Higher Physics – Unit 3

3.3 Optoelectronics and Semiconductors

Irradiance of Light

The **irradiance** (I) of light is defined as the **power per unit area**.

irradiance ($W\ m^{-2}$)

$$I = \frac{P}{A}$$

power (W)

area (m^2)

(note: you may sometimes see irradiance referred to as intensity, particularly in older texts)

Example 1

Light of power 15W falls on an area of $0.5 m^2$. Calculate the irradiance of the light.

$$P = 15\ W$$

$$A = 0.5\ m^2$$

$$I = ?$$

$$I = \frac{P}{A}$$

$$= \frac{15}{0.5}$$

$$I = 30\ W\ m^{-2}$$

Example 2

8 mJ of light energy is incident on a 6 cm x 4 cm rectangular solar cell every second. Calculate the irradiance on the solar cell.

Area

$$A = l \times b$$
$$= (6 \times 10^{-2}) \times (4 \times 10^{-2})$$
$$A = 0.0024\ \text{m}^2$$

Irradiance

$$A = 0.0024\ \text{m}^2$$
$$P = 8\ \text{mW}$$
$$= 8 \times 10^{-3}\ \text{W}$$

8 mJ per second = 8mW of power

Since 1 W = 1 J s^{-1}

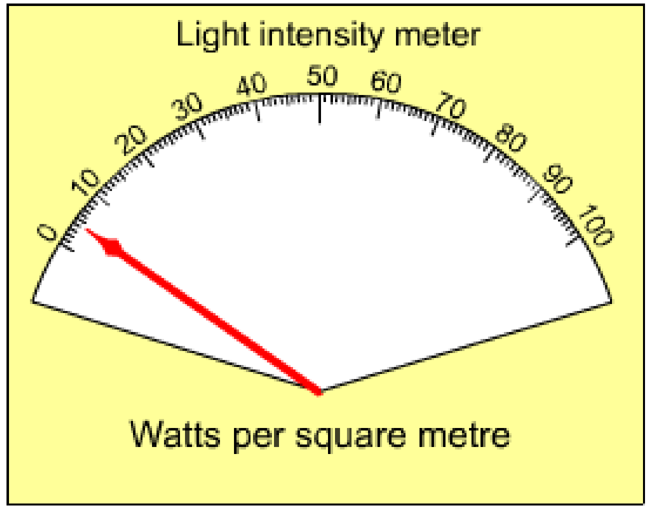
$$I = \frac{P}{A}$$
$$= \frac{8 \times 10^{-3}}{0.0024}$$
$$I = 3.2\ \text{W m}^{-2}$$

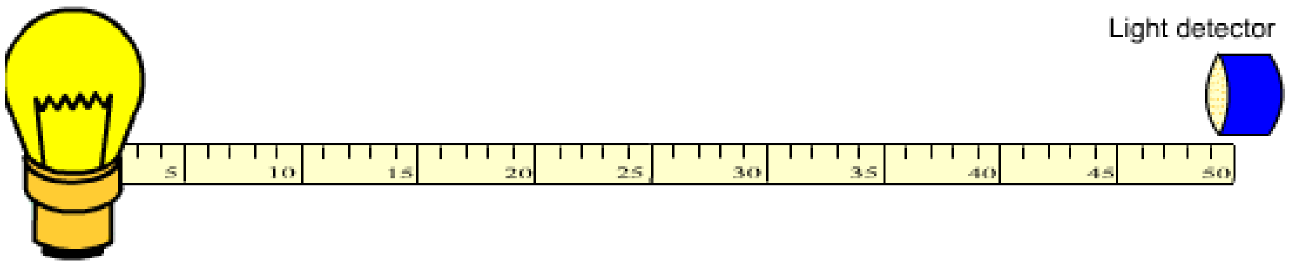
Light, Irradiance, Distance

Aim

To find the relationship between irradiance of a light source and distance.

Method





The light detector is moved to **different distances** from the light source and is measured using a **metre stick**.

The **irradiance** of light at different distances is measured using a **light intensity meter**.

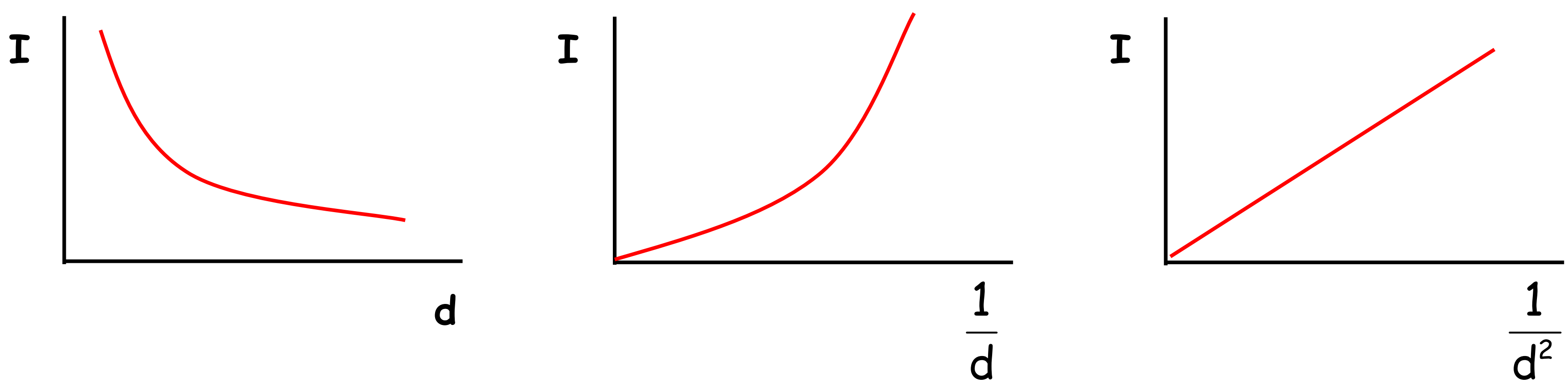
Results

distance (m)	irradiance (Wm^{-2})	d^2	$I\ d^2$

Graph of Results

Plot the following graphs:

1. distance against irradiance
2. 1/distance against irradiance
3. 1/distance^2 against irradiance



Conclusion

$$I\,d^2 = \text{constant}$$

$$I \propto \frac{1}{d^2}$$

The **irradiance** of light from a light source is **inversely proportional** to the **square of** the **distance** from the light source.

This is known as the **inverse square law**.

$$I_1\,d_1^{\,2} = I_2\,d_2^{\,2}$$

The inverse square law **only** applies to **point sources**.

Example 1

The irradiance of light is 48 W m^{-2} at a distance of 3 m from a light source.

(a) Calculate the irradiance of light at a distance of 9 m from the light source.

(b) Calculate the distance from the light source at which the irradiance of light is 60 W m^{-2}.

(c) State one assumption that is made.

(a)

$$I_1 = 48 \text{ W m}^{-2}$$
$$d_1 = 3 \text{ m}$$
$$d_2 = 9 \text{ m}$$
$$I_2 = ?$$

$$I = \frac{k}{d^2}$$
$$I_1 d_1^2 = I_2 d_2^2$$
$$48 \times 3^2 = I_2 \times 9^2$$
$$I_2 = \frac{432}{81}$$
$$I_2 = 5.3 \text{ W m}^{-2}$$

(b)

$$I_1 = 48 \text{ W m}^{-2}$$
$$d_1 = 3 \text{ m}$$
$$I_2 = 60 \text{ W m}^{-2}$$
$$d_2 = ?$$

$$I = \frac{k}{d^2}$$
$$I_1 d_1^{\ 2} = I_2 d_2^{\ 2}$$
$$48 \times 3^2 = 60 \times d_2^{\ 2}$$
$$d_2^{\ 2} = \frac{432}{60}$$
$$d_2^{\ 2} = 7.2$$
$$d_2 = 2.7 \text{ m}$$

(c) Assumption made is that the light is a **point source**.

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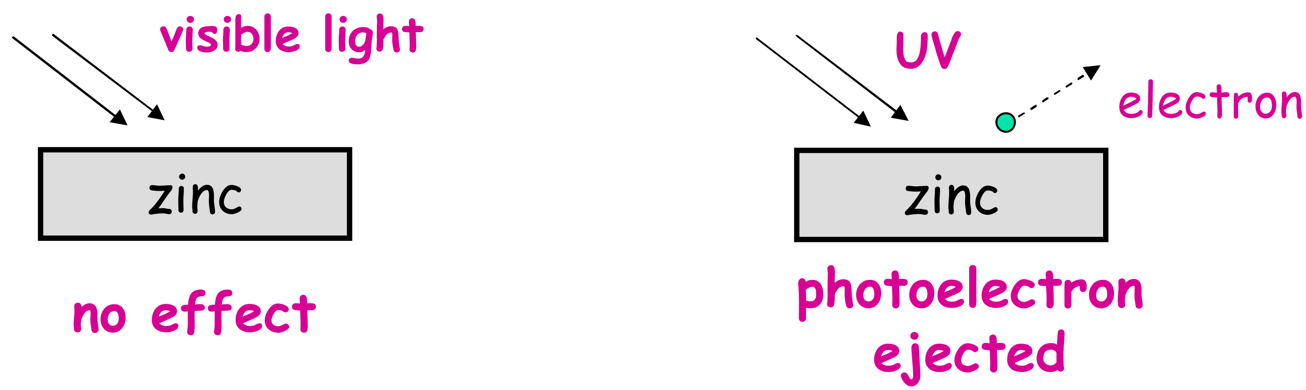
Q37 - Q44

Photoelectric Effect

Photoelectric emission occurs when a **single photon** of electromagnetic **radiation** has a **high enough energy and frequency** to **knock** an **electron** out from the **surface** of a metal.



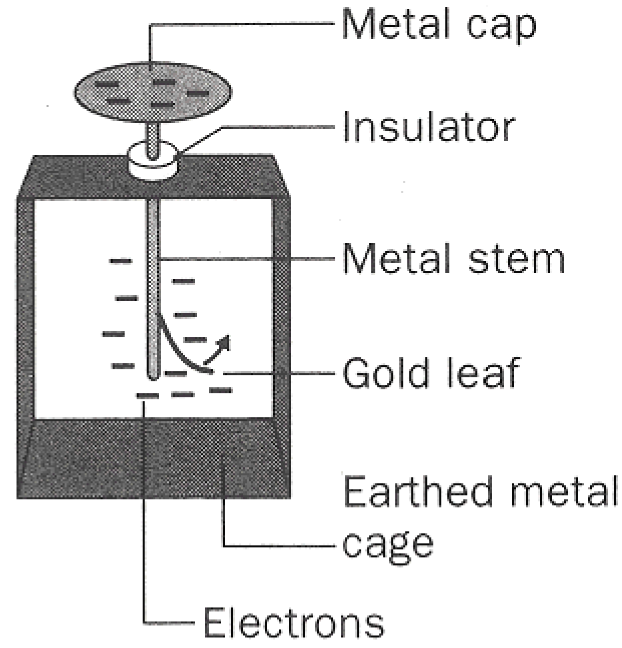
e.g. UV light can be used to eject electrons from zinc but visible light cannot do this (not high enough frequency).

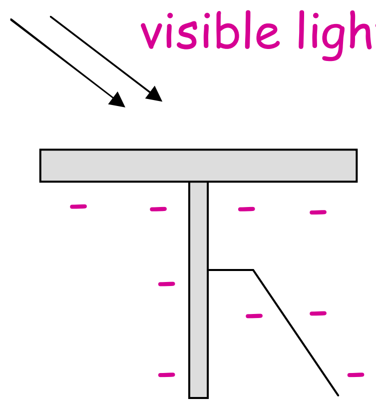
Experiment

An electroscope can be used to demonstrate this.

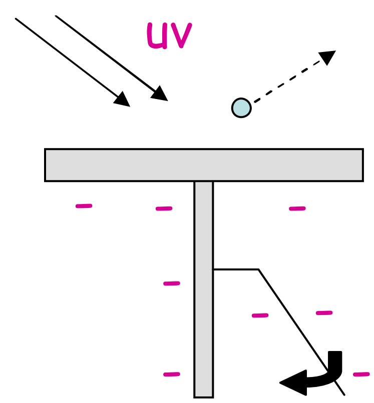
First it is charged negatively (this causes the gold leaf to be repelled).

If the leaf falls when light is incident on the metal, then the electroscope has lost some charge.





no effect



Leaf falls

Electrons have been ejected.

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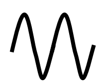
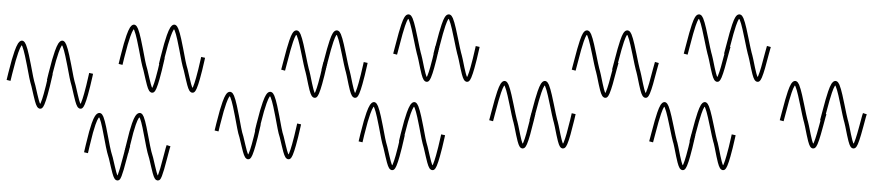
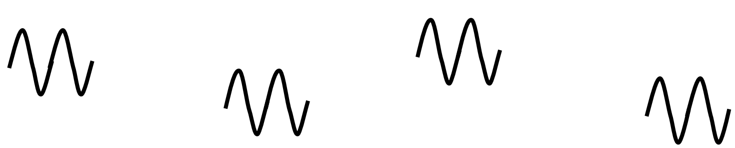
Photons

Light exhibits properties of both a **wave** (interference) and a **particle** (photoelectric effect).

