PHYSICS™

SAMPLE CURRICULUM

PHYSICS

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Materials

From last class:

- Teams of 2 students
- Multimeters (2 per team)
- Wall power supplies for Boe-Bots
- Grooved wheels to serve as pulleys
- Fishing line
- Computers with PBASIC

New for this class:

- Data sheets
- 4 weights for each team; 0.1 to 0.8 pound weighted items
- Digital balance/scale; 1-2 for class
- Stopwatch; 1 per team
- Ruler or tape measure

This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number, 2013-PD-127-000001, Modification #2.

LESSON OBJECTIVES

I. Learning Outcomes

- TLW acquire the data needed to evaluate the efficiency of an electric gear motor lifting various weights.

II. Learning Summary

- Review fundamentals from the last class to provide a context for the experiment. (Provide the big picture.)
- The objective for the class is to acquire all of the data required to characterize the efficiency of a servo motor. Move through the initial discussion quickly to allow as much time as possible for actual data collection.
- Acquire the data and fill in the data sheet.
- Groups can take data for more weights if they finish early. Groups that do not finish can continue later (two class periods from now).

AP EXAM CONCEPTS

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Objective Covered (1 and 2): The Interactions of an Object with Other Objects can be Described by Forces

- **Essential Knowledge 4.B.1:** The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.
- **Essential Knowledge 4.B.2:** The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.

SERVO DATA COLLECTION

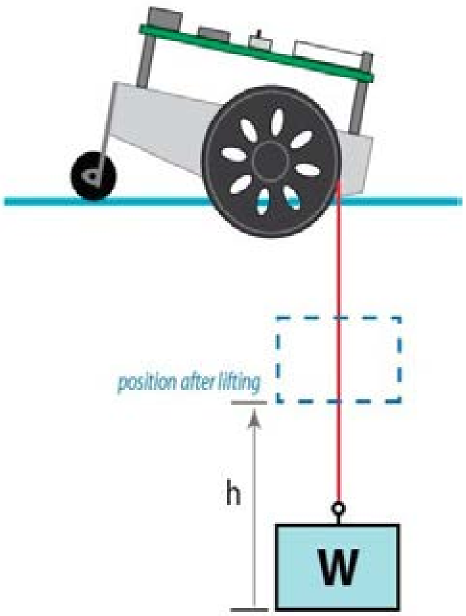
Review of Fundamentals

- Work can be used to lift weights.
- The potential energy change of a lifted weight is proportional to the change in height.
- Energy cannot be created or destroyed; it can only change forms.
  1. Work to heat (dragging a weight across a blanket)
  2. Work to potential energy (lifting a weight)
  3. Electricity to work (servo motor)
- We can determine the amount of energy entering a servo as electricity and the amount of useful energy released as potential energy change of weight.

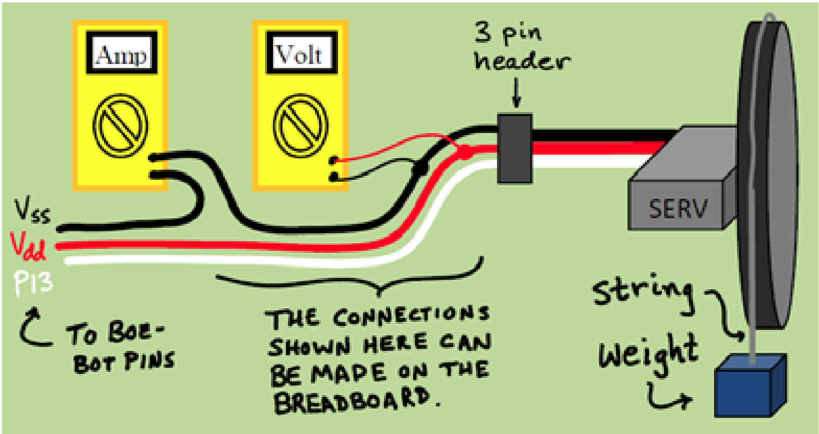
Class Project - Servo Efficiency

Part II - Data Collection:

Today you will perform the necessary measurements to quantify the electrical energy input and the mechanical work output of a servo as it operates under four different loads (weights).



