## Gravitational Energy

- Gravity – gravitational field = g applies force =field * mass.
- Energy to move up/down a field = force * distance = J (joules)
- Field = N/kg (= $m/s^2$) = g=9.81 $m/s^2$ (on earth's surface)
- force=field*mass=N (N=kg*$m/s^2$)
- Energy=J = kg*$m^2/s^2$
- Q:how much required to lift 2 kg vertically 6m?
  E=mgh = 2kg*9.81 $m/s^2$ *6m = 120 J
- Potential energy = how much will be released by moving *with* field = same amount as work energy required to move "up" against field
- A "drop" of 6m means g*d=9.81 $m/s^2$*6m=60 J/kg –means "drop" will release 60 Joules of energy for each kg that falls down it. It will take 60 Joules of work to raise each kg against it.
- Power = Energy/time = rate of energy transfer = Watts (1 W=1 J/s)
- Power bill is in KWH (Kilo-Watt hours) – should be Joules! 1 KWH = 1000 Watts * 1 hour = 1000 Watts * 3600 s = 3.6 MJ. 3.6MJ costs ~$0.10 today

## Electrical Energy

- Charge (Q) is equivalent of mass, electric field equivalent of gravitational field, voltage (V) is equivalent of "drop" = potential energy per unit of charge
- Electric field, force felt in field = field * charge
- Two points in a circuit have a potential energy difference of E=VQ
- Every Coulomb of electrical charge will release 1 Joule of energy if it "falls" down a "drop" of 1 V

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- Water analogy:
  drop,pressure=voltage amount of water=charge flow rate=current
  capacitor=water storage tank with input/output at bottom, pressure builds as water flows in, width of storage tank = capacity
- Current flow = C/s past a point
- Power=voltage*current=J/C*C/s=J/s
- Except during short circuits (BAD), all points along a wire are at the same voltage

## Batteries

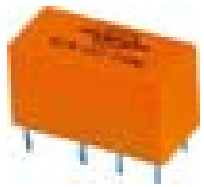
- If 1 C of charge flows from the + to – terminal of a 12V battery then Energy=voltage*charge = VQ =12*1 = 12 Joules
- If a 12V battery has a capacity of 2 AH (Amp-Hours) then it can theoretically hold provide I=1 A of current for 2 hours =2*3600=7200 seconds. Total charge Q=It=1A*7200s=7200 C. Energy storage possible E=VQ=12*7200C = 86400 J
- With some batteries they can typically supply current at 10% of the AH rating, so for 2AH it's reasonable to supply an average of 200mA. Others allow higher.

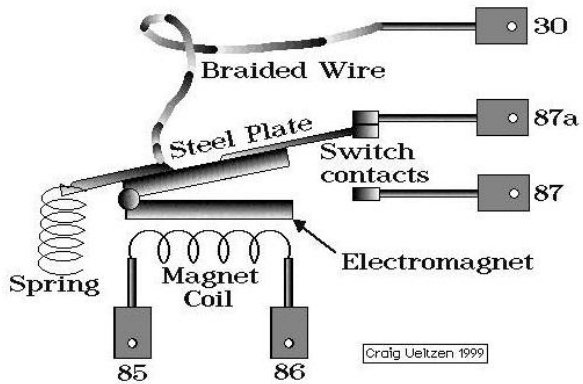
# Batteries

- Batteries in series: their voltages add – similar to two "drops" put one on top of another with gravity fields. Two 1.5V AA batteries in series give 3.0V.
- Series – positive of one connected to negative of another
- Batteries in parallel: their current capacity adds. Two 1.5V AA batteries in parallel provide 1.5V power source with twice the potential current – or a 1.5V power source that lasts twice as long for the same current draw (compared to a single battery)
- Common batteries: AA, AAA, C, D all have ~1.5V for Alkaline (non-rechargeable), ~1.2V for NiCad rechargeables. 9V square batteries = 9V (just composed of 6 smaller cells inside in series), ~7.2V for rechargeable.
- Also common is 9.6V battery packs for RC cars.
- 12V lead acid, 'Gel cells' are also common – in backup lighting and larger mobile robots!
- Q: A toy has 4 AA batteries in series. What voltage will the total battery pack be for 1: Alkaline, 2:Nicad? A: 6.0V, 4.8V
- Lithium batteries have greater energy storage per weight and size, have greater peak current capacity – and don't have Nicad "memory effect". They are used in most cell phones. Drawback is cost.

