)

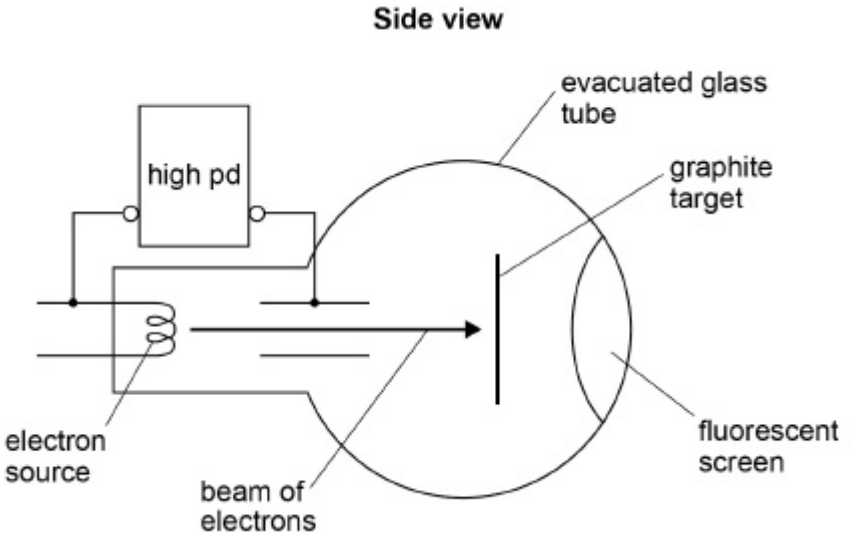
(b) Calculate a value for the Planck constant suggested by the data in the table.

Planck constant = _____ J s

(2)

(c) **Figure 1** shows the side view of an electron diffraction tube used to demonstrate the wave properties of an electron.

Figure 1

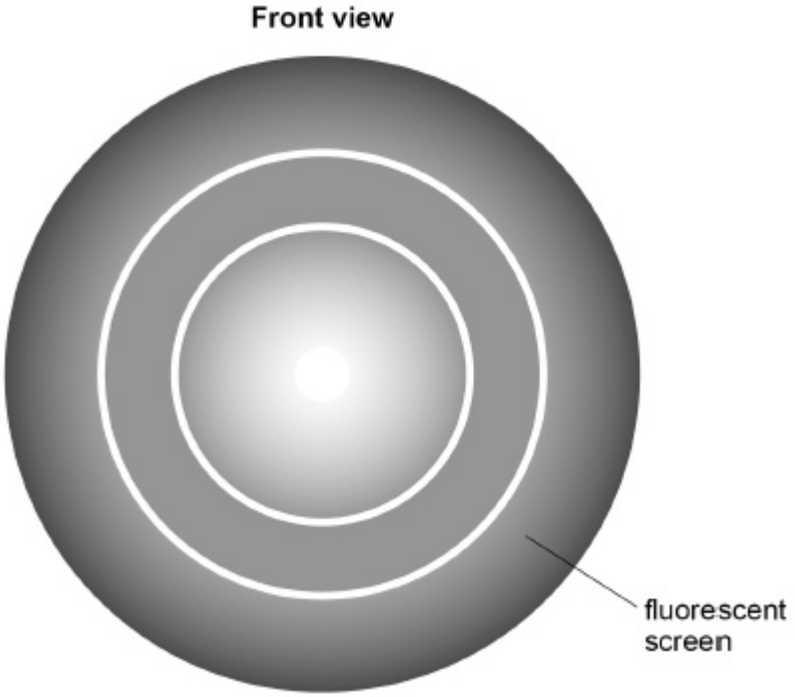


An electron beam is incident on a thin graphite target that behaves like the slits in a diffraction grating experiment. After passing through the graphite target the electrons strike a fluorescent screen.

Figure 2 shows the appearance of the fluorescent screen when the electrons are incident on it.

Figure 2

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Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles.

(3)

(d) Explain how the emission of light from the fluorescent screen shows that the electrons incident on it are behaving as particles.

