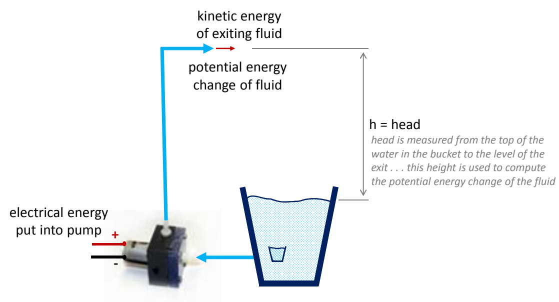
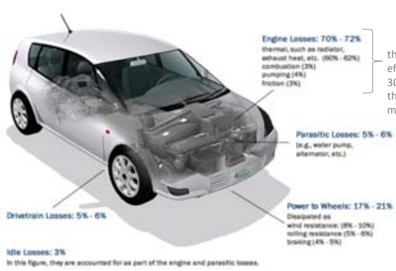
analysis of pump efficiency



efficiency

- efficiency is usually expressed as a percentage between 0% and 100%
- an efficiency of 100% would mean that all the energy put into a system is converted into useful work
- an efficiency of 0% would mean that no useful work is gained from a system



the engine itself is 28 to 30% efficient . . . that is, about 30% of the heating value of the fuel is converted into mechanical energy

www.fueleconomy.gov/feg/atv.shtml#HEVEVPHEV

how efficient are you?

the human body converts around 20% to 25% of food energy into mechanical energy

a calorie is a unit of energy; if you eat a 100 calorie snack, then 20 to 25 of those calories could be used to physically make something happen (move yourself, lift something, . . .)

USA Triathlon Collegiate National Championship 2011
Tuscaloosa, Alabama

efficiency

- we measure the efficiency of energy conversion processes
- efficiency is defined as . . .

$$\text{efficiency} = \eta = \frac{useful\ energy\ output\ of\ a\ system}{energy\ input\ to\ a\ system} \cdot 100\%$$

- the pump converts electrical energy into fluid energy
- at the exit tube, the fluid energy is evaluated as . . .
  - o the potential energy of the fluid due to a change in elevation
  - o the kinetic energy of the fluid at the exit of the tube

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energy input to system

electrical energy input to electric motor = $\underbrace{\text{power}}_{V\,I} \cdot \underbrace{\text{time}}_{t} = \boldsymbol{V\,I\,t}$

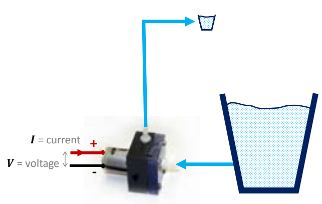
$$watts \cdot seconds$$

$$\frac{J}{s} \cdot s = J$$

the efficiency is . . .

$$\eta = \frac{energy\ output}{energy\ input} \cdot 100\%$$

$$\eta = \frac{energy\ output}{\boldsymbol{V\,I\,t}} \cdot 100\%$$



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energy out of system

potential energy = $\underbrace{\text{weight}}_{} \cdot \underbrace{\text{height}}_{} = \boldsymbol{W\,h}$

$$Newtons \cdot meters$$

$$N \cdot m = J$$

kinetic energy = $\frac{1}{2} \cdot \underbrace{\text{mass}}_{} \cdot \underbrace{\text{velocity}^2}_{} = \boldsymbol{\frac{1}{2} m v^2}$

$$kilograms \cdot \left(\frac{meters}{second}\right)^2$$

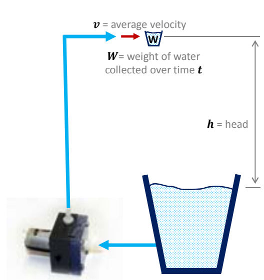
$$kg \cdot \frac{m}{s^2} \cdot m$$

$$N \cdot m = J$$

the efficiency is . . .

$$\eta = \frac{energy\ output}{V\,I\,t} \cdot 100\%$$

$$\eta = \frac{\boldsymbol{W\,h + \frac{1}{2} m\,v^2}}{V\,I\,t} \cdot 100\%$$



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using the efficiency equation

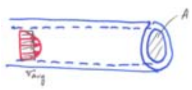
$$\eta = \frac{W\,h + \frac{1}{2}m\,v^2}{V\,I\,t} \cdot 100\%$$

head or height that water is pumped (in)	electrical current needed to power pump (A)	voltage across pump leads (V)	length of time that water is collected (s)	mass of water collected over 20 seconds (g)
height 1			20	
height 2			20	
… height 8 (or more)			20	

we will measure ⇨ I V t m

how do we find W? $W = \underbrace{m \cdot g}_{\text{Newton's 2nd Law}} = m \cdot 9.81\,\frac{m}{s^2}$

how do we find v?



$$v \cdot A = \frac{Vol}{t} \quad \text{where } m = \rho \cdot Vol$$

$$v = \frac{Vol}{A \cdot t} = \frac{m}{\rho \cdot A \cdot t} \qquad \frac{kg}{\frac{kg}{m^3} \cdot m^2 \cdot s} = \frac{m}{s}$$

computing flow rate (Q)

the volume of water pumped per unit time is the flow rate Q . . .

$$Q = v \cdot A = \frac{volume\ pumped}{time} = \frac{liters}{min}$$

1 liter = 0.001 m³

Recall that you final analysis should include . . .

1. a plot of pump head versus (meters) flow rate (liters per minute)
2. a plot of pump efficiency (%) versus pump head (meters)

Class Problem A pump is connected to an electric motor. The motor is supplied with 1 A of current from a 12 VDC source. The apparatus is run steadily for 30 seconds, and the following measurements are recorded:

mass of fluid collected:	500 grams	1000 grams = 1kg
diameter of exit tube:	3/16 inch	1 inch = 25.4 mm
density of water:	1000 kg/m^3	1 L = 0.001 m^3
height of fluid exit above reservoir:	30 inches	1 inch = 25.4 mm

Find:
(a) fluid velocity at exit in m/s
(b) flow rate in L/min
(c) system efficiency

Include ALL units in calculations. It would be very helpful to convert any US Customary units to SI units before beginning the solution to avoid complexity.