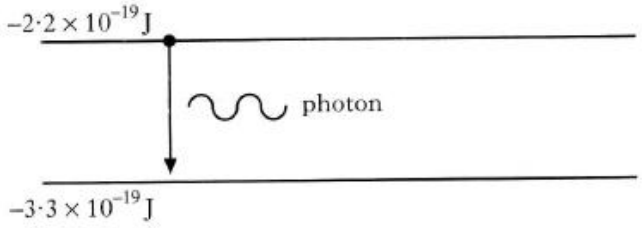
Exercise 12 - Wave- Particle Duality

Past Paper Homework Questions

1. In a laser, a photon of radiation is emitted when an electron makes a transition from a higher energy level to a lower level, as shown below.



The energy in each pulse of radiation from the laser is 10 J. How many photons are there in each pulse?

A $1{\cdot}8 \times 10^{19}$

B $3{\cdot}0 \times 10^{19}$

C $3{\cdot}7 \times 10^{19}$

D $4{\cdot}5 \times 10^{19}$

E $9{\cdot}1 \times 10^{19}$

2. Ultraviolet radiation is incident on a clean zinc plate. Photoelectrons are ejected.

The clean zinc plate is replaced by a different metal which has a lower work function. The same intensity of ultraviolet radiation is incident on this metal.

Compared to the zinc plate, which of the following statements is/are true for the new metal?

I The maximum speed of the photoelectrons is greater.

II The maximum kinetic energy of the photoelectrons is greater.

III There are more photoelectrons ejected per second.

A I only

B II only

C III only

D I and II only

E I, II and III

3. When light of frequency f is shone on to a certain metal, photoelectrons are ejected with a maximum velocity v and kinetic energy E_k.

When light of the same frequency and twice the intensity is shone on the same surface then

I twice as many electrons are ejected per second

II the speed of the fastest electrons is now $2v$

III the kinetic energy of the fastest electrons is now $2E_k$.

Which of the statements above is/are correct?

A I only

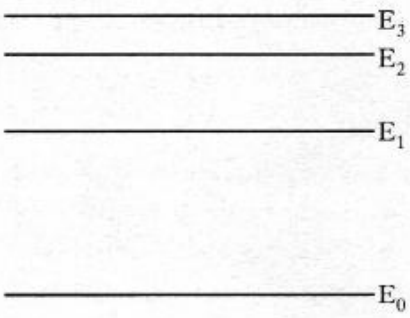
B II only

C III only

D I and II only

E II and III only

4. An atom has the energy levels shown.



Electron transitions occur between all of these levels to produce emission lines in the spectrum of this atom.

How many emission lines are produced by transitions between these energy levels?

A 3

B 4

C 5

D 6

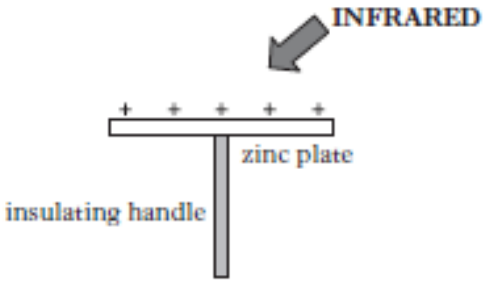
E 7

5. Clean zinc plates are mounted on insulating handles and then charged.

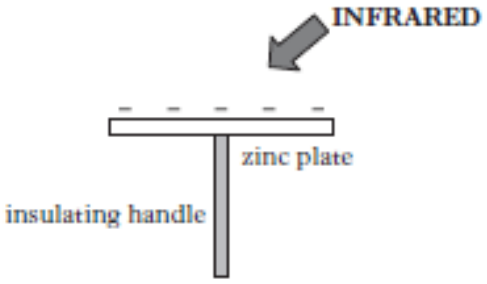
Different types of electromagnetic radiation are now incident on the plates as shown.

Which of the zinc plates is most likely to discharge due to photoelectric emission?

