Problem Set #2

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PSC 320 | HW#2

1 Demographics

(A) a) Which country's average income people can buy a Bugatti Veyron with half their saved annual salary? Price of Bugatti Veyron: $1.7 million

Country	Annual Salary (Avg. income)	Source	½ Salary/annual	How Many People Needed
1) USA	$59,039	Wikipedia: Household income	$29,520	57.6 → 58 people
2) China	~$8,000	Hong Kong FP: 8% avg raise in 2016	$4000	425 people
3) Zambia	$917	Minimum Wage.org	$458	3712 people ✓
4) Israel	$12,493	Minimum Wage.org	$6,246	272 people

beautiful

The right column shows how many people in each country are needed to buy 1 Bugatti Veyron.

b) Percentage of Population of Country makes above $30 million a year

Country	% Making ≥ $30 million/yr	Sources
1) USA	156,000/323 million = 0.048%	cnbc.com (6/23/17)
2) China	{Can't find these}	
3) Zambia		
4) Israel		

The Point: Only a small handful of people on Earth can afford this car. This is the true definition of a luxury anything. ✓

3 Energy Battle: Bicyclist VS Cup of Coffee

(A)

$T_{room\ temp} = 20°C = 293\ K$

$T_{coffee} = 94°C = 367\ K$

$\Delta T = 74\ K$

$m_{me} = 155\ lbs = 70.3\ kg$

$V_{bike} \approx 12\ mph = 19.3\ km/hr = 5.7\ m/s$

$KE = \frac{1}{2} m v^2$

$= \frac{1}{2}(70.3\ kg)(5.7\ m/s)^2$

$\boxed{E_{bike} = 1,142\ J}$ <<< <

$m_{coffee} = 236\ mL = 236\ g$

$C_{H_2O} = 4.184\ J/gK$

$E = mc\Delta T = (236\ g)(4.184\ J/g°C)(74\ K)$

$\boxed{E_{coffee} = 73069\ J}$ ✓

The cup of coffee has more energy than the bicyclist.

4 Energy Battle: Flight of Stairs Climb VS 10°C Hotter Tea

A-

$m_{person} = 70\ kg$

$\Delta h = 3.5\ m$

$E_{PE} = mg\Delta h$

$= (70\ kg)(9.8\ m/s^2)(3.5\ m)$

$E_{PE} = 2401\ J$ ✓ < < <

+KE?

$m_{tea} = 236g$

$\Delta T = 10°C$

$c = 4.184\ J/g°C$

$E_{th} = mc\Delta T = (236\ g)(4.184\ J/g°C)(10°C)$

$E_{th} = 9874\ J$ ✓

The 10°C hotter tea still has more energy than someone climbing one flight of stairs. ✓

5 Adobe House

A-

a) Temperature Gradient: $\frac{\Delta T}{\Delta l} = \frac{T_{out} - T_{in}}{\Delta l} = \frac{21.1 - (-1.1)}{0.9\ m}$

Known Values

$T_{out} = 30°F = -1.1°C$

$T_{in} = 70°F = 21.1°C$

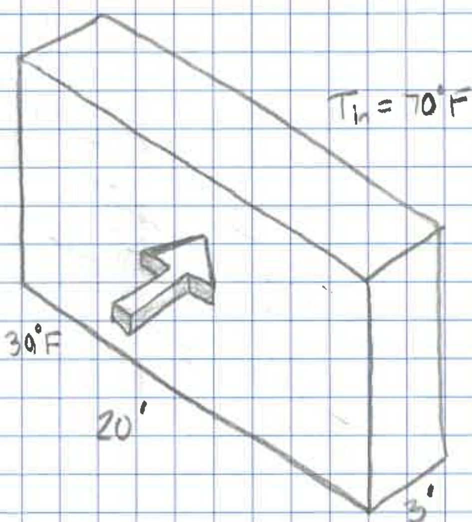
$\Delta h = 10\ feet = 3.05\ m$

$\Delta w = 20\ feet = 6.1\ m$

$\Delta l = 3\ feet = 0.9\ m$

$\frac{\Delta T}{\Delta l} = \frac{22.2°C}{0.9\ m}$

$\frac{\Delta T}{\Delta l} = 24.7°C/m$ ✓



b) Rate of Heat Loss $= P = kA\left(\frac{\Delta T}{\Delta l}\right)$

$k = W/°C\,m$

$k_{adobe\ (earth)} = 0.57\ W/°C\,m$

* Wikipedia *

$\Delta°C = \Delta k$

$P = k(\Delta w \times \Delta h)(24.7°C/m)$

$= k(6.1\ m \times 3.05\ m)(24.7°C/m)$

$= k(459.5°C\,m) = 0.57\frac{W}{°C\,m}(459.5°C\,m)$

$P_{conduction} = 262.14\ W$ for a 10' × 20' × 3' adobe wall. ✓

BTU/hr?

