

living with the lab

### analysis of pump efficiency

kinetic energy of exiting fluid

potential energy change of fluid

h = head  
head is measured from the top of the water in the bucket to the level of the exit. . . this height is used to compute the potential energy change of the fluid

electrical energy put into pump

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### 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

Engine Losses: 70% - 72%  
(thermal, such as radiator, exhaust heat, etc. (50% - 60%)  
combustion (2%)  
pumping (4%)  
friction (2%))

Parasitic Losses: 5% - 6%  
(e.g., water pump, alternator, etc.)

Drivetrain Losses: 5% - 6%

Power to Wheels: 17% - 21%  
(disipated as  
wind resistance (8% - 10%)  
rolling resistance (2% - 5%)  
braking (4% - 5%))

Idle Losses: 3%  
In this figure, they are accounted for as part of the engine and parasitic losses.

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/2011/stronineVPHV

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### 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 Transition Collegiate National Championships 2011  
Tuscaloosa, Alabama

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### efficiency



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

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

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

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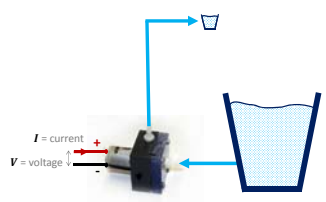
### energy input to system

electrical energy input to electric motor = power · time =  $V I t$

$$\frac{V I}{\text{watts} \cdot \text{seconds}} \cdot t = J$$

the efficiency is . . .

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

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


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### energy out of system

potential energy = weight · height =  $W h$

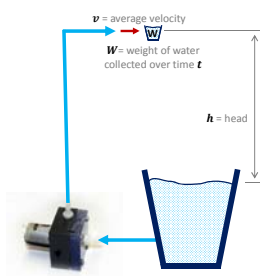
$$\frac{\text{Newtons} \cdot \text{meters}}{N \cdot m} = J$$

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

$$\frac{\text{kilograms} \cdot \left(\frac{\text{meters}}{\text{second}}\right)^2}{\text{kg} \cdot \frac{m}{s^2} \cdot m} = J$$

the efficiency is . . .

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

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


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### using the efficiency equation

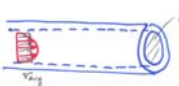
$$\eta = \frac{W}{VIt} + \frac{1}{2}m v^2 \cdot 100\%$$

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  $\rightarrow I \quad V \quad t \quad m$

how do we find W?  $W = m \cdot g = m \cdot 9.81 \frac{m}{s^2}$   
Newton's 2<sup>nd</sup> Law

how do we find v?



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

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


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### computing flow rate (Q)

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

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

1 liter = 0.001 m<sup>3</sup>

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)

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**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 <sup>3</sup>	1 L = 0.001 m <sup>3</sup>
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.*

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