2.000 Homework # 4: Machine components

Name:______________________________________ **Weight: 100 pts**

Due: Day 10 at beginning of lecture (date differs from original syllabus)

You must return your screwdriver in working condition!

1. Screw driver stall torque

a). [10] Perform an experiment to determine if the stall torque listed by the manufacturer is correct. Provide a sketch of your experimental set up, the details of your calculation and the reasoning you used to make your decision about the manufacturer's claim.

b). [5] Perform an experiment to determine if the no-load speed listed by the manufacturer is correct. Provide a sketch of your experimental set up, the details of your calculation and the reasoning you used to make your decision about the manufacturer's claim.

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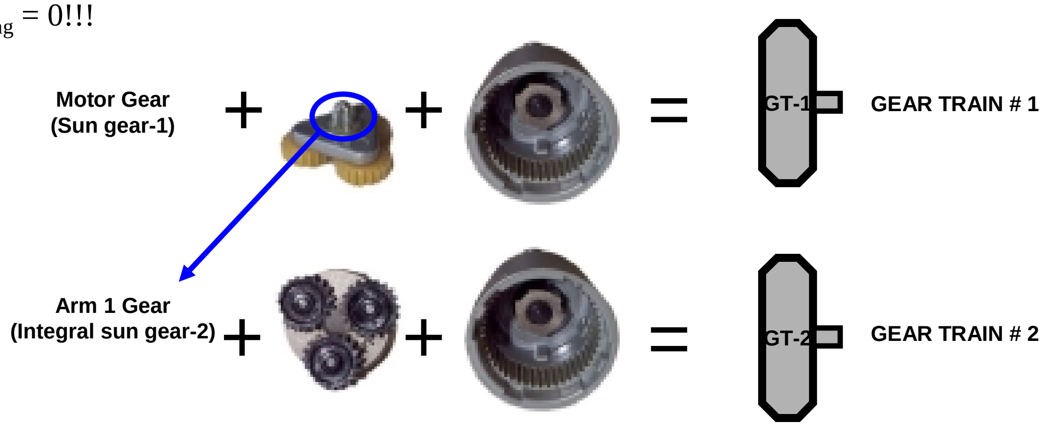
2. Train ratio of combined planetary gear trains

a.). [5] Find T_r of the cordless screw driver. NOTE: $\omega_{in} = \omega_{motor}$ and $\omega_{out} = \omega_{screw\ driver\ shaft}$.

1. Begin by solving for the speed of the arm in the first gear train as function of s1
2. $\omega_{a1} = \omega_{s2}$ and $\omega_{a2} = \omega_{screw\ driver\ shaft}$.
3. $\omega_{ring} = 0$!!!



b). [5] Perform an experiment to verify your calculation. Provide 1-2 sentence explanation of your experiment and the result.

