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2.007 Design and Manufacturing I
Spring 2009

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2.007 –Design and Manufacturing I

Actuators:

Electric Motors, Servomotors, and Pneumatics

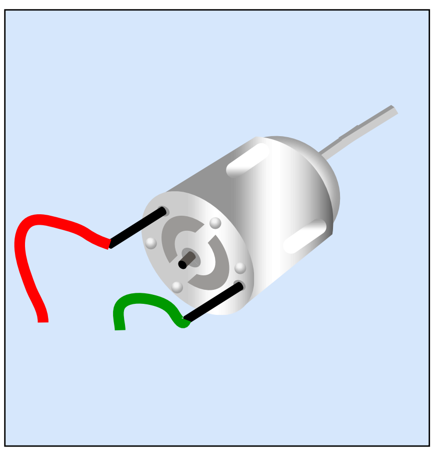
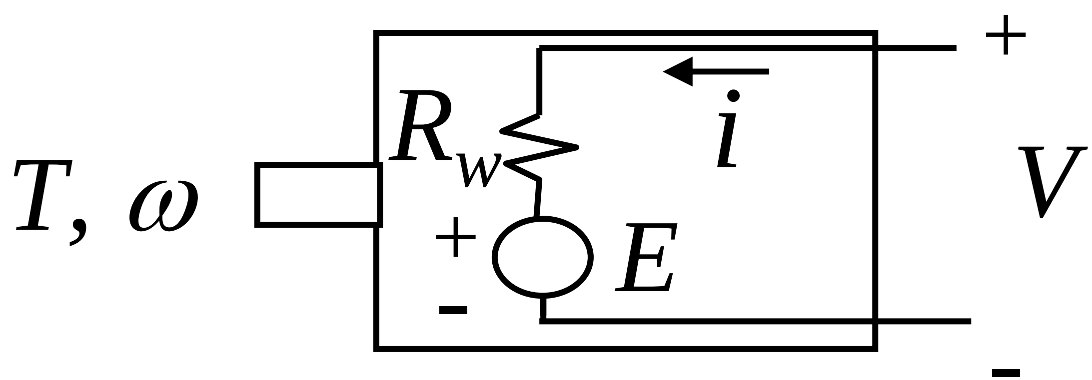


Figure by MIT OpenCourseWare.



Dan Frey

Presented by Dan Frey on 10 FEB 2009

Concept Question

- With this arrangement, I can hold up 1lb of water with less that 1lb of tension in the spring
- What will happen if I swap in a smaller diameter of PVC pipe (reduce the OD from 1.5” to 1.25”)?

The tension will:

1) drop by much more than 20%
2) drop by about 20%
3) stay nearly the same
4) rise by about 20%
5) rise by much more than 20%

Concept Qu

The answer is 3. The capstan equation indicates that the ratio of the two forces is e^(mu*theta). Radius is not a variable in the formula.

- With this arrangement, I can hold up 1lb of water with less that 1lb of tension in the spring
- What will happen if I swap in a smaller diameter of PVC pipe (reduce the OD from 1.5” to 1.25”)?

The tension will:

1) drop by much more than 20%

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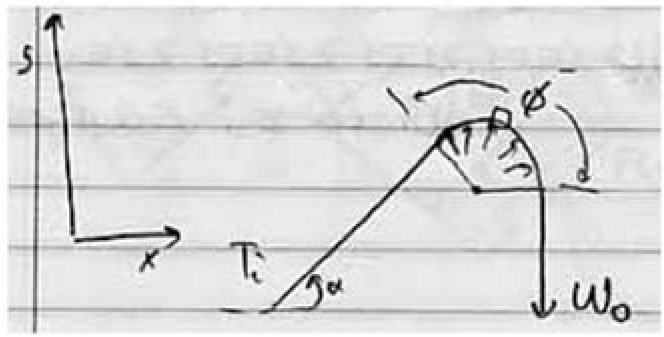
3) stay nearly the same

4) rise by about 20%

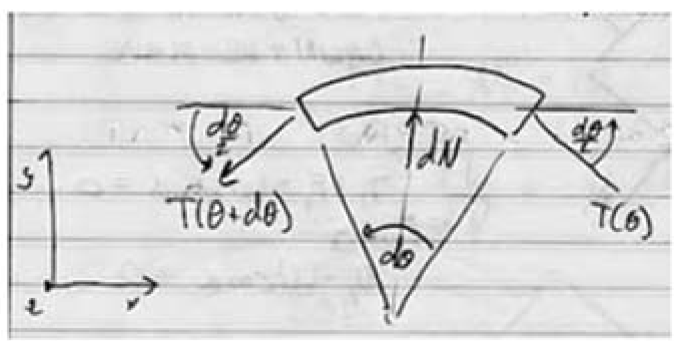
5) rise by much more than 20%

Some Notes on Capstans from 2.001

FBD of Cable



Look at differential element



Courtesy Carol Livermore. Used with permission.

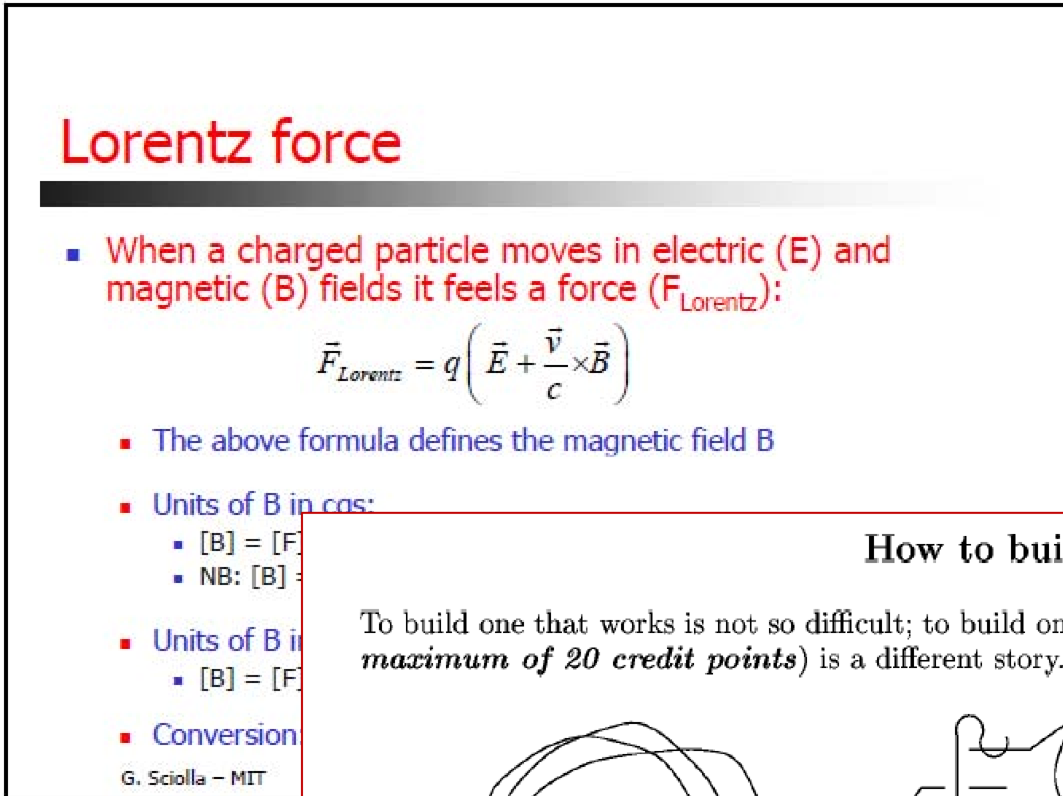
HS-311 Standard Servo spec sheet removed due to copyright restrictions. Please see http://www.hitecrcd.com/product_file/file/45/HS311.pdf