The setup looks like this:



The measurements we need to take are shown in the datasheet provided below.

Weight Name	Weight (lbs)	Pulling Height h (in)	Pulling Time t (s)	Voltage V (V)	Current I (A)

Teacher Notes:

The voltage and current readings will fluctuate slightly. Just record a typical value (near the middle of the range). Use weights ranging from about 0.1 pound to 0.8 pounds, with relatively even spacing between weights. It is hard to juggle everything at once. Students will probably need to rerun experiments several times to have good data.

Weight Name	Weight (lbs)	Pulling Height h (in)	Pulling Time t (s)	Voltage V (V)	Current I (A)
keys	0.1495	25	3.8	4.86	0.13
cell phone	0.3805	25	5.4	4.73	0.18
plastic container	0.6	27	6.2	4.52	0.22
hammer	0.793	18	5.7	4.35	0.26

NAME:

1. Titan is the largest of Saturn's moons and has a dense atmosphere which would allow a helium-filled blimp to easily float above its surface. NASA has proposed "The Aerover Blimp" as a vehicle for collecting atmospheric data at different altitudes as well as data from landings on Titan's liquid hydrocarbon lakes or rocky surface. Titan has a diameter that is almost double that of our moon and about 40% that of earth. Because of the smaller mass of the planet, things on Titan only weigh 14% of what they weigh on earth. If the Aerover Blimp weighs 220 pounds on earth, then estimate the potential energy of the blimp relative to the surface of Titan when the blimp is at an altitude of 1 kilometers (1,000 meters). Please provide your answer in joules.

2. Assume the Aerover Blimp is propelled by a 4-bladed propeller driven by an electric motor.
   a. If 105 watts of electrical power is used for propulsion, then how much current will the electric motor draw if it operates at 12 volts?
   b. How much energy would be consumed by the electric motor in a 24 hour period? Remember that energy (joules) is the product of power (watts) and time (seconds).

HOMEWORK SOLUTIONS

1. Titan is the largest of Saturn's moons and has a dense atmosphere which would allow a helium-filled blimp to easily float above its surface. NASA has proposed "The Aerover Blimp" as a vehicle for collecting atmospheric data at different altitudes as well as data from landings on Titan's liquid hydrocarbon lakes or rocky surface. Titan has a diameter that is almost double that of our moon and about 40% that of earth. Because of the smaller mass of the planet, things on Titan only weigh 14% of what they weigh on earth. If the Aerover Blimp weighs 220 pounds on earth, then estimate the potential energy of the blimp relative to the surface of Titan when the blimp is at an altitude of 1 kilometers (1,000 meters). Please provide your answer in joules.

$mass = 99.8kg \qquad a = 0.14 \cdot 9.81\frac{m}{s^2} = 1.37\frac{m}{s^2} \qquad weight(wt) = mass \cdot a = 137.1N$

$h = 1,000m \qquad U_{p^1} = wt \cdot h = \left(1.37 \cdot 10^5\right)J$

2. Assume the Aerover Blimp is propelled by a 4-bladed propeller driven by an electric motor.
   a. If 105 watts of electrical power is used for propulsion, then how much current will the electric motor draw if it operates at 12 volts?
   b. How much energy would be consumed by the electric motor in a 24 hour period? Remember that energy (joules) is the product of power (watts) and time (seconds).

Part a: $P = 105$ watts $\qquad$ voltage = 12 V $\qquad I = \frac{P}{V} = 8.75$ amps

Part b: $t = 24$ hr = 86400 seconds $\qquad U_{electric} = P \cdot t = \left(9.072 \cdot 10^6\right)J$

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LESSON OBJECTIVES

I. Learning Outcomes

- TLW generate a spreadsheet requiring data input and computation.
- TLW compute servo efficiency under various operating conditions.
- TLW use spreadsheet software to create a properly formatted plot.