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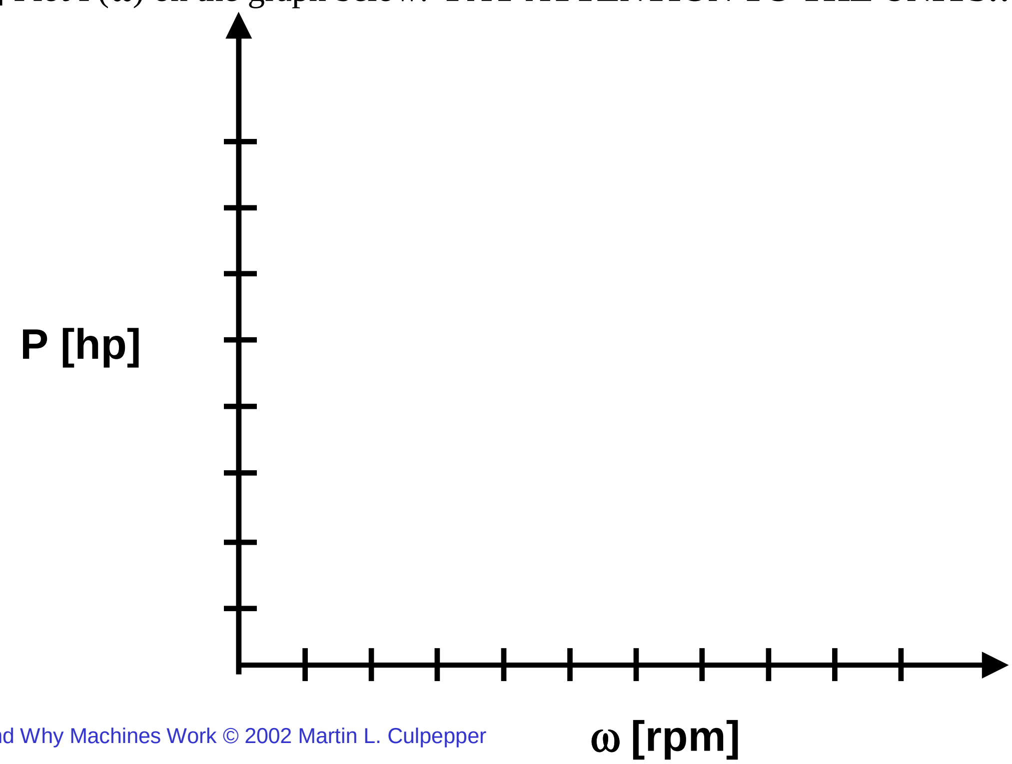
3. Cordless screw driver power-speed characteristics

a). [5] Use the no-load speed and stall torque you found in problem 1 to develop an expression for P(ω). The only variables in this equation should be P and ω. **Units must be consistent (i.e. use units of rpm and hp).**

b). [5] Plot P(ω) on the graph below. **PAY ATTENTION TO THE UNITS!!!**



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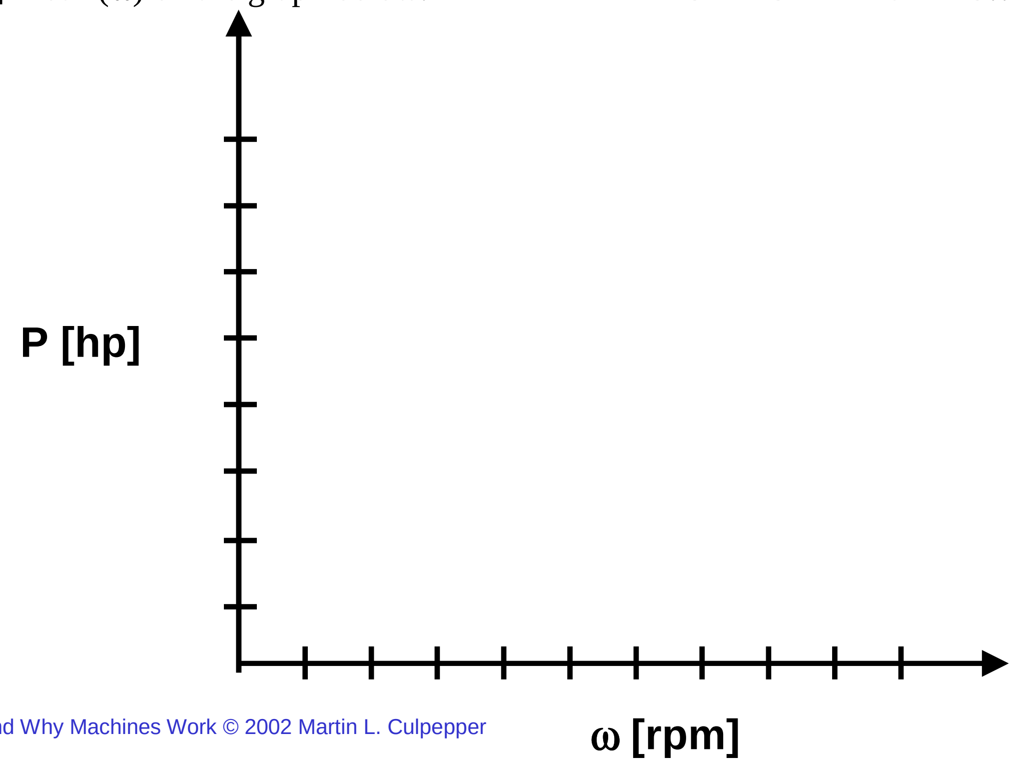
4. DC Permanent magnet motor power-speed characteristics