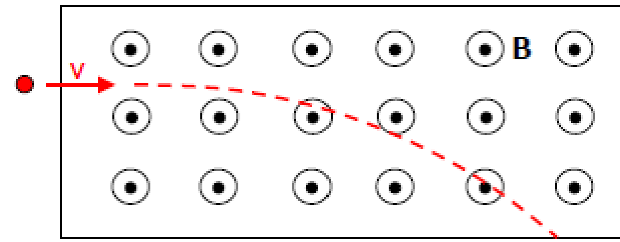
How might I estimate the maximum power available at the output shaft ?
The electrical power consumed ?

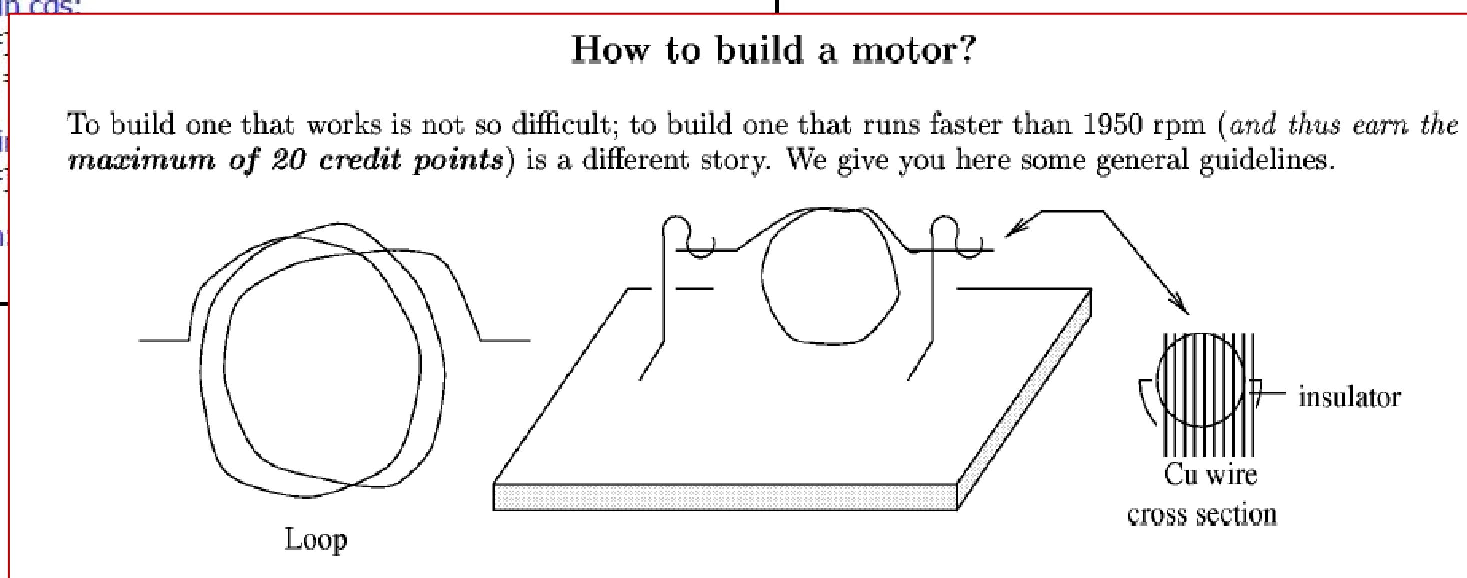
HS-805BB+ Mega ¼ Scale Servo spec sheet removed due to copyright restrictions. Please see http://www.hitecrcd.com/product_file/file/66/hs805.pdf

How do you think power provided by a servo scales with its linear dimensions?

What You May Have Seen







Courtesy Gabriella Sciolla and Walter Lewin. Used with permission.

DC Permanent Magnet Motor

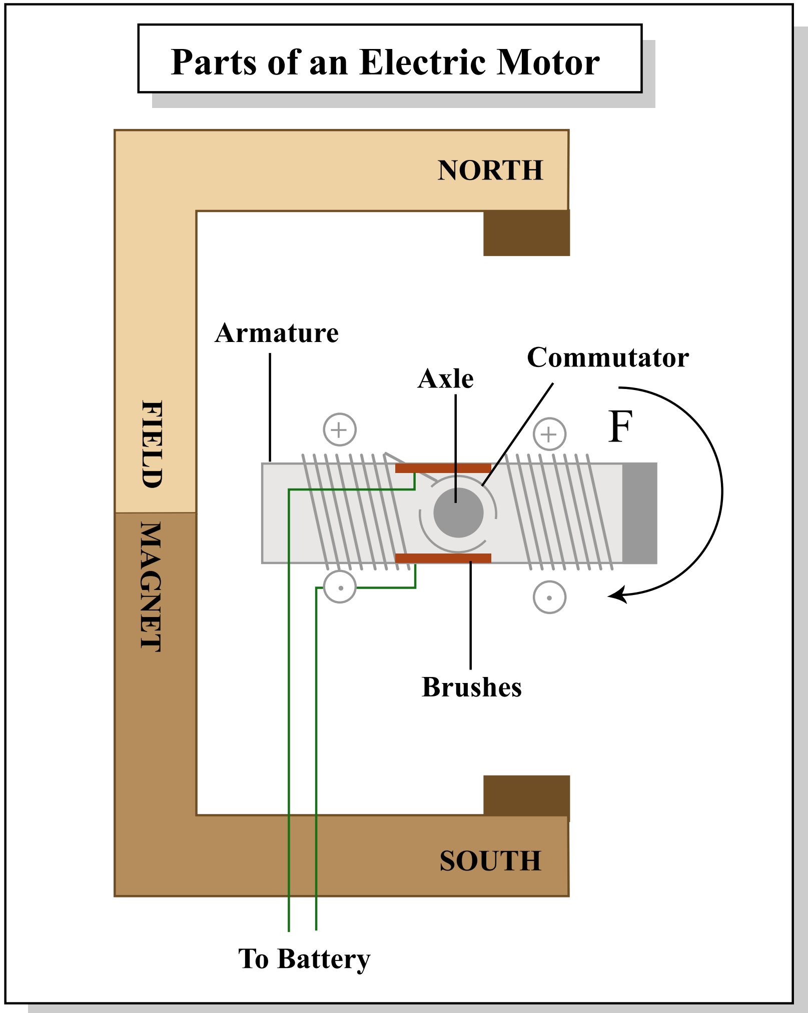


Figure by MIT OpenCourseWare.