Planck and Einstein explained electromagnetic radiation in terms of small **bundles** (or particles) **of wave energy**, called **photons**.


photon

intense light

lots of photons per s

dim light

few photons per second

Energy of a Photon

The energy, E of a photon is proportional to its frequency and is given by:

$$E = h f$$

Energy (J)

Planck's constant
(6.63×10^{-34} J s)

frequency (Hz)

Example 1

Calculate the energy of a photon whose frequency is 8×10^{14} Hz.

$$f = 8 \times 10^{14} \text{ Hz}$$

$$h = 6.63 \times 10^{-34} \text{ J s}$$

$$E = ?$$

$$E = h\,f$$

$$= \left(6.63 \times 10^{-34}\right) \times \left(8 \times 10^{14}\right)$$

$$E = 5.3 \times 10^{-19} \text{ J}$$

Example 2

Calculate the energy of a photon of red light with wavelength 700nm.

$$\lambda = 700\,nm$$
$$= 700 \times 10^{-9}\ m$$
$$v = 3 \times 10^{8}\ ms^{-1}$$
$$f = ?$$

$$v = f\lambda$$
$$3 \times 10^{8} = f \times (700 \times 10^{-9})$$
$$f = 4.29 \times 10^{14}\ Hz$$

$$f = 4.29 \times 10^{14}\ Hz$$
$$h = 6.63 \times 10^{-34}\ J\ s$$
$$E = ?$$

$$E = hf$$
$$= (6.63 \times 10^{-34}) \times (4.29 \times 10^{14})$$
$$E = 2.84 \times 10^{-19}\ J$$

Photons and Irradiance

When N photons per second are incident on a surface the irradiance of radiation is given by:

$$I = Nhf$$

Irradiance (W m^{-2})

Frequency (Hz)

Number of Photons per second per square metre

Planck's Constant (6.63×10^{-34} Js)

Work Function

When a photon is absorbed **all its energy** is given to **one electron**.

Photoemission occurs if **one electron** can **gain enough energy** from **one photon** to escape from the metal.

The **minimum energy** needed is called the **work function (w)**.

Metals all have **different values** of **work function**.

$hf \geq w$ photoelectron ejected

$hf < w$ no photoelectron

Example

A metal has a work function of 2.8×10^{-19} J. Will light of frequency 7×10^{14} Hz cause an electron to be ejected?

$$f = 7 \times 10^{14} \text{ Hz}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$E = ?$$

$$E = h\,f$$
$$= \left(6.63 \times 10^{-34}\right) \times \left(7 \times 10^{14}\right)$$
$$E = 4.6 \times 10^{-19}\,\text{J}$$

$h\,f > w$ so an electron is ejected

Threshold Frequency

The **threshold frequency, f_o** is the **minimum frequency** required to cause **photoemission**.

From: $E = h\,f$

minimum energy = h x minimum frequency

work function = $h\,f_0$

$$w = h\,f_0$$

work function (J)

Planck's constant (J s)

threshold frequency (Hz)

Example

(a) Calculate the threshold frequency of a metal with work function 2.8×10^{-19} J.

(b) What type of light is this?

(a)

$w = 2.8\times10^{-19}\ J$

$h = 6.63\times10^{-34}\ Js$

$f_o = ?$

$$w = h\,f_o$$

$$2.8\times10^{-19} = \left(6.63\times10^{-34}\right)\times f_o$$

$$\underline{\underline{f_o = 4.2\times10^{14}\,Hz}}$$

(b)

$v = 3\times10^{8}\ ms^{-1}$

$f = 4.2\times10^{14}\ Hz$

$\lambda = ?$

$$v = f\,\lambda$$

$$3\times10^{8} = \left(4.2\times10^{14}\right)\lambda$$

$$\lambda = \frac{3\times10^{8}}{4.2\times10^{14}}$$

$$\underline{\underline{\lambda = 714\times10^{-9}\ m}}$$

$\therefore$ red light

Kinetic Energy of the Photoelectron

If the **incident photon** has a **higher frequency** than **f_o** it has **more energy** than the **work function** (the minimum required to release the electron).

The **extra energy** is given to the electron as **kinetic** energy.

$$h f = h f_0 + E_k$$

Energy of incident photon (J)

work function (J)

kinetic energy of electron (J)

$$E_k = h f - w$$

Example 1

A metal has a work function of 2.9×10^{-19} J.

(a) Will light of frequency 3.5×10^{15} Hz cause photoemission?

(b) Calculate the kinetic energy of a photoelectron.

(a)

$$f = 3.5 \times 10^{15} \text{ Hz}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$E = ?$$

$$E = h\,f$$
$$= \left(6.63 \times 10^{-34}\right) \times \left(3.5 \times 10^{15}\right)$$
$$E = 2.32 \times 10^{-18}\,\text{J}$$
$$E = 23.2 \times 10^{-19}\,\text{J}$$

Photoemission **WILL** take place

(b) $f = 3.5\times10^{15}$ Hz

$h = 6.63\times10^{-34}$ Js

$w = 2.9\times10^{-19}$ J

$E_K = ?$

$$E_K = hf - w$$

$$= (6.63\times10^{-34})\times(3.5\times10^{15}) - 2.9\times10^{-19}$$

$$E_K = 2.03\times10^{-18}\ \text{J}$$

Example 2

A metal has a work function of 3.4×10^{-19} J.

A photon of frequency 8.4×10^{14} Hz causes photoemission.

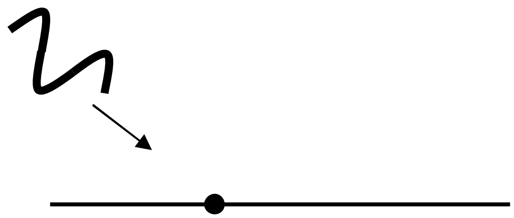
Calculate the kinetic energy of this photoelectron.

$$w = 3.4\times10^{-19}\ \text{J}$$
$$f = 8.4\times10^{14}\ \text{Hz}$$
$$h = 6.63\times10^{-34}\ \text{Js}$$
$$E_K = ?$$

$$E_K = h\,f - w$$
$$= (6.63\times10^{-34})\times(8.4\times10^{14}) - 3.4\times10^{-19}$$
$$E_K = 2.17\times10^{-19}\ \text{J}$$

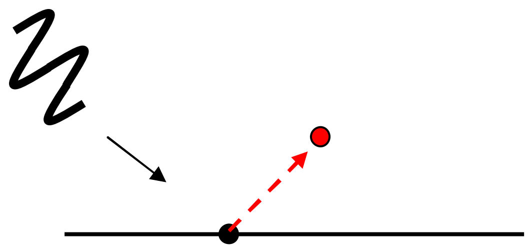
Properties of the photoelectric effect

$f < f_0$



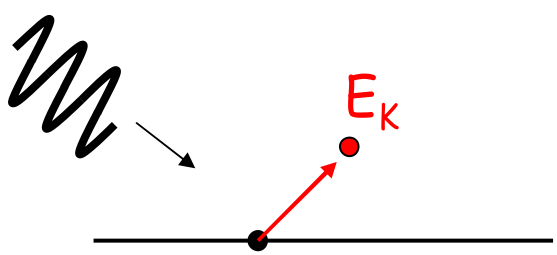
electron NOT ejected

$f = f_0$



electron IS ejected

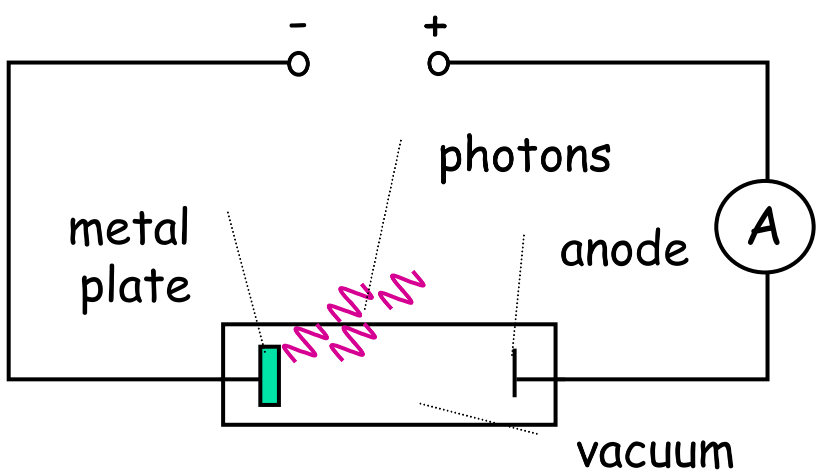
$f > f_0$



electron IS ejected with kinetic energy E_K

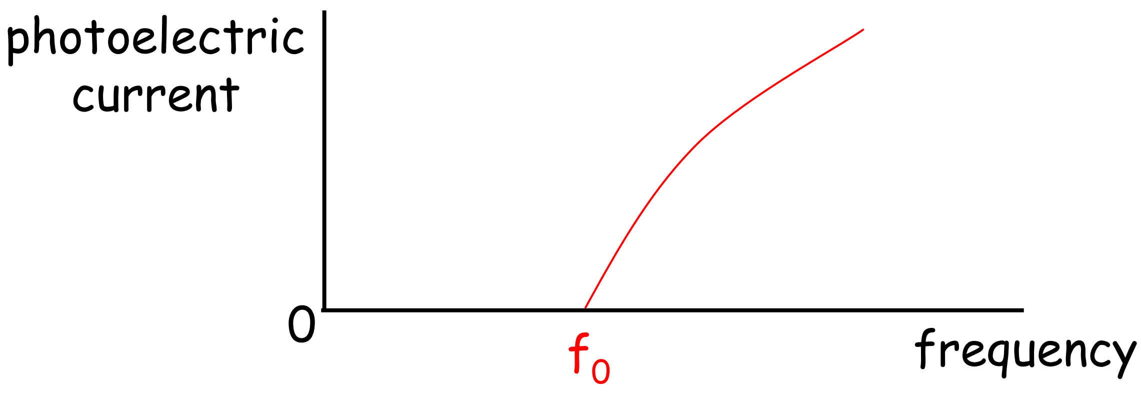
Photoelectric Current

A metal plate is illuminated by electromagnetic radiation of different frequencies:



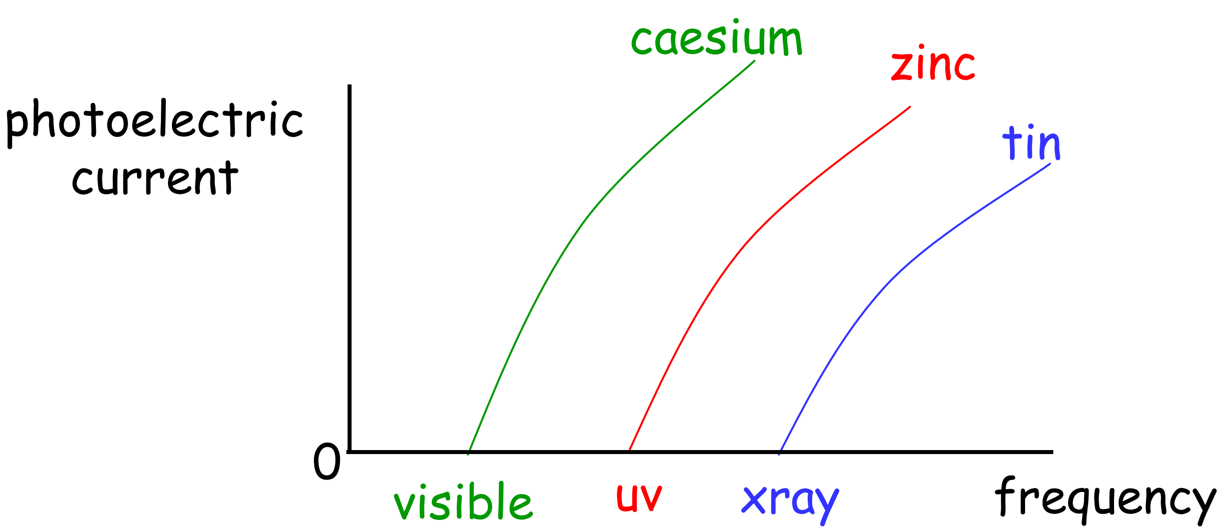
Photoelectrons ejected from the metal plate will **move** to the anode and create a **current** (measured by the ammeter).

The graph shows how the **photoelectric current** varies with the **frequency** of the photons.



f_0 is the **threshold frequency** for photoemisson for that metal.

Different **metals** have **different threshold frequencies** for photoemission.



http://www.youtube.com/watch?v=RlPvzn5sG30

http://www.youtube.com/watch?v=YBxlmPHcm5c

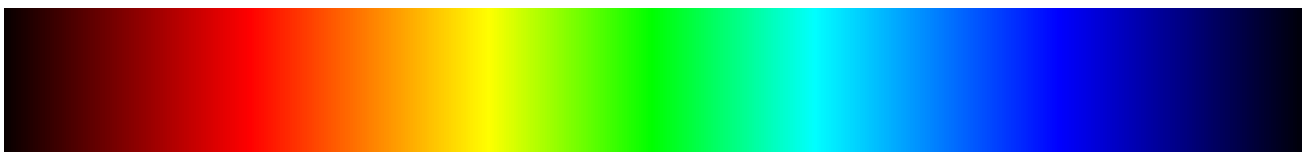
(from 2mins 20 in)

P&N Booklet

Q46 - 56

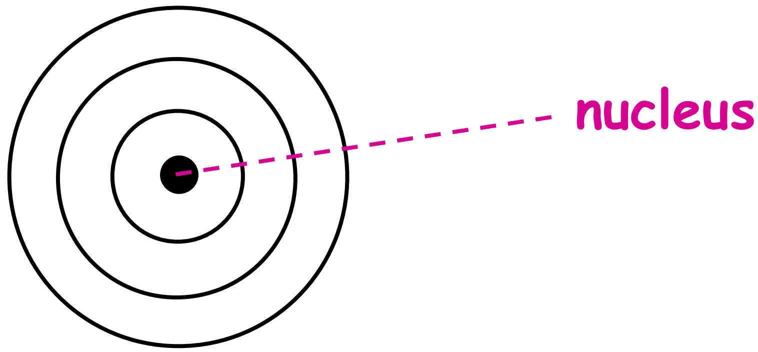
Line Spectra

Examining **white light** (day light) through a spectroscope shows a **continuous spectrum**.



When light is examined from a sodium lamp, it is found to consist of a series of narrow lines of light. The brightest being a yellow-orange line.