## Relays

- Electromechanical device – small current through input coil allows control of larger current.
- Equivalent to closing a switch, except that it's done by an electromagnet
- Spring loaded to return switch to default position when electromagnet turns off
- "click" sound.
- Cannot be turned on and off rapidly (eg. Cannot turn a relay on and off 100 times a second)
- Benefit: control a lot of current with a small device






## Configurations

Relays, like switches, have various configurations:

- SPST-NO = single pole, single throw, Normally Open
- SPST-NC = single pole, single throw, Normally Closed
- SPDT = single pole, double throw: both a normally open and normally closed contact
- DPDT = double pole, double throw: two separate switches controlled from the same electromagnet, each switch has both a normally open and normally closed contact

Image source: http://www.classictruckshop.com/clubs/earlyburbs/projects/bosch/relay.htm

Image source: http://www.maplin.co.uk/searchtemplate.asp?criteria=2V%20RELAY

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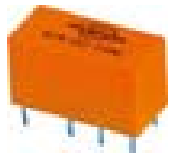

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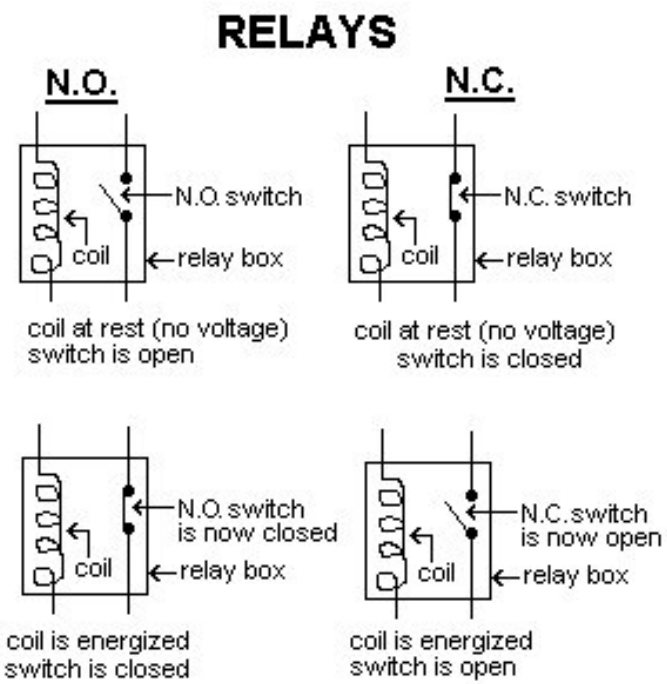


Image source: http://www.electronicsguru.co.cc/2009/07/29/27/

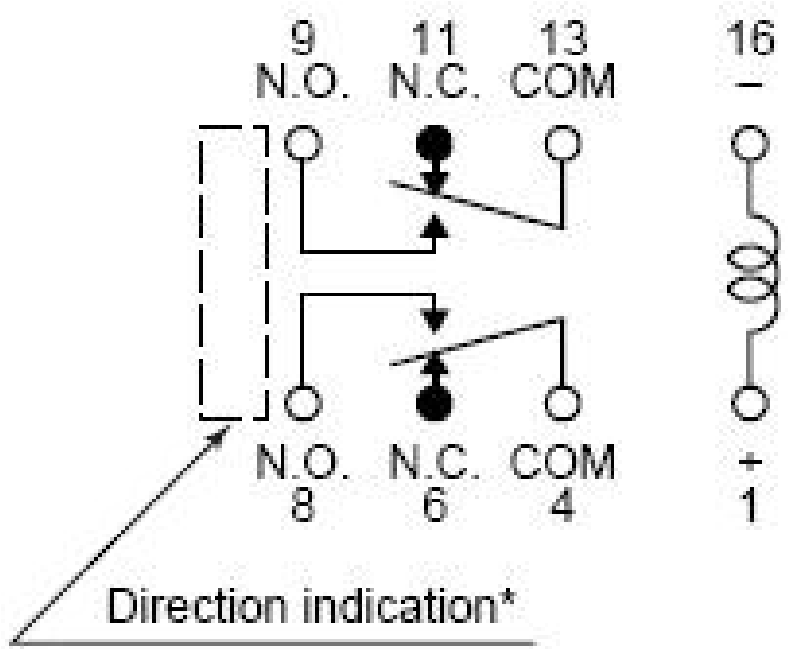


Image source: http://profmason.com/?cat=6&paged=2

## DC Motors

- DC motors use a constant voltage source, current flows in just one direction (DC=direct current)
- Apply a voltage to a DC motor and it applies a torque on its shaft. If the torque exceeds external torques (friction, load) then the shaft starts rotating (angular acceleration)
- The larger the voltage you apply to a DC motor, the faster it goes (to be explained later in the course)
- To make the motor turn the other direction, reverse the voltage applied to the motor

## Using Switches (or Relays) to Control Motors (one direction)

- To turn a motor on and off you need to connect or break the flow of current. You can connect the + terminal of a battery through a switch to one terminal of the motor, with battery – connected to the other motor terminal. Alternatively you can put the switch between the motor and battery – instead.
- With a single voltage source you only need 1 switch to control the motor.

## Using Switches (or Relays) to Control Motors (both directions)

- Assuming you have a single voltage source, such as a battery (or battery pack), to make the motor spin one way you need to connect + to one motor terminal, and – to the other. To spin the other way you need to disconnect + to the first terminal and connect -, likewise disconnect – from the second and connect +.
- With a single voltage source you need 4 switches to control the motor.

