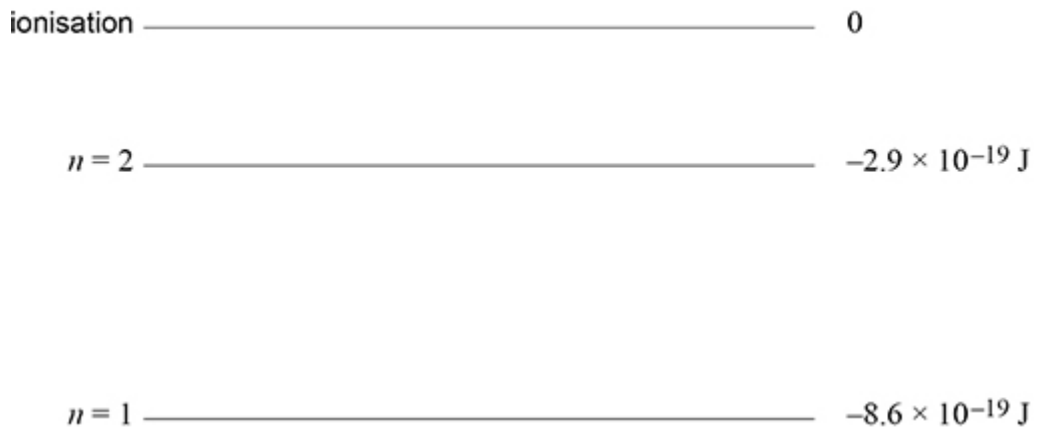
A LEVEL PHYSICS

WORKED SOLUTIONS

2.2. Electromagnetic Radiation and Quantum Phenomena MCQ

Worked Solutions by Lewis Matheson from
ALevelPhysicsOnline.com in collaboration
with **PhysicsAndMathsTutor**.com

1. Some energy levels of a lithium atom are shown below.



A free electron with kinetic energy 6.0×10^{-19} J collides with a stationary lithium atom in its $n = 1$ energy level. The lithium atom is excited to the $n = 2$ energy level.

What is the kinetic energy of the free electron after the collision?

A 0.3×10^{-19} J ●

B 2.6×10^{-19} J ○

C 3.1×10^{-19} J ○

D 5.7×10^{-19} J ○

(Total 1 mark)

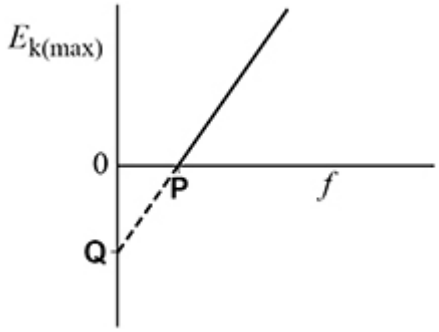
$\Delta E = E_2 - E_1 = (-2.9 - (-)8.6) \times 10^{-19}$

$= 5.7 \times 10^{-19}$ J

$\Delta E_k = 6.0 \times 10^{-19} - 5.7 \times 10^{-19}$

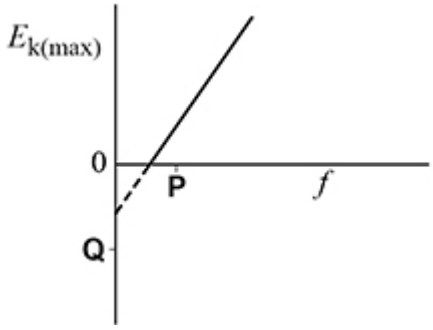
$= 0.3 \times 10^{-19}$ J

2. The graph shows how the maximum kinetic energy $Ek_{(max)}$ of photoelectrons emitted from a metal surface varies with the frequency f of the incident radiation.
P is the intercept on the f axis. **Q** is the intercept on the $Ek_{(max)}$ axis.

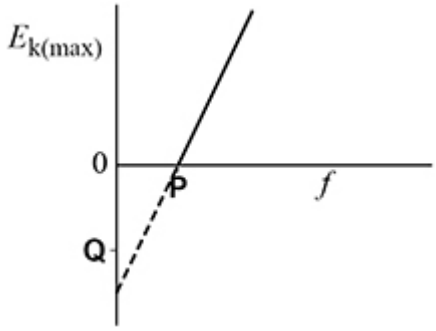


Which graph shows the variation of $Ek_{(max)}$ with f for a metal with a greater work function?

