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Phy 232
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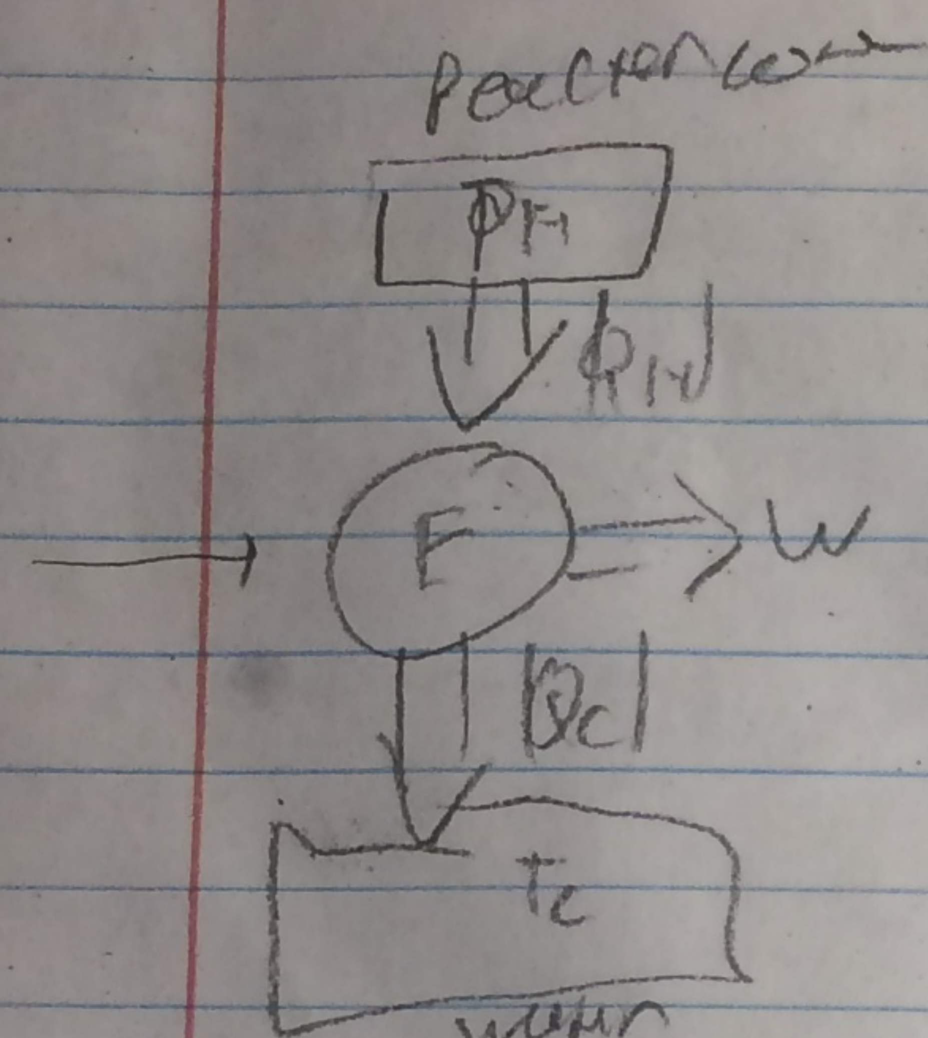
HW for 12/6/17
T9M.9
T10R.3

T9M.7
Consider the nuclear power plant described in section T9.4. Suppose that we route water from a nearby river into cooling towers. Suppose the river near the plant is 67 m wide, an average of 3 m deep, and flows at a rate of 0.5 m/s. About what fraction of the river must evaporate in the cooling towers to carry away the plant's waste heat?



Here we have $e = \frac{|W|}{|Q_H|} = 0.34$

For a plant generating 1000 MJ of work every second, the engine absorbs
$|Q_H| = \frac{W}{e} = \frac{1000\,MJ}{0.34} = 2941\,MJ$ every second, and since $|Q_H| - W = |Q_C|$,
the water absorbs $2941\,MJ - 1000\,MJ = 1941\,MJ$ every second.