II. Learning Summary

- Review how efficiency is computed for an electric motor that lifts a weight.
- Enter the servo data collected earlier into a spreadsheet. Use this data to compute the efficiency of the servo.
- Create a properly formatted plot of servo efficiency versus weight lifted. The plot must have a title and axis labels with units.

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Teacher Notes:

SERVO EFFICIENCY ANALYSIS

Review of Fundamentals

Efficiency is a measure of how successfully energy can be utilized to do a job. For the servo the efficiency is:

$$\eta = \frac{PE\ change\ of\ weight}{electrical\ energy\ consumed\ by\ servo} \cdot 100\% = \frac{wt \cdot \Delta h}{V \cdot I \cdot t} \cdot 100\%$$

$$\underbrace{\frac{wt \cdot \Delta h}{V \cdot I \cdot t}} = \frac{J}{\frac{J}{s} \cdot s} = \frac{J}{J} = \frac{energy\ out}{energy\ in}$$

$wt \cdot \Delta h$: J

$W = \frac{J}{s}$; t: s

Wt	=	weight (N)
Δh	=	change in height of weight (m)
V	=	voltage to servo (V)
I	=	current drawn by servo (A)
t	=	time the servo is operated (s)

Analysis of Servo Data

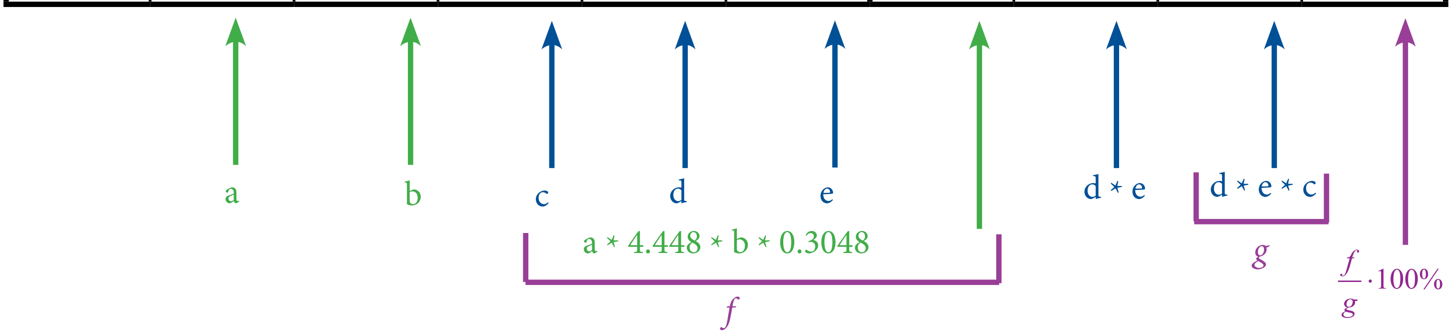
If students still need to collect data, they can do that during this class period and complete the analysis as homework.

Student groups should do the following:

1. Enter the data collected in the previous class into a spreadsheet which includes a title and column titles with units.
2. Embed the equation above into the spreadsheet to calculate the efficiency for each weight lifted.
3. Plot the efficiency as a function of the weight lifted.

Example Spreadsheet:

Weight Name	Weight (lbs)	Pulling Height h (in)	Pulling Time t (s)	Voltage V (V)	Current I (A)	PE Change (J)	Electrical Power (W)	Electrical Energy (J)	System Efficiency (%)
keys	0.1495	25	3.8	4.86	0.13	0.42	0.63	2.40	17.6
cell phone	0.3805	25	5.4	4.73	0.18	1.07	0.85	4.60	23.4
plastic container	0.6	27	6.2	4.52	0.22	1.83	0.99	6.17	29.7
hammer	0.793	18	5.7	4.35	0.26	1.61	1.13	6.45	25.0



Example Plot: