FY2290 Exam 2015
FY2200 Eksamen 2015

Note there is an Appendix with useful information attached to the back of the exam. Write all your calculations and answers in the exam book.

Appendiks med nyttig informasjon er vedlagt på baksiden av eksamensoppgaven. Vis alle beregninger og svar i eksamensbesvarelsen.

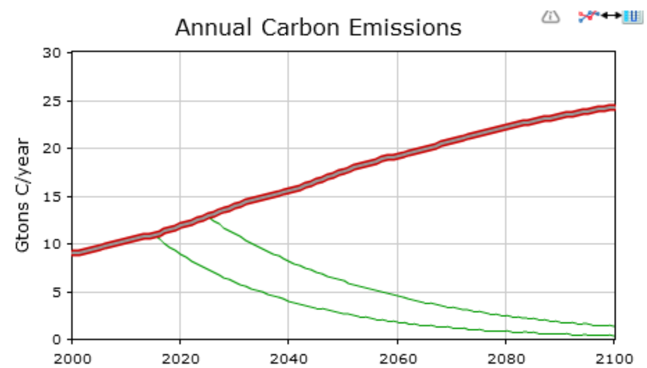
I. SHORT ANSWER QUESTIONS - KORTSVARSOPPGAVER

(points for each question are shown as subscripts)
(Poeng for hver oppgave er markert med senket skrift)

A. $_6$ Briefly define Energy, Entropy and Exergy
   $_6$ *Definer kort begrepene energi, entropi og eksergi.*

Energy is the ability to do work (kinetic + potential + mass) on an absolute scale
Entropy is a measure of the disorder of the system related to the number of possible configurations
Exergy is a measure of how far out of equilibrium *with the surroundings* that a system is, and represents the part of the energy that can be used to do work in a particular situation

B. The graph below is from the EnRoads simulation used in the last day of class.
   Grafen under er fra EnRoads-simuleringen benyttet i siste forelesning.



$_4$What do the green lines represent?
$_4$*Hva representerer de grønne linjene?*

The green lines are the bounds of CO_2 output allowable in the various models associated with a 2 °C increase in global temperature.

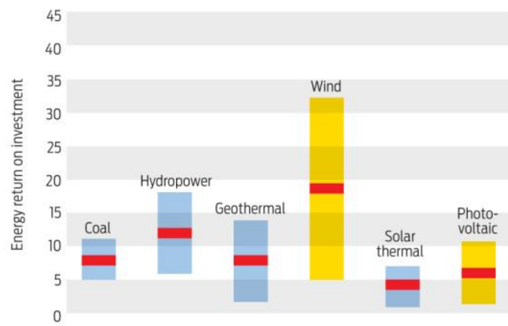
C. $_2$What are the equivalents of the voltage and current when considering the case of thermal resistance of a building?
   $_2$*Hva tilsvarer spenning og strøm når en ser på termisk resistanse i en bygning?*

Voltage ~ temperature difference and current ~heat flow

D. $_3$Briefly explain two problems with the use of biofuels.
   $_3$*Beskriv kort to problemer med bruk av biodrivstoff.*

Competition between food and fuel crops, land use change release of greenhouse gases, low energy density

E. $_{5}$Define EROI and rank two technologies from higher to lower value.
$_{5}$Definer EROI og rangér to teknologier fra høyest til lavest verdi.
Energy return on investment



F. $_{4}$How can the latent heat of fusion be used as part of a household energy system?
$_{4}$Hvordan kan latent smeltevarme bli brukt som del av et husholdningsenergisystem?
Using a salt that melts/freezes near a comfortable room temperature stabilizes the temperature of a thermal mass in a passive solar system, e.g. Glauber's salt.

G. $_{6}$What causes the electrons and holes inside a solar cell to move in opposite directions?
$_{6}$Hva er årsaken til at elektroner og hull inni en solcelle beveger seg i motsatt retning?
The transfer of charges when a p-type material contacts an n-type material leads to the formation of an internal electric field. Since electrons and holes have opposite effective charges, they move in opposite directions in the field.

II PROBLEMS - OPPGAVER

All questions should be answered.
NO CREDIT will be given for a correct numerical answer unless the work is shown!!
Alle oppgaver skal besvares.
INGEN POENG gis for riktig tallverdi hvis ikke utledning er vist!!

1. $_{6}$Calculate the power in megawatts during outflow from a tidal power plant that encloses a rectangular area of 1.2x2.5 km, and which fills to a height of 3.7 m above the outlet. Assume an efficiency of 95%, and an emptying time of 2 hours.
$_{6}$Beregn effekten i megawatt under utstrømming i et tidevannskraftverk som dekker et rektangulært område på 1,2x2,5 km, og som fylles til en høyde av 3,7 m over utslippet. Anta 95% effektivitet og at tømming skjer over 2 timer.

