Photoelectric effect: Observations

- Increase of light intensity leads to
  - increase of current
  - no change in maximum KE of electrons

- Increase of light frequency leads to
  - current above threshold frequency
    - (threshold frequency depends on metal)
  - linear increase of maximum KE of electrons

- Current appears with no time delay

Einstein’s postulates

1. Light consists of discrete energy quanta (“photons”) with $E = h*f$

2. One photon is absorbed (interacts)

   - by *one* electron in metal
   - *entirely* (**not** in halves, or other fraction)
   - *instantaneously*

Light consists of discrete energy quanta with $E = h*f$

Planck's constant: $h = 6.63 \times 10^{-34}$ J s

$= 4.14 \times 10^{-15}$ eV s

Approximately, what is the energy of red (f ≈ 475 THz) light quanta?

(A) 30 J

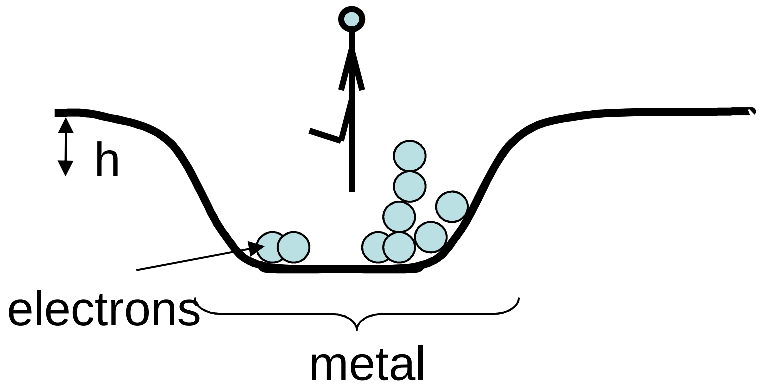
(B) 2 eV

(C) 30×10^{-34} J

(D) 2×10^{-12} eV

Photoelectric effect: Kicker analogy

Light = Kicker
kicker kicks one ball at a time
kicks always with same strength



Energy conservation:

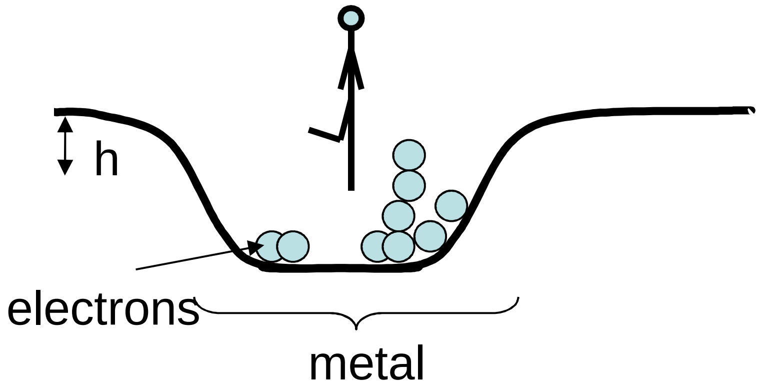
KE = kick energy
- mgh

mgh: energy to make
it up the hill and
out (for ball at top)

analogous to work
function

Photoelectric effect: Kicker analogy

Light = Kicker
kicker kicks one ball at a time
kicks always with same strength



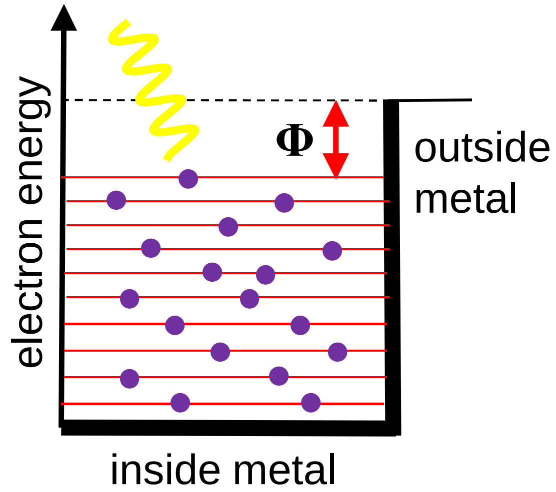
Different kicker
kick with different energy

analogous to light of different color

mgh depends on height of pit

analogous to work function on metal

Photoelectric effect



Φ: Work function
Energy needed to free most loosely bound electron

Photon energy: E = hf

Energy conservation:

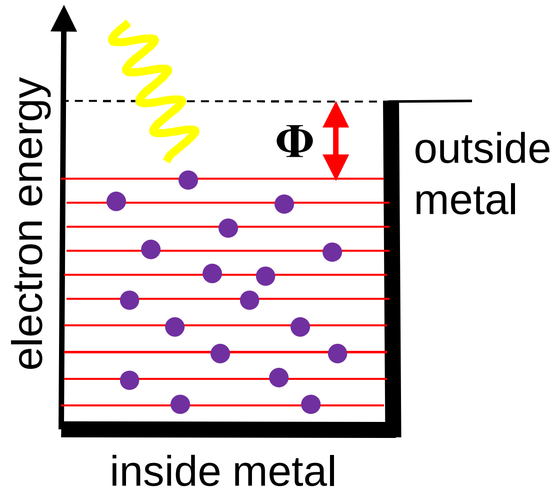
$$KE = hf - \Phi$$

→ Threshold frequency
linear dependence

If hf < Φ:
no electrons emitted
→ no current
excitation (heating)

