Power/1st law/heat engine class problems

47. A 70 kg student consumes 2500 Cal each day and stays the same weight. One day, he eats 3500 Cal and wanting to keep from gaining weight, decides to "work off" the excess by jumping up and down. With each jump, he accelerates to a speed of 3.3 m/s before leaving the ground. How many jumps must he make?

20. 600 J of heat energy are transferred to a system that does 400 J of work. By how much does the system's thermal (internal) energy change? Is this an increase or decrease?

24. A heat engine does 20 J of work while exhausting 30 J of waste heat. What is the engine's efficiency?

28. A heat engine operating between energy reservoirs at 20^0C and 600 ^{0}C has 30% of the maximum possible efficiency. How much energy does this engine extract from the hot reservoir to do 1000 J of work?

49. The resistance of an exercise bike is often provided by a generator; that is, the energy that you expend is used to generate electric energy, which is then dissipated. Rather than dissipate the energy, it could be used for practical purposes.

a. A typical person can maintain a steady energy expenditure of 400 W on a bicycle. Assuming a typical efficiency for the body, and a generator that is 80% efficient, what useful electric power could you produce with a bicycle-powered generator?

b. how many people would need to ride bicycle generators simultaneously to power a 400 W TV in the gym?

(Not in book) An inventor tells you he has a prototype engine that uses a vat of boiling water as its heat reservoir, and a vat of ice/water as its cold reservoir. This engine, he claims, has an efficiency of 30%. Is this engine possible?

Power/1st law/ heat engines group problems

21. 300 J of energy are transferred to a system in the form of heat while the thermal energy increases by 150 J. How much work is done? Is this work done by the system, or on the system by its environment?

26. A heat engine with an efficiency of 40% does 100 J of work. How much heat is (a) extracted from the hot reservoir; and (b) exhausted into the cold reservoir?

MC 32. 200 J of heat is added to two gases, each in a sealed container. Gas 1 is in a rigid container that does not change volume. Gas 2 expands as it is heated, pushing out a piston that lifts a small weight. Which gas has the greater increase in its thermal energy? Explain.

MC 33. An inventor approaches you with a device that he claims will take 100 J of thermal energy input and produce 200 J of electricity. You decide not to invest your money. Which thermodynamic law or laws would this device violate? Explain.

53. A heat engine with a high-temperature reservoir at 400 K has an efficiency of 0.20. What is the maximum possible temperature of the cold reservoir?

56. An engine operating at its maximum theoretical efficiency is 40% efficient, and its cold reservoir is at 7^0C. By how much should the temperature of the hot reservoir be increases to raise the efficiency to 60%?

48. To make your workouts more productive, you can get an electrical generator that you drive with the rear wheel of your bicycle when it is mounted on a stand.

a. Your laptop charger uses 75 W. What is your body's metabolic power use while running the generator to power your laptop charger, given the typical efficiency of such task? Assume that the generator itself is 100% efficient.

b. Your laptop takes 1 hour to recharge. If you run the generator for 1 hour, how much energy does your body use? Express your result in both joules and Calories.

11-47 Wants to burn 1000 Cal = 4.19×10^6 J

We do not know the height he reaches, but he gives himself $v = 3.3$ m/s as he stretches muscles.
Gains Kinetic E.

$$e = \frac{\text{OUTPUT}}{\text{INPUT}} = \frac{\frac{1}{2}mv^2}{\text{Energy used in one jump}}$$

$$0.25 = \frac{\frac{1}{2}(70\text{ kg})(3.3\text{ m/s})^2}{E \text{ used}}$$

E used per jump = 1524 J

$$n(1524\text{ J}) = 4.19 \times 10^6\text{ J}$$

$$n = 2750 \text{ jumps.}$$

OR: Find ΔY you get + OUTPUT = $mg\Delta Y$

11-48 You want to generate 75 J/s

$$e = \frac{\text{OUTPUT}}{\text{INPUT}}$$

$$0.25 = \frac{75\text{ J/s}}{\text{INPUT}}$$

a. You are putting in 300 J/s

b. $E = P\Delta t$

$= (300\text{ J/s})(3600\text{ s})$

$= 1.08 \times 10^6$ J

$$= \frac{1.08 \times 10^6\text{ J}}{4190\text{ J/Cal}}$$

$= 258$ Cal

11 - 24 $W_{out} = 20\text{ J}$

$Q_c =$ ~~40×10^{-3} J~~ 30 J

$W_{out} = Q_H - Q_c$

$20\text{ J} = Q_H -$ ~~40×10^{-3}~~ 30 J

$Q_H = 50\text{ J}$

$e = \frac{W_{out}}{Q_H} = \frac{20}{50} = .40$

11 - 25 $W_{out} = 200\text{ J}$, $Q_c = 600\text{ J}$

(HW)

$W_{out} = Q_H - Q_c$

$200\text{ J} = Q_H - 600$

$Q_H = 800\text{ J}$

$e = \frac{W_{out}}{Q_H} = \frac{200}{800} = 0.25$

11 - 53 $T_H = 400\text{ K}$, $e = 0.20$

max eff is ~~to~~ given by

$e_{max} = 1 - T_c/T_H$

So this engine cannot have e greater than this.

