ECSE-211

Lecture 18

15 February 2016

Design VIII

Friday Mid Term 1135

Group Meeting - Mon 22 Feb

watch MyCourses

The Project

- Available Wednesday, 10 February
- Start Monday, 22 February
  - Identify the problem, set up the tasks, identify the resources, complete the documents
- Milestones?
  - 14 March– initial mechanical design, software architecture
  - 21 March – Mechanical design complete, initial software running (Beta 1)
  - 30 March – Beta 2 Demonstration
  - 13 April – Final Design Demonstration

The Project

- Weekly meetings with professors – max half an hour for each team each week
- Major tasks:
  - Mechanical design
  - Software architecture
  - R&D to calibrate sensors, measure performance of mechanical system
  - Documentation

The Project

- Major Tasks (Cont'd)
  - Design tests
  - Component testing
  - Integration testing (min 2 weeks)
- Resources
  - Tasks need resources to be allocated to allow them to be implemented

  Completing the Gantt chart requires the process to be understood…

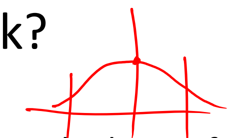
Building the Gantt Chart - Management

- A few rules
  - Get all team members commitments for the entire time of the project
  - Do not overload any team member in the first draft
  - Do not create a task on the timeline which runs more than 2 or 3 days – in the context of this work, this is a very long time and if a problem occurs you need to be able to identify it as soon as possible

Building the Gantt Chart - Management

- A Few Rules (Cont'd)
  - Clearly identify dependencies between tasks
  - Do not forget to include documentation tasks and, in particular, the tasks involved in developing the presentation of the project.

How do you Estimate the Time Needed to Complete a Task?



- Experience
- General metrics – for example estimate the lines of code needed for a task and then the number of lines per person per day.

50 loc

- Generate a "most likely time", an "optimistic time" and a "pessimistic time"
- Combine the estimates into an "expected time" - the average time a task would take if it were repeated on a number of occasions. E.g.
  - $\mathbf{T_E = (O + 4M + P) \div 6}$

Motors and Actuators
Energy, Power, Efficiency

AA

1500 mAH.

volt? 1.5

VAH = WH

2.25 wH

2day.

VHF 20w
Google 10w
Flashlight 5w

35w

48 hours

750

M&A 2

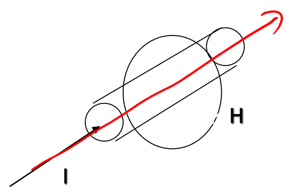
- To interact with an external environment, the robot system uses devices which can convert electrical energy into mechanical force
  - These are *motors* (and *actuators*)
- Such systems perform *Electromechanical Energy Conversion*
- Mechanical Force can be produced by:
  - The interaction between electrical charges
    - Similar charges repel, opposite charges attract.
  - The interaction between magnets
    - Similar magnetic poles repel, opposite poles attract.
  - These attraction and repulsion forces form the basis of all systems which convert electrical energy into mechanical effects (and vice versa)

M&A 3

- Some History:
  - The forces between electrical charges have been known for at least two millennia
  - The forces between magnetic poles have been known for as long, if not longer (lodestone in navigation)
  - However, these are *static* effects and not much use in most practical situations….
  - In 1821 Oersted recognizes that a current in a wire attracts a magnet..
    - i.e. a moving electrical charge acts like a magnet (creates a magnetic field)
    - Hence a *current can be used to create a controllable magnetic field*.
  - 1821 Ampere translates Oersted's discovery into an equation:

$$\oint H.dl = I$$

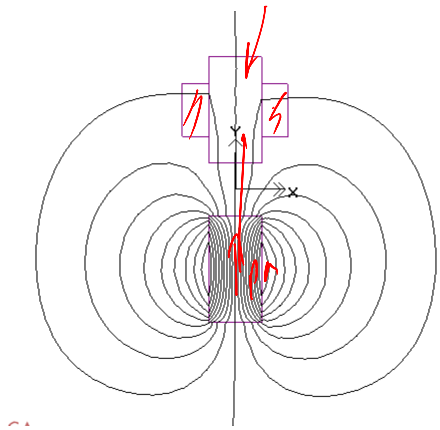
M&A 4



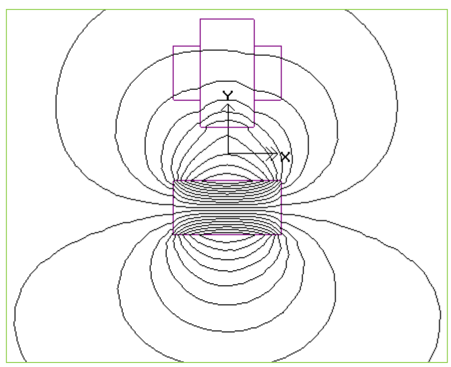
- So – motion can be created by placing a permanent magnet near to a current carrying wire…
  - The magnet will rotate until its magnetic field lines up with the wire…

M&A 5

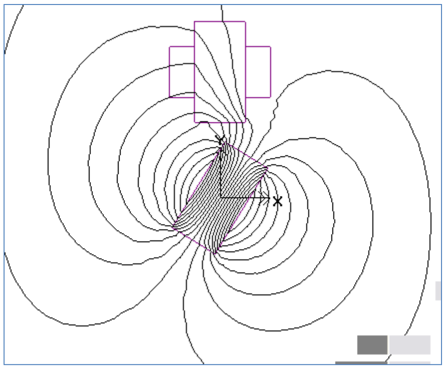
- Iron is a magnetic material – it acts as a conductor of magnetic flux…



M&A 6

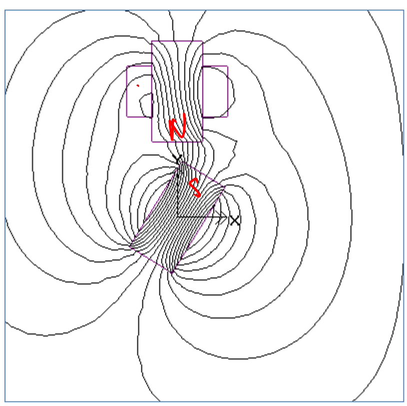


M&A 7



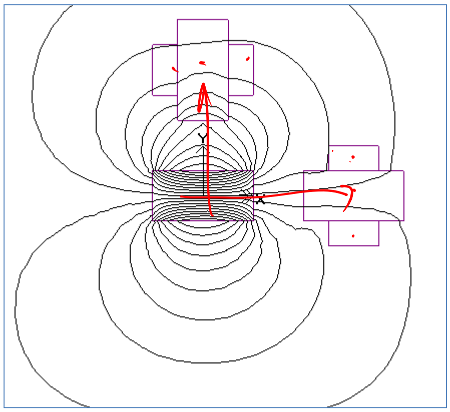
M&A 8

- Now add current in the coil:



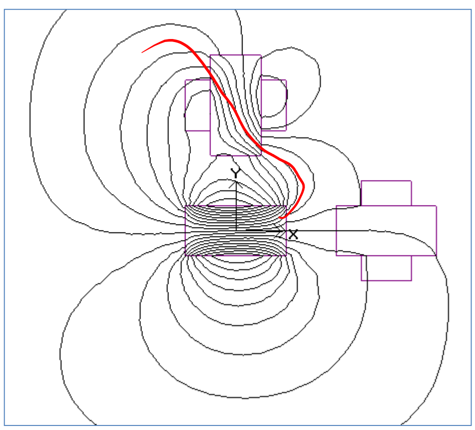
M&A 9

- Now add in a second pole but no current..