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_____

_____

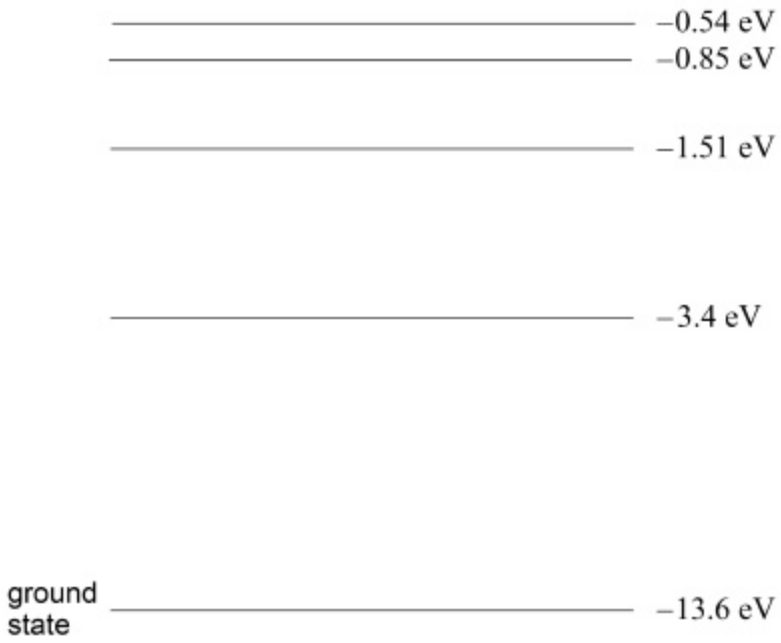
_____

(3)

(Total 10 marks)

Q7.

The diagram shows an energy-level diagram for a hydrogen atom.



Electrons, each having a kinetic energy of 2.0×10^{-18} J, collide with atoms of hydrogen in their ground state. Photons are emitted when the atoms de-excite.

How many different wavelengths can be observed with incident electrons of this energy?

A 1 ⬭

B 3 ⬭

C 6 ⬭

D 7 ⬭

(Total 1 mark)

Q8.

Photons of wavelength 290 nm are incident on a metal plate. The work function of the metal is 4.1 eV

What is the maximum kinetic energy of the emitted electrons?

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A 0.19 eV ⬭

B 4.3 eV ⬭

C 6.9 eV ⬭

D 8.4 eV ⬭

(Total 1 mark)

Q9.

Which statement suggests that electrons have wave properties?
Tick (✓) the correct answer.

Electrons are emitted in photoelectric effect experiments. ☐

Electrons are released when atoms are ionised. ☐

Electrons produce dark rings in diffraction experiments. ☐

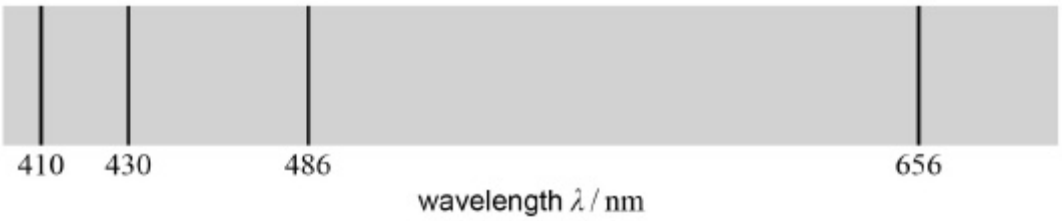
Electron transitions in atoms produce line spectra. ☐

(Total 1 mark)

Q10.

In a discharge tube a high potential difference is applied across hydrogen gas contained in the tube. This causes the hydrogen gas to emit light that can be used to produce the visible line spectrum shown in **Figure 1**.

Figure 1



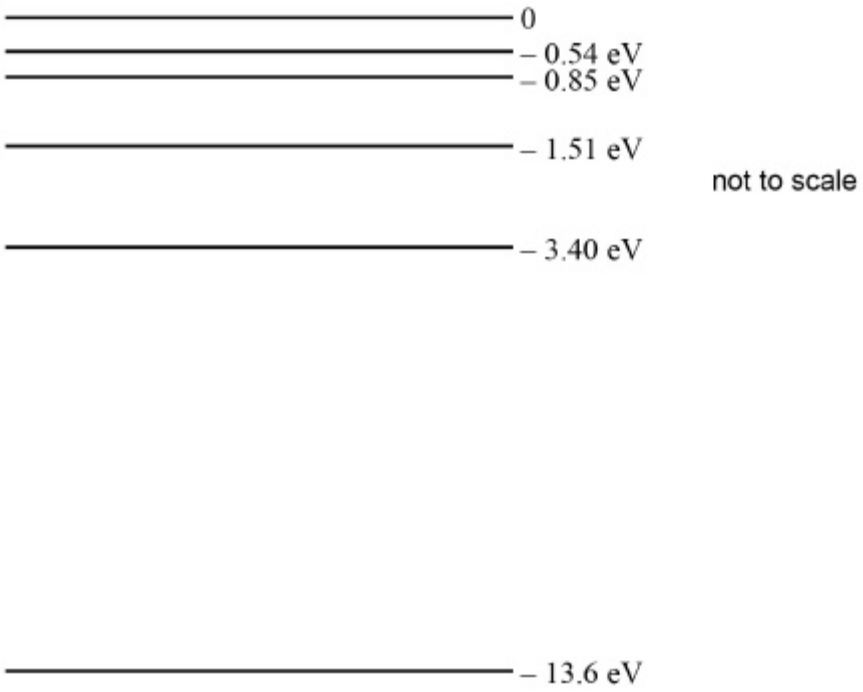
The visible line spectrum in **Figure 1** has been used to predict some of the electron energy levels in a hydrogen atom.