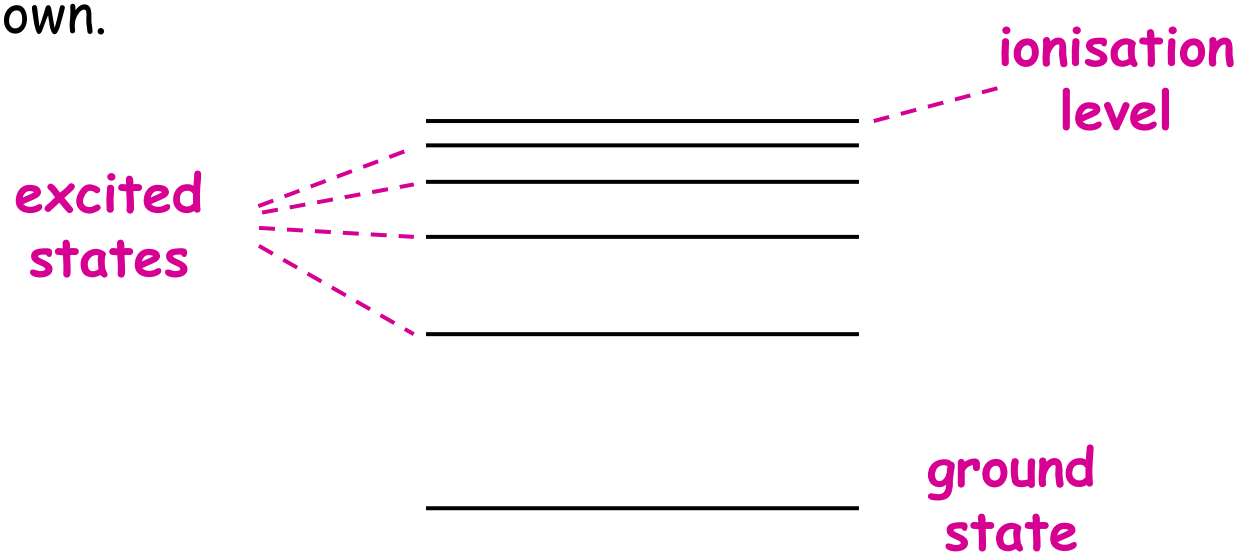
The line spectra is explained in terms of orbiting electrons.



If an electron takes in (absorbs) energy it can jump to a higher orbit or energy level.

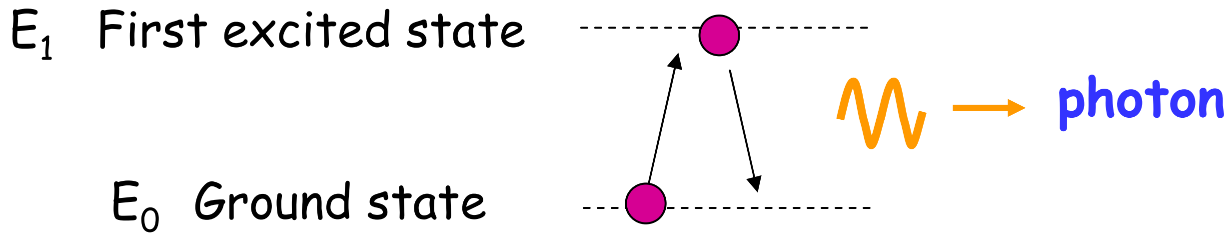
If an electron loses energy it falls to a lower orbit or energy level and emits light.

The **energy levels** in an atom are often represented by **horizontal lines** as shown.



Energy levels are spaced further apart near ground state and closer near the ionisation level.

When an **electron** takes in (**absorbs**) **energy** and jumps to a **higher orbit** the electron is said to be **excited**.

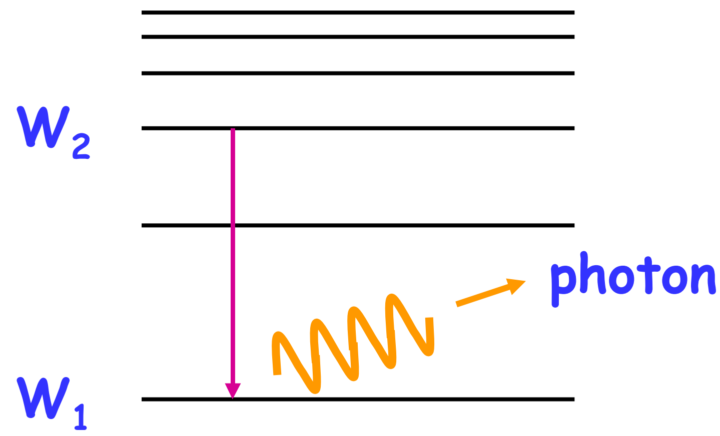


Line (emission) **spectra** are produced when **electrons fall** from excited states to **lower energy levels**.

The line appears **brighter** if **more electrons** make a particular transition.

Energy of Emitted Photon

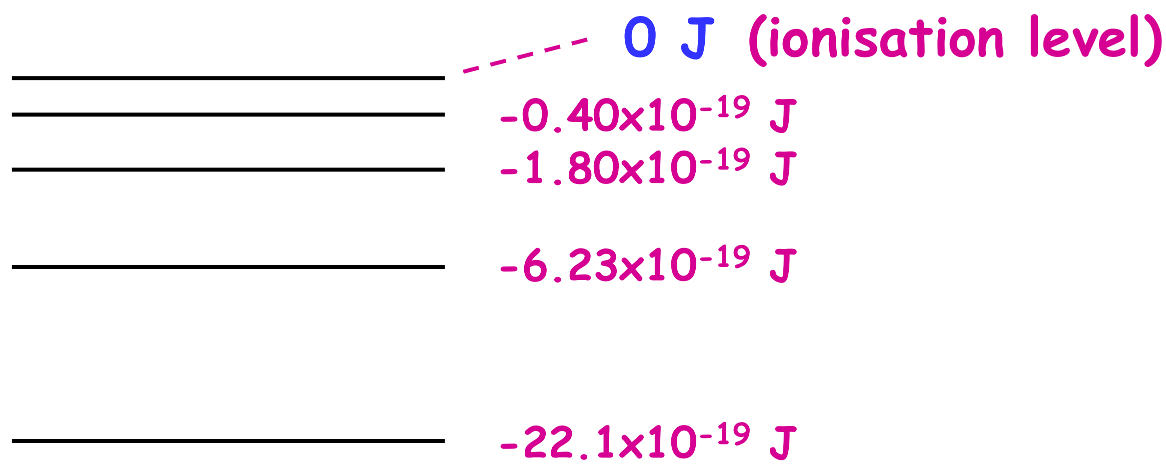
As an **electron falls** to a lower energy level, a **photon** is created. The **electron energy** is converted to the **photon**.



The energy of the photon is equal to the difference between the energy levels.

$$h\,f = W_2 - W_1$$

Energy Levels



An **electron** which has just been **removed** from the atom is considered to have **zero energy**.

In order to promote an electron to this state, energy must be given to the electron.

Since **energy** is **added** to reach **zero**, the electron must initially have a **negative level of energy**.

Example

The energy level diagram of an element is shown.

- - - - - - - - - - - E_2 = -9.4×10^{-19} J

- - - - - - - - - - - E_1 = -15.7×10^{-19} J

- - - - - - - - - - - E_0 = $-18.5 \times \times 10^{-19}$ J

(a) Calculate the frequency and wavelength of the spectral line associated with the transition $E_1 \rightarrow E_0$.

$$hf = W_2 - W_1$$
$$= -15.7 \times 10^{-19} - (-18.5 \times 10^{-19})$$
$$\underline{\underline{hf = 2.8 \times 10^{-19}\ J}}$$

Frequency

$$h = 6.63 \times 10^{-34}\ \text{Js}$$
$$E = 2.8 \times 10^{-19}\ \text{J}$$
$$f = ?$$

$$E = h\,f$$
$$2.8 \times 10^{-19} = \left(6.63 \times 10^{-34}\right) \times f$$
$$\underline{\underline{f = 4.2 \times 10^{14}\ \text{Hz}}}$$

Wavelength

$$v = 3 \times 10^{8}\ \text{ms}^{-1}$$
$$f = 4.2 \times 10^{14}\ \text{Hz}$$
$$\lambda = ?$$

$$v = f\,\lambda$$
$$3 \times 10^{8} = \left(4.2 \times 10^{14}\right) \times \lambda$$
$$\lambda = 714 \times 10^{-9}\ \text{m}$$
$$\underline{\underline{\lambda = 714\ \text{nm}}}$$

(b) Which transition corresponds to the highest frequency line?

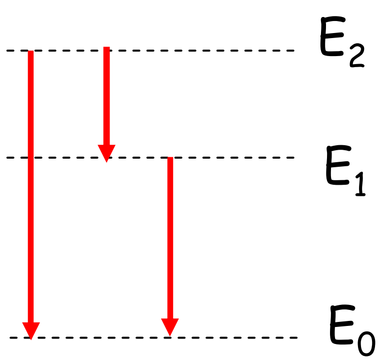
$E_2 = -9.4 \times 10^{-19}$ J

$E_1 = -15.7 \times 10^{-19}$ J

$E_0 = -18.5 \times \times 10^{-19}$ J

$E_2 \rightarrow E_0$ as it has the greatest energy (from $E = hf$).

(c) How many emission lines are produced by transitions between these levels.

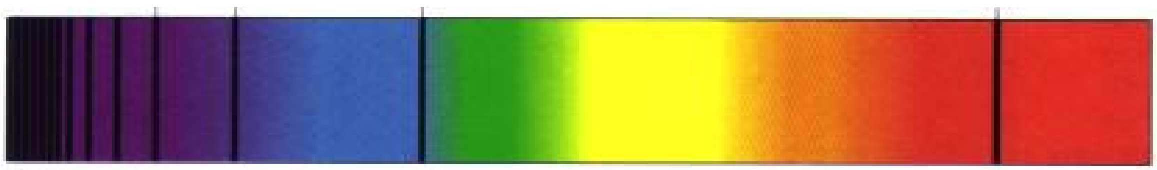


3 emission lines.

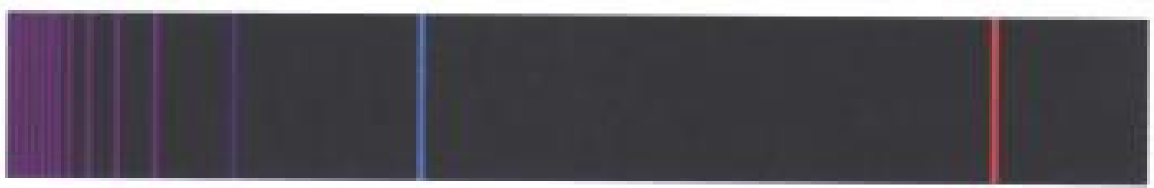
Absorption Spectra

An **absorption spectrum** is a visible spectrum with **dark lines** in it.

absorption spectra



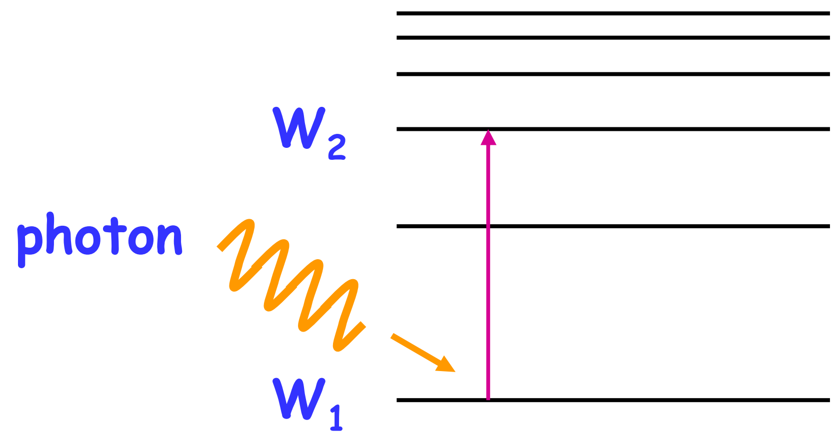
line emission spectra



Absorption spectra are produced when **electrons absorb energy** from a photon of radiation and **move up energy levels**.

Energy Absorbed

Only **photons** whose **energy** corresponds to the **exact** value in the **difference** between energy **levels** are absorbed.