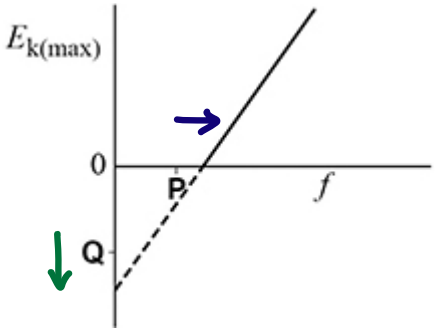
A



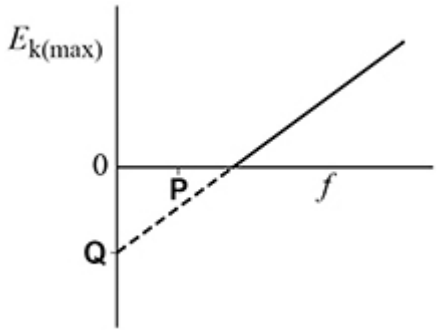
B



C



D



A ○
B ○
C ●
D ○

$\phi\uparrow \therefore f_0\uparrow \therefore$ f intercept further along to the right of P

More energy required to liberate e^-, so line will move down the $E_{k(max)}$ axis

(Total 1 mark)

3. Monochromatic light with a photon energy of 4.1×10^{-19} J is incident on a metal surface. The maximum speed of the photoelectrons released is 4.2×10^{5} m s^{-1}.

What is the work function of the metal?

$hf = \phi + E_{K(max)}$

$\phi = hf - E_{K(max)}$

$= 4.1 \times 10^{-19} - \frac{1}{2} \times 9.11 \times 10^{-31} \times (4.2 \times 10^{5})^2$

$= 3.296 \times 10^{-19}$ J

A 2.5×10^{-19} J ○

B 3.3×10^{-19} J ●

C 4.1×10^{-19} J ○

D 4.9×10^{-19} J ○

(Total 1 mark)

4. What is the role of the mercury vapour in a fluorescent tube?

A It absorbs photons of UV light and emits visible light. ○

B It absorbs photons of visible light and emits UV light. ○

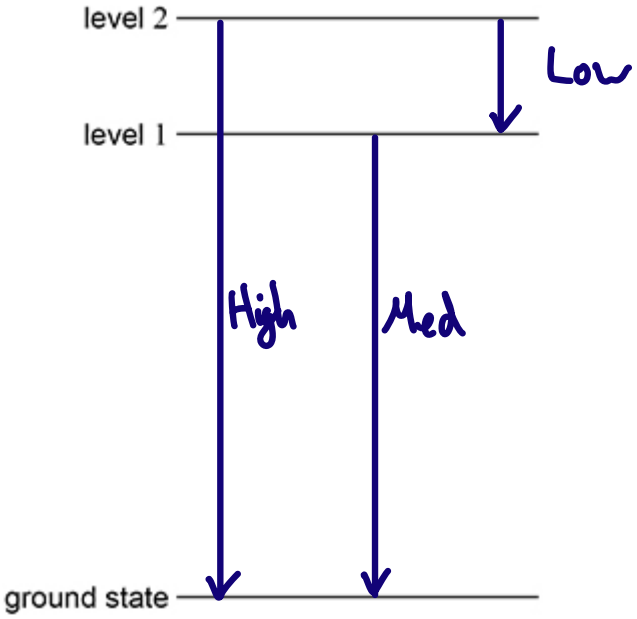
C It emits photons of visible light following ionisation or excitation. ○

D It emits photons of UV light following ionisation or excitation. ●

(Total 1 mark)

5. The diagram shows the three lowest energy levels for an atom.

The energy levels have been drawn to scale.



Transitions of electrons between these energy levels produce photons of the following frequencies:

	f	E	
4.56×10^{14} Hz	Low	Low	2 → 1
2.46×10^{15} Hz	Med	Med	1 → 0
2.92×10^{15} Hz.	High	High	2 → 0

What is the difference in energy between the ground state and energy level 1?

A 0.3×10^{-18} J ○

B 1.3×10^{-18} J ○

C 1.6×10^{-18} J ●

D 1.9×10^{-18} J ○

$E = hf$

$= 6.63 \times 10^{-34} \times 2.46 \times 10^{15}$

$= 1.63 \times 10^{-18}$ J

(Total 1 mark)

6. A muon and an electron are travelling at the same speed.

Which row gives the particle with the greater kinetic energy and the particle with the longer de Broglie wavelength?