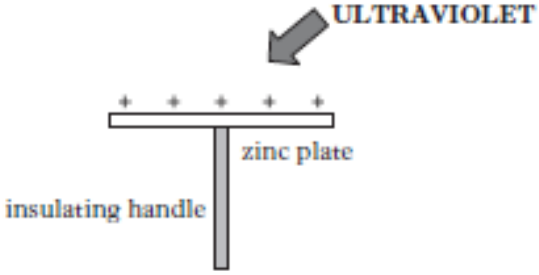
A



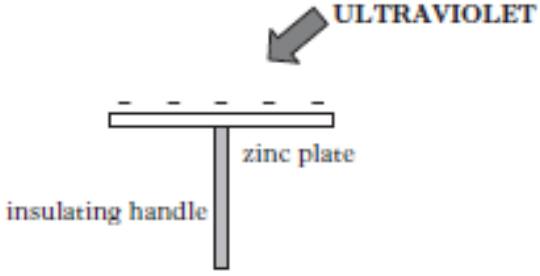
B



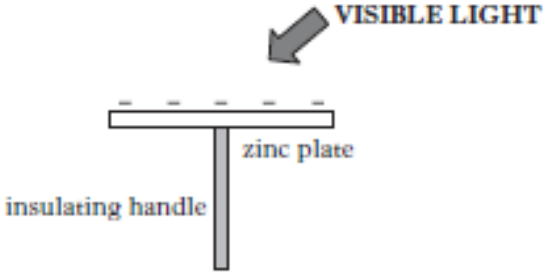
C



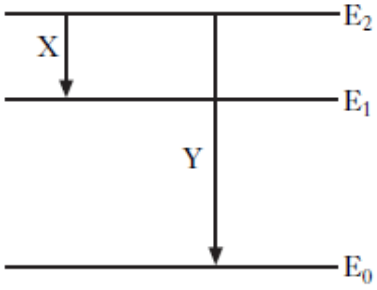
D



E



6. Part of the energy level diagram for an atom is shown.



X and Y represent two possible electron transitions.
Which of the following statements is/are correct?

I Transition Y produces photons of higher frequency than transition X.

II Transition X produces photons of longer wavelength than transition Y.

III When an electron is in the energy level E_0, the atom is ionised.

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

7. Photons of energy $7{\cdot}0 \times 10^{-19}$ J are incident on a clean metal surface. The work function of the metal is $9{\cdot}0 \times 10^{-19}$ J.

Which of the following is correct?

A No electrons are emitted from the metal.

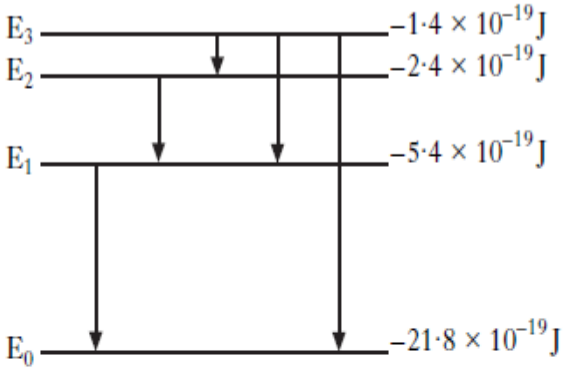
B Electrons with a maximum kinetic energy of $2{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

C Electrons with a maximum kinetic energy of $7{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

D Electrons with a maximum kinetic energy of $9{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

E Electrons with a maximum kinetic energy of 16×10^{-19} J are emitted from the metal.

8. The diagram represents some electron transitions between energy levels in an atom.



The radiation emitted with the shortest wavelength is produced by an electron making transition

A E_1 to E_0

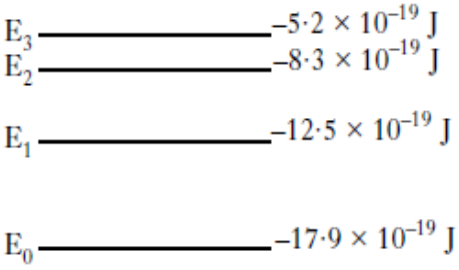
B E_2 to E_1

C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

9. The diagram represents some of the energy levels for an atom of a gas.



White light passes through the gas and absorption lines are observed in the spectrum.

Which electron transition produces the absorption line corresponding to the lowest frequency?

A E_3 to E_2

B E_2 to E_3

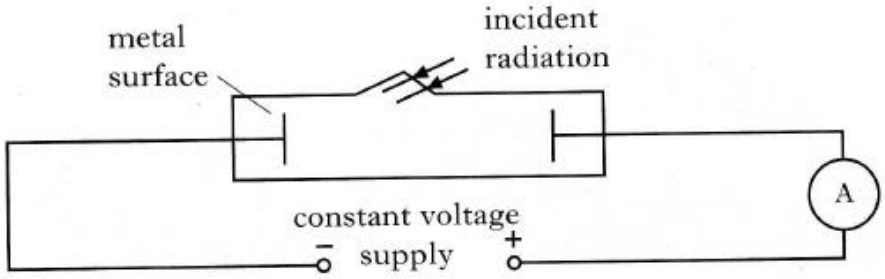
C E_1 to E_0

D E_0 to E_1

E E_0 to E_3

10. (*a*) The apparatus shown below is used to investigate photoelectric emission from a metal surface when electromagnetic radiation is shone on the surface.

The intensity and frequency of the incident radiation can be varied as required.