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Stair Climb Scenario

2 (B+)

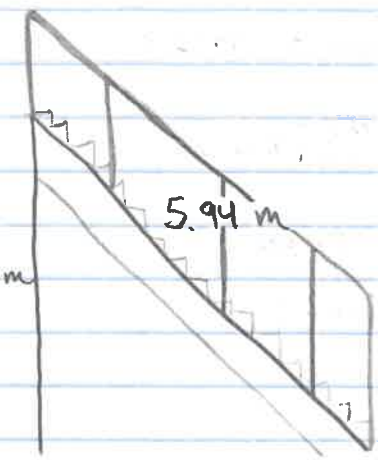
Known values:

$m_{Brandon} = 156\ lbs / 2.2\ lbs/kg = 71.0\ kg$

$m_{total} = 186\ lbs / 2.2\ lbs/kg = 84.5\ kg$ (2nd experiment)

$\Delta h_{stairs\ 2nd\ floor} = 3.49\ m$

$\Delta t_{climb} = 21\ s$



ⓐ $PE = mg\Delta h = (71\ kg)(9.8\ m/s^2)(3.49\ m)$

$\boxed{\Delta E = 2428\ J}$ Potential energy difference due to change in height ✓

ⓑ $P = \frac{\Delta E}{\Delta t} = \frac{2428\ J}{21\ s} = \boxed{1156\ W}$ ← Power Output of human body ✓

1 horsepower = 745.7 W

$P = \frac{1156\ W}{1\ hp} = \frac{1156\ W}{745.7\ W} = \boxed{1.55\ hp}$ ✓

1 BTU = 1055 W

1 BTU/hr = 0.2931 W

$P = \frac{1156\ W}{1\ BTU/hr} = \frac{1156\ W}{0.293\ W} = \boxed{3945\ BTU/hr}$ ✓

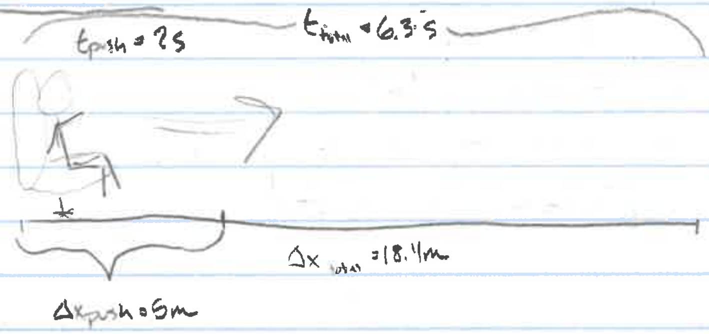
ⓒ 1 kiloWatt hour = 3,600,000 J = $3.6 \times 10^6\ J$

(1000 W × 3600 s)

$t = \frac{1\ kWhr}{P_{Brandon}} = \frac{3.6 \times 10^6\ J}{1156\ J/s} = 3114\ s = \boxed{51.9\ min}$ ✓

to charge a 1 kWh battery w/ Brandon's power output

Chair Push Scenario



known values:

$m_{total} = 84.5 \text{ kg}$ (person + chair)

$\Delta x_{total} = 18.4 \text{ m}$

$\Delta x_{push} = 5 \text{ m}$

$t_{total} = 6.3 s$

$t_{push} = 2 s$

(a) $KE = \frac{1}{2}mv^2 = \frac{1}{2}(84.5 \text{kg})\left(\frac{\Delta x_{push}}{t_{push}}\right)^2$ close, you have the info you need

$KE = \frac{1}{2}(84.5 \text{kg})\left(\frac{5m}{2s}\right)^2 = \boxed{264.1 \text{ J} = \Delta E}$

Energy of stair climb

(b) $P_W = \frac{\Delta E}{\Delta t} = \frac{264.1 \text{ J}}{2 s} = \boxed{132 \text{ W}}$ ✓

$P_{hp} = \frac{P_W}{1 \text{ hp}} = \frac{132 \text{ W}}{745.7 \text{ W/hp}} = \boxed{0.177 \text{ hp}}$ ✓