	Greater kinetic energy	Longer de Broglie wavelength	
A	muon	~~muon~~	○
B	muon	electron	●
C	~~electron~~	~~muon~~	○
D	~~electron~~	electron	○

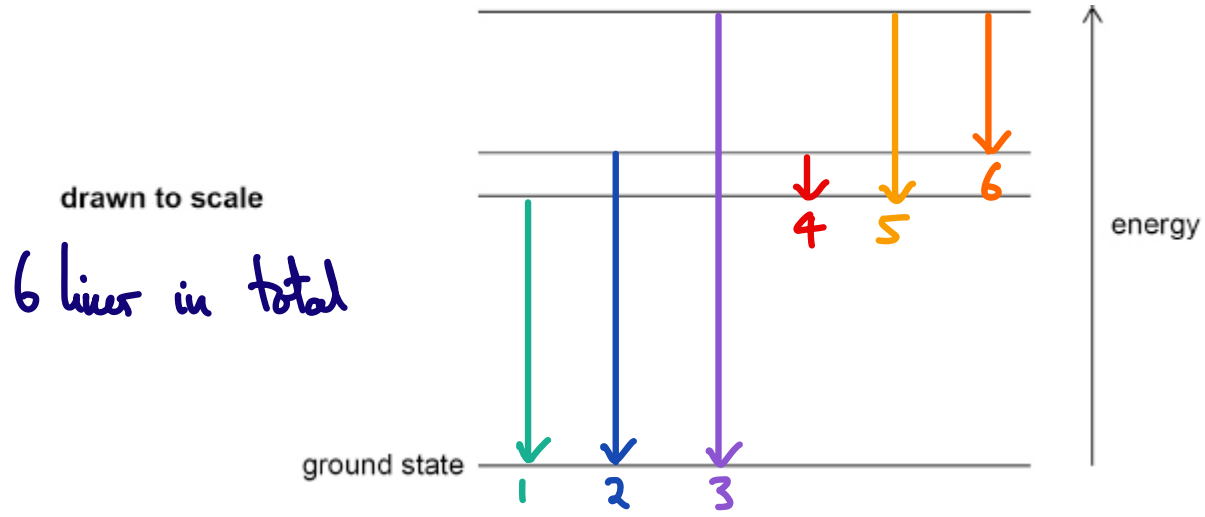
(Total 1 mark)