The energy levels predicted from the visible line spectrum are those between 0 and −3.40 eV in the energy level diagram.

Some of the predicted energy levels are shown in **Figure 2**.

Figure 2

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(a) Calculate the energy, in eV, of a photon of light that has the lowest frequency in the visible hydrogen spectrum shown in **Figure 1**.

energy of photon = _____ eV

(3)

(b) Identify the state of an electron in the energy level labelled 0.

_____

_____

(1)

(c) Identify the state of an electron that is in the energy level labelled –13.6 eV.

_____

_____

_____

(1)

(d) Explain why the energy levels are negative.

_____

_____

_____

(1)

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(e) Discuss how the discharge tube is made to emit electromagnetic radiation of specific frequencies.

In your answer you should:

- explain why there must be a high potential difference across the tube
- discuss how the energy level diagram in **Figure 2** predicts the spectrum shown in **Figure 1**
- show how one of the wavelengths of light is related to two of the energy levels in the energy level diagram.

(6)

(Total 12 marks)

Q11.

When light of a certain frequency greater than the threshold frequency of a metal is directed at the metal, photoelectrons are emitted from the surface.
The power of the light incident on the metal surface is doubled.

Which row shows the effect on the maximum kinetic energy and the number of photoelectrons emitted per second?

	Maximum kinetic energy	**Number of photoelectrons emitted per second**	
A	remains unchanged	remains unchanged	⬭
B	doubles	remains unchanged	⬭
C	remains unchanged	doubles	⬭
D	doubles	doubles	⬭

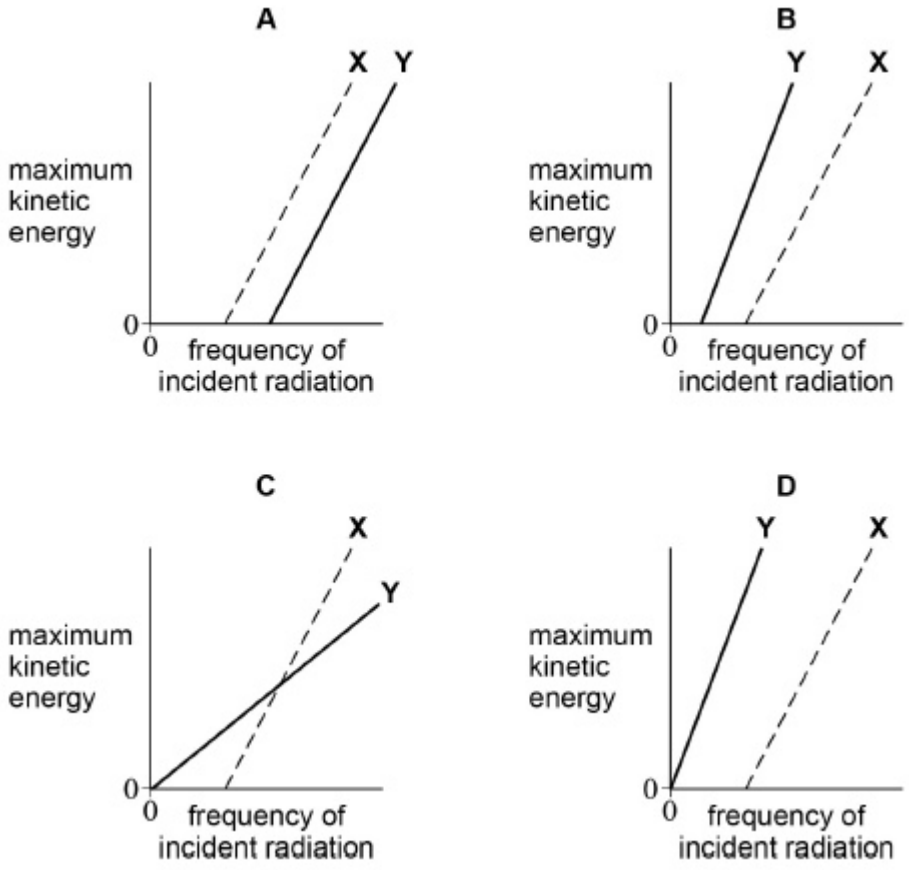
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(Total 1 mark)

Q12.

Line **X** on the graphs below shows how the maximum kinetic energy of emitted photoelectrons varies with the frequency of incident radiation for a particular metal.

Which graph shows the results for a metal **Y** that has a higher work function than **X**?



A ⬭

B ⬭

C ⬭

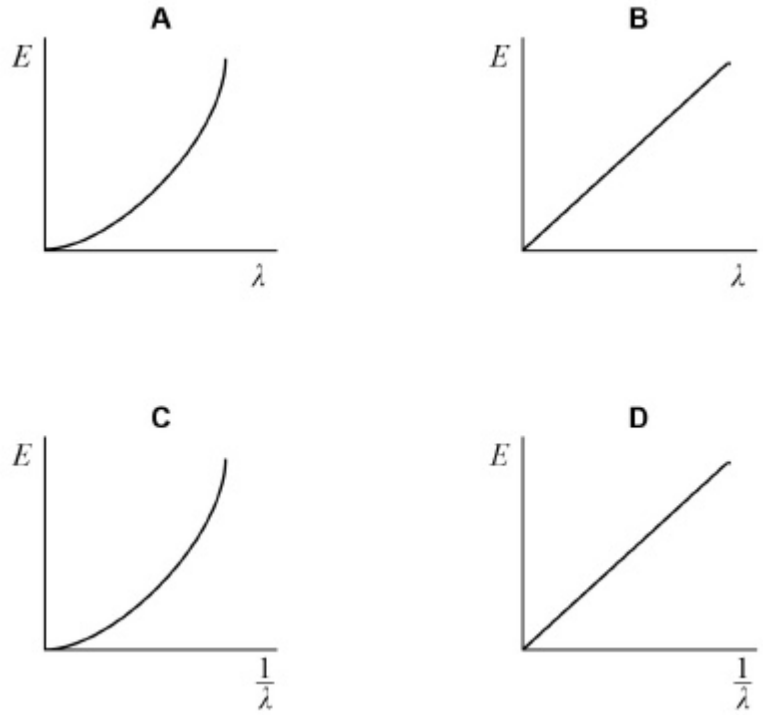
D ⬭

(Total 1 mark)

Q13.

Which graph best shows the relationship between photon energy E and wavelength λ of a photon of electromagnetic radiation?

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A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q14.

A beam of light of wavelength λ is incident on a clean metal surface and photoelectrons are emitted. The wavelength of the light is halved but energy incident per second is kept the same.

Which row in the table is correct?

	Maximum kinetic energy of the emitted photoelectrons	**Number of photoelectrons emitted per second**	
A	Increases	Unchanged	⬭
B	Decreases	Increases	⬭
C	Increases	Decreases	⬭
D	Decreases	Unchanged	⬭

(Total 1 mark)

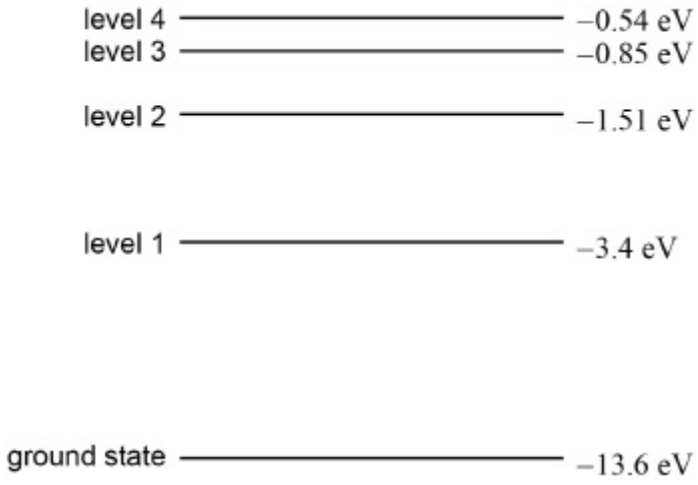
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Q15.

The diagram shows an energy level diagram for a hydrogen atom.

Electrons with energy 13.0 eV collide with atoms of hydrogen in their ground state.

What is the number of different wavelengths of electromagnetic radiation that could be emitted when the atoms de-excite?



A 0 ⬭

B 3 ⬭

C 6 ⬭

D 7 ⬭

(Total 1 mark)

Q16.

(a) Describe what occurs in the photoelectric effect.

_____

_____

_____

_____

(2)

(b) Violet light of wavelength 380 nm is incident on a potassium surface.

Deduce whether light of this wavelength can cause the photoelectric effect when incident on the potassium surface.

work function of potassium = 2.3 eV

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(4)

(c) The photoelectric effect provides evidence for light possessing particle properties.

State and explain **one** piece of evidence that suggests that light also possesses wave properties.

_____

_____

_____

_____

_____

(2)

(Total 8 marks)

Q17.

In an experiment to demonstrate the photoelectric effect, a charged metal plate is illuminated with light from different sources. The plate loses its charge when an ultraviolet light source is used but not when a red light source is used.

What is the reason for this?

A The intensity of the red light is too low. ⬭

B The wavelength of the red light is too short. ⬭

C The frequency of the red light is too high. ⬭

D The energy of red light photons is too small. ⬭

(Total 1 mark)

Q18.

Which of the following classes of electromagnetic waves will **not** ionise neutral atoms?

What is the reason for this?

A ultraviolet ⬭

B X radiation ⬭

C gamma radiation ⬭

D microwave ⬭

(Total 1 mark)

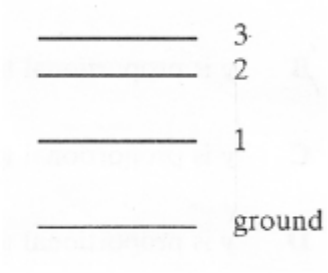
Q19.

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The values of the lowest three energy levels in a particular atom are shown in the table.

The diagram shows these levels together with the ground state of the atom.

Level	Energy/eV
3	–0.85
2	–1.51
1	–3.39



When an electron moves from level 3 to level 1, radiation of frequency 6.2×10^{14} Hz is emitted.

What is the frequency of the radiation emitted when an electron moves from level 2 to level 1?

A 2.3×10^{14} Hz ⬭

B 3.5×10^{14} Hz ⬭

C 4.6×10^{14} Hz ⬭

D 8.3×10^{14} Hz ⬭

(Total 1 mark)

Q20.

Experiments on which of the following suggested the wave nature of electrons?

A electron diffraction by a crystalline material ⬭

B β^- decay ⬭

C line spectra of atoms ⬭

D the photoelectric effect ⬭

(Total 1 mark)

Q21.

Electromagnetic radiation incident on a metal surface can cause electrons to be emitted.

Which of the following statements is correct?

A Every photon incident on the surface causes an electron to be emitted. ⬭

B All the emitted electrons have the same energy. ⬭

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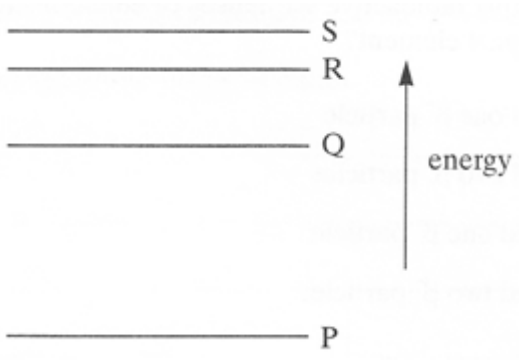
C The range of energy of the emitted electrons depends on the intensity of the radiation. ⊙

D If the incident radiation is of a single frequency, the number of electrons emitted per second increases if the intensity of the radiation increases. ⊙

(Total 1 mark)

Q22.

The diagram shows the four lowest energy levels for an electron in an atom. P, Q, R and S represent, to scale, the relative energy values of these energy levels.



An electron transition from level R to level Q is accompanied by the emission of a photon of visible light.

Which electron transition would be accompanied by the emission of a photon of infrared radiation?

