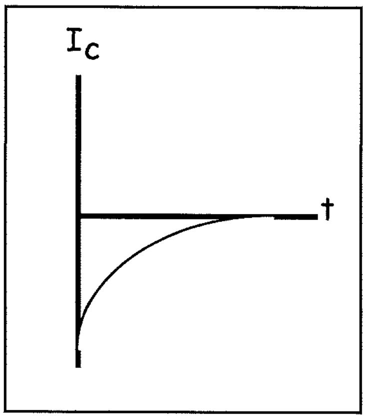
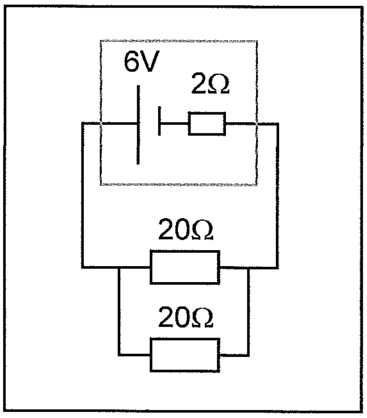
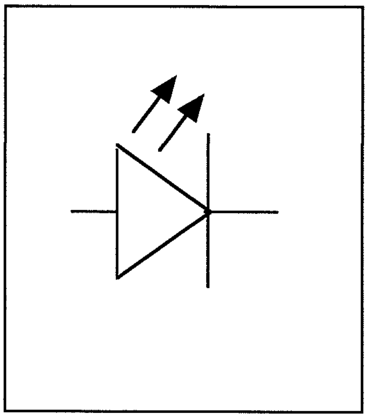
Higher Physics

Unit 3

Electricity





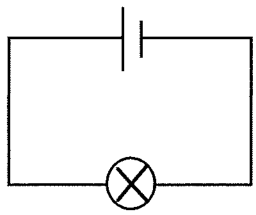


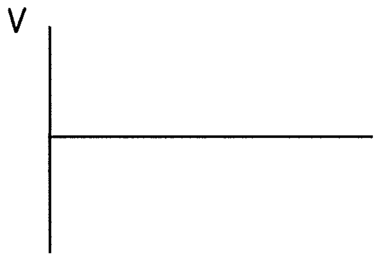
Summary Notes

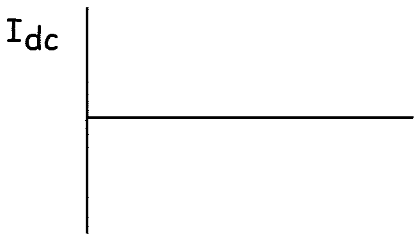
1. A.C/D.C

Direct Current d.c

In d.c circuits the voltage is a constant size and ______________
so the current is a constant size and
____

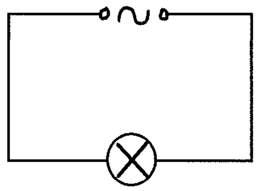


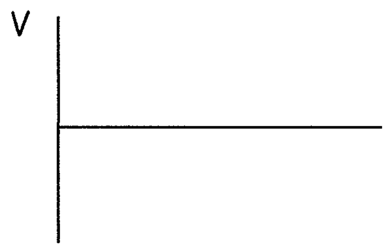


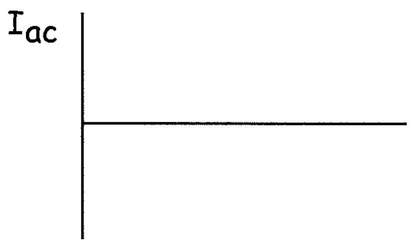


Alternating Current a.c

In a.c circuits the size and direction of the voltage is a constantly
________________________ so the size and direction of a.c current is constantly ________________________

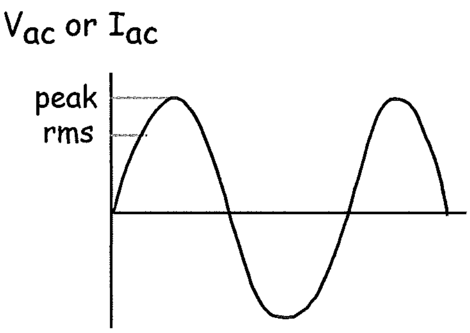






Measuring ac current and voltage.

Measuring dc current and voltage is easy because they are constant. But to measure ac current or voltage we can describe then by their max value of average or root mean square values (rms) The rms is about 70% of the peak.



$$V_{rms} = \frac{V_{peak}}{\quad}$$

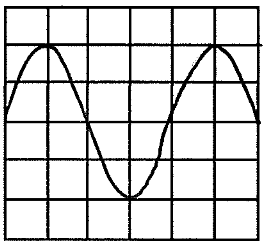
$$I_{rms} = \frac{I_{peak}}{\quad}$$

When we use equations such as V=IR, P=IV $P = I^2R$ the values of I and V are always the _________ values so remember to convert peak to rms

Measuring peak rms voltage of an ac signal

The Y- gain button on the oscilloscope tells you the value of each _______________ box on the screen. If it is set at 5V/cm each vertical box = _____.

So peak voltage = height of the trace x Y- Gain setting.