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

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Discussion Question:

How can I design a DC motor to provide high stall torque?

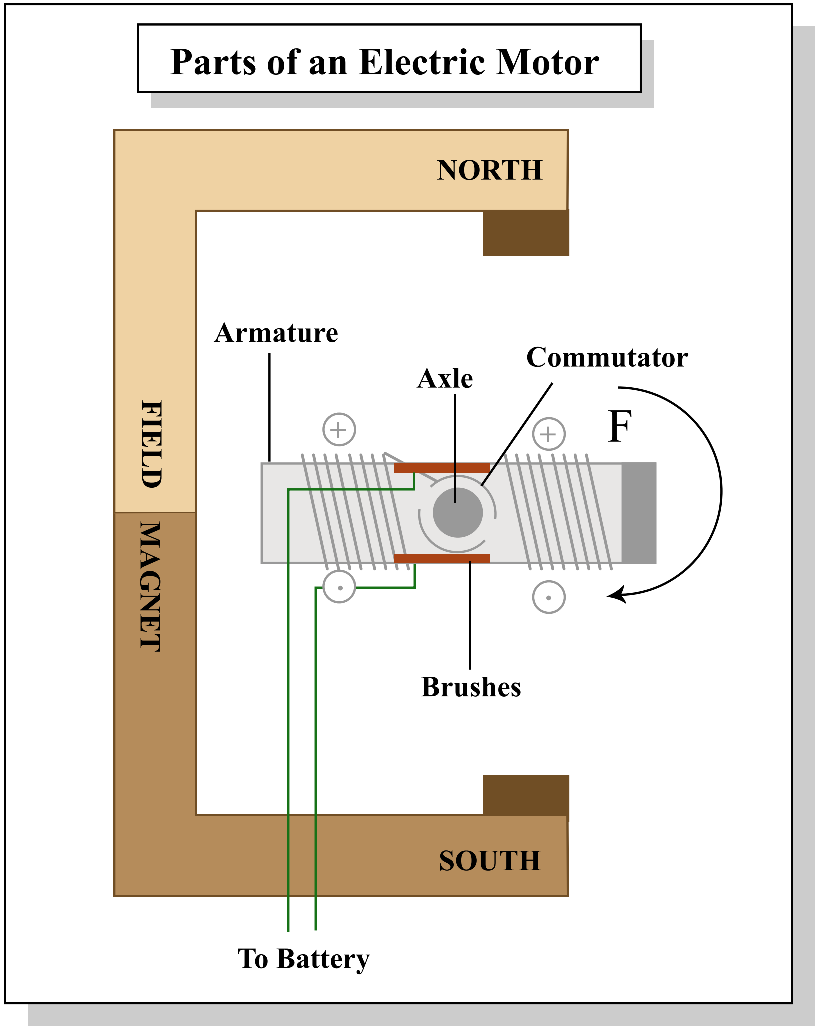


Figure by MIT OpenCourseWare.

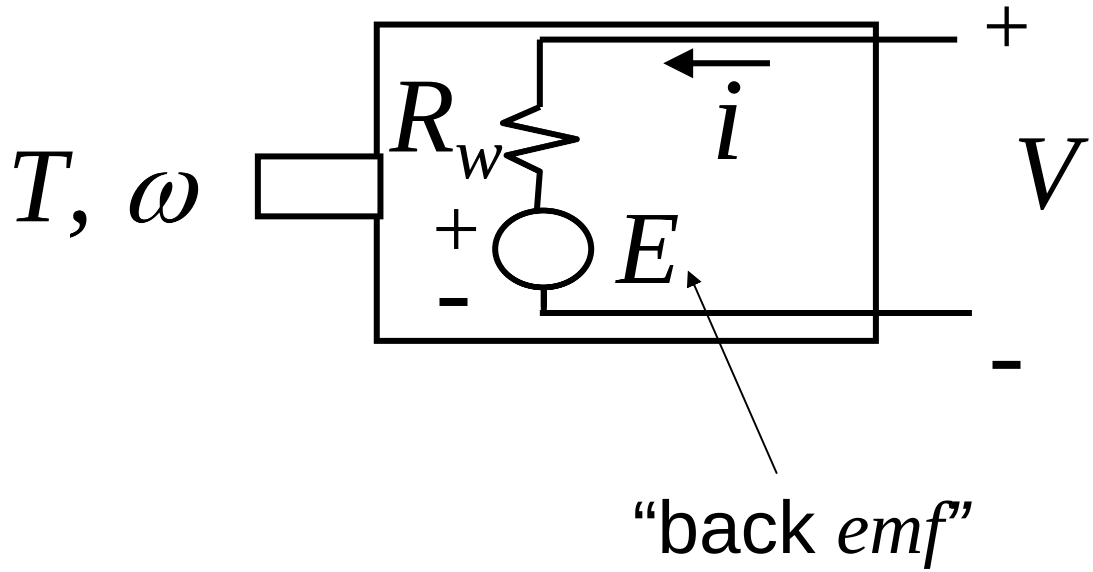
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

Some options include increasing the magnetic field, increasing the radius at which the force acts, increasing the number of windings, and increasing the current flow through each winding (such as by raising the voltage).