$E_K \propto m$ $\lambda \propto \frac{1}{p}$ and $p \propto m$

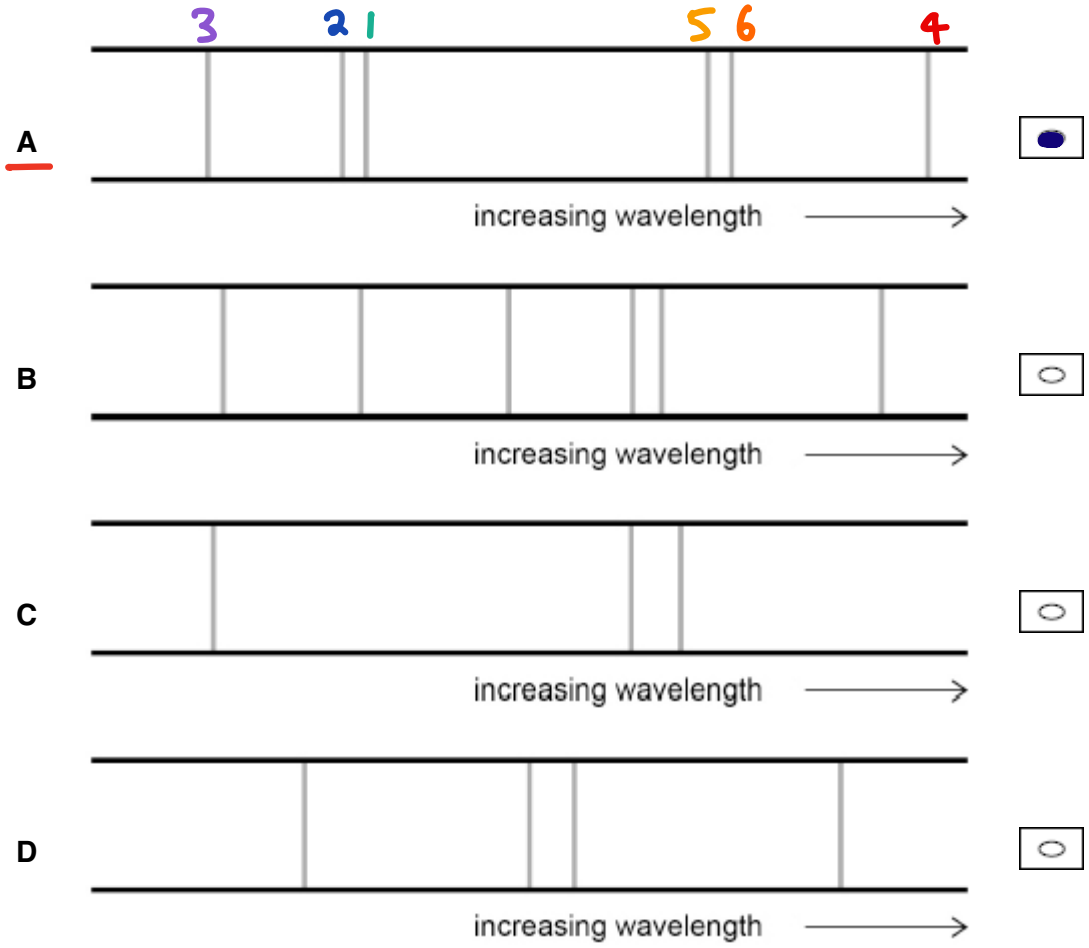
$m_\mu > m_e$

μ has greater m and p $\therefore E_K \uparrow$ and $\lambda \downarrow$

7. The diagram shows four energy levels of an atom drawn to scale. These energy levels give rise to part of an emission spectrum.



Which pattern of lines will be observed from these energy levels?



(Total 1 mark)

8. A particle has a kinetic energy of E_k and a de Broglie wavelength of λ.

What is the de Broglie wavelength when the particle has a kinetic energy of $4E_k$?

A $\frac{\lambda}{2}$ ●

B $\frac{\lambda}{\sqrt{2}}$ ○

C $\sqrt{2}\lambda$ ○

D 2λ ○

$\lambda = \frac{h}{p}$ $E_K = \frac{p^2}{2m}$ $\lambda = \frac{h}{\sqrt{2mE_k}}$

$\lambda\sqrt{E_k} = \frac{h}{\sqrt{2m}} = \text{constant}$

$\frac{\lambda_2}{\lambda_1} = \frac{\sqrt{E_{k1}}}{\sqrt{E_{k2}}}$ $\lambda_2 = \lambda\frac{\sqrt{E_K}}{\sqrt{4E_K}} = \lambda\frac{\sqrt{E_K}}{2\sqrt{E_K}} = \frac{\lambda}{2}$

(Total 1 mark)

9. A photon has energy of 1×10^{18} eV.
An object of mass 0.03 kg has kinetic energy equal to the energy of the photon.

What is the speed of the object?

A 1 m s^{-1} ○

B 3 m s^{-1} ●

C 10 m s^{-1} ○

D 30 m s^{-1} ○

$E_K = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_K}{m}} = \sqrt{\frac{2 \times 1\times10^{18} \times 1.60\times10^{-19}}{0.03}}$

$v = 3.3\ \text{m s}^{-1}$

(Total 1 mark)

10. An electron collides with an isolated atom and raises an atomic electron to a higher energy level.

Which statement is correct?

A The colliding electron is captured by the nucleus of the atom. ○

B A photon is emitted when the electron rises to the higher energy level. ○

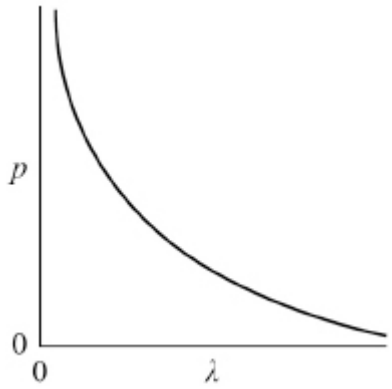
C An electron is emitted when the excited electron returns to the ground state. ○