Y-Gain

10V/cm

Peak voltage = _____ x ______

Peak voltage = _________V

Therefore $V_{rms} = \frac{V_{peak}}{\sqrt{2}}$ = ____ =

Measuring the frequency of an ac signal

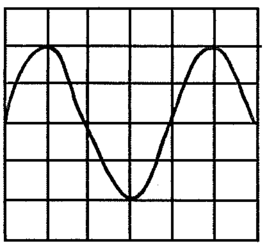
The frequency tells you how many times the current changes direction each _______.
Mains ac electricity has a freq of _____Hz. So current in household bulbs changes direction _______ times each __________________.

The time base tells you how long it takes the electron beam to travel across one horizontal box. So the time to make one wave as it travels across the screen is called the period of the wave or T for short .

Period of wave = time base setting x number of horizontal boxes making one wave.

Frequency $f = \frac{1}{T}$

Period = TB setting x no of horiz boxes



Time base

2ms/cm

T = ______ x _______

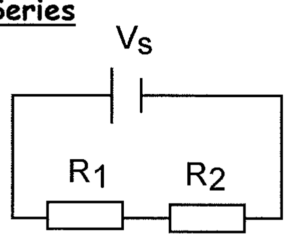
T = ___________s

Freq = $\frac{1}{T}$ = $\frac{1}{\_\_}$ =

If you increase the y gain setting, the amplitude of the wave on the screen will ______________________. If you increase the time base setting the beam travels across the screen ________________ so __________waves will be drawn in this time.

2. Circuits

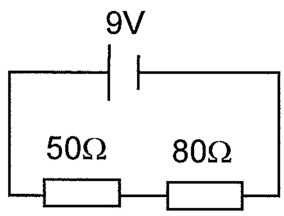
Series



Current at all points is ____________________.
Voltage across components adds up to the ____________________ voltage Vs.

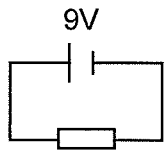
$R_T = R_1 + R_2 + R.........$

Ex



What is the total resistance?

$= R_T =$ ____ + ____ = ______Ω



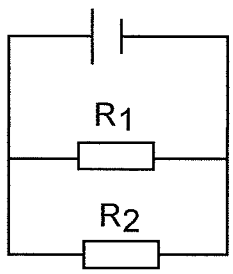
What is the total current?

V=IR so I = ―― =―― =

What is the voltage across 50Ω resistor?

V_{50} = IR = _____ x _____ = V_{80} = _____

Parallel

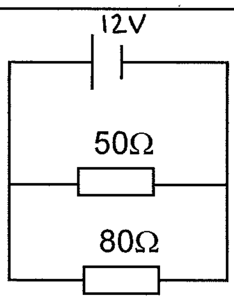


Current in each branch adds up to the _________ current drawn from the battery.
Voltage across each branch is the ___________ and equal to the ____________________ voltage

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

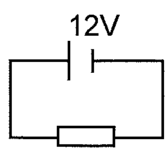
If the resistors are of the same value the total resistance = the size of the resistor / the number in parallel.

Ex



What is total resitance R_T $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{\_\_} + \frac{1}{\_\_} =$

So R_T = =



What is total current

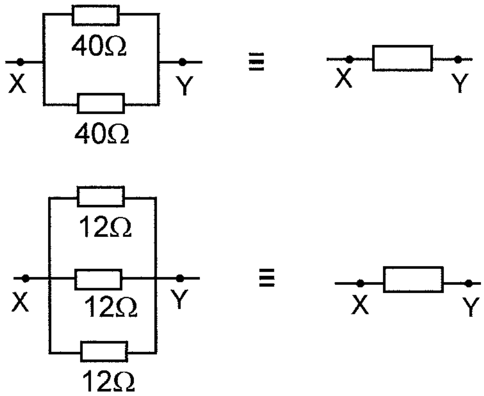
V=IR so I = = =

What is current through 50Ω resistor V = IR so I = V/R =

Resistors in parallel with same value

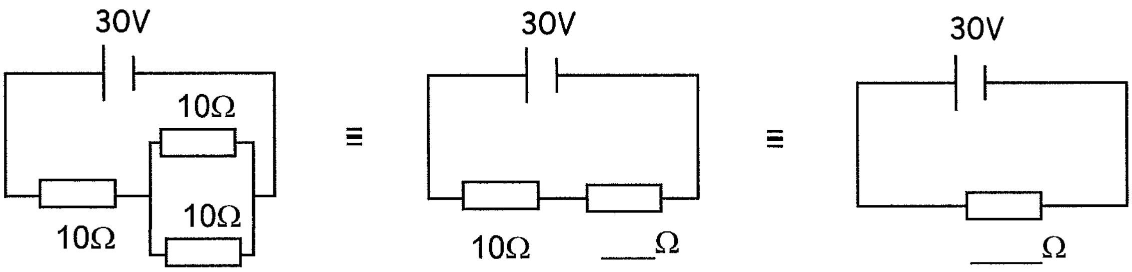
$R_T = \dfrac{\text{value of resistor}}{\text{number in parallel}}$

What is total resistance between X and Y in these circuits



Combined Series and parallel circuits.