If it is as perfect as possible:

$0.20 = 1 - T_c/$~~T_H~~ 400 K

$T_c = 320\text{ K}$

$T_H = 600°C = 873\ K$

its $e = 0.30\, e_{max}$, and $e_{max} = 1 - T_C/T_H$

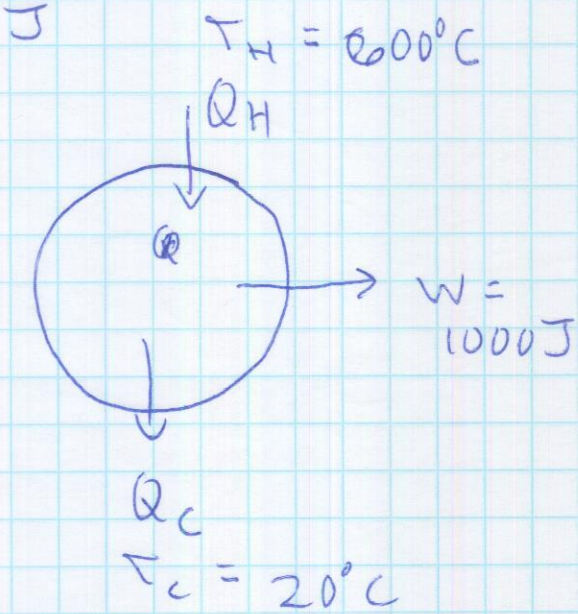
so $e = 0.30\,(1 - 293/873)$

$e = 0.20$

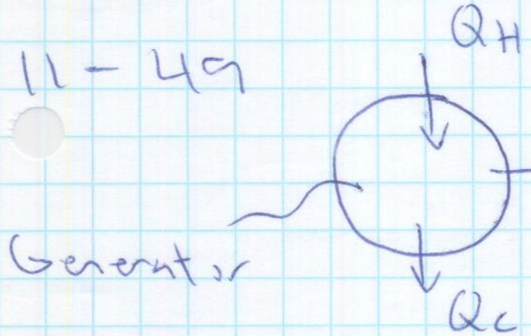
and $e = \frac{W_{out}}{Q_H} = \frac{Q_H - Q_C}{Q_H} = 1 - Q_C/Q_H$

$0.20 = 1000\,J / Q_H$

$Q_H = 5000\ J$



11 - 49



Q_H = what you give it.

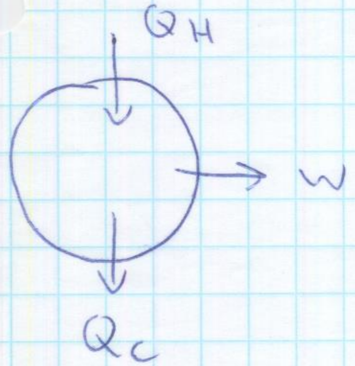
$Q_H = 0.25(400\ J/s)$
$= 100\ J/s$

$e_{generator} = 0.80 = W/Q_H$

$W = 0.80(100\ J/s) = 80\ J/s$

so 5 people would give $5(80\ J/s) = 400\ J/s$ to power TV

11 - 56



$T_c = 7°C$
$= 280\ K$

right now, $e = e_{max} = 0.40$

$e_{max} = 1 - T_c/T_H$

$0.40 = 1 - \frac{280\ K}{T_H}$

$T_H = 467\ K = 194°C$

To get $e'_{max} = 0.60$:

$0.60 = 1 - \frac{280\ K}{T_H'}$

$T_H' = 700\ K = 427°C$

$\Delta T_H = 233\ K$ (= 233 C°, too)

Ch 11

MC 32 $\Delta E_{TH} = Q + W$

both have same $+Q$

1 : $W = 0$

2 : W is negative: system does work on environment.

So 1 has greater ΔE_{TH}

MC 33 $Q_H = 100\,J$, $W = 200\,J$

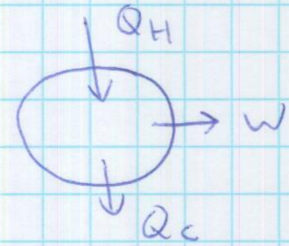
1st : $W = Q_H - Q_C$: Violates

2nd : Q_C cannot be zero; or $e \neq 1$. So e cannot be > 1!

Pr ~~24~~ 26

$e = 0.40$

$W = 100\,J$



$e = W / Q_H$

$Q_H = \frac{W}{e} = \frac{100\,J}{0.40} = 250\,J$

$W = Q_H - Q_C$

$Q_C = Q_H - W = 250 - 100 = 150\,J$