a). [10] Assume the screw driver is 100% efficient, what is P(ω) of the motor? You will find the train ratio and control volume on the following page very helpful in solving this problem.

b). [5] Plot P(ω) on the graph below. **PAY ATTENTION TO THE UNITS!!!**



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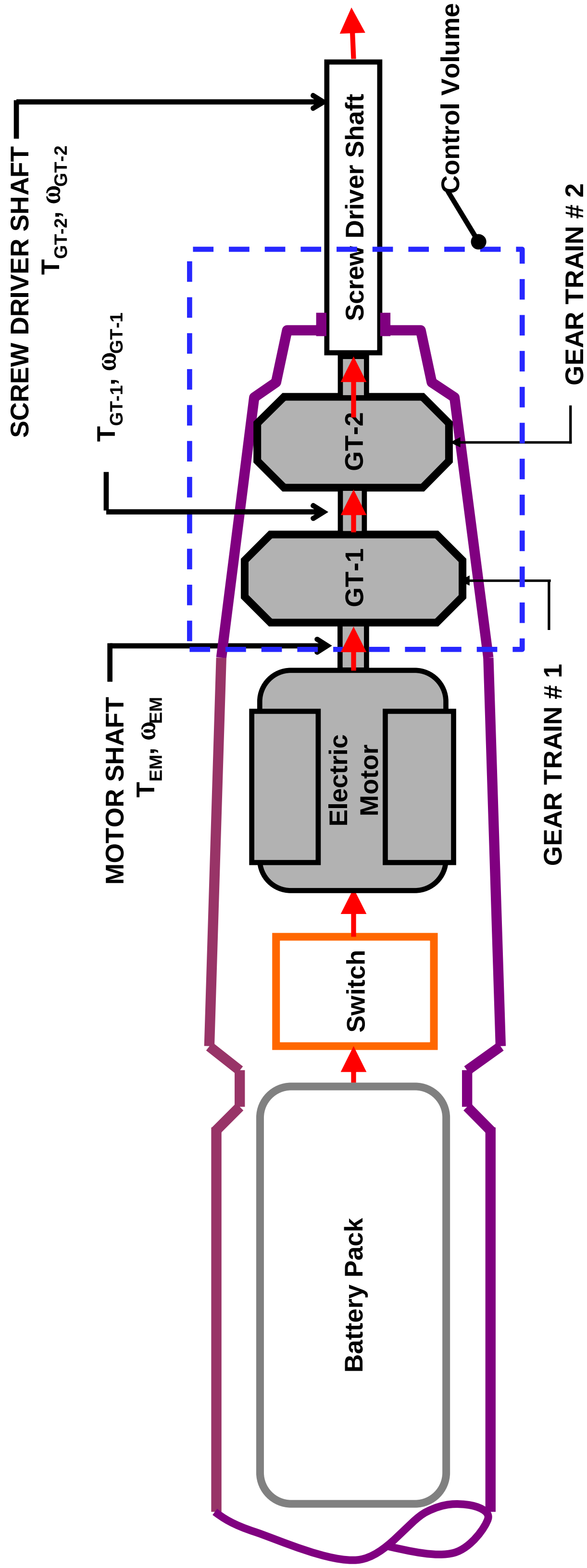
Control volume for problem 4a