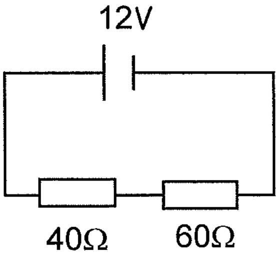
Work out (a) total resistance (b) Total current (c) Voltage across 10Ω resistor



V_{10} =

$I_T = \dfrac{V_T}{R_T} = \dfrac{\quad}{\quad} =$

The voltage divider formula



This formula allows you work out the voltage across resistors in series much more quickly than finding the total resistance then current.

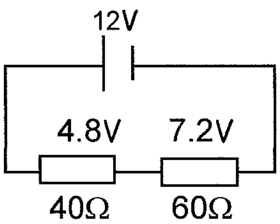
$$V_1 = \frac{R_1}{R_1 + R_2} \times V_s$$

$V_{40} = \dfrac{\quad}{\quad} \times 12$

$V_{40} = \dfrac{\quad}{\quad} \times 12$

$V_{40} =$ _______ so $V_{60} =$

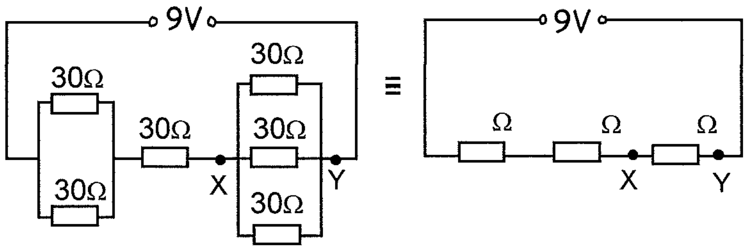
Also for a voltage divider-



$\dfrac{R_1}{R_2} = \dfrac{V_1}{V_2}$ $\dfrac{\quad}{\quad} = \dfrac{\quad}{\quad}$

Ex

What is the voltage between X and Y? - Simplify and use the voltage divider formula.

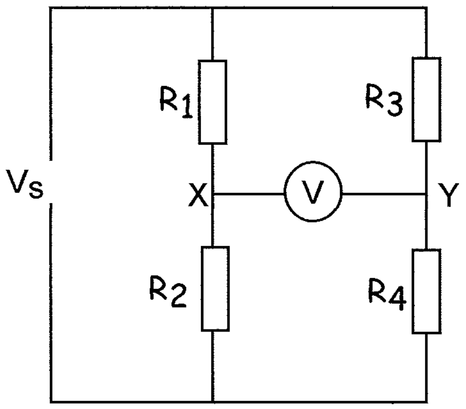


V_{xy} =

When resistors are placed in parallel the total resistance of the circuit

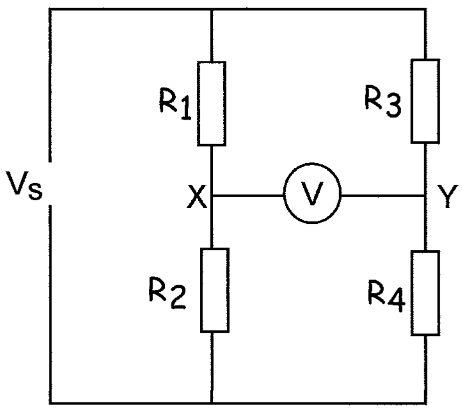
______________________.

Two facing potential dividers (Wheatstone Bridge)



Resistors can be chosen so the pd at X = pd at Y. This is called a balanced circuit. In a balanced circuit -

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$



In an out of balanced circuit we can find voltage at X and Y and calculate the pd between X and Y. (Measured on voltmeter)

$$V_X = \frac{R_2}{R_1 + R_2} \times V_s$$

$$V_Y = \frac{R\ \ }{R\ \ + R\ \ } \times V_s$$

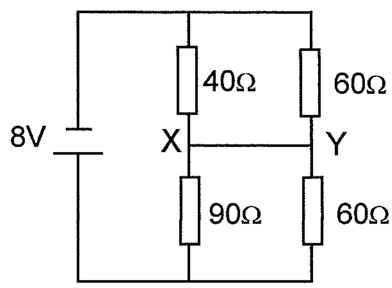
V read by voltmeter = $V_x - V_y$

Ex What is voltage at X?

V_X = ——— x 8 = ——— x 8 =

What is voltage at Y? V_y = ____

Potential difference between X and Y = _____



Power

The electrical power of a device tells you the amount of electrical ______________ the device uses each second. Here are 3 useful equations:

$P = IV$ $\quad$ $P = I^2R$ $\quad$ $P = \frac{V^2}{R}$

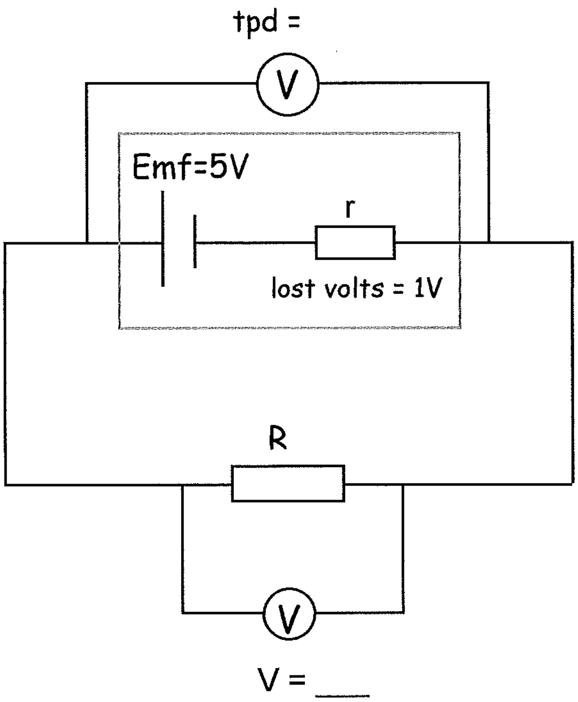
Internal Resistance

An electrical battery or cell uses a chemical reaction to drive current round the circuit. But some energy is always lost in the process.