$P_{BTU/hr} = \frac{P_W}{1 \text{ BTU/hr}} = \frac{132 \text{ W}}{0.2931 \text{ W/(BTU/hr)}} = \boxed{450.4 \text{ BTU/hr}}$ ✓

Power output of human body

(c) $1 \text{ kWhr} = 3.6 \times 10^6 \text{ J}$

$t = \frac{1 \text{ kWhr}}{P_W} = \frac{3.6 \times 10^6 \text{ J}}{132 \text{ J/s}} = 2.727 \times 10^4 s = 454.5 \text{ hr}$

$\boxed{t = 7.58 \text{ days}}$ to charge a 1 kWh battery w/ human power output

[3] On first paper of homework
&
[4]

6 Different Engines (A+)

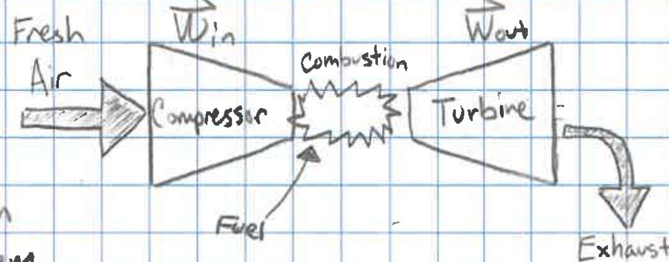
a) Reciprocating Engines

A two-stroke engine has all its action in one cylinder where everything is completed in two strokes. On the down stroke, the fuel enters the top chamber from the left and fuel leaves out the right. The other stroke is the compression/explosion. A four-stroke engine has these events take place with more strokes and more gears and space used. Two-strokes are more compact and useful for things like lawn mowers, chain saws, etc.

b) Diesel VS Gas Engine

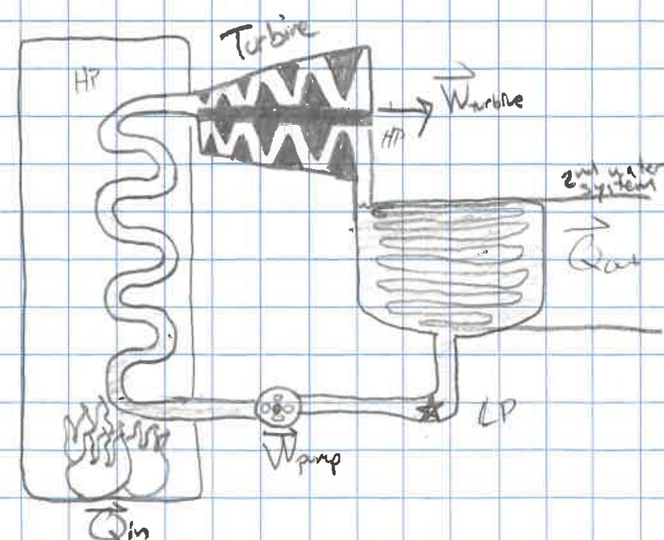
While both the two-stroke and four-stroke engine, both mainly gasoline engines, help combustion with a spark from a spark plug or the like, a diesel engine combusts purely from the rapid decrease in volume / spike in pressure. The intake/outtake valves open and close by rotating two things against them, pushing at different times.

c) Brayton Cycle (Gas Turbine)



The Brayton Cycle compresses air ($\vec{W}_{in}$) using multiple blades and then injects fuel ($\vec{E}_{chem}$) that gets ignited in the compressed air region. This heat from the fuel raises the temperature of the compressed air, thus increasing the pressure of the air that is waiting to expand in volume. This leads to a surge out of the exhaust which helps propel the plane forward ⇒ thus get more air compressed and this process can continue.

d) Rankine Cycle (Steam Turbine)



If starting from the ☆ position on the figure, the pump ($\vec{W}_{in}$) takes the water from the low pressure region, and while pumping through a hot chamber (Q_{in}) turns into steam (1000x more volume than liquid form). The work of the steam pushing the blades is $\vec{W}_{out}$ and the steam cools in a cooling chamber where it comes into contact with cool pipes from secondary water and condenses back into water itself.

e) Stirling Engines

The Stirling Engine works off of a temperature difference between the bottom plate and top plate. For instance, if the displacer is along the bottom plate and that plate gets hot, the air between the displacer and plate gets hot and expand. This pushes the displacer up which affects the primary piston