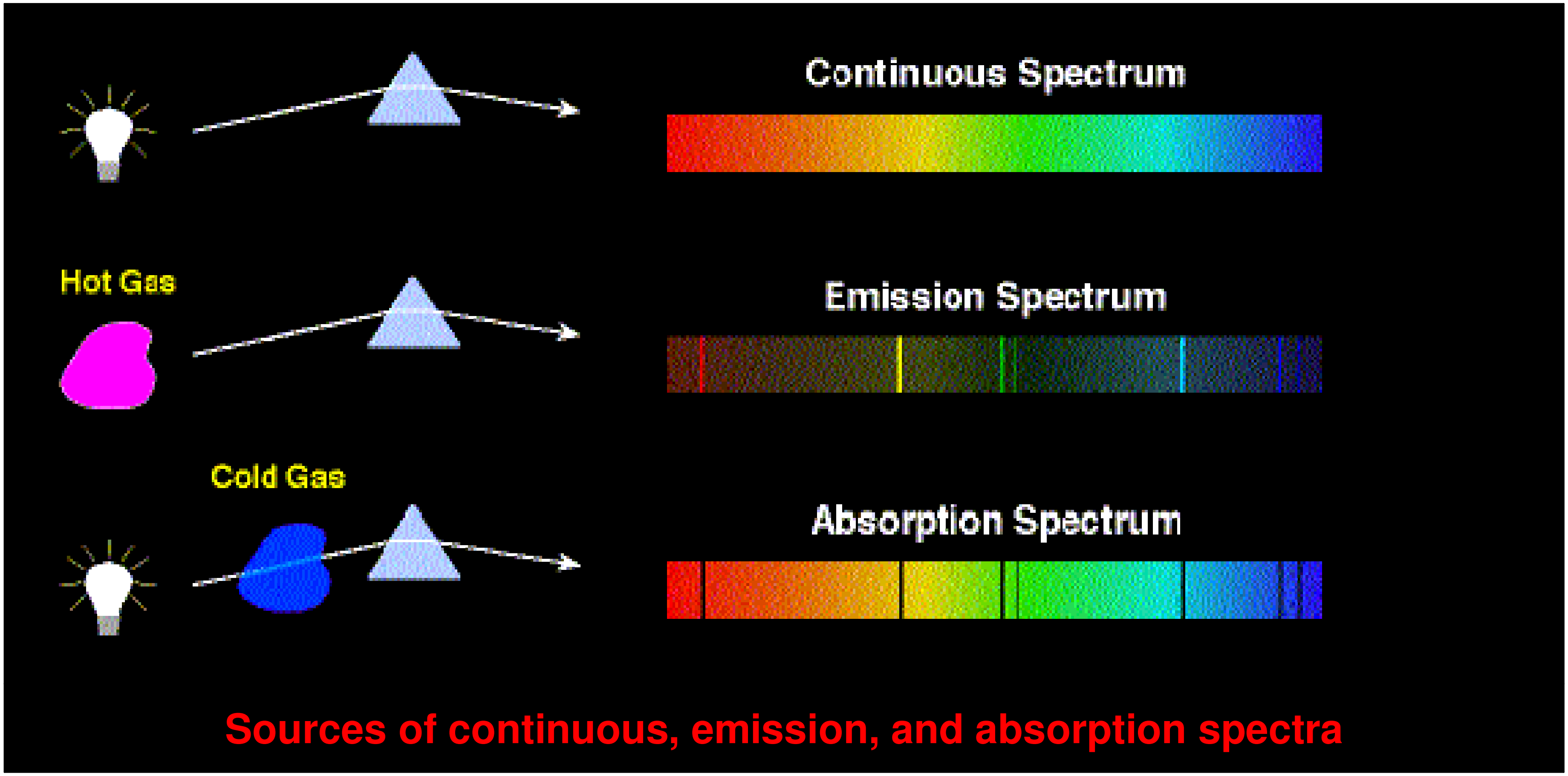


The amount of **energy absorbed** by the electron is given by

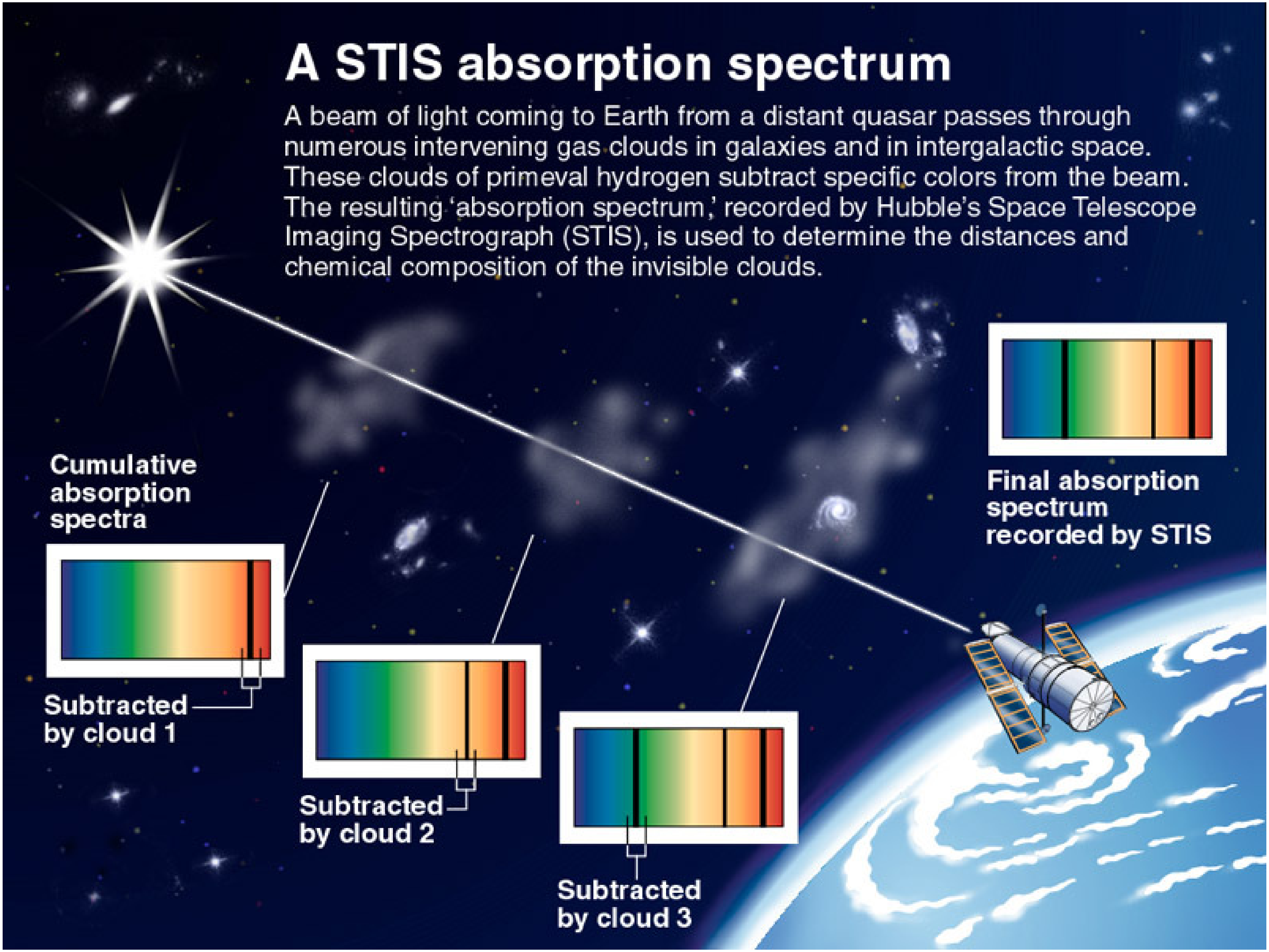
$$hf = W_2 - W_1$$

Producing Absorption Spectra

Absorption spectra are produced by passing white light through low pressure gas.



Absorption Spectra for Gases


A STIS absorption spectrum
A beam of light coming to Earth from a distant quasar passes through numerous intervening gas clouds in galaxies and in intergalactic space. These clouds of primeval hydrogen subtract specific colors from the beam. The resulting 'absorption spectrum,' recorded by Hubble's Space Telescope Imaging Spectrograph (STIS), is used to determine the distances and chemical composition of the invisible clouds.
Cumulative absorption spectra
Subtracted by cloud 1
Subtracted by cloud 2
Subtracted by cloud 3
Final absorption spectrum recorded by STIS

P&N Booklet

Q57 - 60 and 63

Purple Book

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Q1, 3, 6, 7, 9, 10

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Q1 - 8

Type of Emission

When an electron is in an **excited state** and **falls** to a lower level a **photon** is **emitted**.

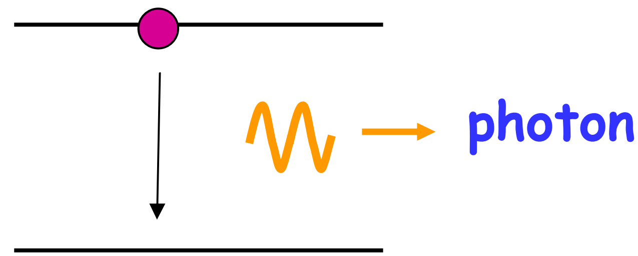
The **two types** of emission are:

- **spontaneous** emission
- **stimulated** emission

Spontaneous Emission

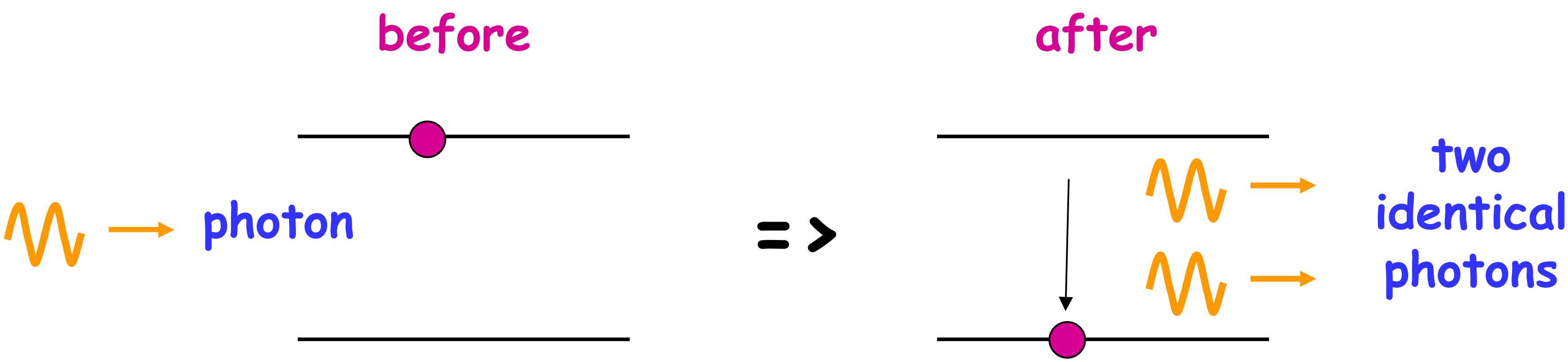
Spontaneous emission is a **random** process.

It is completely random and the time at which it happens **cannot be predicted**.



Stimulated Emission

Stimulated emission occurs when an **incident photon** causes an identical photon to be released.



The incident and emitted radiation are both

- **in phase**
- travelling in **same direction**

Lasers

The word laser means

Light

Amplification by

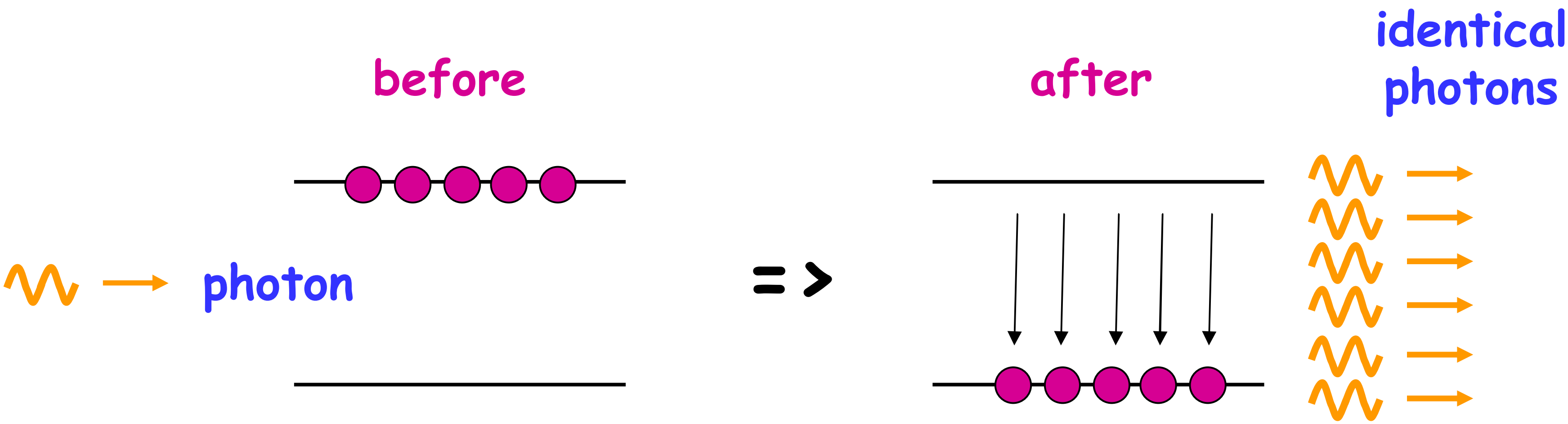
Stimulated

Emission of

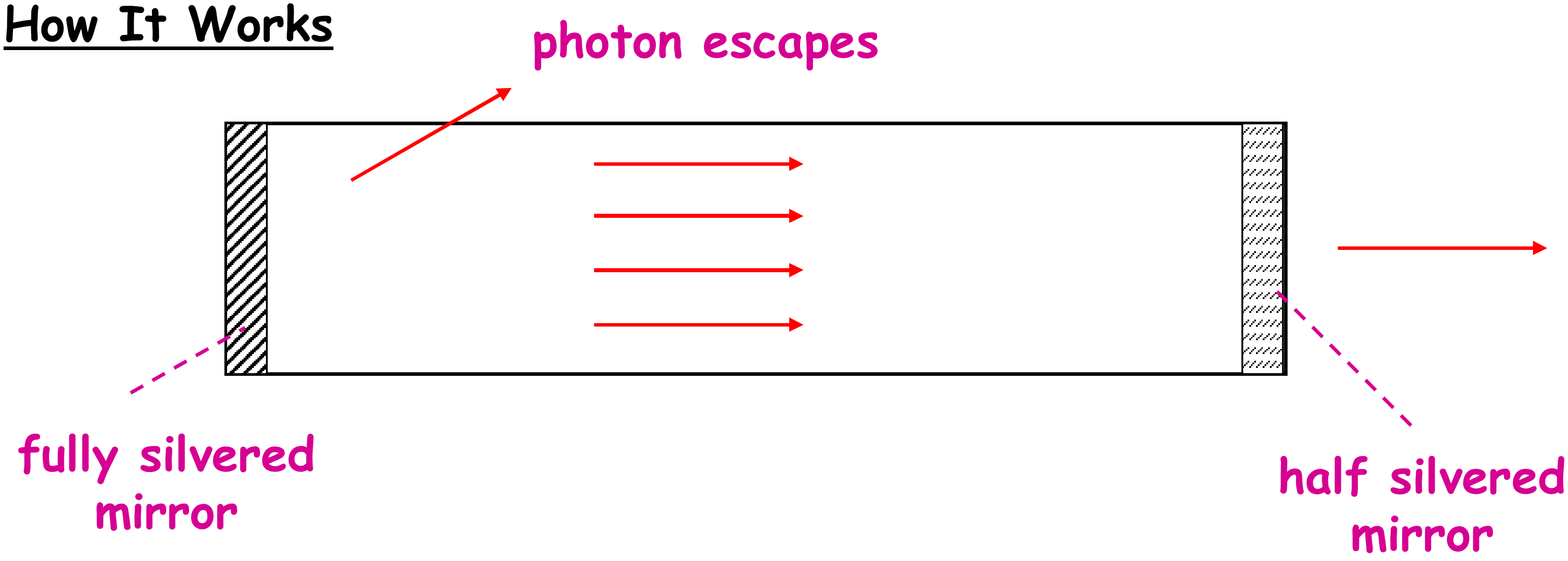
Radiation

Producing Light

An **incident photon stimulates** the **emission** of many identical photons.