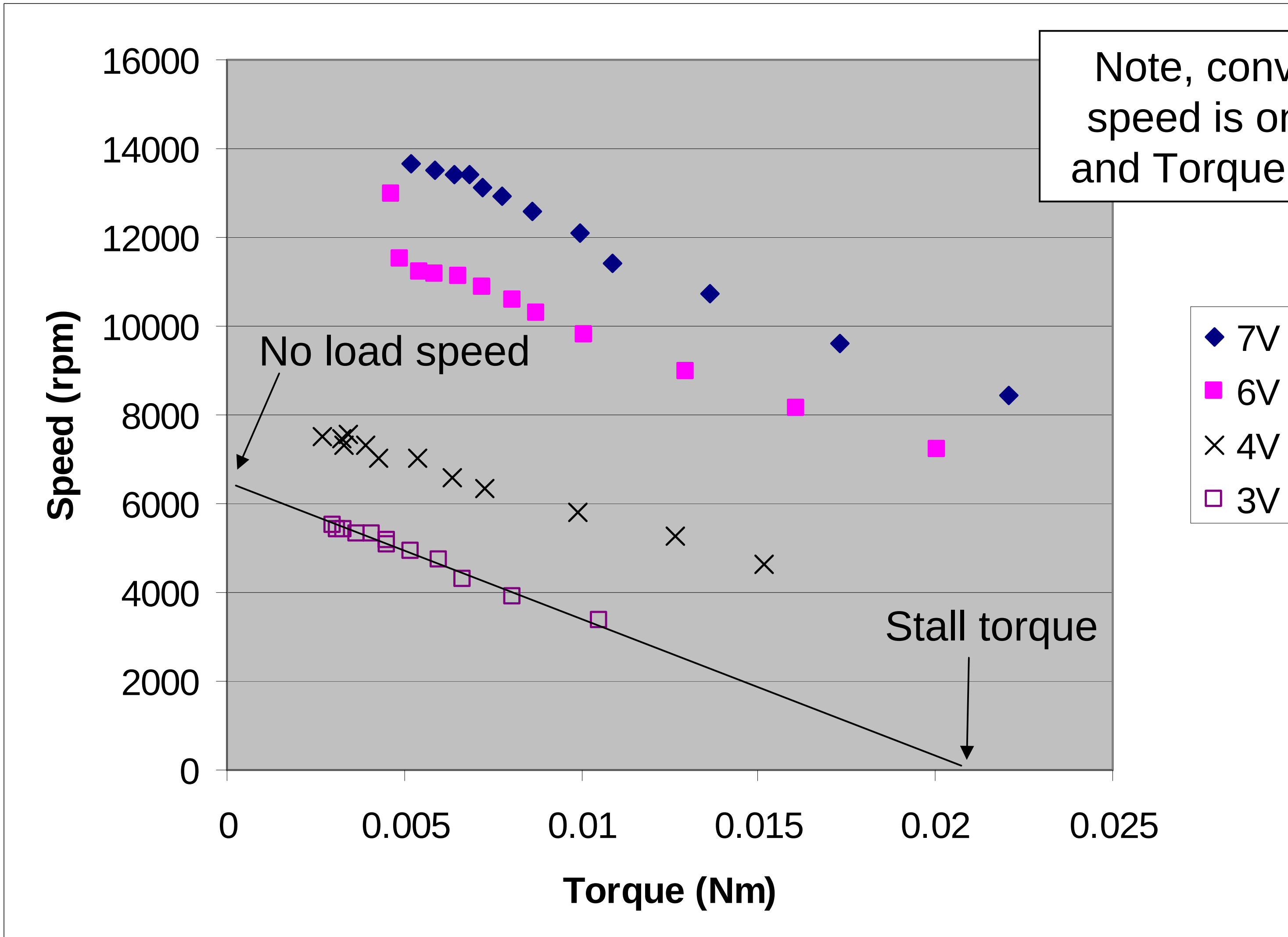
Image remove due to copyright restrictions. Please see http://static.howstuffworks.com/gif/motor7a.jpg

A Model of a Motor (Steady State)

$$E = V - R_w i$$



Torque Speed Curves



Note, conventionally, speed is on the x axis and Torque is on the Y.

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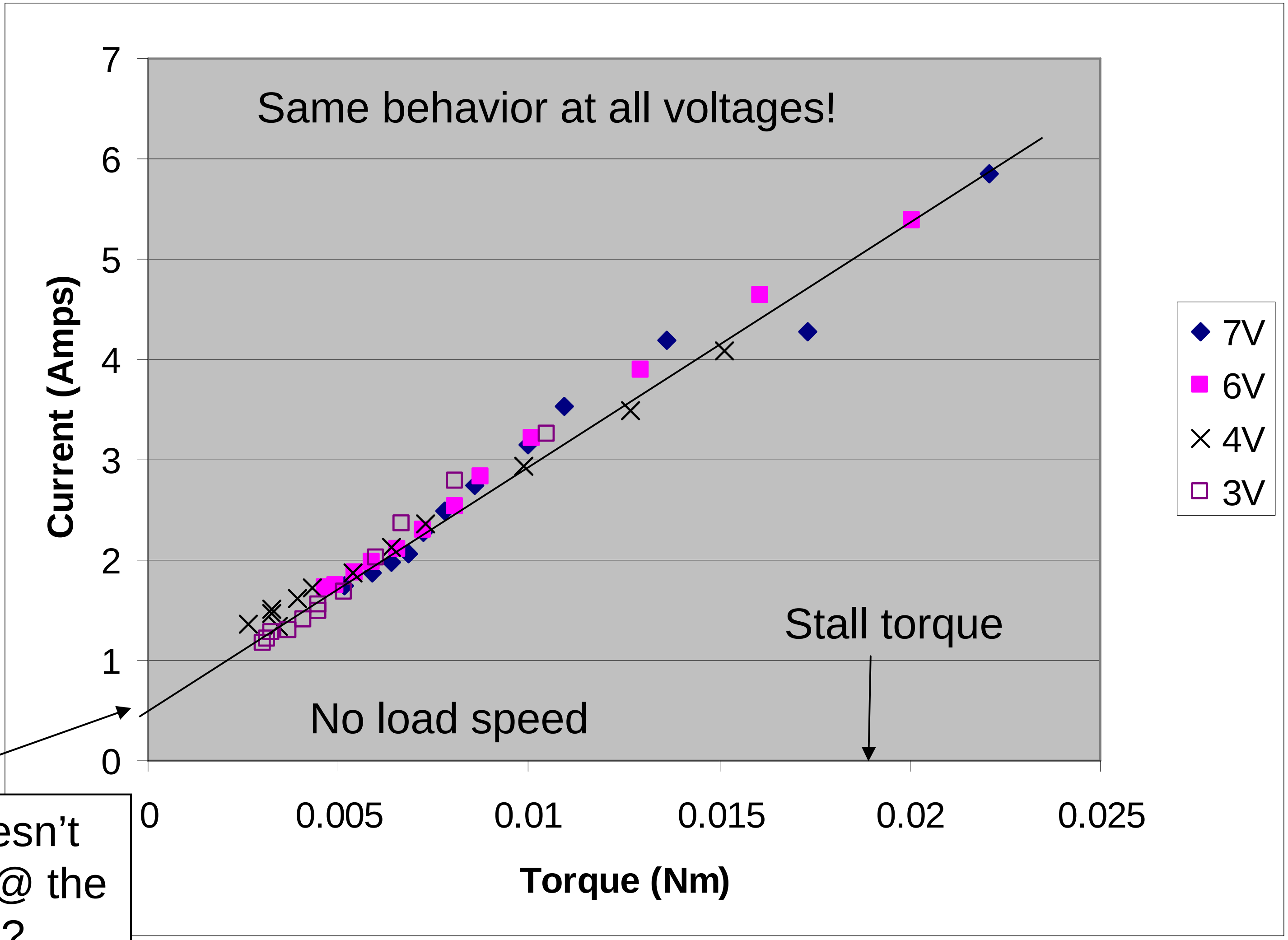
http://www.robotmarketplace.com/images/store_speed400.jpg

Torque Current Curves



Why doesn't intercept @ the origin?