A S to R ⊙

B S to Q ⊙

C Q to P ⊙

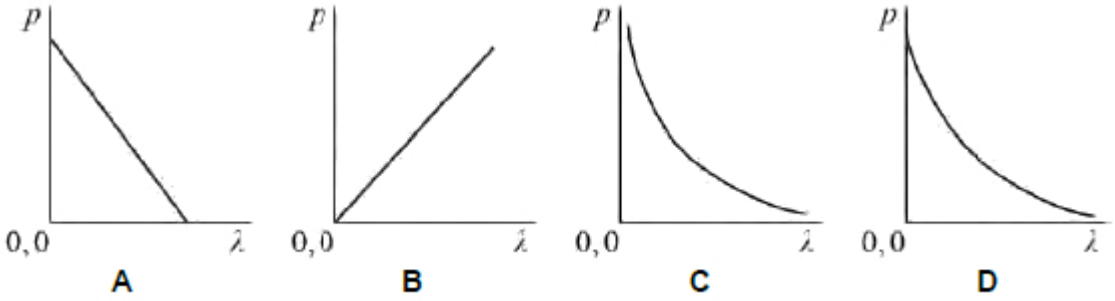
D R to P ⊙

(Total 1 mark)

Q23.

Which graph best shows the relationship between the momentum p and the wavelength λ for photons?

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A ☐

B ☐

C ☐

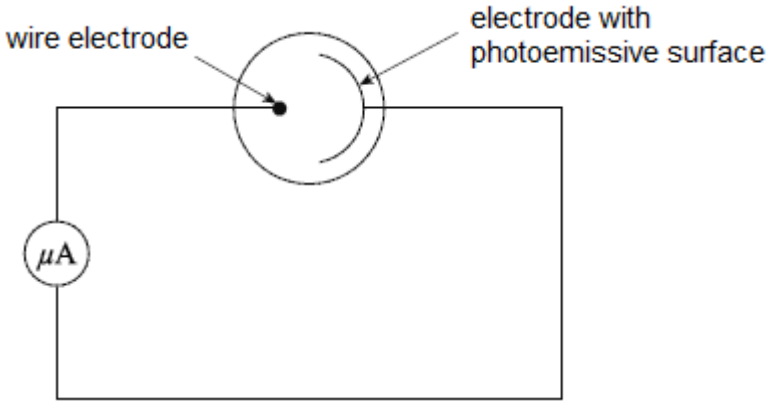
D ☐

(Total 1 mark)

Q30.

Figure 1 shows a photocell which uses the photoelectric effect to provide a current in an external circuit.

Figure 1



(a) Electromagnetic radiation is incident on the photoemissive surface.

Explain why there is a current only if the frequency of the electromagnetic radiation is above a certain value.

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(3)

(b) State and explain the effect on the current when the intensity of the electromagnetic radiation is increased.

_____

_____

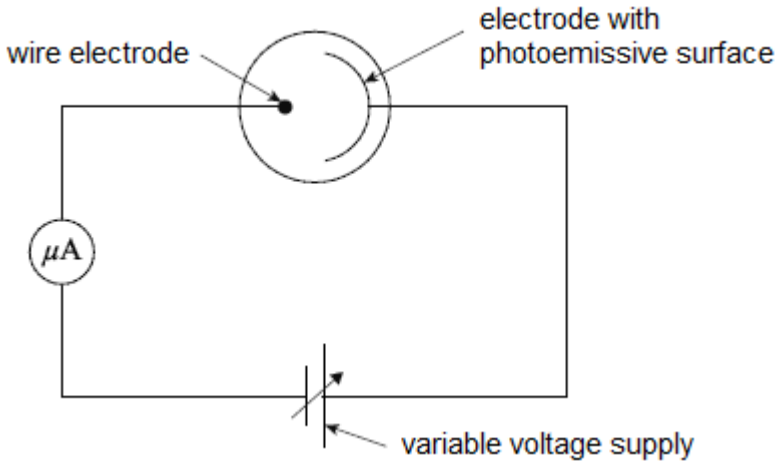
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_____

(2)

(c) A student investigates the properties of the photocell. The student uses a source of electromagnetic radiation of fixed frequency and observes that there is a current in the external circuit.
The student then connects a variable voltage supply so the positive terminal is connected to the electrode with a photoemissive surface and the negative terminal is connected to the wire electrode. As the student increases the supply voltage, the current decreases and eventually becomes zero. The minimum voltage at which this happens is called the stopping potential. The student's new circuit is shown in **Figure 2**.

