2.005 Pset 1

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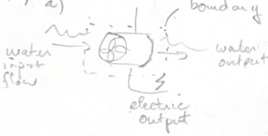
Problem 1

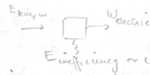
i) A system is closed when it does ~~not~~ undergo mass transfer (c)
A closed system can undergo work and heat transfer with the environment (a,b)

a) Yes
b) Yes
c) No (unless internal)

ii) a)

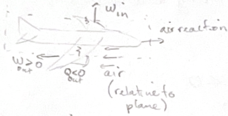


i) open and interacting system
ii) $Q \sim 0$? $W < 0$ into system more than out. net work.
iii) $\Delta E = 0$?



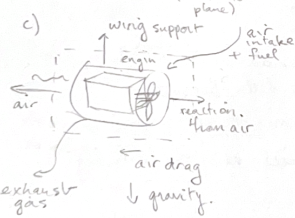
otherwise energy would build up in the system

b)



i) open and interacting
ii) cooling $Q < 0$ and $(W_{out} - W_{in}) > 0$ (maybe)
iii) $\Delta E < 0$, burning fuel to maintain speed + altitude

c)



i) open and interacting
ii) cooling? $Q < 0$ $W > 0$ use fuel energy to work on air unless excluded from syst then W?
iii) $\Delta E = 0$?

d)

i) closed and interacting
ii) $Q > 0$ $W > 0$ electric power is consumed.
iii) $\Delta E = Q - W$?

Problem 2

ii) candle burning

"perfectly insulated" → $Q=0$

→ $W_{air}=0$

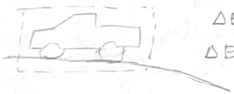
a) since $Q=0$,
no heat transfer
with environment

b) chemical energy in
candle → heat
no net energy change

$\Delta E = \cancel{Q_{1\to2}}^{0} - \cancel{W_{1\to2}}^{0}$
$= 0$.

iii) Assuming the system includes the air and fan
and is bound by the walls of the room, the air
could be slightly heated by the inefficiencies
in the fan's power transfer. Assuming no
cooling in neighboring rooms, as well.
The air in the room wouldn't cool
just by mixing with itself if starting at a uniform T°.

i) Probably an optical illusion.



$\Delta E_{gravitational} < 0$

$\Delta E_{kinetic} > 0$.

assuming the car is actually rolling downhill,
we might think it is moving up hill because of
sense of where the horizon is might be confused
by the angle of surrounding trees, and the viewing
angle with respect to the road.

Problem 3 $\boxed{\text{SYS: Nause bottle - closed}}$

- does temp change based on depth?
→ probably since fixing thermometer value is necessary.

system properties: a, b, c, d, g, i, k, m, n, o?, p?,

depends on "sea surface" variability: e, f

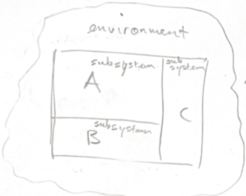
not property: h, j?, l, q?, r

$\boxed{\text{SYS: An electric toothbrush}}$

system properties: a, b, d, e, f, g, k?, l,

Not property: c, h, i, j?, m, n?.

Problem 4



$\Delta E_A = 4 \Delta E_B$

a) entire system
30 kJ into system
→ $Q > 0$
→ $Q = 30\,kJ$
$W = 0$
$\Delta E = Q - W = 30\,kJ$

b) environment (as a system).
30 kJ out.
→ $Q = -30\,kJ$
$W = 0$
$\Delta E = Q - W = -30\,kJ$

c) subsystem A
$Q = 30 - 6 + 4 = 28\,kJ$
$W = 20\,kJ$ (out of system)
$\Delta E = 8\,kJ$

d) subsystem B
$Q = 6 - 4 = 2\,kJ$
$W = 0$
$\Delta E = 2\,kJ$

e) subsystem C
$Q = 0$
$W = -20\,kJ$
$\Delta E = +20\,kJ$

f) subsystem A+B
$Q = +30\,kJ$
$W = 20\,kJ$
$\Delta E = 10\,kJ$

state 1 → state 2.