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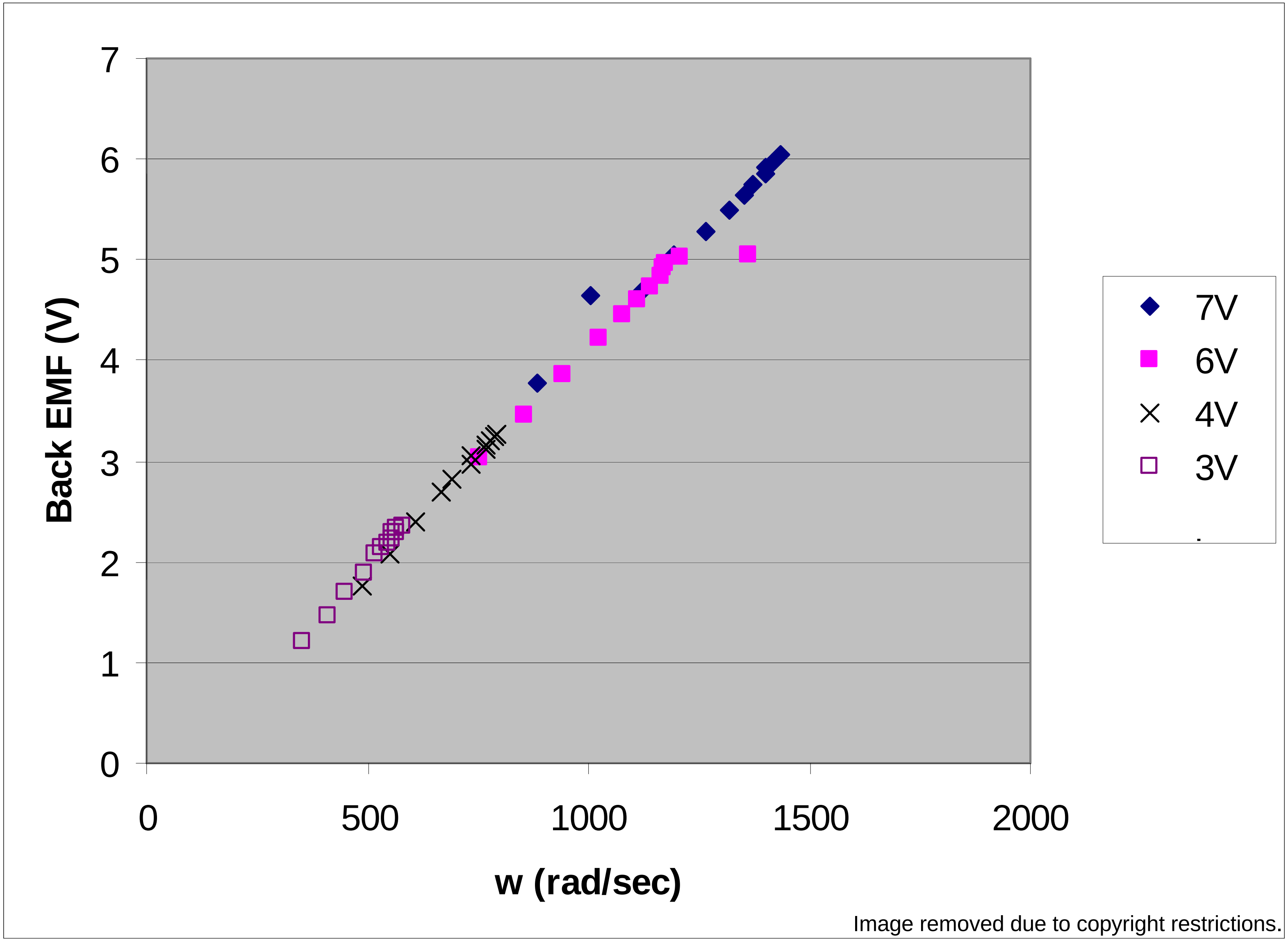
Back *emf* versus speed



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Concept Question

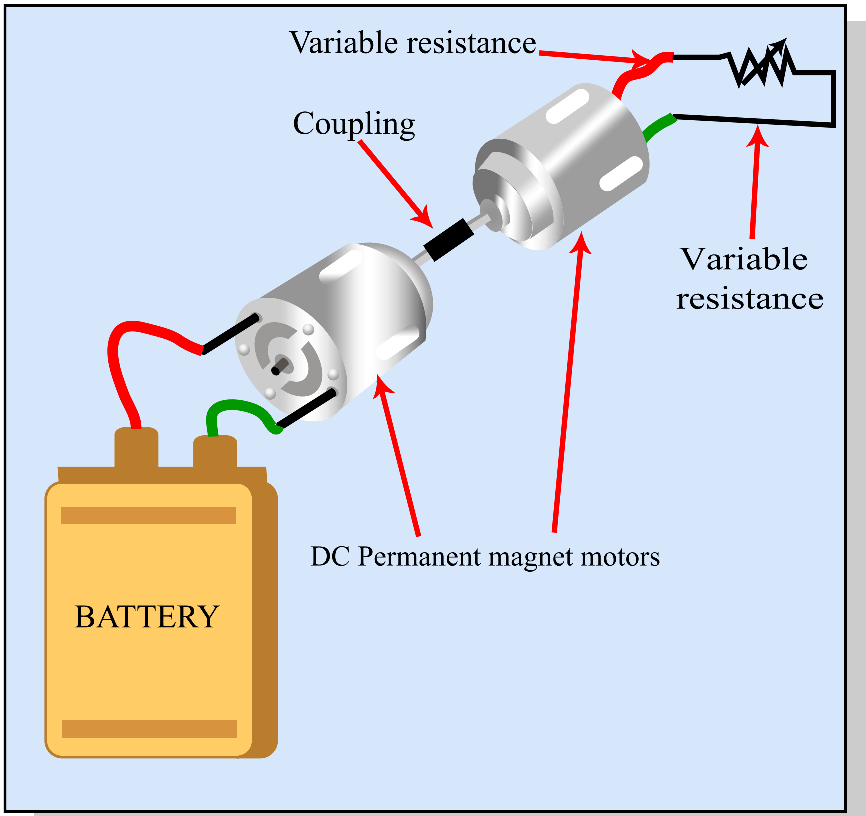

Figure by MIT OpenCourseWare.

As the resistance is increased:

1) The shaft speed rises monotonically
2) The shaft speed drops monotonically
3) The shaft speed rises, reaches a maximum, then falls
4) The shaft speed falls, reaches a minimum, then rises

DC permanent magnet motors

Concept Qu

The answer is 1. As the resistance increases it decreases the current flow. When the resistance is very high, it's as if the terminals were an open circuit. An electric potential will be present at the terminals, but no current flows. With no current, there are no forces applied to the armature. The motor connected to the battery can turn freely and approximates its "no load" speed.