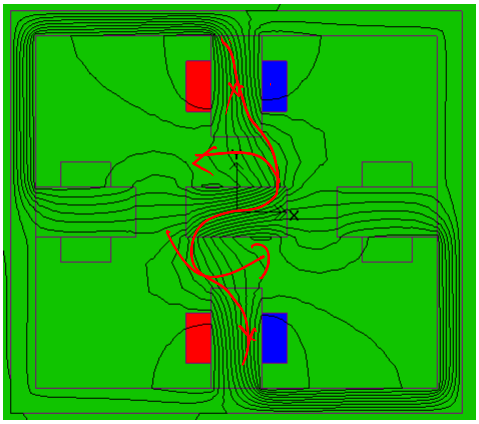
M&A 10

- Energize the first pole:



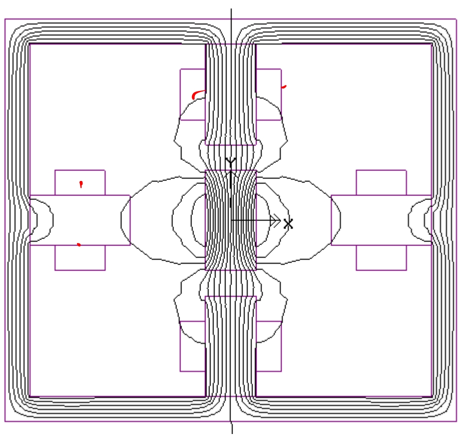
M&A 12

- Now add two more poles and a better iron circuit and excite the vertical poles:



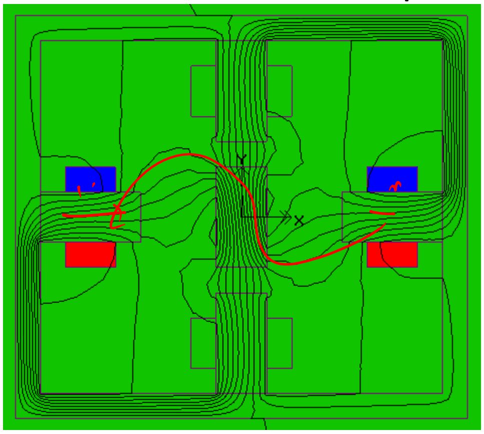
M&A 13

- When magnet moves to vertical position, turn off the current:



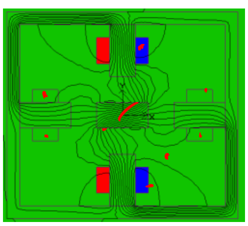
M&A 14

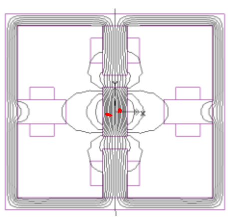
- And turn on the horizontal poles:

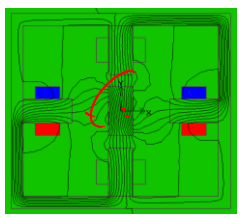


M&A 15

- So the whole sequence:







M&A 16

- So.. we have:
  - By energizing a pole, the magnet will line up with it.
  - If the current is removed when it lines up, the magnet will stay “locked in”.
  - If the next set of poles is energized, the magnet will move to line up with them..
- Thus, if we apply a current in sequence to each pair of poles, the magnet will keep rotating – *A Motor*!
- The torque on the magnets is more or less proportional to the current and the magnet strength.
  - *Thus torque is increased by increasing the current*

M&A 17

- Now Newton’s equation of motion states:

$$F = m.a$$

- In rotational systems, this becomes:

$$T = I\,\ddot{\theta}$$

- Thus, the greater the torque, the faster the magnet will rotate.
- However, in 1831, Faraday discovered that an electric circuit which “sees” a changing magnetic flux will have a voltage induced in it..