P=ηmgh(h/2)/t = (0.95)(1.2x 103m) (2.4x 103m)(3.7m)(1.02x 103kg/m3) (9.8m/s2)(3.7m/2)/(3600s*2)=
26 MW

2. $_{8}$The production of a certain resource is increasing at 5% per year, and is predicted to be exhausted in 30 years if this continues (sudden exhaustion, no Hubbert model). A new discovery increases the total known resource by a factor of 5. How many years will it now take to exhaust the resource, assuming the growth rate remains constant?

8*Produksjonen av en gitt ressurs ø ker med 5% hvert år og spås tom om 30 år hvis trenden fortsetter (plutselig tømming, ingen Hubbellmodell). En ny oppdagelse øker total kjent mengde av ressurser med 5 ganger. Hvor mange år vil det nå ta før det går tomt for ressursen, hvis man antar at vekstraten forblir konstant.*

$N = N_0(1.05)^t \Rightarrow k = \ln(1.05) = 0.048$

$$Q_T = \int_0^T N_0 e^{kt} dt = \frac{N_0}{k}(e^{kT} - 1)$$

$$5Q_T = \frac{5N_0}{k}(e^{k30} - 1)$$

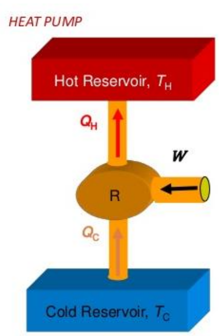
$$5Q_T = \frac{N_0}{k}(e^{kt_2} - 1)$$

$$5(e^{k30} - 1) = (e^{kt_2} - 1) \quad ;$$

$$e^{kt_2} = (5*4.32) - 4 = 17.6$$

$$t_2 = 59.7 yrs$$

3. 2A)Draw a diagram showing energy flow for a heat pump.
   2*A) Tegn et diagram som viser energiflyten for en varmepumpe.*
   6B)A particular heat pump uses 1 kW of electrical power. Every second, it removes 2.5 x 10^3 joules from a low temperature reservoir. What is the COP?
   6*B)En gitt varmepumpe har en effekt på 1 kW. Hvert sekund fjerner den 2,5 x 10^3 joule fra et lav-temperaturreservat. Hva er COP for varmepumpen?*



http://www.slideshare.net/smilingshekhar/thermal-engineering-om

$$C.O.P. = \frac{Q_H}{Q_H - Q_C} = \frac{3.5kW}{3.5kW - 2.5kW} = 3.5$$

4. 10How much would the temperature of the earth change (and in what direction) if the albedo were increased by 1%? Assume there is no atmosphere.
   10*Hvor mye ville temperaturen til Jorden endre (og i hvilken retning) hvis albedoen ble økt med 1%? Anta ingen atmosfære.*

   Energy absorbed by earth/area/second has to be same as radiated

$$\frac{1}{4}I_0(1-\alpha)=\varepsilon\sigma T^4$$

$$\frac{1}{4}I_0(1-\alpha_2)=\varepsilon\sigma T_2^4 \qquad \textit{divide}$$

$$\frac{(1-\alpha)}{(1-\alpha_2)}=\frac{T^4}{T_2^4}=\frac{.69}{.68}$$

$$T/T_2=1.0037$$

Temperature decreases by ~0.4 %.

(T without atm would be 254; so temperature change ~ 1K)

[8]The oceans contain about 1.3 x 10^{24} cm^3 of water. Deuterium constitutes 0.028% by mass of natural hydrogen. [8]*Verdenshavene inneholder ca. 1,3 x 10^{24} cm^3 vann. For naturlig hydrogen er ca. 0,028% av masen deuterium.*

5.

a) What is the total energy in Joules available from this Deuterium by D-D fusion? Assume 4. 0 MeV per fusion event.

a)Hva er total mengde tilgjengelig energi (i joule) fra deuteriumet ved D-D fusjon? Anta 4,0 MeV per fusjonsbegivenhet.

a)(1.3 x 10^{24} cm^3)(1.02g/ cm^3)=1.33 x 10^{24} g H_2O; ~2/18 of this is hydrogen, and 2.8 x 10^{-4} of that is Deuterium, so 4.13x10^{19}g D. Atomic number 2 -> each 2 grams contains 6.02x10^{23}atoms. It takes two D for each fusion event.

Energy available

(1.24 x 10^{43}atoms/2(atoms/fusion))(4 x 10^6eV/fusion)(1.6x10^{-19}J/eV)=**3.97x10^{30}J**

(answers that had correct formulation without numerical values for constants received full credit)

b) For how many years could fusion reactors with 50% efficiency supply 2.0 million MW?

b)Hvor mange år kan fusjonsreaktorer med 50% effektivitet forsyne 2,0 millioner MW?

b) Reactor energy input per year = (1/0.5) (2x10^{12}J/s) (3.15x10^7s/year)=1.26x10^{20}J (Total available)/(use per year)~**3x10^{10} years.** The hard parts are extracting the D from the ocean and building the reactors…

6.[5]The world primary energy usage in 2013 was approximately 13 000 Mtoe. Assuming that flat panel, non-tracking solar cells at a sunny location can harvest 8kWh/m^2/day, what area is required (at that location) to supply the energy needs of the earth?