D The colliding electron transfers energy to the atomic electron. ●

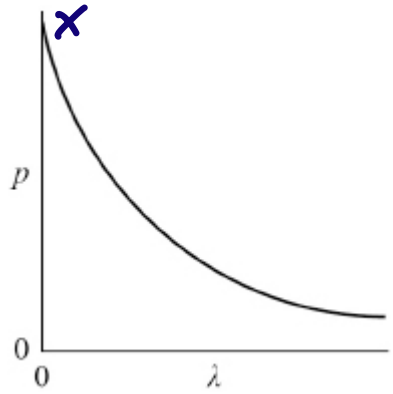
(Total 1 mark)

11. Which graph shows the variation of momentum p with wavelength λ of a photon?

A



B



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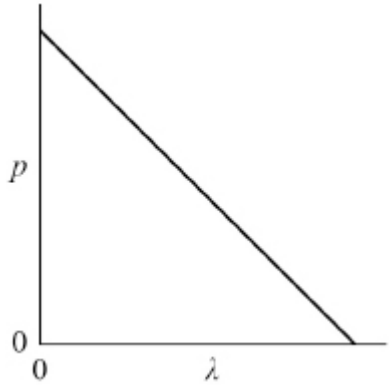

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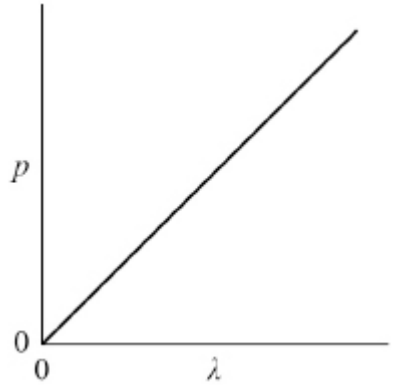


$\lambda = \frac{h}{p}$ $\lambda \propto \frac{1}{p}$

A ●

B ○

C ○

D ○

(Total 1 mark)

12. Photons of energy 1.0×10^{-18} J are incident on a metal surface and cause the emission of electrons from the metal surface.

$hf = \phi + E_{k(max)}$

Which statement about the emitted electrons is correct?

A They each have a kinetic energy of 1.0×10^{-18} J. ○

B They each have a kinetic energy that is a multiple of 1.0×10^{-18} J. ○

C Their mean kinetic energy is 1.0×10^{-18} J. ○

D The kinetic energy of each must be less than 1.0×10^{-18} J. ●

(Total 1 mark)

13. Evidence of the wave-like properties of electrons is

A the emission of electrons when short-wavelength light falls on a metal surface. ○

B the movement of electrons in an electric current. ○

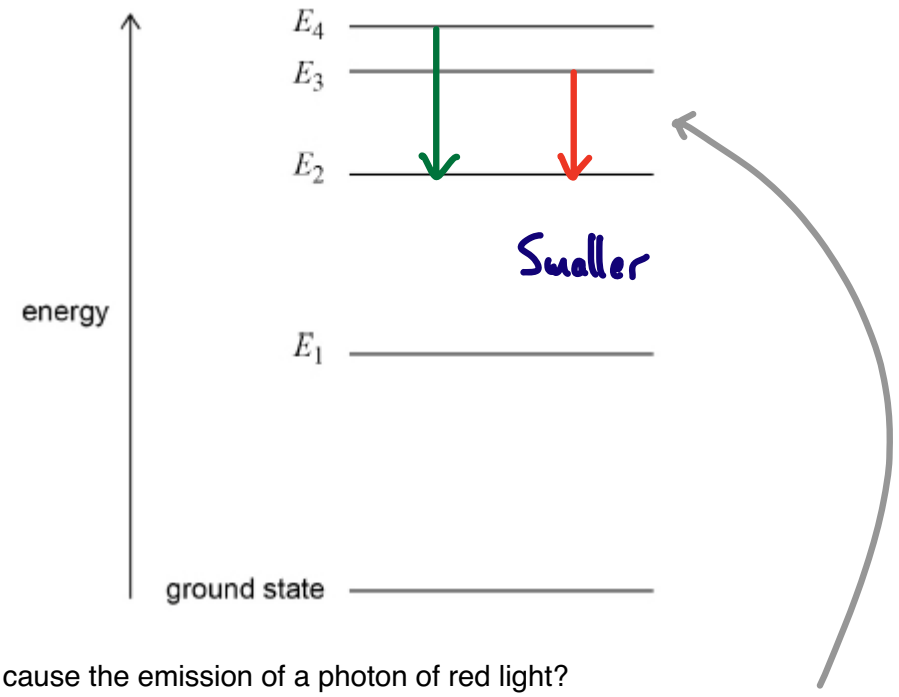
C the diffraction of electrons by a metal crystal. ●

D the annihilation of an electron with a positron. ○

(Total 1 mark)

wave behaviour

14. The diagram shows the energy levels in an atom drawn to scale. A transition from E_4 to E_2 causes the emission of a photon of green light.