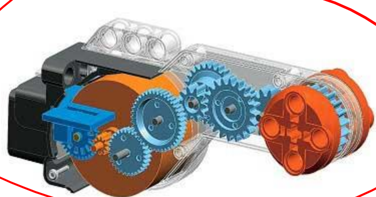
$$e = -\frac{d\phi}{dt}$$

M&A 18

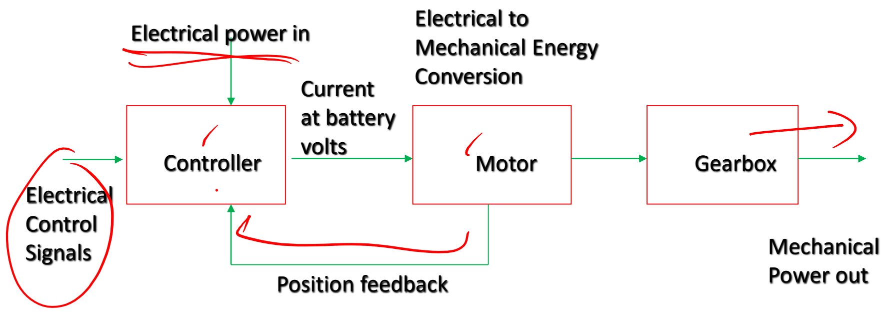
- In effect, when the magnet rotates, the coil sees a changing magnetic flux and thus a voltage is induced in the coil which counteracts the supply voltage…
- Thus the current in the coil is reduced..
- At some point, the current in the system cannot be increased and a maximum speed is reached, i.e. if the induced voltage reaches the level of the supply voltage, there is no current.
- The motor in the NXT is basically a version of a permanent magnet machine – but is circular rather than square!

M&A 19

- Note that, if the current is continuously moved from one pole to the next, there is continuous rotation. However, by applying a single pulse to one pole, the motor will rotate and lock – thus it can be stepped from one position to the next.
- The rotation angle (and the speed of rotation) seen at the shaft of the NXT motor unit is much less than the rotation at the motor because the output goes through a reduction gearbox:



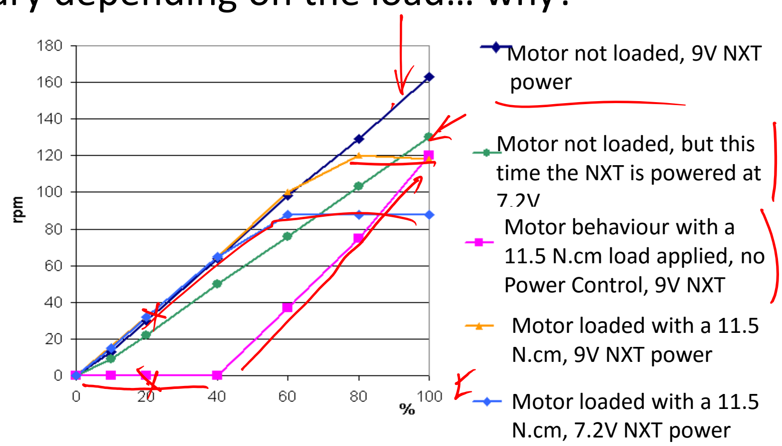
M&A 19a



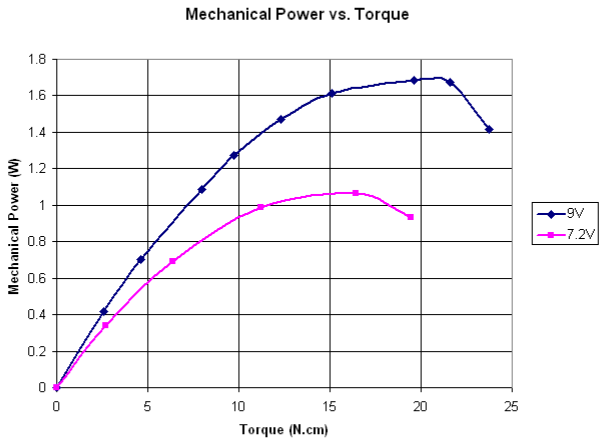
- The Drive System

M&A 20

- The input power vs speed curves of the motor vary depending on the load… why?