Emf (E) = Electromotive ______________ of the cell. This is the maximum amount of _____________ energy given to each coulomb. It is the max available voltage.

lost volts (v)= The voltage __________ inside the cell due to driving the current. This lost voltage is turned to ____________ in cell. We imagine it dropped across an internal _____________________ (r).

tpd (V) = terminal _____________________ difference. This is the actual voltage measured across the cell once you have taken lost volts away from the _______. This tpd is dropped across the external load which we denote as R.



tpd = Emf - ________

tpd = ______- ________

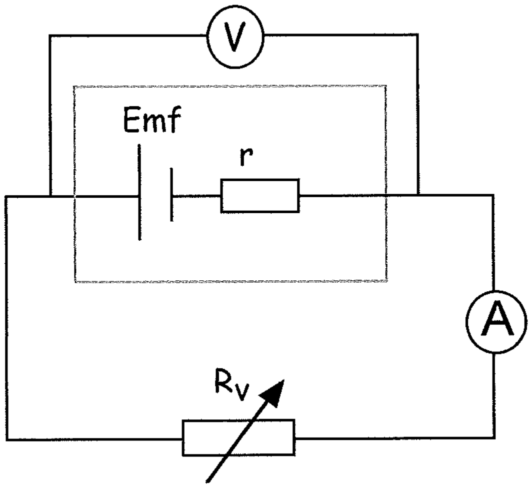
The tpd is _____V. This is the voltage available to the external load. So the voltage across R =

Big R and small r are in series so the total resistance of circuit = ___ + ___.

We can also use the voltage divider formula to find lost volts or tpd.

Graphical method of measuring E and r

tpd =



E = tpd + lost volts

$E = V + Ir$

$V = -Ir + E$

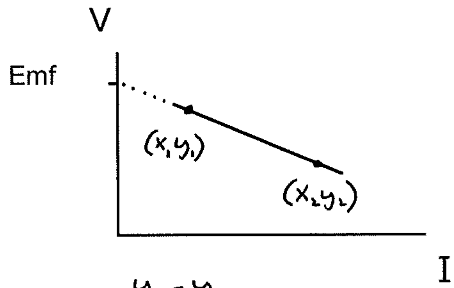
$V = -rI + E$

$y = mx + c$

So plotting I vs V gives a straight line where r = - gradient and it cuts y axis at (0, E)

Set variable resistor to a high value. Therefore current drawn is ___________.
So as lost volts v=Ir the lost volts will also be small. Therefore the tpd will be _______.

As R is decreased the current ______________so the lost volts ___________________ and the tpd_________________________. If we plot I vs V the graph looks like this



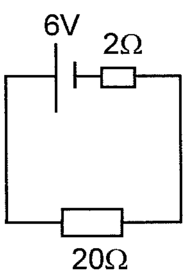
gradient = - r & y-intercept = ____

gradient $m = \frac{y_2 - y_1}{x_2 - x_1}$

Ideal supply

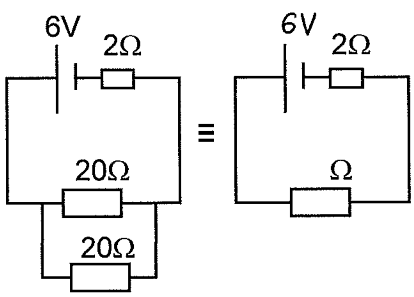
The maximum power transferred to a load is when the load resistance R = the _________________________resistance r. This is called Load ________________.

In many applications placing more and more external resistors in parallel ____________________________ the total resistance of the circuit. Therefore the current drawn from the battery __________________________ so as lost voltage v=Ir the lost voltage _______________________ and the useful voltage or tpd ______________________.



tpd = $V_{20\Omega}$

$V_{20\Omega} = \text{——} \times 6$

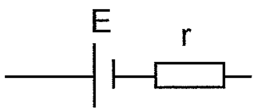


tpd = V Ω

V Ω = —— x 6

Short Circuit

A short circuit is created when a wire provides a short cut for electricity to flow directly from one side of the ________ to the other by missing out the load resistor.



