PHYS 320 | PROBLEM SET 2 |

1) According to Edmunds.com, a Bugatti Veyron has a price tag of **1.5 million USD**.
   a) How many average income individuals in the following countries would it take to buy this $1.5 million car if they saved up half their salary for a year?

Country	**Average Income***	**Calculations**	**Answer**
USA	US$ 53,400 p.a.	1,500,000/26,700=	57
China	US$ 13,300 p.a.	1,500,000/6,650=	226
Zambia	US$ 4,030 p.a.	1,500,000/2,015=	745
Hong Kong	US$ 53,900 p.a.	1,500,000/26,950=	56

*Statistics from GapMinder

   b) The following Statistics are estimates based on data collected by the Boston Consulting Group (# of millionaires per country), and GapMinder (# of billionaires per country)

Country	**# 'super' Millionaires**	**% population**
USA	13,500,000	6.4
China	1,200,000	0.1
Zambia	<10	0.01
Hong Kong	200,000	0.05

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2) For our first experiment, I walked down a corridor to see what my walking wattage was:
   a) Raw Data: Time: 14.93s, Distance = 24.68m, Weight = 68.039 kg

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(68.039kg)\left(\frac{24.68m}{14.93s}\right)^2$$
$$= 93.03kgm^2s^{-2} = 93.03J$$

1BTU ~ 10^3 J
hr ~ 3.6×10^3 s

   b) Calculating Power

$$Power = \frac{Energy}{Time} = \frac{93.03J}{14.93s} = 6.23W$$
$$6.23W \times \frac{0.001341HP}{1Watt} = 0.00836\ HP$$
$$6.23W \times \frac{3.412\ BTU/hr}{1\ Watt} = 21.26\ BTU/hr$$

A

Because you acquired your KE in the 1st second (likely) your power was really ~93W for the 1st second and zero after that.

   c) How long would it take to charge a 1 kWh Battery with this power?

$$Time = \frac{Energy}{Power} = \frac{3.6 \times 10^6 J}{6.23W} = 57{,}770s = 160.5\ hrs$$

For our second experiment, we measured how much time it would take me to move twelve 1lb. weights onto the surface of a workbench/

   a) Raw Data: Height = 0.913m, Weight = 12lb = 5.443kg, Time = 20.05s

$$GPE = mgh = 5.443kg \times 9.81ms^{-2} \times 0.913m = 48.751J$$

   b) Calculating Power

$$Power = \frac{Energy}{Time} = \frac{48.751J}{20.05s} = 2.4315W$$
$$2.4315W \times \frac{0.001341HP}{1Watt} = 0.00326HP$$
$$2.4315W \times \frac{\frac{3.412BTU}{hr}}{1Watt} = \frac{8.297BTU}{hr}$$

   c) How long would it take to charge a 1kWh Battery with this power?

$$Time = \frac{Energy}{Power} = \frac{3.6 \times 10^6 J}{2.4315W} = 1{,}480{,}567s = 411.2687hrs$$

this amount of precision is incorrect

~400 hrs.

That's way fast ~66 mph!

3) Assuming the cup of coffee is freshly brewed (at 100°c) and the room is at 26°c... and using the density and specific heat capacity of water...

$$Q = mc\Delta T = 300g \times 4.184JK^{-1}g^{-1} \times 74°C = 92.9kJ$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 68.039kg \times (30ms^{-1})^2 \approx ~~1kJ~~ \quad 30\ kJ$$

The heat energy stored in the coffee is a lot higher than the KE of a person riding a bike consistently at 30m/s.

4) When running up stairs, energy is mostly converted into KE and GPE.
Raw data: Height = 4.9m, Distance = 11.1m, Time = 5.02s, Mass = 80.739kg

$$KE + GPE = \frac{1}{2}mv^2 + mgh = \frac{1}{2}(80.739kg)\left(\frac{11.1m}{5.02s}\right)^2 + (80.739kg)(9.81ms^{-2})(4.9m)$$

$$= 197.37489J + 3877.0869J = 4074.46J \quad \sim 4kJ$$

On the other hand, heating up 500ml (500g) of tea by 10c would take...

$$Q = mc\Delta T = (500g)(4.184JK^{-1}g^{-1})(10°C) = 20.9kJ \quad \sim 21kJ$$

So in conclusion: it still takes more energy to heat up the tea, even not to boiling point.

5) Adobe has a conductivity of 0.57W/(mK). Through a temperature difference of 22.2°C...

$$Thermal\ Gradient = \frac{\Delta T}{\Delta l} = \frac{22.2°C}{0.914m} = 24.29°Cm^{-1}$$

As such, the heat loss would be:

$$P = kA\frac{\Delta T}{\Delta l} = (0.57Wm^{-1}K^{-1})(18.6m^2)(24.29°Km^{-1}) = 257W$$

$$257W \times \frac{3.412BTU/hr}{W} = ~~878.63BTU/hr~~ \quad \approx 900\ BTU/hr$$

0.57 J / s m K

6) Working with animated Engines:

a) Because the two stroke engine exhausts as it pulls in new air, it only requires two strokes of the piston to achieve the full ~~Otto~~ cycle. Because of this, they usually produce a higher power, but are less efficient due to the large amount of fuel that escapes along with the exhausted air. Due to their simpler, more compact design however, they are often favoured for smaller items like chainsaws.

b) Unlike gasoline engines, the fuel in diesel engines is not injected into the main chamber along with intake, but when the air in the chamber is compressed and hot enough to ignite the fuel.

c) Through a set of turbines, air is compressed and forced into the combustion chamber, where fuel is ignited and thus the air expands ~~even more~~. This increase in ~~pressure~~ Volume causes the hot air to move through an exhaust turbine, whose torque and KE is converted into electricity, usually by means of electro-magnetic coils.

d) The Rankine cycle is similar to that of a Brayton cycle, though the medium of heat transfer is water. As the water heats up, it turns into steam, which rises and is forced to rotate a turbine which generates electricity. The water is condensed and returned to the start of the cycle.

e) A Carbon Dioxide motor is unlike the Brayton or Rankin cycle in that in a sense, the fuel is pre-compressed. As the piston moves up, compressed air is forced into the chamber and expands. As it can be relatively small, it is often used to power toy airplanes, however, I would imagine that the power would slowly decrease as the CO2 reservoir drains, as will gradually be less and less pressure.

0°K-1°K

0°C 1°C

273°K, 274°K