M&A 21



M&A 22

- Power and Energy:
- Power is the rate at which work is performed or energy transferred:

$$P = \frac{dE}{dt} = \frac{dW}{dt}$$

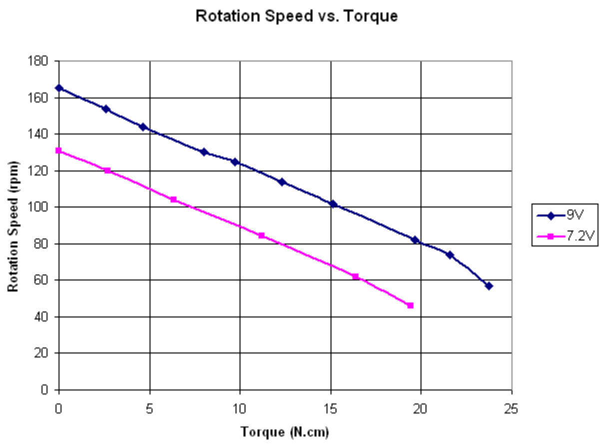
- Mechanical work is:

$$W = \int F.ds = \int T.d\theta$$

- Instantaneous mechanical power is:

$$P(t) = T(t).\dot{\theta}$$

M&A 23



M&A 23

- The electrical power being input to the system is:

$$P(t) = I(t).V(t) = I^2 R = \frac{V^2}{R}$$

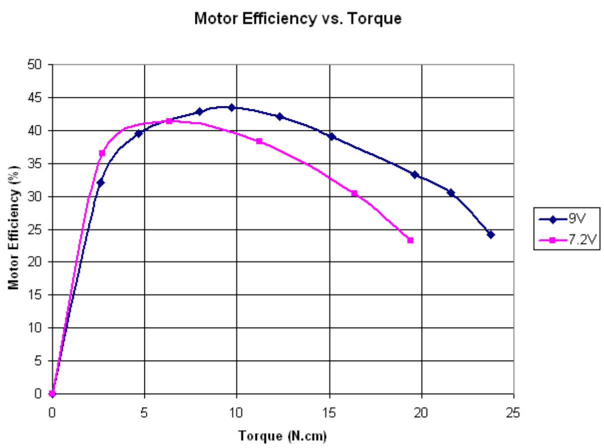
- Efficiency is described as the energy output over the energy input:

$$\eta = \frac{Mech\,Power\,Out}{Elec\,Power\,In} = \frac{T.\dot{\theta}}{I.V}$$

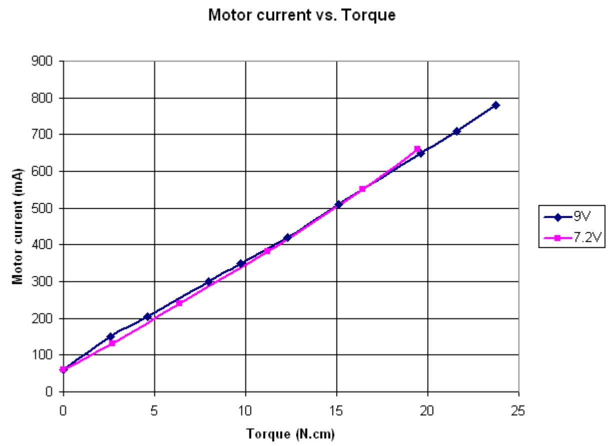
M&A 24

- Some definitions:
- 1 Watt:
  - When a voltage of one volt is applied across a device that has one amp flowing through it.
- 1 Horsepower:
  - Defined in imperial units = 33000 lb.ft/minute
  - =746 watts..
- Note that energy has the units of:
  - Mass*acceleration*length = $M.L^2/T^2$

M&A 24



M&A 25



- The motor data is from: http://www.philohome.com/nxtmotor/nxtmotor.htm

M&A 26

- So why is the motor not 100% efficient?
- Where is the power (energy) going?
- What is this lack of efficiency going to mean to your project?
- What happens if the motor stalls (i.e. you request too much torque)?