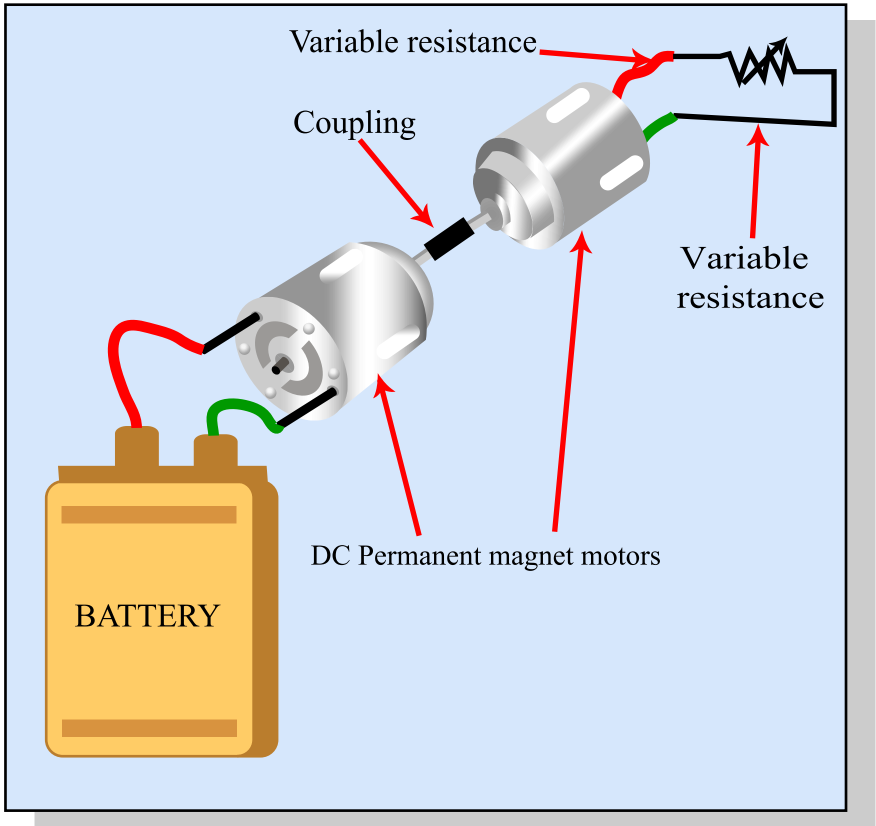

Figure by MIT OpenCourseWare.

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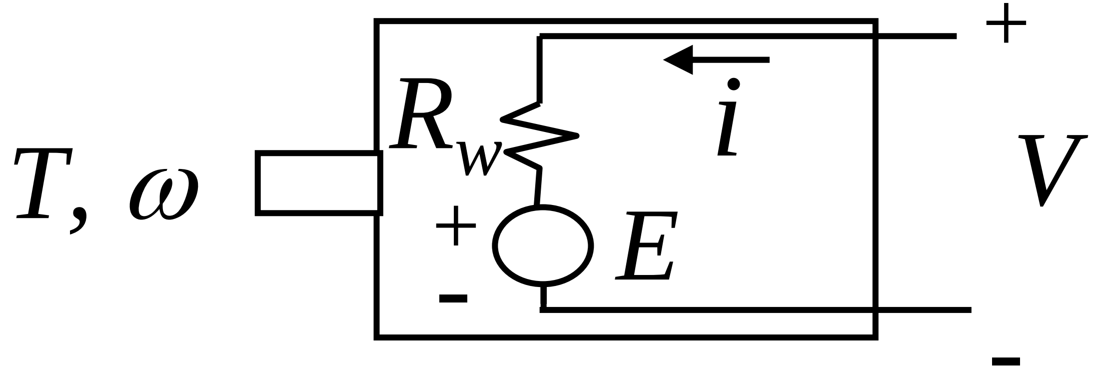
1) The shaft speed rises monotonically
2) The shaft speed drops monotonically
3) The shaft speed rises, reaches a maximum, then falls
4) The shaft speed falls, reaches a minimum, then rises

DC permanent magnet motors

Discussion Question:

How do the things I might do to raise stall torque affect back *emf*?

$$E = V - R_w i$$



Most of the things I can think of to raise the stall torque will also increase back emf. That applies to increasing the magnetic field, increasing the radius of the armature, and increasing the number of windings.

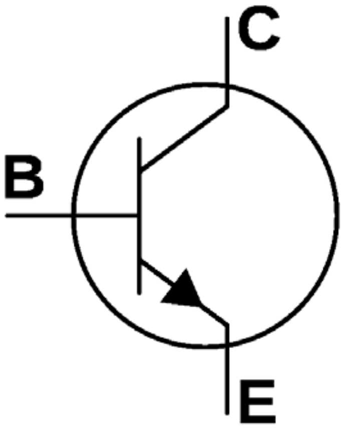
Speed Control for DC Motors

Screenshot of a JETI JE300MC controller
description removed due to copyright restrictions.

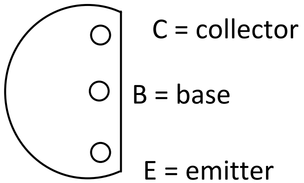
Switching!