[5]*Verdens primære energibruk i 2013 var ca. 13000 Mtoe. Anta at flate, ikke sporende solceller i et solrikt område kan produser 8kWh/m^2/dag. Hvor stort areal (i det solrike området) trengs for å forsyne verdens energibehov?*

13000Mtoe= 13x 10^9toe/(8.6 x$10^{-5}$$_{toe/kWhr)}$=1.5x$10^{14}$kWhr/year

(8kWhr/day-m^2)*365 = 2920kWhr/m^2

1.5x10^{14}kWhr/(2920kWhr/m^2)=**5.2x$10^{10}$$m^2$**

Appendix/Vedlegg

Energy conversion factors

	J	kWh	Btu	toe
1 Joule (J)	1	2.78 x 10^{-7}	9.5 x 10^{-4}	2.38 x 10^{-11}
1 kilowatt-hr (kWh)	3.6 x 10^{6}	1	3413	8.6x10^{-5}
1 calorie (cal)	4.184	1.16 x 10^{-6}	3.97x 10^{-3}	1x 10^{-10}
1 British thermal unit (Btu)	1055	2.93 x 10^{-4}	1	2.5 x 10^{-8}
1 Electron volt (eV)	1.6x 10^{-19}	4.45x 10^{-26}	1.52 x 10^{-22}	3.8 x 10^{-30}

Equations

$$P(t) = \frac{1}{\beta}\left(1 - \frac{Q(t)}{Q_\infty}\right)Q(t)$$

$$Q(t) = \frac{Q_\infty}{1 + Ae^{-t/\beta}}$$

$$P(t) = P_0\left(\frac{Q_\infty}{Q_0}\right)^2 \frac{e^{-t/\beta}}{(1 + Ae^{-t/\beta})^2}$$

$$\beta = (Q_\infty - Q_0)\frac{Q_0}{Q_\infty P_0}$$

$$t_m = \left(1 - \frac{Q_0}{Q_\infty}\right)\frac{Q_0}{P_0}\ln\left(\frac{Q_\infty}{Q_0} - 1\right)$$

$$P_m = P(t_m) = \frac{Q_\infty{}^2 * P_0}{4Q_0(Q_\infty - Q_0)}$$

$$Q_T = \frac{N_0}{k}(e^{kT} - 1)$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\eta = 1 - \frac{Q_L}{Q_H}$$

$$\eta_{carnot} = 1 - \frac{T_L}{T_H}$$

$$COP = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$$

$$E = \frac{hc}{\lambda}; \quad hc = 1.98x10^{-25}\, J.m$$

$$hc = 1.23x10^{-6}\, eV \cdot m$$

$$P = I^2 R$$

$$\frac{P}{A} = \varepsilon\sigma T^4 \qquad \sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$$

$$I_0 \frac{\pi R^2}{4\pi R^2} = 342\ W/m^2$$

$$\tfrac{1}{4}I_0 = \tfrac{1}{4}\alpha I_0 + I_A$$

$$\lambda_m[\mu m] = \frac{2898}{T(K)}$$

$$E_{pot} = mgh = \rho Vgh$$

$$E_{kin} = \frac{1}{2}mv^2$$

$$\frac{P}{A} = 6.1x10^{-4}v^3[kW/m^2]$$

$$A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$$

$$\frac{\Delta Q}{\Delta t} = \frac{A}{R}\Delta T = AU\Delta T$$

$$R = 1/k$$

$$Q = mC\Delta T$$

$$m = \rho V$$

$$F = ma = m\frac{\Delta v}{\Delta t}$$

$$V = IR$$

$$P = 0.59\ A/2(\rho u^3)$$

$$J = E*cg \sim 1\ kW/m^3s *T\,H^2$$

Storage material	MJ per kilogram	MJ per liter (litre)
Uranium-235	83 140 000[3]	1 546 000 000
Hydrogen (compressed at 70 MPa)	123	5.6
Gasoline (petrol) / Diesel	~46	~36
Propane (including LPG)	46.4	26
Fat (animal/vegetable)	37	
Coal	24	
Carbohydrates (including sugars)	17	
Protein	16.8	
Wood	16.2	

Density of water 1.02 x10^3kg/m^3
density of air ~1.2 kg/m^3
acceleration due to gravity 9.8 m/sec^2
Avogadro's number 6.02 x 10^{23}(# per mole)