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5. Derive (show all steps) the following for a DCPMM:

a). [5] $\omega_{PMAX} = \frac{\omega_{NL}}{2}$

b) [5] . $P_{MAX} = T_S \cdot \left(\frac{\omega_{NL}}{4} \right)$

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6. Switch

a). [5] Explain how the switch in the screw driver works. Be explicit and use the 5 "F"s

7. Return screwdriver in working condition [20 pts]

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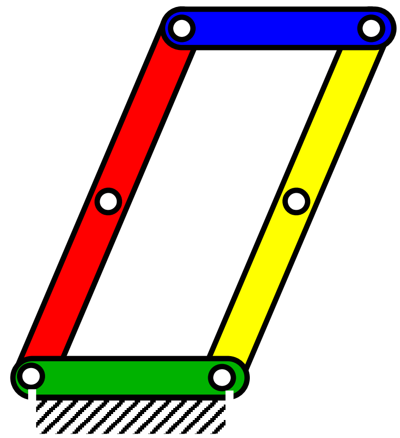
8. Linkages

a). [5] Provide a geometric proof to show that opposing links in a parallel link 4-bar linkage are always parallel.



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9. Threaded mechanisms

In many threaded mechanisms where low force and lubrication are used, the energy loss due to friction and the energy stored in the bolt due to stretching are negligible compared to the work done on the threaded mechanism. IF we can disregard the loss and stored energy, we can develop an important relationship between the applied torque and exerted force. However, it is not good practice to simply ignore the energy loss and stored energy in our calculations, we must make sure they are small compared to the other quantities involved. Mathematically, we need:

$$\frac{\Sigma E_{loss} + \Sigma E_{stretch}}{\Sigma E_{exerted}} <<< 1$$

"How much smaller" than 1 depends on our desired accuracy. The smaller this ratio is, the more accurate our answer will be. Typically, the ratio should be less than 5%.

a). [5] Assume the preceding ratio is small enough so that the loss and stored energy may be neglected, derive the following relationship using an energy balance and the relationship between lead and travel for a single thread threaded mechanism: $x = \frac{\theta}{2\pi} l$ $\quad (l = \text{lead})$

$$\text{Prove: } F_{exert} = \frac{2\pi T_{applied}}{l}$$

b). [5] If the ratio is 0.1, how accurate would the preceding equation be?

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2.000 Preferred Units & Conversion Factors

PREFERRED UNITS

Quantity	English	Metric
Power	hp	W
Energy	ft-lbf	J
Mass	slug or lbm	kg
Length	in or ft or mile	cm or m or km
Velocity	ft/s or mph	m/s or kph
Temperature	^{o}F	^{o}C
Pressure	psi	Pa

UNIT DECOMPOSITION

Unit	Quantifies	Base Units
N	Force	kg (m/s^2)
psi	Pressure	lbf / in^2
Pa	Pressure	N / m^2
J	Energy	N m
W	Power	J / s

CONVERSION FACTORS

Power	1hp / 745.7 W	1 hp s / 550 ft lbf	1 Btu/s / 1055 W
Energy	1.356 J / 1 ft lbf	1 Btu / 1055 J	1 cal / 4.1868 J
Mass	1 kg / 2.205 lbm	14.59 kg / 1 slug	
Length	1 in / 2.54 cm	1 m / 3.281 ft	1 mile / 1609 m
Velocity	1 mph / 1.609 kph	1 m/s / 3.281 ft/s	
Volume	0.01 m^3 / 1 L	7.481 gallon / 1 ft^3	35.315 ft^3 / m^3
Temp	^{o}F = 1.8 ^{o}C + 32	^{o}K = ^{o}C + 273.15	^{o}R = ^{o}F + 459.67
Pressure	1 atm / 1.0131 bar	1 bar / 10^5 Pa	1 psi / 6894.8 Pa