The change in energy of the water is $\Delta U = +m \cdot L$, where m is the mass of water, L is latent heat (in this case, of vaporization, 2257 kJ/kg for water)
So the mass of water that absorbs $|Q_C|$ in 1 second is

$$m_{ev.} = \frac{1941\,MJ}{2257\,\frac{kJ}{kg} \cdot \frac{1\,MJ}{1000\,kJ}} = 860\,kg.$$

The actual amount of water that flows into the reactor in 1 s is

$$M_{tot} = \rho \cdot |\vec{V}| \cdot A_c \cdot 1\,s = 1000\,kg/m^3 \cdot 0.5\,m/s \cdot (3\,m \cdot 63\,m) \cdot 1\,s = 94500\,kg.$$

So the fraction of the river that evaporates in a second is
$\frac{860\,kg}{94500\,kg} = 0.009 \approx 0.9\%$ of the river. Assuming $|Q_C|$ is constant, and $|\vec{V}|$ is constant, this ratio is true over any interval of time.

So the reactor evaporates 0.9% of the river
Right units, reasonable magnitude!

$T(n)$ = temp of earth at time t

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T(n(t)) at year ... $t_0 = t_0 - 30$)

TLOR 3

Suppose that in 2015 we start reducing the net carbon added to the atmosphere linearly from the current value of 2ppm/y to zero. According to the model developed in this chapter, what does that decrease need to be to avoid exceeding the 289 K limit that most think is when damage to the ecosystem will be extreme and irreversible?

The model developed says that $T(n) = (n+1)^{1/4} \cdot T_0$ where $n = 0.163 \cdot \left(\frac{[CO_2]}{280}\right)^{1/2} + 0.442$ is the number of opaque levels, $T_0 = 255K$.

We can solve this using differential equations. Let $y(t) = [CO_2]$ as a function of time. So $y' = 2 - \gamma t$, where γ is the rate of change of y'.

So $y = \int 2 - \gamma t \, dt = 2t - \frac{1}{2}\gamma t^2 + C$

Let's define initial conditions to solve for C. With t=0 ~~...~~ the year 2015,

$y(0) = 400$ ppm

So $y(t) = 2t - \frac{1}{2}\gamma t^2 + 400$

So $n(t) = 0.163 \cdot \left(\frac{y(t)}{280}\right)^{1/2} + 0.442$ at t_0

We want a concentration $y(t_0)$ such that $T(n(t_0)) = 289K$. Note that the time at which $T(n) = 289K$ is 30 years AFTER t_0 in the model, so

$289K = (n+1)^{1/4} \cdot T_0 \Rightarrow \left(\frac{289K}{255K}\right)^4 - 1 = n = 0.65$

$0.65 = 0.163 \cdot \left(\frac{y(t_0)}{280}\right)^{1/2} + 0.442 \Rightarrow \left((0.65 - 0.442) \div 0.163\right)^2 \cdot 280 = y(t_0) = 466$

So $466 = 2 \cdot t_0 - \frac{1}{2}\gamma t_0^2 + 400 \Rightarrow 2 \cdot t_0 - \frac{1}{2}\gamma t_0^2 - 66 = 0 \Rightarrow t_0^2 - \frac{4}{\gamma}t_0 + \frac{132}{\gamma} = 0$

$t_0 = \frac{\frac{4}{\gamma} \pm \sqrt{\frac{16}{\gamma^2} - 4 \cdot \frac{132}{\gamma}}}{2} \Rightarrow \frac{\frac{4}{\gamma} \pm \sqrt{\frac{16}{\gamma^2}(1 - 33\gamma)}}{2} \Rightarrow t_0 = \frac{2 \pm 2\sqrt{1 - 33\gamma}}{\gamma}$

The largest γ that gives a real valued t_0 is $\gamma = \frac{1}{28}$. So $t_0 = \frac{2}{1/28} = 56$

So the year at which $y'(t) = 0$ is $2015 + 56 = 2071$.

NOTE: approximating $\frac{1}{28}$ as 0.03 gives the "correct" answer of 2055. I stand by my answer of 2071 as ~~...~~ ... error in the reasoning nor in the calculations.

[illegible]