(i) Explain what is meant by *photoelectric emission* from a metal.

(ii) What is the name given to the minimum frequency of the radiation that produces a current in the circuit?

(iii) A particular source of radiation produces a current in the circuit.

Explain why the current in the circuit increases as the intensity of the incident radiation increases.

4

(*b*) A semiconductor chip is used to store information. The information can only be erased by exposing the chip to ultraviolet radiation for a period of time.

The following data is provided.

Frequency of ultraviolet radiation used	= $9{\cdot}0 \times 10^{14}$ Hz
Minimum intensity of ultraviolet radiation required at the chip	= 25 W m^{-2}
Area of the chip exposed to radiation	= $1{\cdot}8 \times 10^{-9}$ m^2
Time taken to erase the information	= 15 minutes
Energy of radiation needed to erase the information	= 40·5 μJ

(i) Calculate the energy of a photon of the ultraviolet radiation used.

(ii) Calculate the number of photons of the ultraviolet radiation required to erase the information.

(iii) Sunlight of intensity 25 W m^{-2}, at the chip, can also be used to erase the information.

State whether the time taken to erase the information is greater than, equal to or less than 15 minutes.

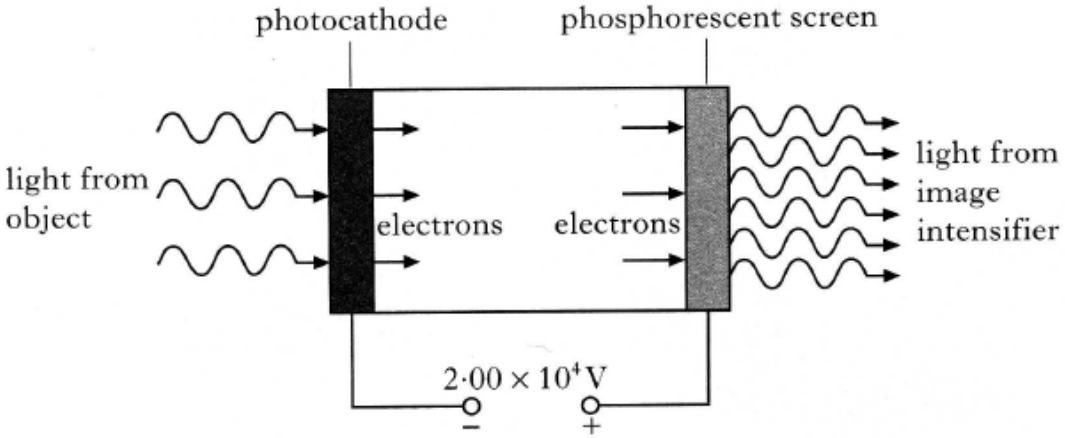
You must justify your answer.

5

(9)

11. An image intensifier is used to improve night vision. It does this by amplifying the light from an object.

Light incident on a photocathode causes the emission of photoelectrons. These electrons are accelerated by an electric field and strike a phosphorescent screen causing it to emit light. This emitted light is of a greater intensity than the light that was incident on the photocathode.



The voltage between the photocathode and the phosphorescent screen is $2{\cdot}00 \times 10^4$ V.

The minimum frequency of the incident light that allows photoemission to take place is $3{\cdot}33 \times 10^{14}$ Hz.

(*a*) What name is given to the minimum frequency of the light required for photoemission to take place? **1**

(*b*) (i) Show that the work function of the photocathode material is $2{\cdot}21 \times 10^{-19}$ J.

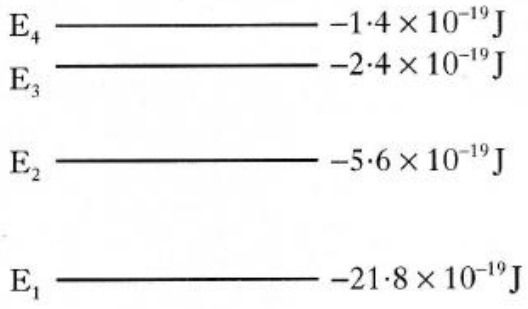
(ii) Light of frequency $5{\cdot}66 \times 10^{14}$ Hz is incident on the photocathode. Calculate the maximum kinetic energy of an electron emitted from the photocathode.

(iii) Calculate the kinetic energy gained by an electron as it is accelerated from the photocathode to the phosphorescent screen. **6**

(7)

12. (*a*) Electrons which orbit the nucleus of an atom can be considered as occupying discrete energy levels.

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



(i) The transition between which two of these energy levels produces radiation with the longest wavelength? You must justify your answer.

(ii) Calculate the frequency of the photon produced when an electron falls from E_3 to E_2. **5**

30 marks