Which transition could cause the emission of a photon of red light?

A E_2 to E_1 ○

B E_3 to E_1 ○

C E_3 to E_2 ●

D E_4 to E_1 ○

Red has a longer λ, lower f so a smaller energy change

(Total 1 mark)

15. An electron collides with an isolated atom and raises an orbiting electron to a higher energy level.

Which statement is correct?

A The colliding electron is captured by the nucleus of the atom. ○

B A photon is emitted when the electron rises to the higher energy level. ○

C An electron is emitted when the excited electron returns to the ground state. ○

D Energy is transferred from the colliding electron to the orbiting electron. ●

(Same as Q10)

(Total 1 mark)

16. 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?

$E = \phi + E_{k(max)}$

$E_{k(max)} = \frac{hc}{\lambda} - \phi$

$E_{k(max)} = \frac{6.63\times10^{-34} \times 3.00\times10^{8}}{290\times10^{-9} \times 1.60\times10^{-19}} - 4.1$

convert to eV

$E_{k(max)} = 0.184$ eV

A 0.19 eV ●

B 4.3 eV ○

C 6.9 eV ○

D 8.4 eV ○

(Total 1 mark)

17. 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	○

(Total 1 mark)

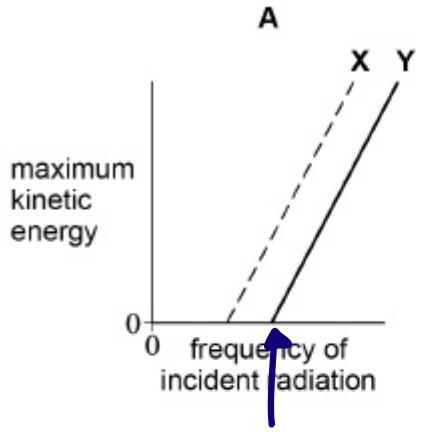
$E_{k(max)} \propto f \therefore$ unchanged

no. e^- emitted $\propto I \propto P \therefore$ doubled

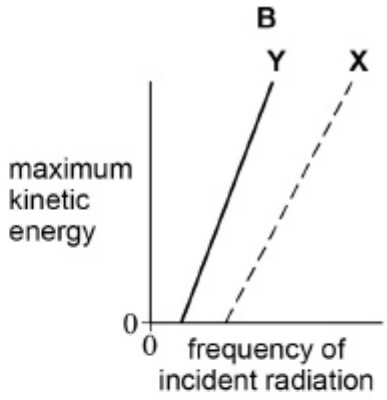
18. Line **X** on the graphs below shows how the maximum kinetic energy of emitted photoelectrons varies with the frequency of incident radiation for a particular metal.

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

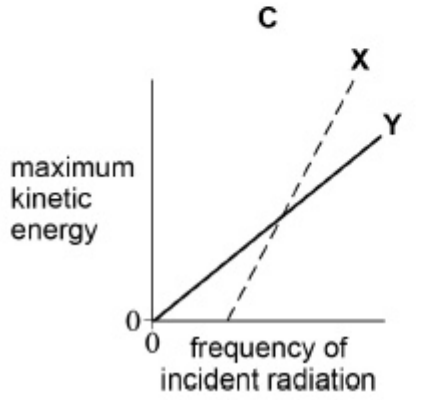
A



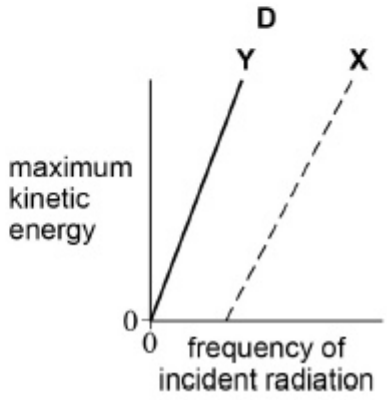
B



C



D



A ☐

B ☐

C ☐

D ☐

Higher work function ∴ intercept with x axis (frequency) increases.

(Total 1 mark)