How It Works



Photons are **reflected** back and forth by the mirrors.

As the reflected **photons** move back and forth they **stimulate more emission** (amplification – produces more energy than it loses).

Only **some** of the **photons** pass through the half silvered mirror to produce the **laser beam**.

Not all photons are **released** as some are required to cause **further stimulated emission**.

Laser light is

- **monochromatic**

  (single colour since all photons have identical frequency)

- **coherent**

  (all photons are in phase)

- **intense**

  (all photons are concentrated in a small area)

Example 1

The irradiance of laser light is compared to the irradiance of a light bulb.

(a) The power of the laser is 0.1 mW while the diameter of the beam 10 m away is 1 mm.

Calculate the irradiance of the laser beam.

(b) A 100 W light bulb is used and the irradiance measured from 10 m away.

Calculate the value for the irradiance of a light bulb.

(c) State and explain which is most dangerous.

(a) Laser light

$$P = 0.1\,mW$$
$$= 0.1 \times 10^{-3}\ W$$
$$A = \pi r^2$$
$$= \pi \times \left(0.5 \times 10^{-3}\right)^2$$
$$= 7.85 \times 10^{-7}\ m^2$$
$$I = ?$$

$$I = \frac{P}{A}$$
$$= \frac{0.1 \times 10^{-3}}{7.85 \times 10^{-7}}$$
$$I = 127\ Wm^{-2}$$

(b) Light Bulb

$$P = 100\ W$$
$$A = 4\,\pi\,r^2$$
$$= 4\pi \times 10^2$$
$$= 1.26 \times 10^3\ m^2$$
$$I = ?$$

$$I = \frac{P}{A}$$
$$= \frac{100}{1.26 \times 10^3}$$
$$I = 0.08\ Wm^{-2}$$

(c) Laser light is the most dangerous.

The laser light is the most dangerous because its irradiance is higher.

The power is concentrated in a small area (small enough for all light to enter the pupil of the eye).

P&N Booklet

Q64 - 68

Semiconductors

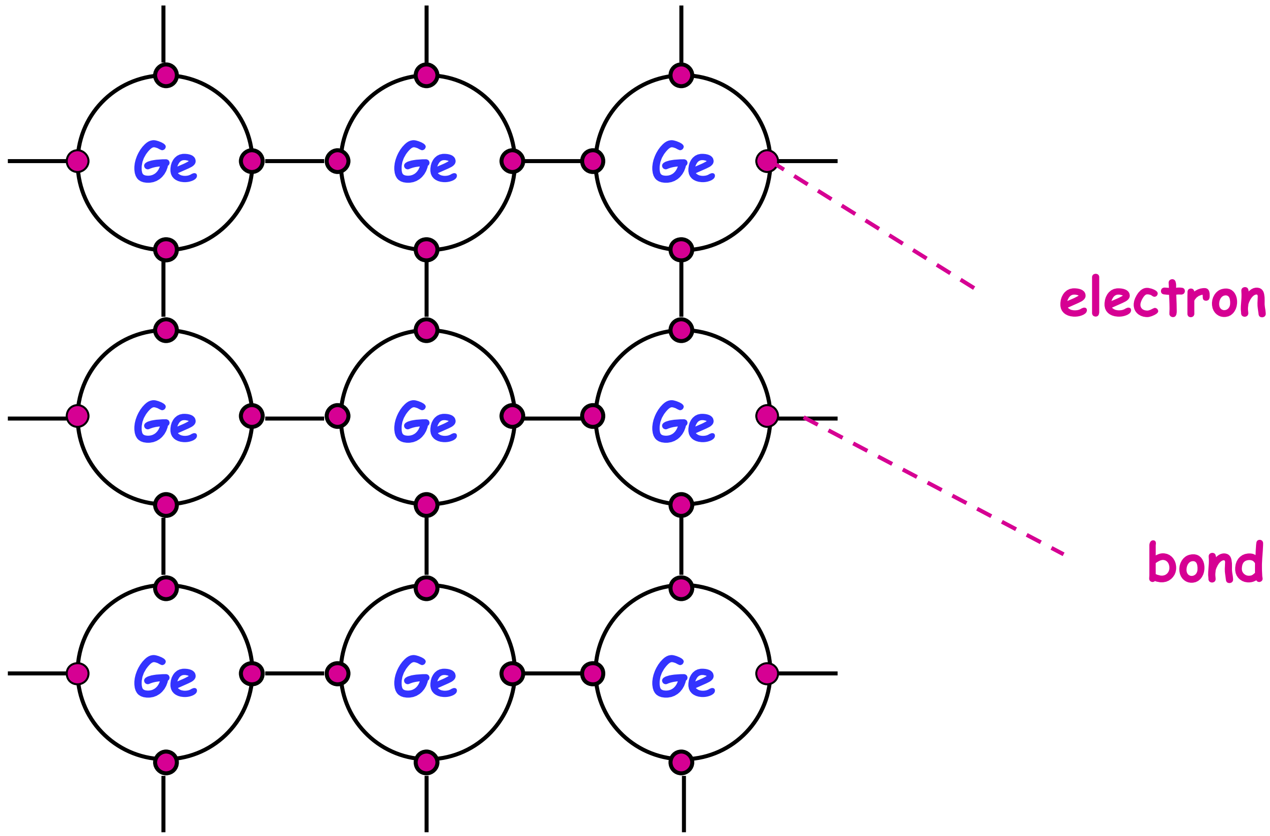
Materials can be classified into three categories according to their electrical conductivity:

Category	Description
insulators	high resistance (plastic, rubber, glass)
conductors	low resistance (metals, graphite)
semiconductors	behave like insulators when pure (silicon, germanium)

Doping

The **resistance** of a **semiconductor** is **reduced** and its conductivity improved by a process called **doping**.

Germanium (Ge)



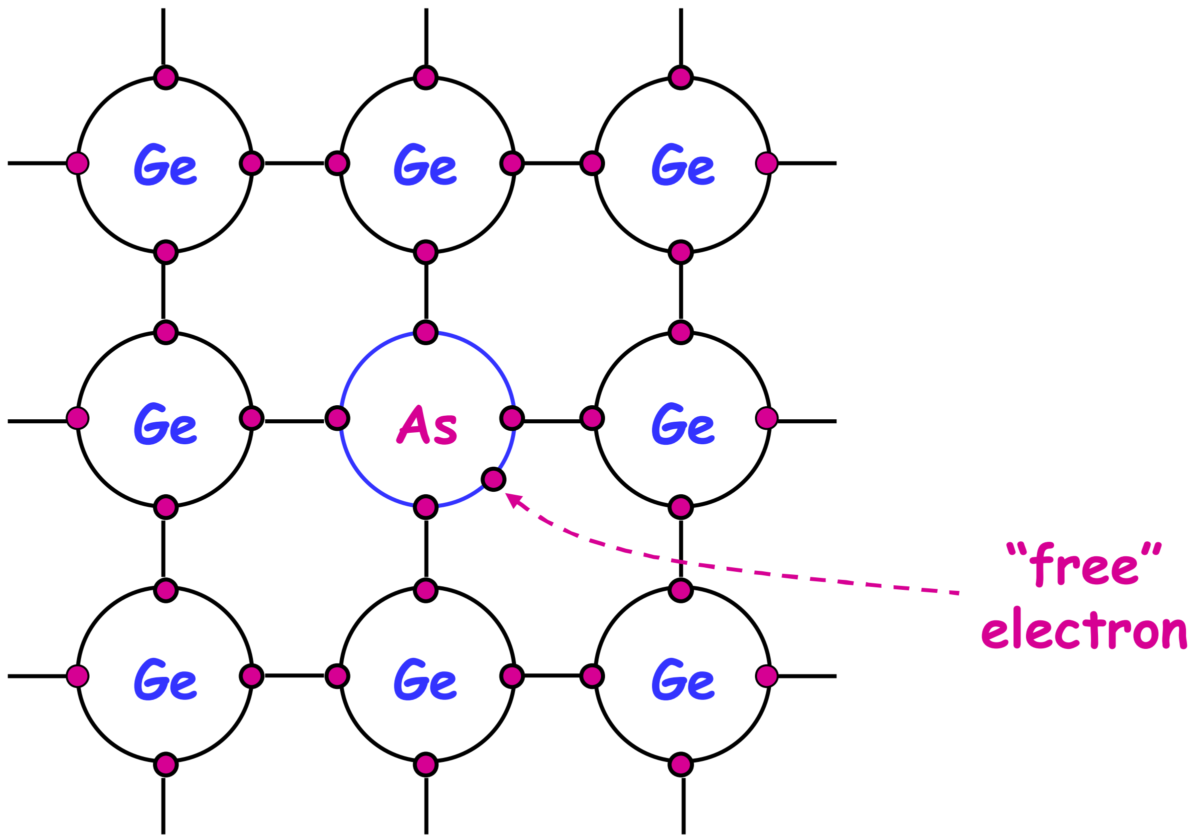
Each germanium atom has **four outer electrons**.

These four outer electrons are used to **bond** the germanium atom to another **four germanium atoms**.

'N-Type' Doping

An **impurity atom** with **five outer electrons** is added (e.g. arsenic).

This allows for a **'free' electron**.



When a voltage is connected across **'n-type' germanium 'free' electrons flow** towards the positive end of the supply producing an **electric current**.

This type of doping **adds 'free' electrons**.

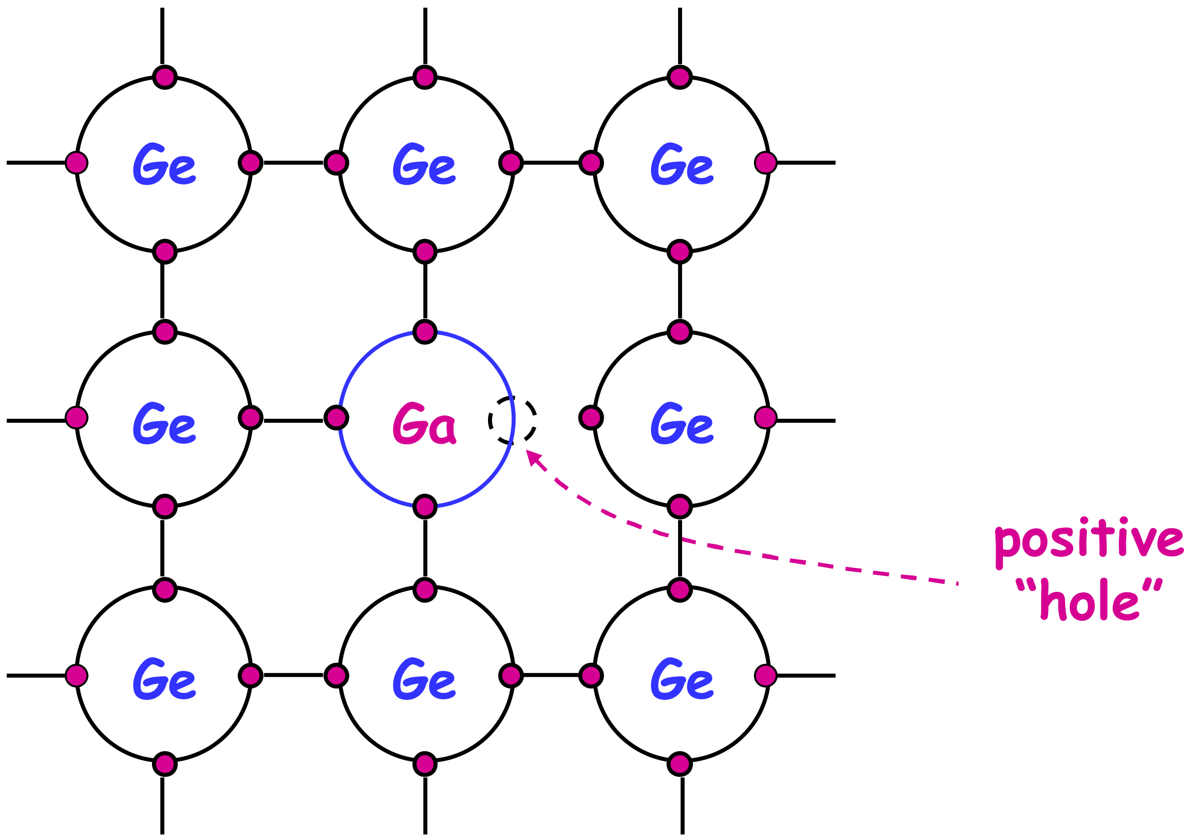
This is called **'n-type' doping**.

Majority of **charge carriers** are **negative**.

'P-Type' Doping

An **impurity atom** with **three outer electrons** is added (e.g. gallium).

One bond is missing due to the shortage of electrons – this is called a **positive 'hole'.**



A ‘**hole**’ can be **filled** with an **electron**, but this causes another ‘hole’ elsewhere.

Electrons move towards **positive** end of the voltage supply, the **holes move** towards the **negative** end of the supply.

The ‘**hole**’ is behaving like a **positive charge**.

This is called **‘p-type’ doping**.

Majority of **charge carriers** are **positive**.

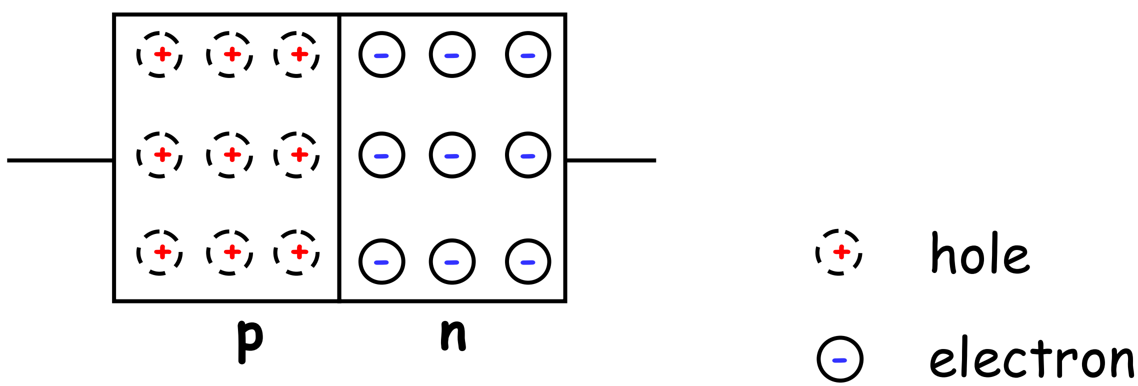
Overall Electrical Charge

The **overall electrical charge** for both '**p-type**' and '**n-type**' semiconductors is **neutral**.

Even when an impurity atom with 5 outer electrons is added (n-type) the overall charge remains neutral. Every **electron** added with a negative charge has a **corresponding proton** with a positive charge.

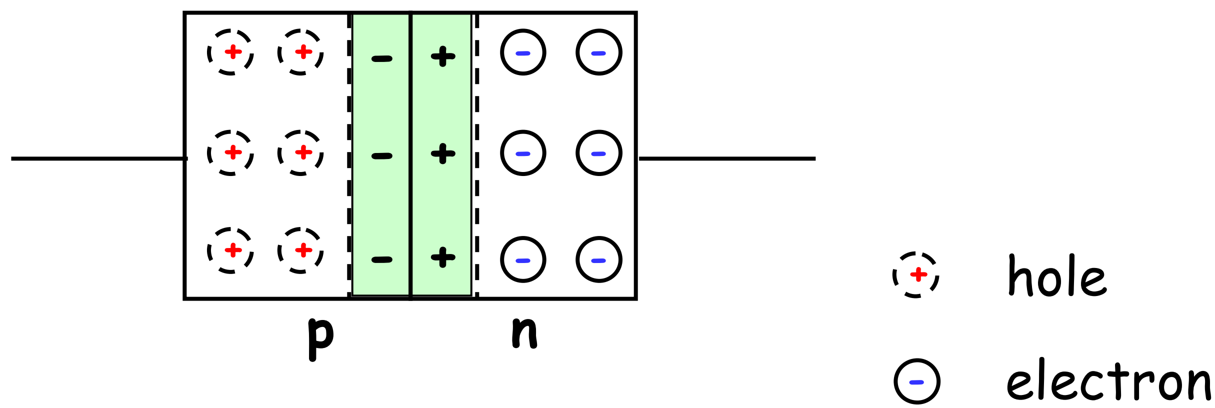
The Diode (P-N Junction)

When a semiconductor is grown so that one half is **p-type** and the other half is **n-type**, the product is called a **p-n junction diode**.



Near the junction however, some of the **free electrons** will **cross** the **junction** **filling** some of the **positive holes**.

This can also be thought of as positive holes crossing the junction and being filled by electrons.



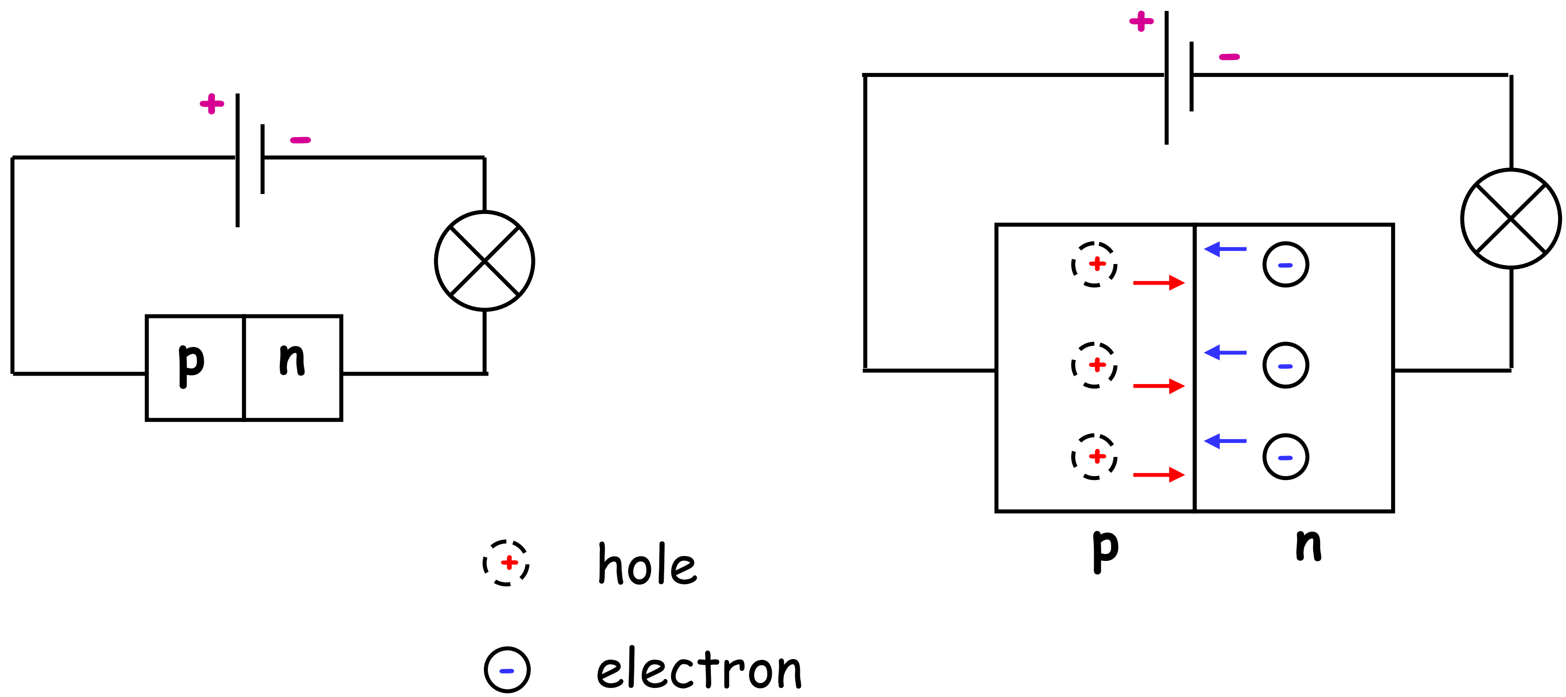
This region is called the **depletion layer**.

It is a region that has lost virtually all of its free charge carriers.

Flash Physics Animations - PN Junction

Semiconductors --> pn junction

Forward Bias (Current Flow)

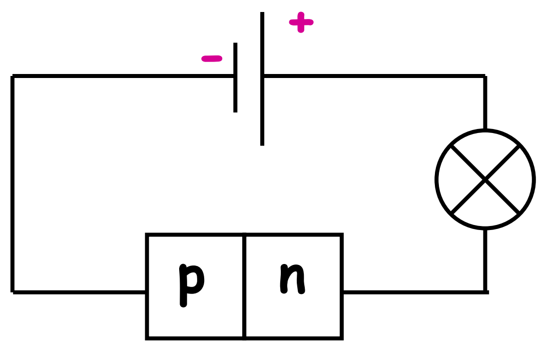


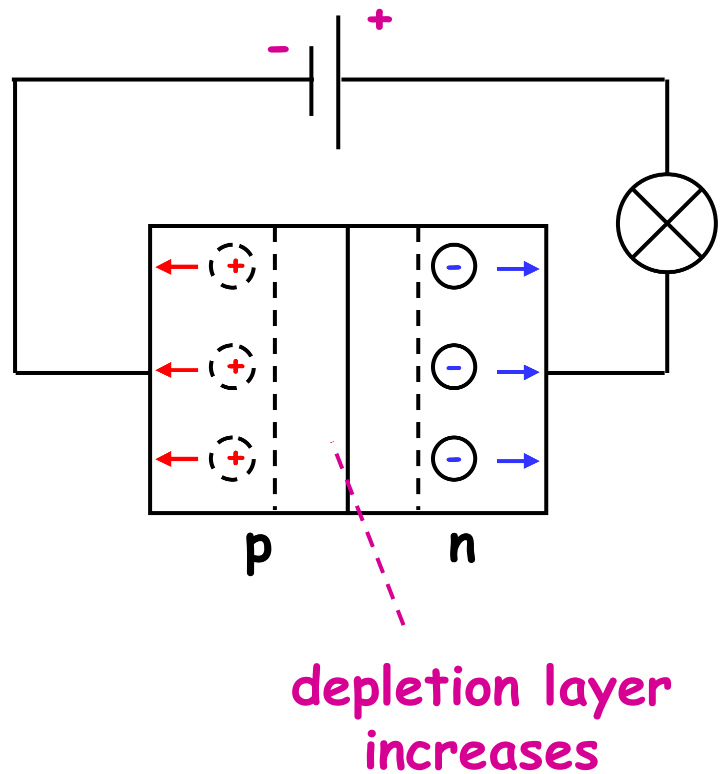
Negative charge carriers in the ‘n-type’ and positive charge carriers in the ‘p-type’ flow towards the junction.

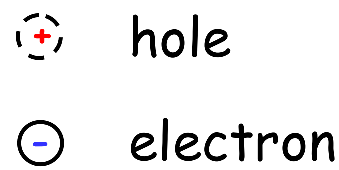
They combine at the junction.

A current flows.

Reverse Bias (No Current Flow)







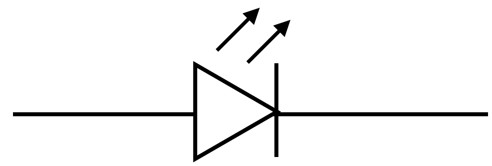
Negative charge carriers in the 'n-type' and positive charge carriers in the 'p-type' flow away the junction.

The diode does not conduct.

No current.

Light Emitting Diode (LED)

The circuit symbol for an LED is:



The **LED** is a special type of **p-n junction diode**.

A **forward biased** LED emits **photons of light** when **electrons** and '**holes**' **recombine at the junction**.

[Flash Physics Animations - Light Emitting Diode]

Semiconductors --> Light Emitting Diode

Example 1

In an LED, the energy released when an electron and hole recombine is 2.8×10^{-19} J.

Calculate the wavelength of the light released **and** identify it.

$$E = 2.8 \times 10^{-19}\ \text{J}$$

$$h = 6.63 \times 10^{-34}\ \text{J s}$$

$$f = ?$$

$$E = h f$$

$$2.8 \times 10^{-19} = \left(6.63 \times 10^{-34}\right) \times f$$

$$f = \frac{2.8 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$\underline{\underline{f = 4.2 \times 10^{14}\ \text{Hz}}}$$

$$f = 4.2 \times 10^{14}\ \text{Hz}$$

$$v = 3 \times 10^{8}\ \text{ms}^{-1}$$

$$\lambda = ?$$

$$v = f \lambda$$

$$3 \times 10^{8} = \left(4.2 \times 10^{14}\right) \lambda$$

$$\lambda = \frac{3 \times 10^{8}}{4.2 \times 10^{14}}$$

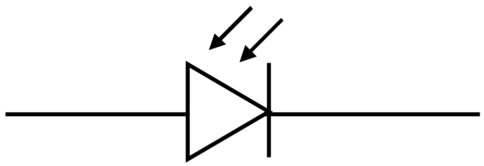
$$\lambda = 714 \times 10^{-9}\ \text{m}$$

$$\underline{\underline{\lambda = 714\ \text{nm}}}$$

RED LIGHT

Photodiode

The circuit symbol for a photodiode is:



A **photodiode** contains a **p-n junction**.

A **photon** of **light energy** falling on the p-n junction, **creates** an **electron-hole pair**.

Increasing the **intensity** of light at the photodiode:

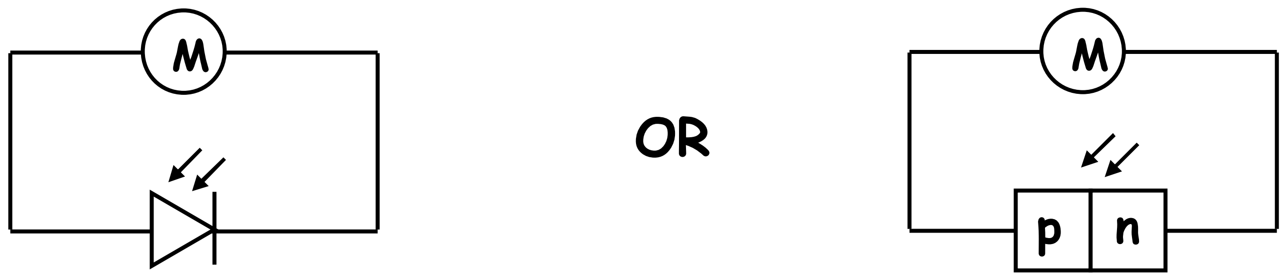
- **increases** the **number of photons** of light at the p-n junction
- creates **more electron hole pairs**.

Two ways in which the photodiode can be used are:

- the **photovoltaic** mode
- the **photoconductive** mode

Photovoltaic Mode

In this mode, the photodiode is commonly known as a solar cell.



As **photons** of light land on the junction they **create electron hole pairs**.

A **voltage** across the junction is created.

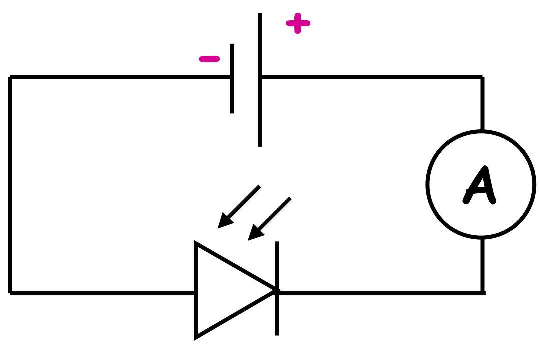
When **brighter light** is shone on the junction:

- **more photons** of light hit the junction
- **more electron hole pairs** are produced at the junction
- creating a **larger voltage** across the junction.

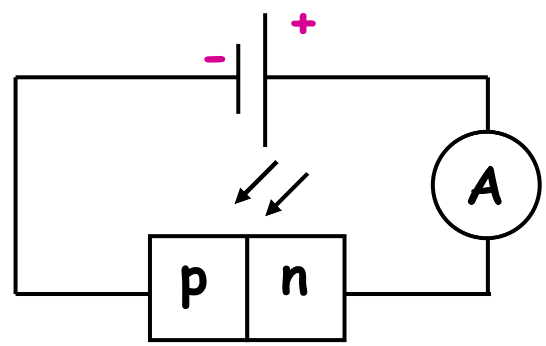
Flash Physics Animations - Photodiode (Photovoltaic Mode)

Semiconductors --> Photodiode – photovoltaic mode

Photoconductive Mode



OR



In **dark conditions no current** flows (ordinary diode in reverse bias).

In **light conditions electron hole pairs** are **formed** at the junction.

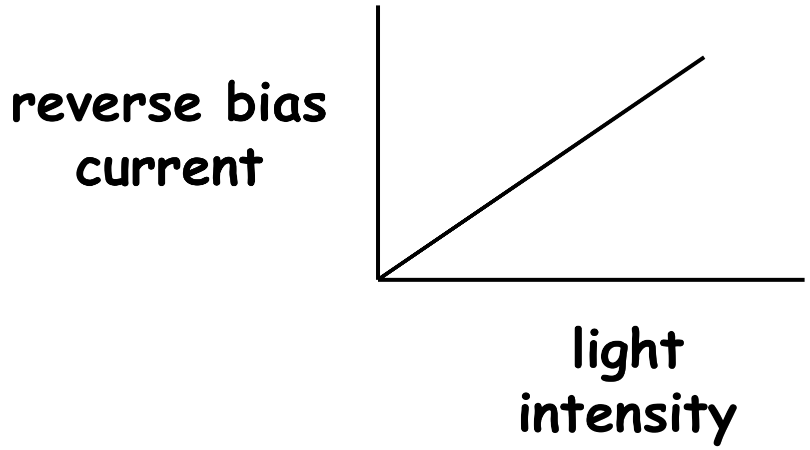
These electron hole pairs act as **charge carriers**.

This allows a **current** (called reverse leakage current) to **flow**.

Flash Physics Animations - Photodiode (Photoconductive Mode)

Semiconductors --> Photodiode – photoconductive mode

The electric **current** is **proportional** to **light intensity**.



Brighter light contains **more photons**,

which produces **more electron hole pairs**,

meaning **more charge carriers**,

the result is a **larger electric current**.

Use

A photodiode in photoconductive mode can be used as the light sensor in a light gate (LDR).

Quick response (switching on/off) of a photodiode makes it suitable in devices such as optical fibre receivers.

The MOSFET

<u>n-channel enhancement MOSFET</u>

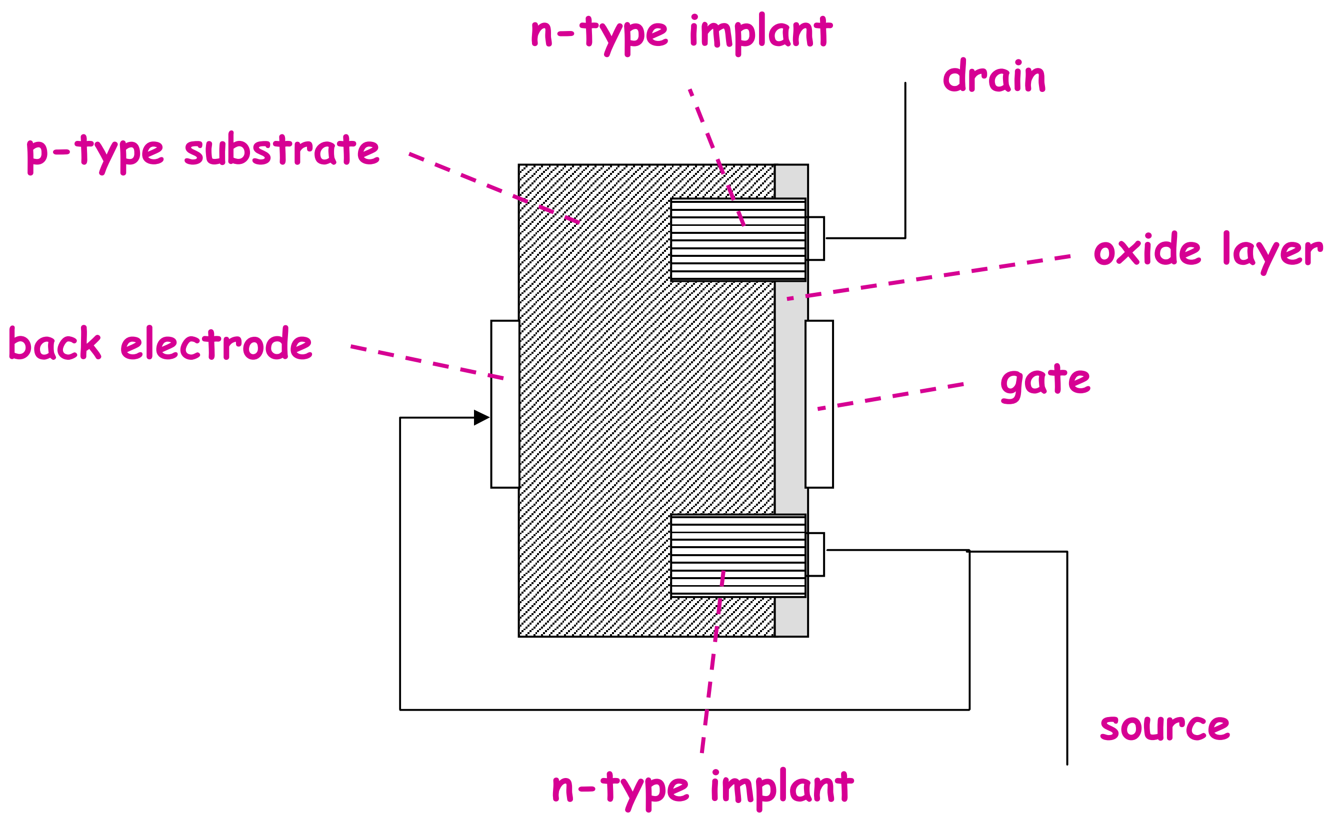
The **MOSFET** is a type of **transistor** used in nearly all modern electronic devices.

(The npn-transistor is practically obsolete in modern electronics)

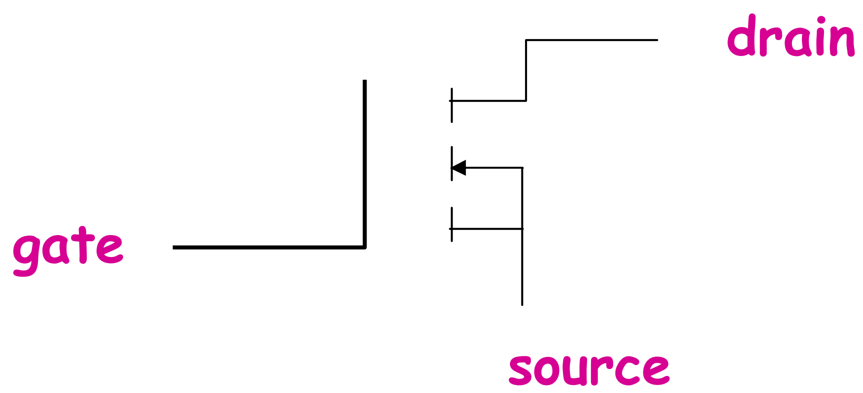
MOSFET stands for **M**etal **O**xide **S**emiconductor **F**ield **E**ffect **T**ransistor.

<u>VIDEO – MOSFET's (4 min 50 s)</u>

MOSFET Structure



MOSFET Symbol



$V_{GATE} < 2\,V$	OFF
$V_{GATE} \geq 2\,V$	ON

When the transistor switches on a **current flows** from the **source to the drain**.

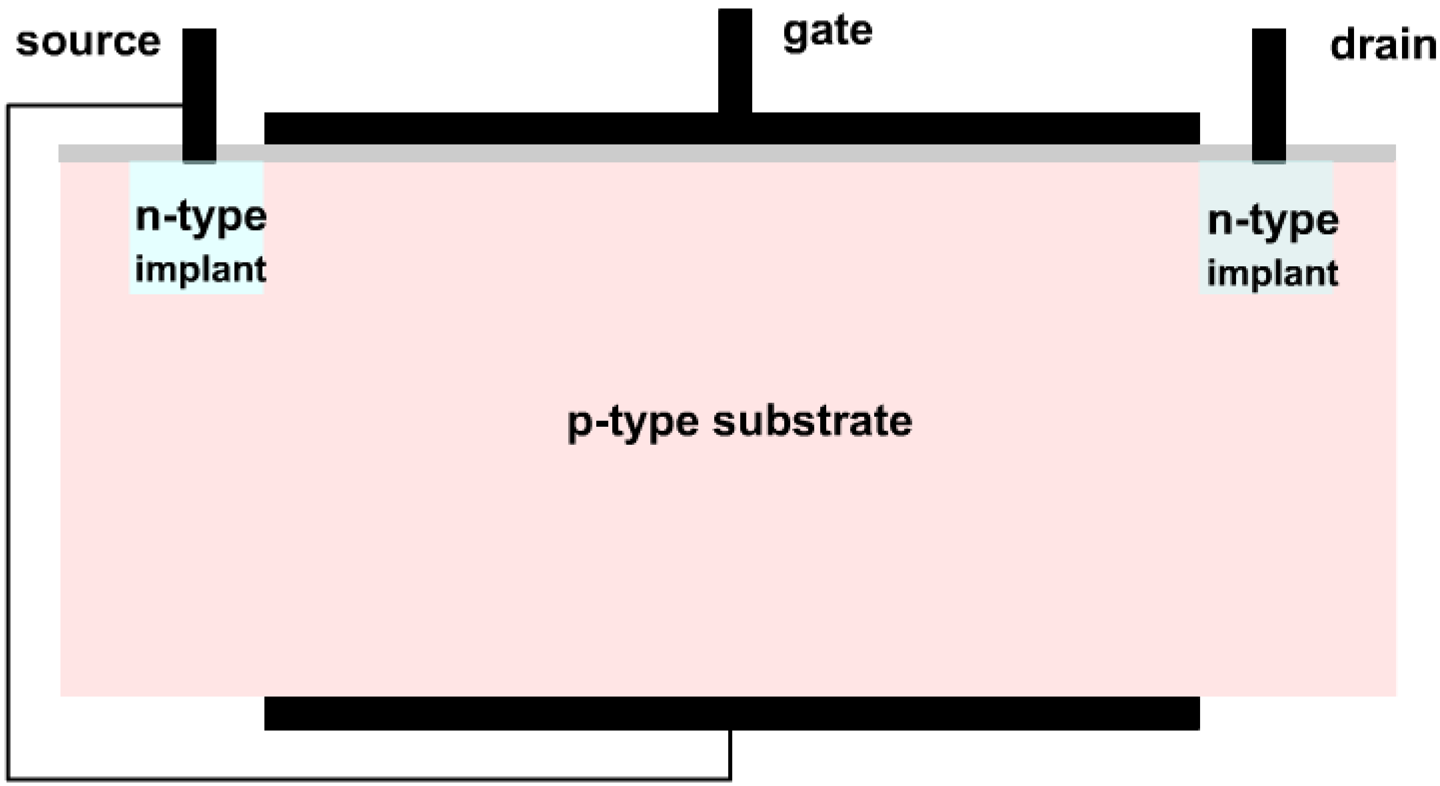
MOSFET's can tolerate much greater currents than npn transistors.

Use

An n-channel enhancement MOSFET can be used as an **amplifier**.

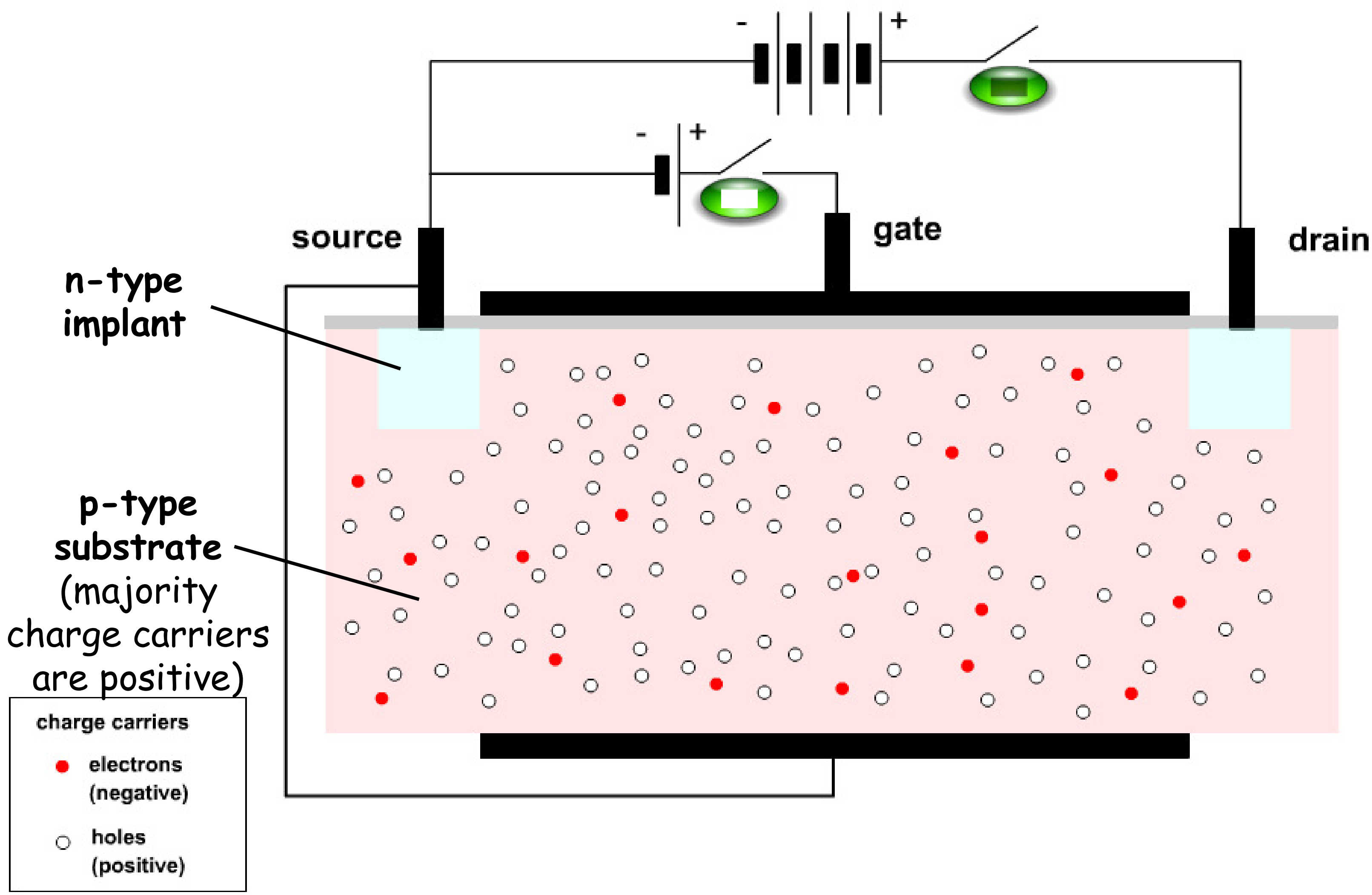
MOSFET

n-channel enhancement



MOSFET

n-channel enhancement



MOSFET

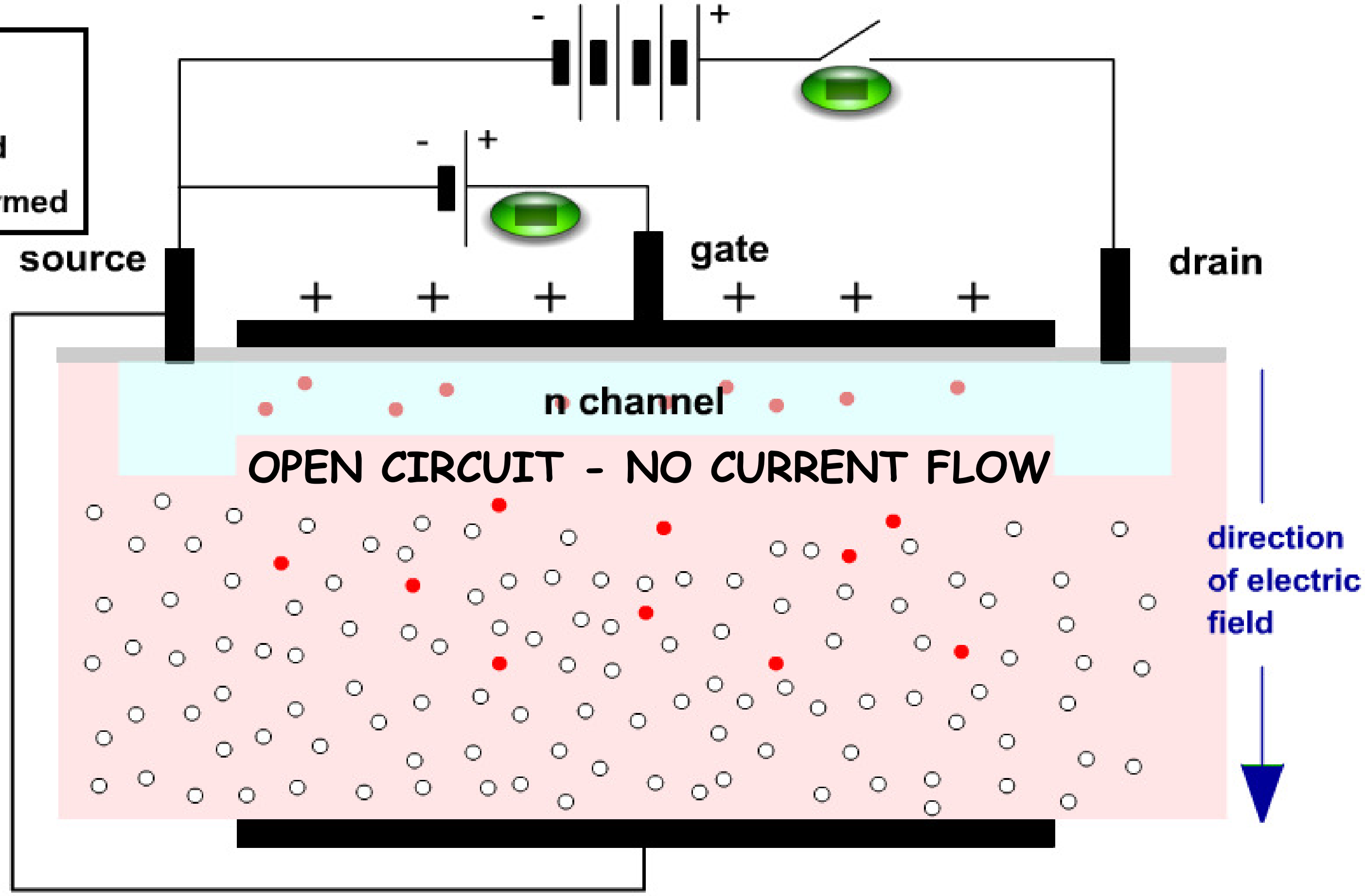
n-channel enhancement

$V_{gate\text{-}source}$

Gate positive

electrons attracted

n-type channel formed



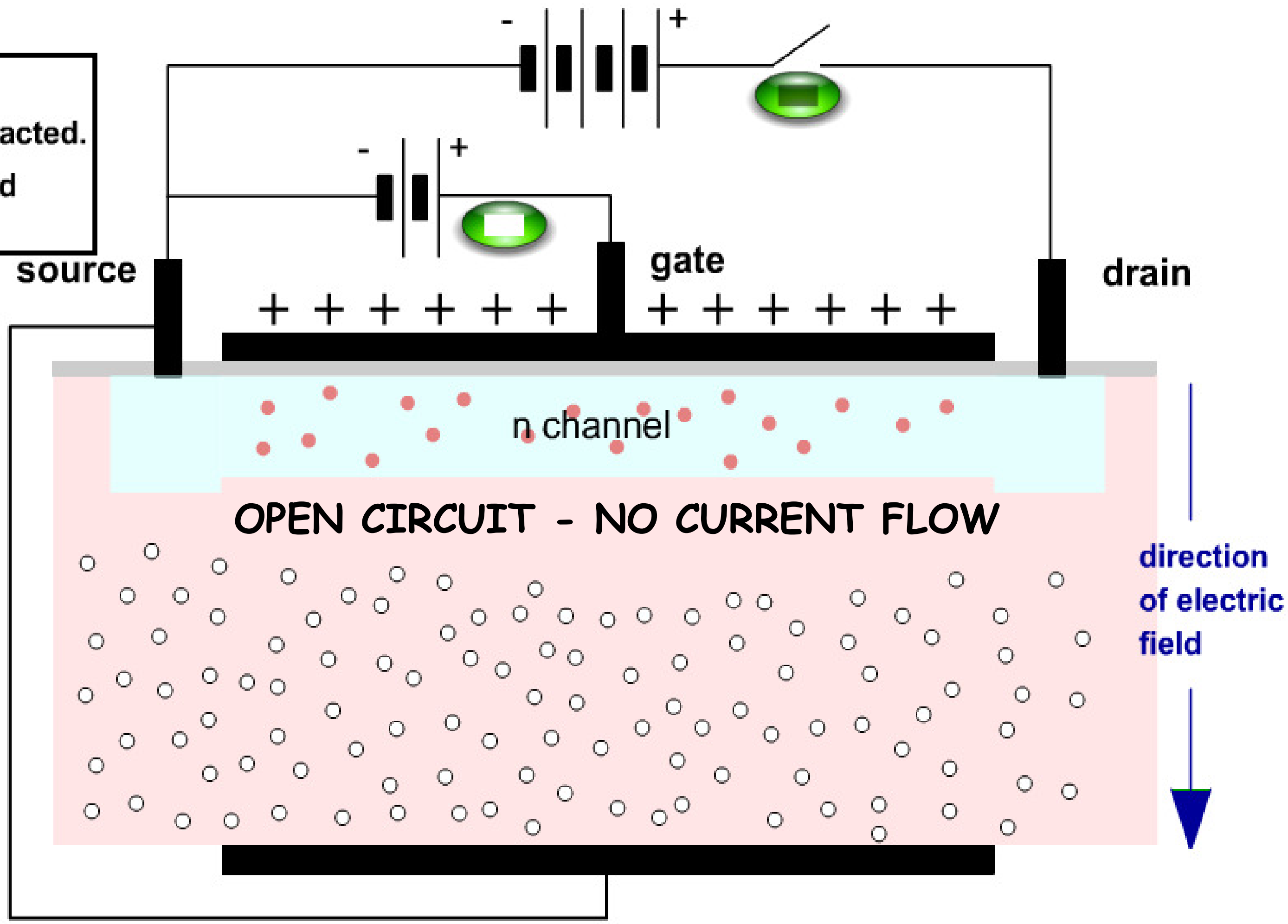
charge carriers

- electrons (negative)
- holes (positive)

MOSFET

n-channel enhancement

Larger $V_{gate\text{-}source}$
more electrons attracted.
n-channel enhanced (widened).

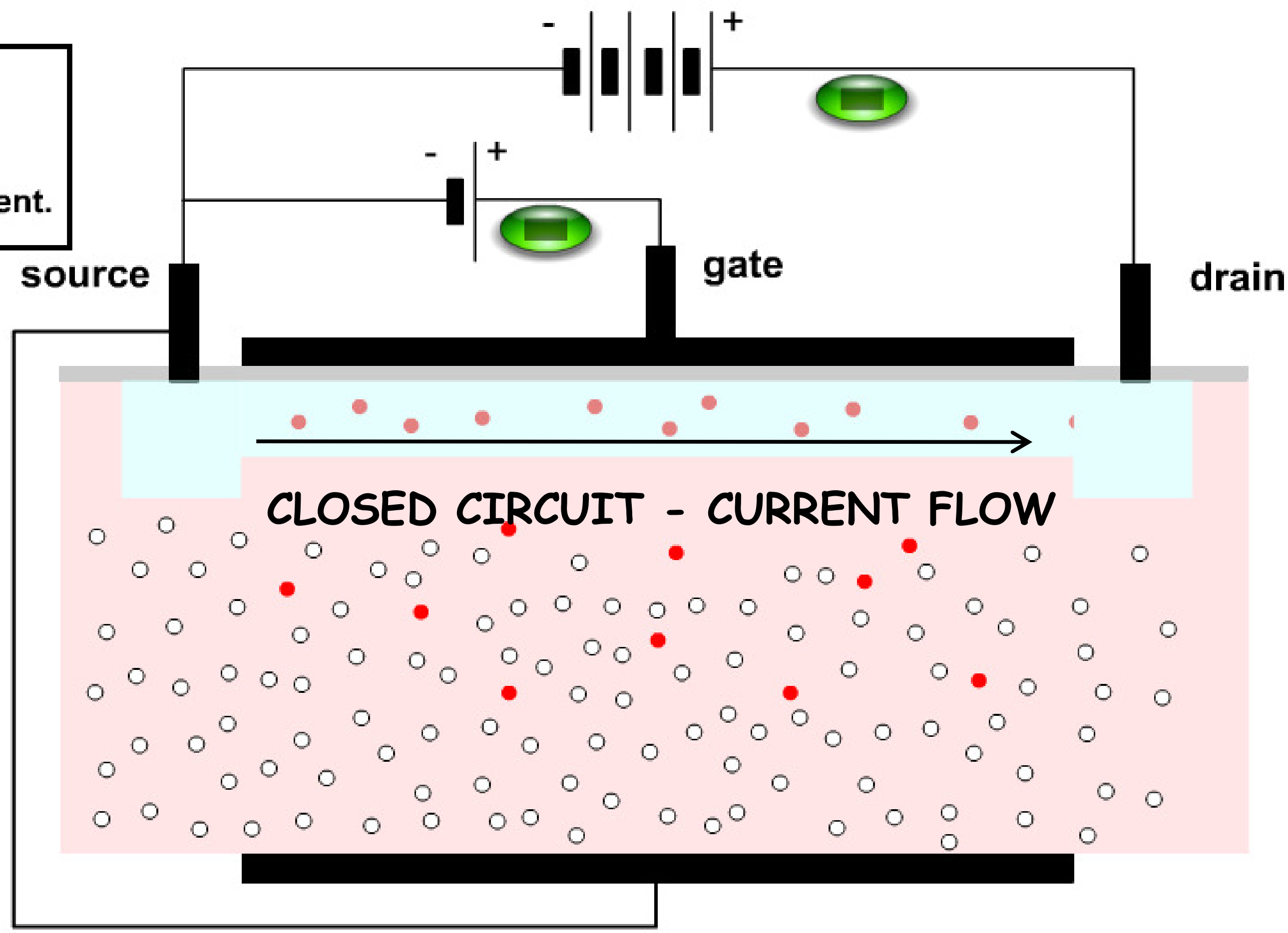


charge carriers

- electrons (negative)
- holes (positive)

MOSFET
n-channel enhancement

V drain-source.
V gate-source.
Source-drain current.



charge carriers
- electrons (negative)
- holes (positive)

V gate
Text off

How it Works

P-type semiconductor **implanted** with two sections of **n-type material**.

A **voltage across the gate and source** forms a channel (known as an **n-channel**) between the two n-type implants.

On connecting a **voltage across the drain and source**, an **electric current** in the n-channel **flows**.

The **electric current** is the flow of **negative charges** called electrons.