Figure 2



The photoemissive surface has a work function of 2.1 eV. The frequency of the electromagnetic radiation the student uses is 7.23×10^{14} Hz.

Calculate the maximum kinetic energy, in J, of the electrons emitted from the photoemissive surface.

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maximum kinetic energy = _____ J

(3)

(d) Use your answer from **part (c)** to calculate the stopping potential for the photoemissive surface.

stopping potential = _____ V

(1)

(e) The student increases the frequency of the electromagnetic radiation.

Explain the effect this has on the stopping potential.

_____

_____

_____

_____

_____

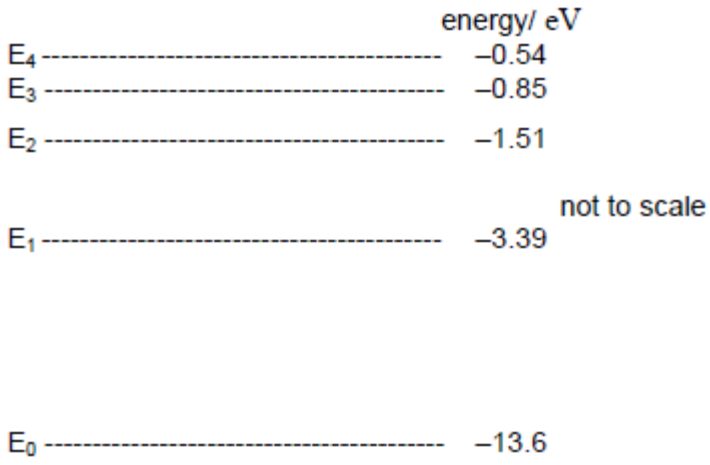
_____

(3)

(Total 12 marks)

Q31.

The diagram gives some of the energy levels of a hydrogen atom.



The transition of an excited hydrogen atom from E_3 to E_1 causes a photon of visible light to

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be emitted.

Which transition causes a photon of ultraviolet light to be emitted?

A E_4 to E_3 ⬭

B E_3 to E_2 ⬭

C E_2 to E_1 ⬭

D E_1 to E_0 ⬭

(Total 1 mark)

Q32.

A proton moving with a speed v has a de Broglie wavelength λ.

What is the de Broglie wavelength of an alpha particle moving at the same speed v?

A $\frac{\lambda}{4}$ ⬭

B λ ⬭

C 2λ ⬭

D 4λ ⬭

(Total 1 mark)

Q33.

(a) The mercury atoms in a fluorescent tube are excited and then emit photons in the ultraviolet region of the electromagnetic spectrum.

(i) Explain how the mercury atoms become excited.

_____

_____

_____

_____

_____

_____

(3)

(ii) Explain how the excited mercury atoms emit photons.

_____

_____

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_____

_____

_____

_____

(2)

(b) Explain how the ultraviolet photons in the tube are converted into photons in the visible part of the electromagnetic spectrum.

_____

_____

_____

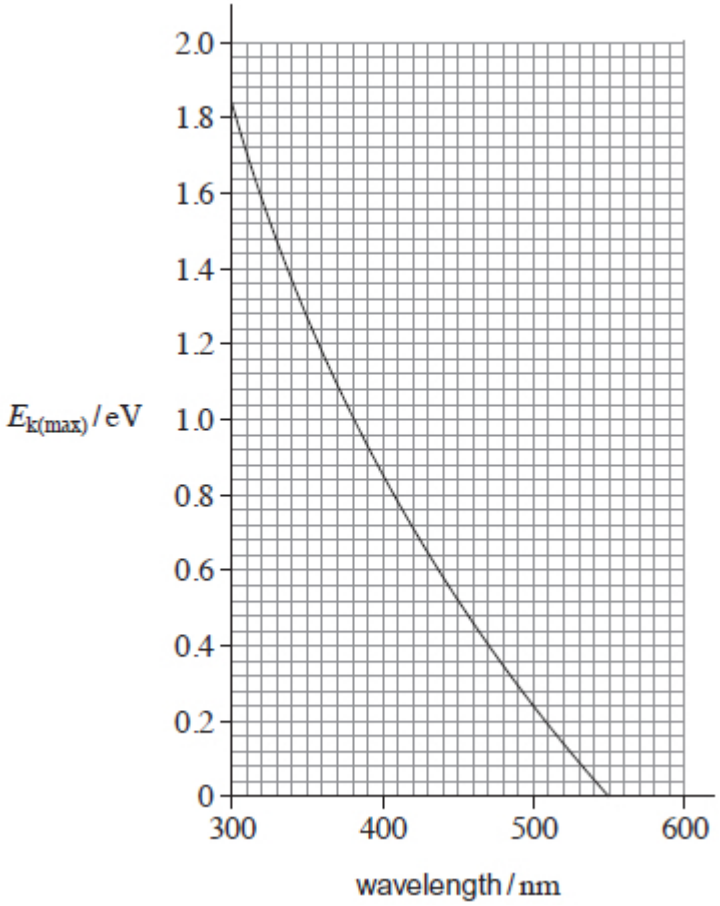
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(2)