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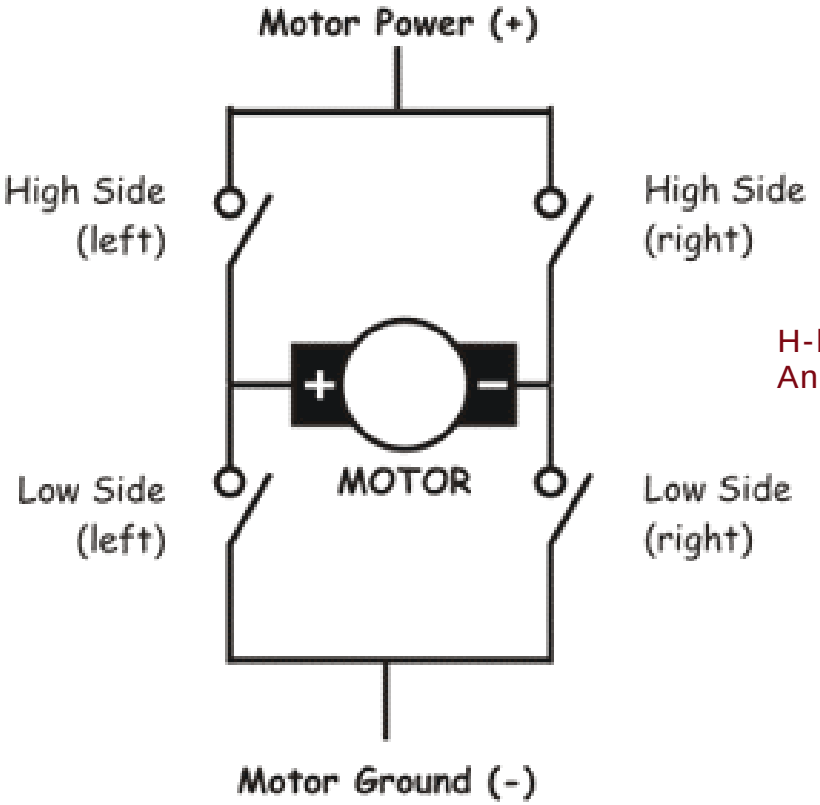


H-bridge tutorials: link below from image,
And http://en.wikipedia.org/wiki/H-bridge

Image source: http://www.mcmanis.com/chuck/robotics/tutorial/h-bridge/index.html

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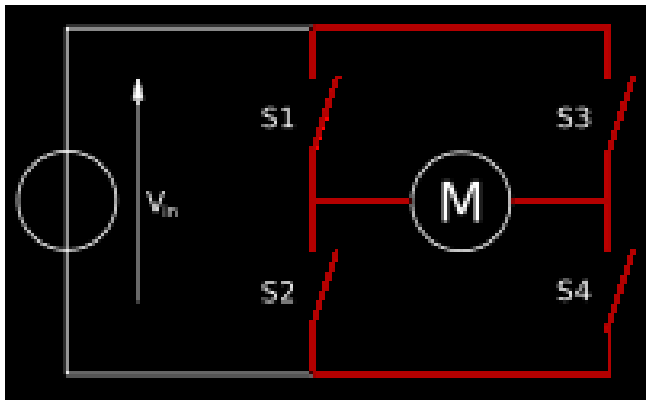


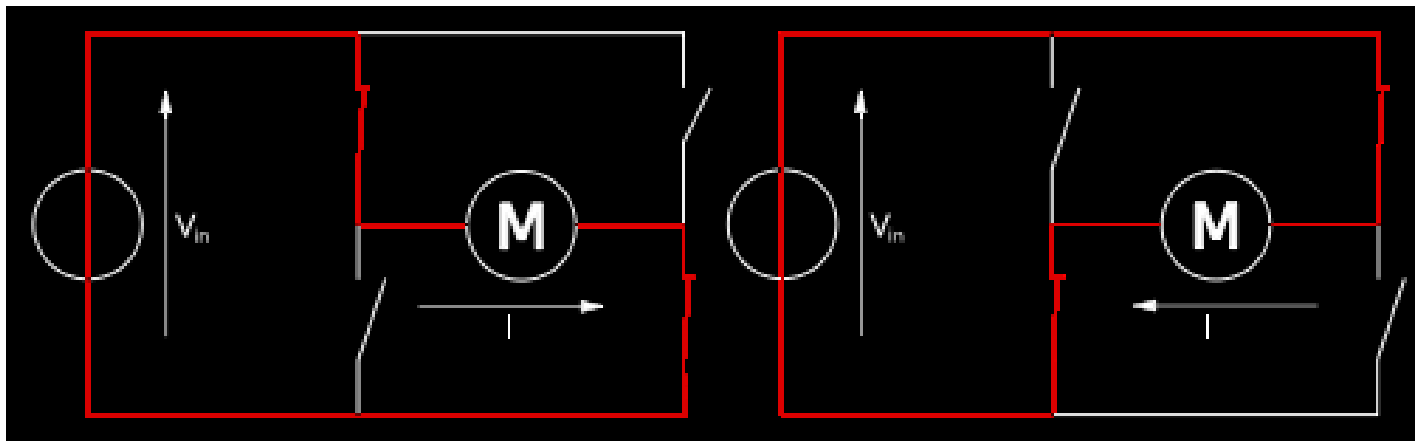


Image source and H-bridge tutorials: http://en.wikipedia.org/wiki/H-bridge