If hf > Φ:
electrons can be
either emitted (current)
or excited (heating)

Photoelectric effect

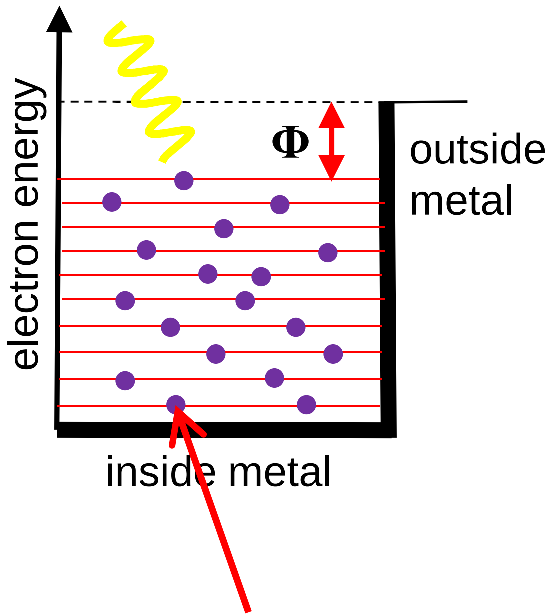


KE = hf – Φ

The work function for gold (5.1 eV) is larger than that of aluminium (4.28 eV).

The threshold wavelength to free an electron from gold is (A) larger or (B) smaller than that for aluminium.

Photoelectric effect



tightly bound electrons, need more energy to escape

Experiment (PhET simulation) shows that electrons come out with different kinetic energies.

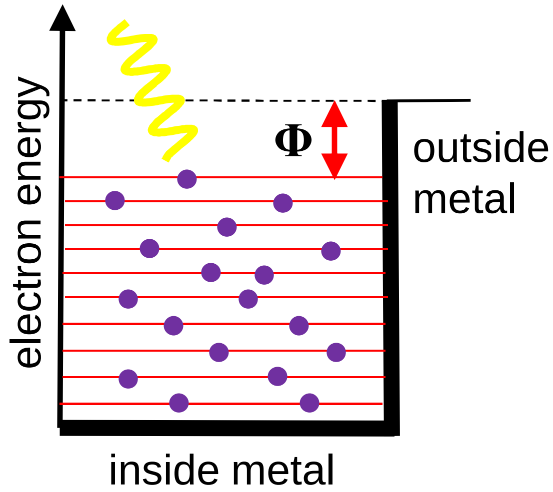
Why?

Φ: Energy to free most *loosely* bound electron

$$KE = hf - \Phi$$

Formula for *maximum* kinetic energy

Photoelectric effect



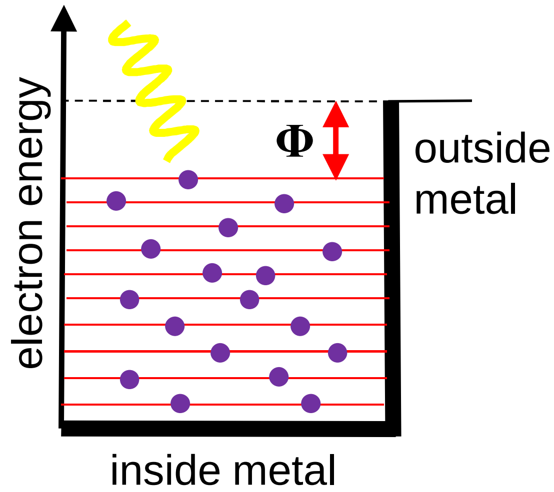
Energy conservation:

$$KE = hf - \Phi$$

(Maximum) kinetic energy does not depend on light intensity

→ Stopping voltage is independent of intensity

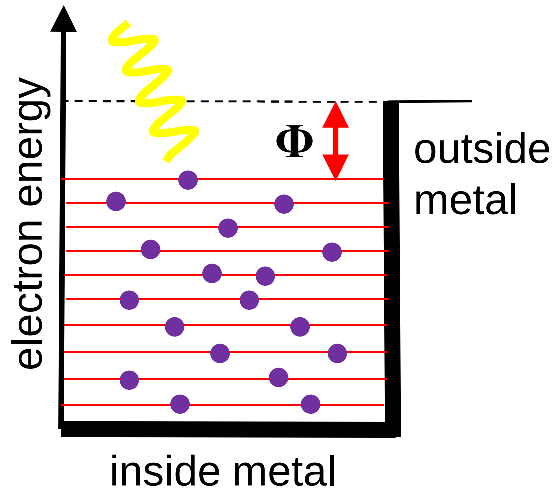
Photoelectric effect



intensity =
(N*h*f) / (time*area)

Intensity
~ number of light quanta
~ number of absorbed light quanta
~ number of ejected electrons
~ current

Photoelectric effect



Each energy quantum
is absorbed

instantaneously

by one electron in metal

→ No time delay

Light as energy quanta vs. observations

- Increase of light intensity leads to
  increase of current and ✓
  no change in maximum KE of electrons ✓

- Increase of light frequency leads to
  current above threshold frequency ✓
  (threshold frequency depends on metal) ✓
  linear increase of maximum KE of electrons ✓

- Current appears with no time delay ✓