(Total 7 marks)

Q34.

The maximum kinetic energy, $E_{k(max)}$, of photoelectrons varies with the wavelength of electromagnetic radiation incident on a metal surface.
This variation is shown in the graph.



(a) (i) Define the term work function.

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_____

_____

_____

(2)

(ii) Show that the work function of the metal is approximately 4×10^{-19} J.

Use data from the graph in your calculation.

(3)

(b) Monochromatic radiation is incident on the metal surface.
Photoelectrons are ejected with a maximum speed of 4.6×10^{5} m s^{-1}.

Determine the wavelength of the incident radiation.

wavelength _____ m

(3)

(Total 8 marks)

Q35.

Sodium metal has a work function of 2.28 eV. An atom of sodium has an ionisation energy of 5.15 eV.

(a) (i) State what is meant by work function.

_____

_____

(2)

(ii) State what is meant by ionisation energy.

_____

_____

(2)

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(b) Show that the minimum frequency of electromagnetic radiation needed for a photon to ionise an atom of sodium is about 1.2×10^{15} Hz.

(2)

(c) Electromagnetic radiation with the frequency calculated in part (b) is incident on the surface of a piece of sodium.

Calculate the maximum possible kinetic energy of an electron that is emitted when a photon of this radiation is incident on the surface.
Give your answer to an appropriate number of significant figures.

maximum kinetic energy = _____ J

(3)

(d) Calculate the speed of an electron that has the same de Broglie wavelength as the electromagnetic radiation in part (b).

speed = _____ m s^{-1}

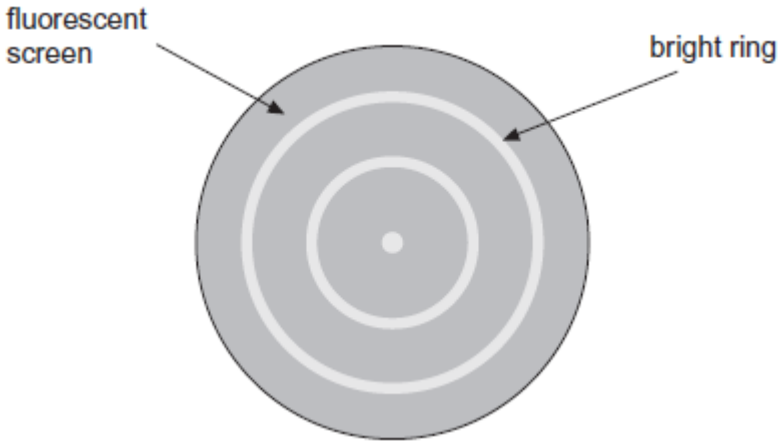
(3)

(Total 12 marks)

Q36.

In an electron diffraction tube, high speed electrons are produced by an electron gun at one end of the tube. The electrons are incident on a thin slice of a polycrystalline material. The diagram shows the pattern of bright rings that is formed on the fluorescent screen at the other end of the tube.

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(a) Explain how the production of bright rings suggests that the electrons behave like waves.

_____

_____

(1)

(b) The electrons in the tube have a velocity of 3.5×10^{7} m s^{-1}.

Calculate the de Broglie wavelength of the electrons.

de Broglie wavelength _____ m

(2)

(Total 3 marks)

Q37.

Observations of the H-α line in the spectrum of a star indicate the presence of hydrogen. The H-α line has a wavelength of 656 nm and is produced by a transition of electrons into the −3.4 eV energy level.

Calculate the energy level that the electron moves from when emitting a photon corresponding to a wavelength of 656 nm. Give your answer in **J**.

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energy level _____ J

(Total 4 marks)

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