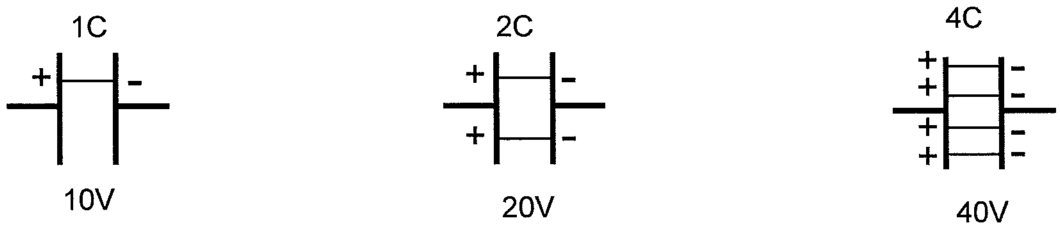
so short circuit current $I_{SC} = \frac{E}{r}$

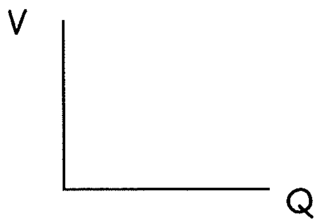
Open circuit

An open circuit is one where no current flows in the circuit. As there is no current then there is no lost voltage (ie v=Ir, I=0 so v=0). So tpd = _______.

Capacitors

A capacitor is a device which stores ________________ on two metal plates. This creates an electric field between the plates which stores electrical ________________. As we place more charge on the plates the pd or voltage between the plates ____________________. as shown on the diagrams and graph.





The area under the QV graph tells us the amount of electrical _____________ stored on the capacitor

E =

Dividing Q by V gives us a constant which we call the ________________________of the capacitors.

$$C = \frac{Q}{V}$$

Q = charge, units - Coulombs C
V = voltage, units volts V
C = capacitance, units - Farads F

A Capacitance of 5F means you need to put __C of charge on plates to create a pd of 1V.

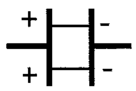
Substituting this equation into the energy equation gives us two more equations for the energy stored on a capacitor.

E =   E =

Different sizes of capacitors

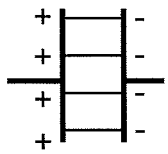
As a capacitor gets bigger it takes more ______________ to produce a pd of 1V.

Small capacitor



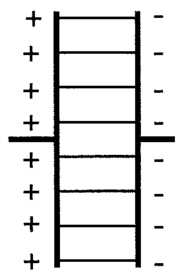
takes 2C to produce 1V so $C = 2F$

Medium capacitor



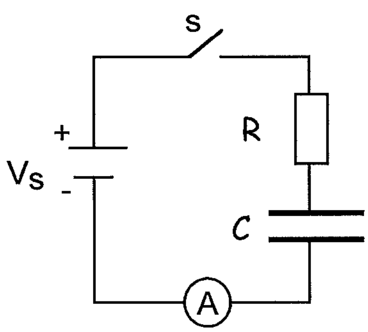
takes 4C to produce 1V so $C = 4F$

Big capacitor



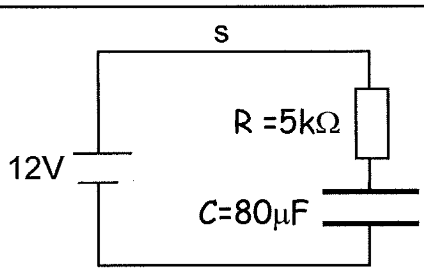
takes 8C to produce 1V so $C = 8F$

Charging a Capacitor



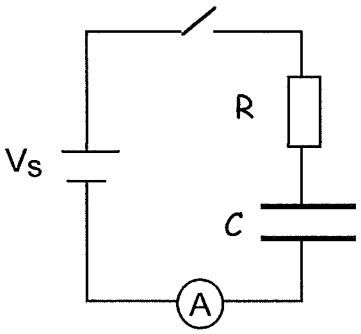
When switch S is closed, the top plate of the capacitor becomes very ______________ charged so there is a huge attraction for electrons to flow onto the bottom plate. At first the current rises very ______________ because the attraction is very ________. But as time passes the electrons already on plate start repelling electrons arriving at plate so the current __________________ until no more electrons can get on. At this point the capacitor is fully charged and its voltage = ____. Current is now ____________.

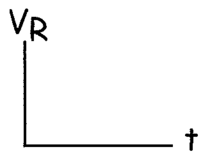
At all points during charging $V_S = V_R +$ ______

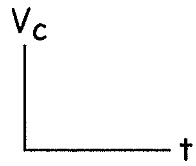


When fully charged $V_c =$ ____V

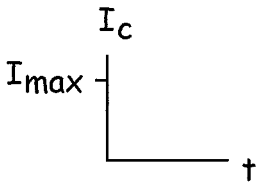
Energy stored =







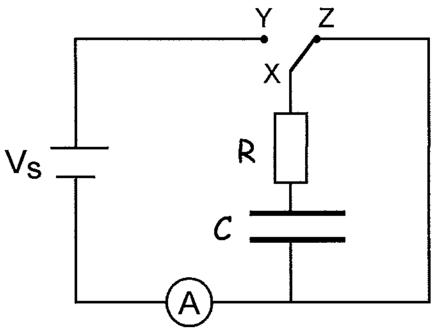
Just as switch is closed all voltage is dropped across _____ because capacitor is empty. At this point current is maximum. $I_{max} = V_s/R$. This is called the initial charging current.
As time goes by the voltage across the capacitor _______________ as it charges up. The voltage across the resistor decreases. When the capacitor is fully charged the voltage across the capacitor = the _____________ voltage. At this point the current = __________ and V_R = _____