Switching On/Off a Load

Image from Wikimedia Common,
http://commons.wikimedia.org

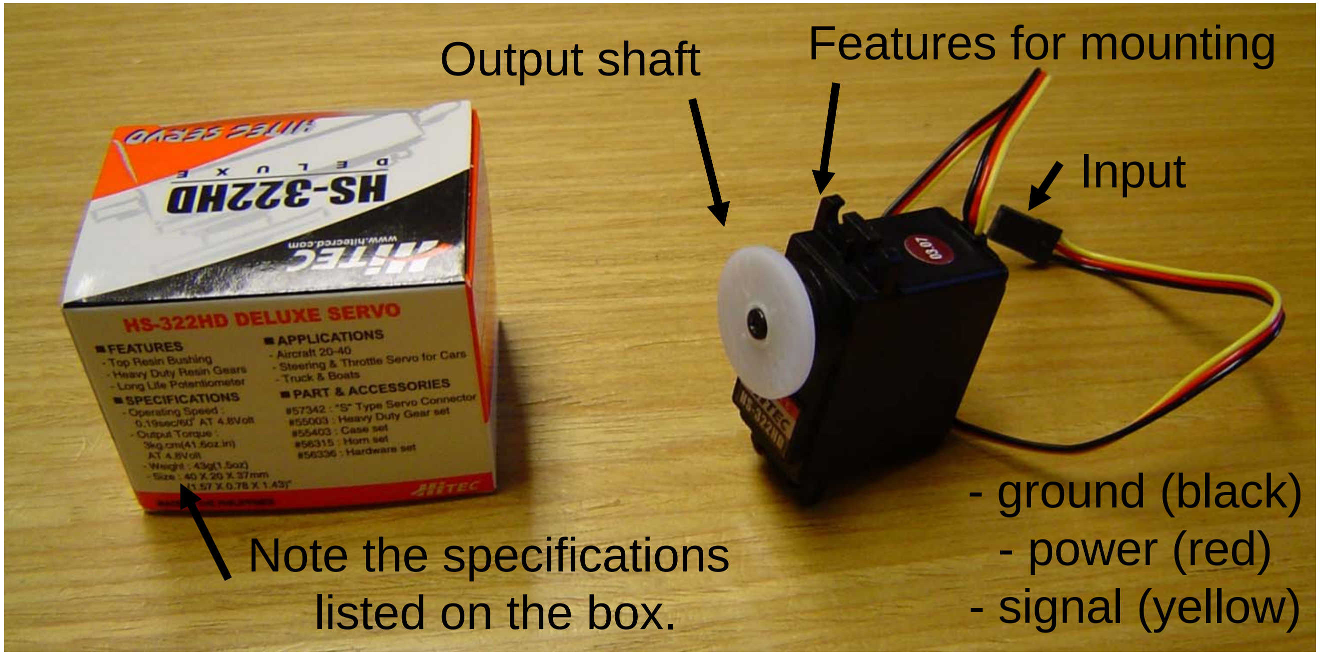


The symbolic representation of the transistor
How the transistor (as packaged) looks literally



Servo Motors

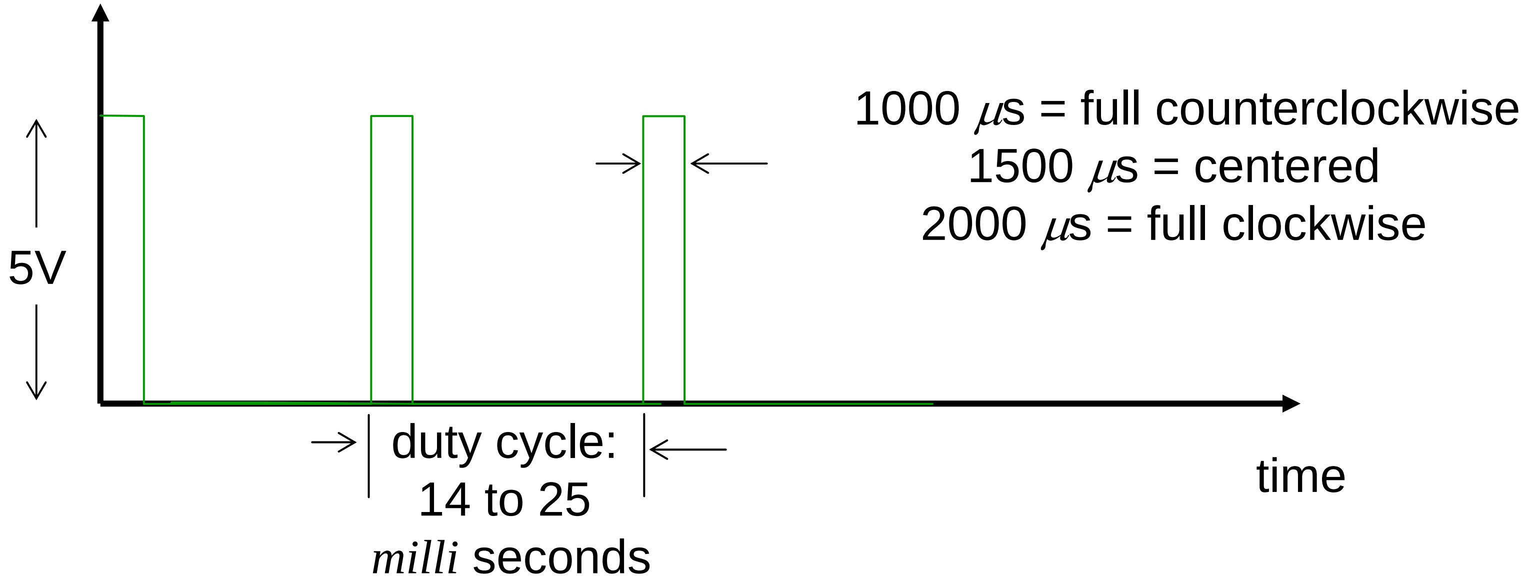
- Actuators that attain and hold a commanded position
- The type you have are commonly used in radio controlled cars and planes



Pulse Width Modulation (PWM)

- The duration of the pulse is interpreted as a commanded position

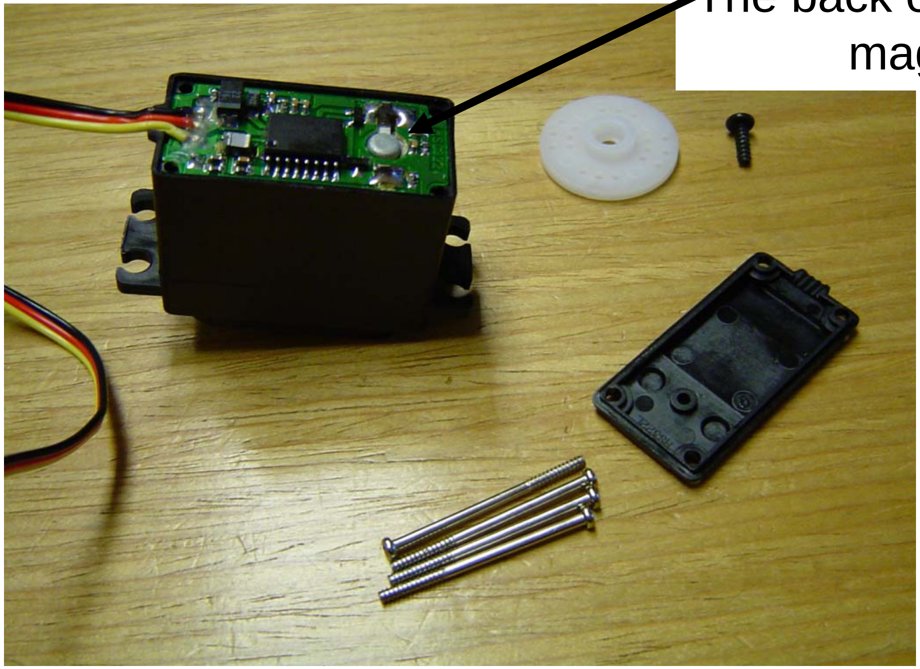
Voltage on yellow (or white) wire



Electronics Within the Servo

- Receive the commanded position
- Sense the position of the output shaft
- Supply voltage to the motor (either polarity) depending on the error