Env $\xrightarrow{30kJ}$ A (HT)

A ⟷ B (HT)
$\frac{4}{5}30$ $\frac{1}{5}30$

A $\xrightarrow[20kJ]{}$ C (WT)

A ⟷ B (HT)
$-\frac{4}{5}20$ $-\frac{1}{5}20$

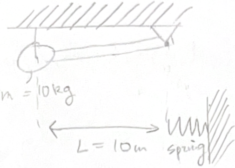
End result

B: + 6 kJ (HT)
− 4 kJ (HT)
$\Delta = 2\,kJ$

A: + 30 kJ (HT)
− 6 kJ (HT)
− 20 kJ (WT)
+ 4 kJ (HT)
$\Delta = 8\,kJ$

C: + 20 kJ (WT)
$\Delta = 20\,kJ$

Problem 5

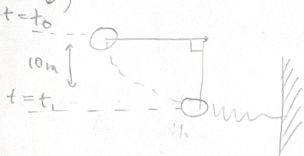


a) 1) after the string is cut, the sphere will swing like a pendulum until it reaches the spring.

2) Once the sphere reaches the spring, assuming a clean collision, the kinetic energy of the sphere is converted to elastic potential energy of the spring. Energy may be dissipated as heat due to friction, internal defomation, etc.

3) Assuming the spring is strong and stiff enough to only deform elastically, and not break, at some equilib. point, the spring will start decompressing and accelerate the sphere back. The pendulum and spring will oscillate back and forth until air drag and other inefficiencies dissipate all the energy.

b)

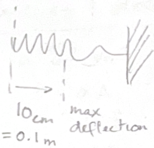


$$W = \int F \cdot \delta r$$

$$= 10\,kg \times 9.81 \times 10\,m = \boxed{981\,J}$$

(leaving system)

c)



$$E_{elastic} = \frac{1}{2} k x^2_{max}$$

$$= \frac{0.01}{2} k$$

At max deflection, assuming no energy loss

$$E_{elastic\_max} = E_{gravitational\_initial}$$

$$\rightarrow \frac{0.01}{2} k = 981\,J$$

$$\rightarrow k = \boxed{196200\,Nm}$$

Problem 6

5cm

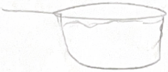
$\bigcirc$ x 6 $t_{init} = 2°C$

egg as sphere

5cm

$\bigcirc$ x 6 $t_{end} = 80°C$

after 15 min in water



100 °C
adiabatic

? °C
95 °C c)

initial

end

parameters

$\rho_w = 1000 \, kg/m^3$

$c_w = 4.187 \, \frac{kJ}{kg K}$

$\rho_{egg} = 1020 \, kg/m^3$

$c_{egg} = 3.3 \, \frac{kJ}{kg K}$

$V_{egg} = \frac{4}{3}\pi(0.025)^3$
$= 6.54 \times 10^{-5} \, m^3$

$m_{egg} = \rho \times V = 66.8g$
$= 0.0668 \, kg$

a) As a simple model for the HT to the egg we can use $Q = m_e c_e \Delta T$

where the system is the egg at final end state.

This assumes no W is done, no phase change or other energy sinks, and the the amount of water is consistent (+adiabatic)

b) $\Delta E = Q - \cancel{W}^{0} = m_e c_e (T_{end} - T_{init})$

$= \underset{(\times 6)}{\rho_{egg} \times V_{egg}} \times 3.3 \times 10^3 (80-2)$ temp difference is same in K°

$= 0.4 \times 3.3 \times 10^3 (78)$

$= 103\,102 \, J$

or $\boxed{103 \, kJ}$

c) $Q_{water} = m_{water} c_w \Delta T_w = 103 \, kJ$

$\Rightarrow m = \frac{103.102}{4.187 \times (100-95)}$

$= 4.9 \, kg$

$\rightarrow$ 4.9 liters or $\boxed{0.0049 \, m^3}$

d) to find the number of eggs n

Assuming the amount of time/energy lost by water remains the same $\rightarrow$ 15 min / 103 kJ :

$n = \frac{Q_{water}}{Q_{egg\,(single)\,to\,70°}} = \frac{103 \, kJ}{0.0668 \times 3.3\,(68) \, kJ} \; (\approx 15)$ $\boxed{\sim 6.87 \text{ so at least } 6 \text{ eggs}}$

e) since 103 kJ is enough to cook 6.87 eggs to 70°C we can lose 0.87 x the energy cost of 1 egg

$\rightarrow \sim 15 \, kJ \times 0.87$
$\approx 13 \, kJ$