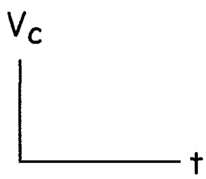
I_{max} = ____

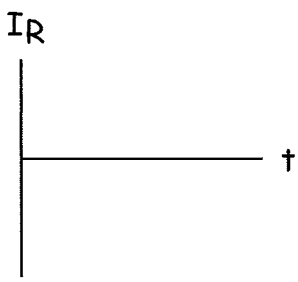
Discharging a Capacitor

When X is connected to Y the capacitor ____________ up through R. When fully charged it is full of electrical ________________. and Vc = ____. When X is connected to Z the capacitor discharges through R and electrons now have a path to get round to positive plate.

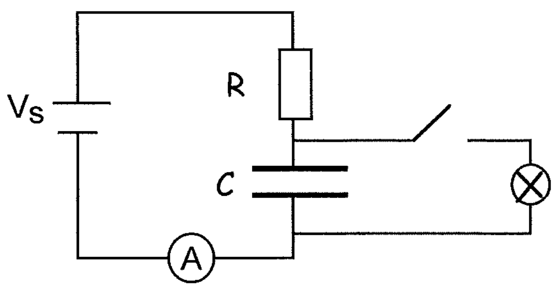


discharging graphs





If the capacitor is discharged very quickly all this energy can be converted to another form very quickly. For instance a camera's ______________________ or the pads on a hospital__________________________ machine. As power is energy per second a small amount of energy delivered in a short time can create a ___________power output.



Energy stored on fully charged capacitor-

$$E = \frac{1CV^2}{2}$$

$$\text{Power output } P = \frac{E}{t}$$

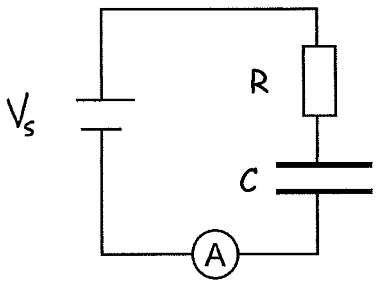
Changing R and C

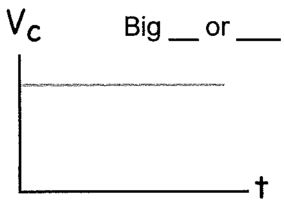
Increasing R means that it is more difficult for ______________ to flow round the circuit therefore it takes __________________ for the capacitor to charge up and ___________________ for it to discharge.
Changing R has ____ effect on the final voltage and charge stored on capacitor.

Increasing C means that it takes __________________ for the capacitor to charge up and ___________________ for it to discharge.

If Capacitance increases then it will take __________ charge to reach the max voltage. C= Q/V so that is why it takes longer.

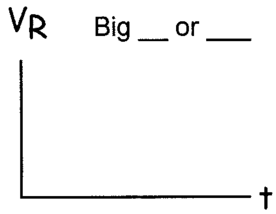
Charging





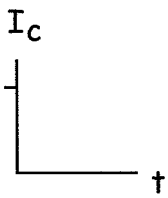
Big __ or __

Small __ or __



Big __ or __

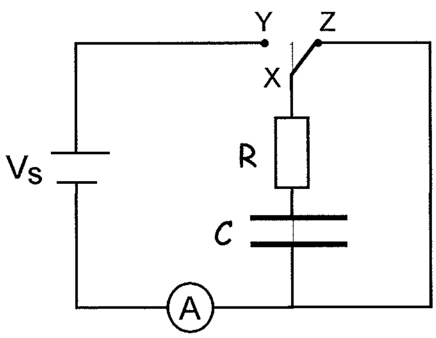
Small __ or __

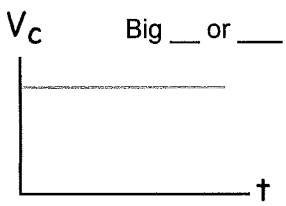


Small __ or __

Big __ or __

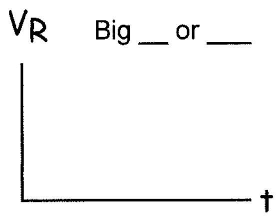
Discharging





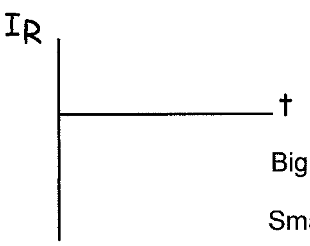
Big __ or __

Small __ or __



Big __ or __

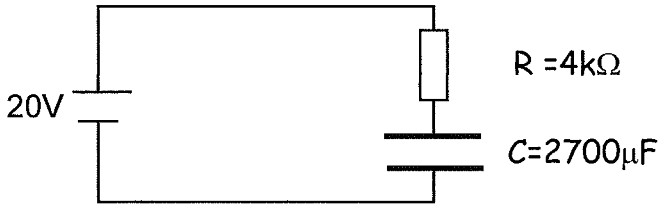
Small __ or __



Big __ or __

Small __ or __

Ex The following circuit was set up to charge a capacitor.



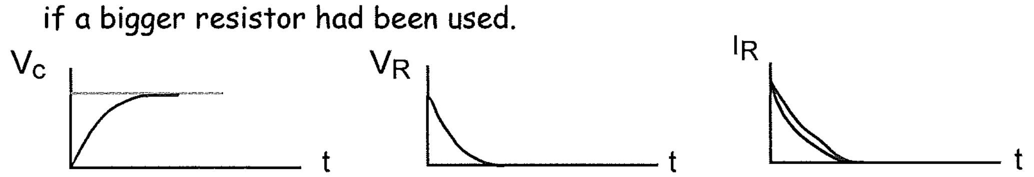
(a) Calculate the initial charging current.

(b) At one point the current in the circuit is 2mA. What is the voltage across the capacitor at this point?

(c) Calculate the charge stored on the plates of the capacitor when it is fully charged.

(d) Calculate the energy stored on the capacitor when it is fully charged.

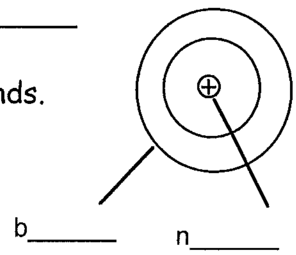
(e) Below are the graphs showing voltage caross capacitor and resistor and current through resistor during charging. Draw trace which you would get if a bigger resistor had been used.



Semiconductors

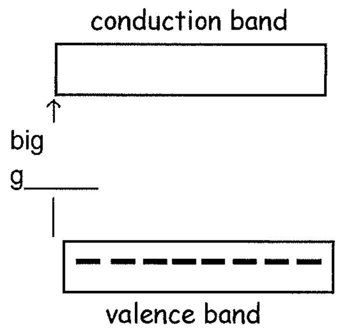
An atom is made up from a nucleus containing positive p__________ and n_______________ which have no c______________.
Electrons can only exist in discrete e__________ levels or bands.
Electrons fill the bands nearest to the n_____________.

Electrons which break free of the atom are said to be in the c__________________ band.



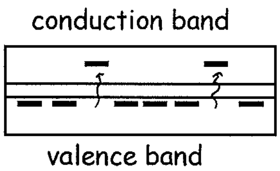
Insulators

In insulators the highest occupied band is the v______________ band. There are no free e______________ so there are no electrons in the c__________________ band. Even h__________ will not cause electrons to move from the v______________ to the c____________ band as there is a big band g_______.



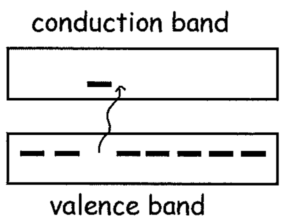
Conductors

In conductors like metals the valence band is n___ full so this allows electrons to move into the c________________ band. From here they can move from atom to atom if a pd is applied. Bands o________.



Semiconductors

Semiconductors are materials where the valence band is c________ to the conduction band so the addition of heat or voltage can cause electrons to move from the v_______________ band to the conduction band thus increasing its c____________.



The conductivity of a semiconductor can be further i__________________ by d________.

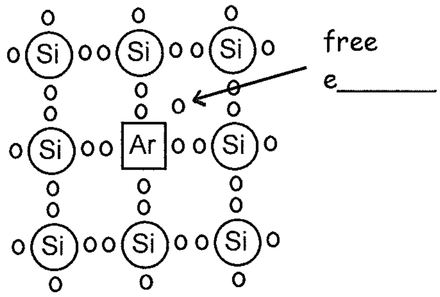
Doping

A pure or intrinsic semiconductor can be made from s_____________ or germanium and are insulators at r_________ temperature. They each have___ electrons in their valence band. So to create a full valence band it requires to bond with another atom with ___ outer valence electrons.

Doping is the process of adding an i______________ atom to a pure semiconductor . This has the effect of increasing the semiconductor's c___________________ and decreasing its r____________________.

n-type semiconductor.

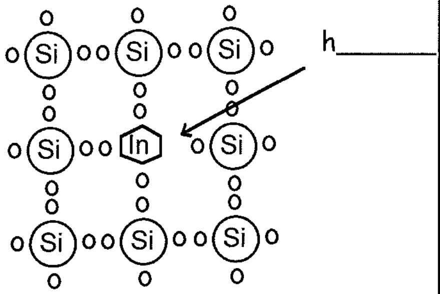
Atoms in a silicon atom have 4 outer electrons. An Arsenic atom has ____ outer electrons. So if the Si is doped with an Ar atom 4 electrons in each atom bond which leaves a free electron which moves into the c______________ band.



We say that the majority charge carrier in an n type semiconductor are n__________ e________________.

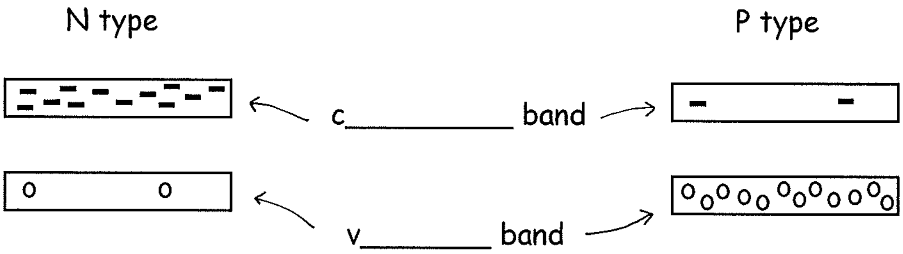
p-type semiconductor.