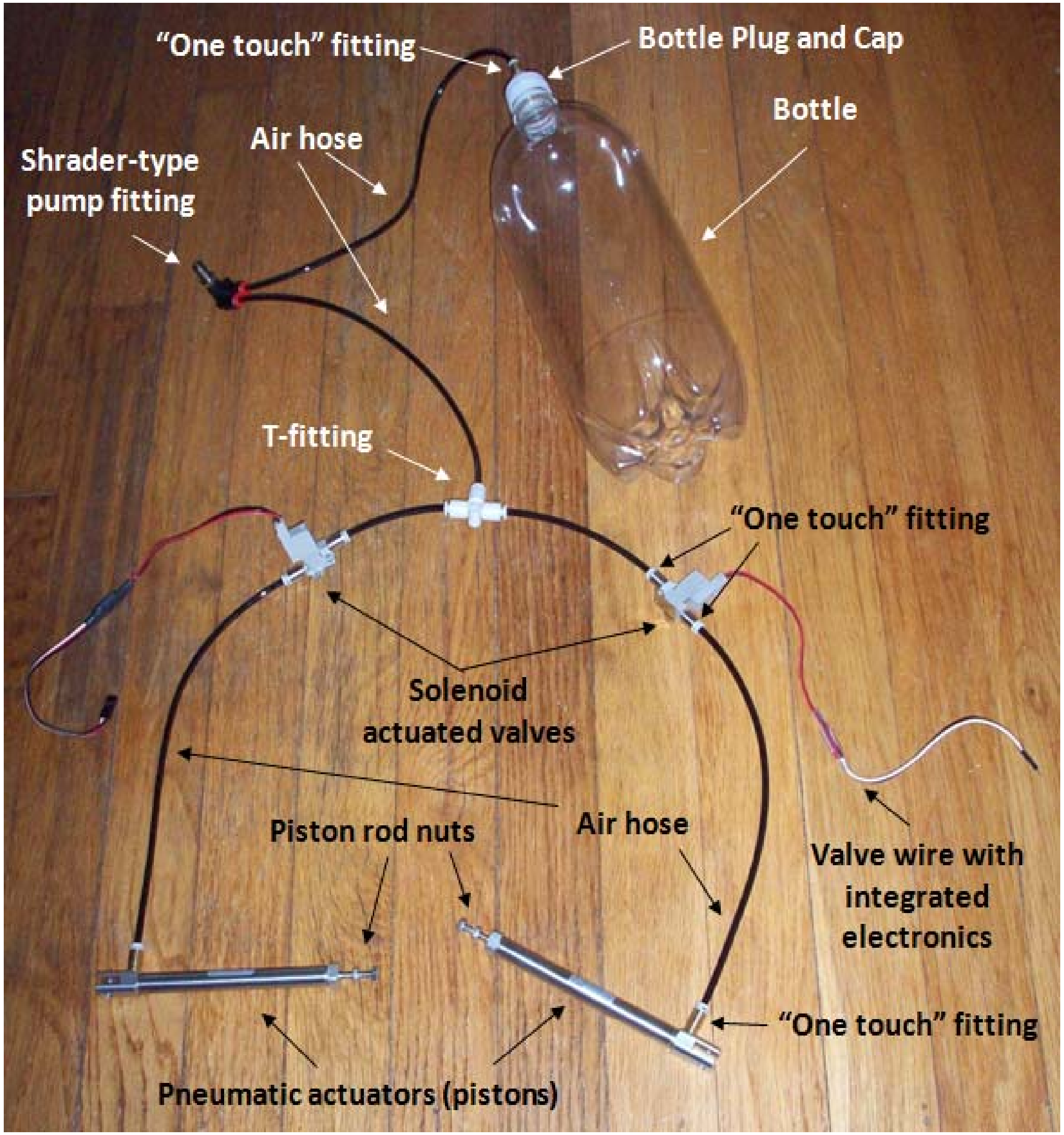
The back of a small, DC, permanent magnet electric motor



Running a Servo via PBASIC

```
' {$STAMP BS2}
' {$PBASIC 2.5}
Reps VAR Byte
DO
FOR Reps=1 TO 100
  PULSOUT 0, 760
  PAUSE 16
NEXT
FOR Reps=1 TO 100
  PULSOUT 0, 9000
  PAUSE 16
NEXT
LOOP
```

Pneumatic System



Power Comparison (Steady)

Pneumatic	Electric
3.2 lbs 4 ft^3/min at 90 psig	4.5 lbs 7.8 amps at 120VAC

Photos of a pneumatic and electric drill removed due to copyright restrictions.

Concept Question

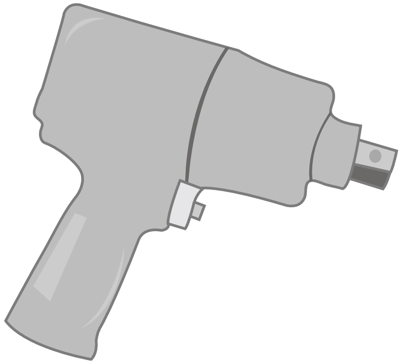


Figure by MIT OpenCourseWare.

http://www.irtools.com/

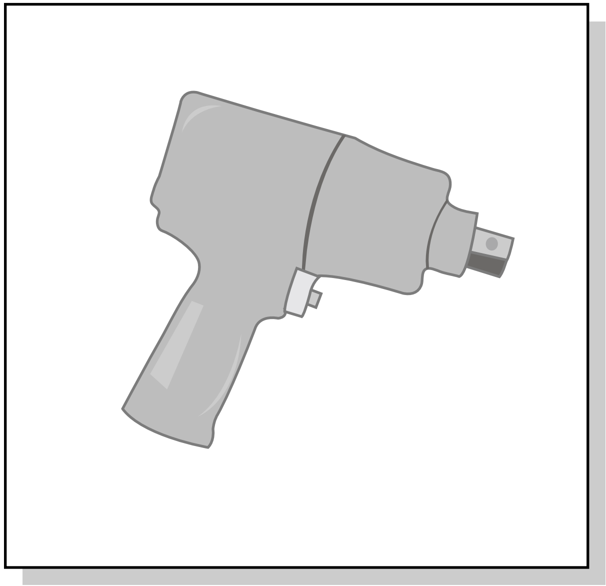
2141P 3/4" Air Impact Wrench

Weighing just 7 lbs and only 8.2" long, the 2141P is the smallest, lightest 3/4" impact on the market. The composite, ergonomic design is durable and comfortable and the 1200 ft-lbs of max torque will get the job done quickly.

About how much force must the user's hand apply to the pistol grip during use?

1) 1 lb
2) 10 lbs
3) 100 lbs
4) 1000 lbs

Concept Question



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About how much force must the user's hand apply to the pistol grip during use?

1) 1 lb
2) 10 lbs
3) 100 lbs
4) 1000 lbs

Dividing the torque applied by the air impact wrench on a nut by the lever arm through which your hand acts, you might surmise the answer is 4. But this cannot possibly be true as it would render the tool practical. If you try using the tool, you'll find answer 2 is about right. The tool apparently applies these loads briefly and the inertia of the tool smoothes out the peaks as in PWM control of an electric motor.

Next Steps

- Thursday 12 FEB, 11 AM
  - Lecture on drawing
- All week
  - Participate in Lab
  - Bring your SAFETY GLASSES & tools
  - Bring old VHS tapes if that’s easy to do
- Homework #1 due 24 FEB by 11AM