Atoms in a silicon atom have 4 outer electrons. An Indium atom has ____ outer electrons. So if the Si is doped with an In atom 4 electrons in the Si outer band bond with the ____ electrons in the Indium atoms outer band. This leaves a space or h_________ where an electron should be. We treat this hole as a P___________ charge carrier



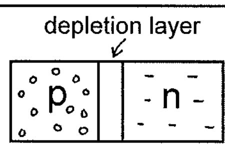
We say that the majority charge carrier in an p type semiconductor are p_________ h______________.

Energy band diagram for a n and p type semiconductor



N and p type semiconductors are still electrically n____________ as every electron present is balanced by a p____________ in the atom's nucleus

PN junction diode



When a p type and an n type semiconductor are grown together we create a pn j___________ diode. An area at the junction is formed called the d______________ layer. There are no c__________ carriers in this layer.

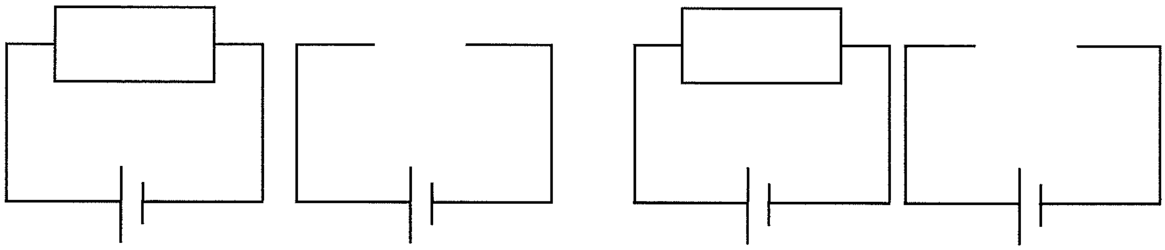
Draw the symbol for a pn junction diode here

Biasing

When a voltage is applied to a diode it can either be forward or r__________ biased.

F_________ bias - charges are pulled a_________ junction and a current flows

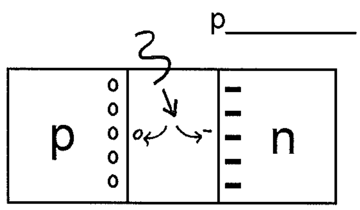
R___________ bias - charges are pulled a_______from junction and no current flows



The photodiode

When a piece of clear plastic is placed over the depletion layer p___________ of light can enter the diode. The photons hit the depletion layer and produce e_____________ h __________ pairs. This has the effect of increasing the emf across the d_____________ layer. This emf can be used as a source of electrical e____________. The brighter the light the bigger the e___.

Draw the symbol for a photodiode here



This is called the p______________________ effect because photons are being used to produce a v_______________ or emf. The photodiode is acting as a solar c_________.

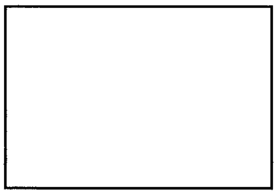
Calculating pd across junction

A photon of frequency 6.8×10^{14}Hz is incident on a photodiode.
What is the maximum voltage this photon can produce across the junction?

Light emitting diode LED

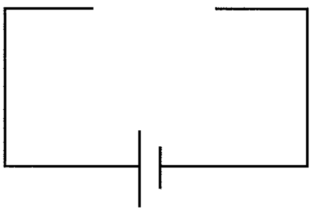
When a photodiode is placed in a f_______________ biased circuit electrons and holes are pulled across the junction. Occasionally they meet and r________________. This recombination produces a p_____________ of light. The distance between the conduction and valence band determines the c__________ of light produced.

Draw the symbol for a photodiode here

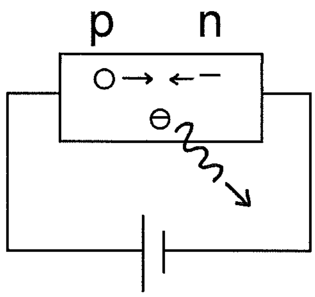


These two diagrams show a photodiode in forward bias.

Draw the symbol for a photodiode in forward bias



hole and electron r____________ and produce a p_________

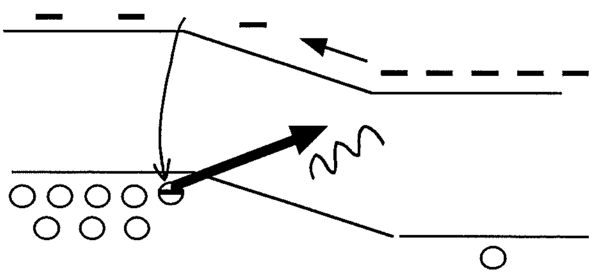


The recombination energy when an electron and hole meet is 4×10^{-19}J

(a) Calculate the frequency of the emitted photon.

(b) Calculate the wavelength of the emitted photon.

Energy band diagram for an LED



electron moves across junction in the c______________ band. Once across they fall into valance band and recombines with a h_______.