NTNU – Trondheim
Norwegian University of
Science and Technology

Department of Physics

Examination paper for FY2290 Energy Resources

Academic contact during examination: Turid Worren Reenaas

Phone: 4121 5871

Examination date: May 16, 2017

Examination time (from-to): 9-13

Permitted examination support material: any non-graphing calculator

Other information:

Language: English and Bokmål

Number of pages:

Number of pages enclosed

Checked by:

Date Signature

FY2290 Exam 2017

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.

NO CREDIT will be given for a correct numerical answer unless the work is shown, and answers without units will not earn points.

All questions should be answered. (Points for each question are shown as subscripts)

SHORT ANSWERS

1)$_5$ Approximately how many more years are fossil fuels expected to last (not counting methane clathrates)? (give a range that is not more than a factor of two wide)

2)$_5$ Define methane clathrates and give one danger of their release to the atmosphere
3)$_5$ Name a method associated with a high cost per kW of electricity, and one much lower
4)$_6$ Name two major ways in which humans have altered methane emissions on earth
5)$_4$ Which of the following units are energy (not power)?
kWh, GW, BTU, EJ, eV, Watts, Quads
6)$_6$ When an energy resource is tapped, the time evolution is often expressed by the equation $dQ/dt = (1/\beta)\, Q\, (1 - Q/Q_T)$
Identify the terms, and give three different temporal regions that can be used to approximate the equation as the resource is used. (Use a graph)
7)$_4$ What is the difference between an energy resource and an energy vector? Give two examples of each.
8)$_5$ What is the chemical difference between oil, coal and a carbohydrate, and how are they related to their use/efficiency as fuels?
9)$_4$ What are known environmental problems associated with shale gas extraction? (mention at least 2)
10)$_6$ How can you store electrical energy? Explain two methods and give a challenge for each of them.This question judged ambiguous - full credit given to all

11)$_5$ Compare blackbody radiation from the sun and the earth, giving numerical values of important parameters.
12)$_5$ Explain the reason the equilibrium temperature of the earth is higher than that given by a simple energy balance calculation

PROBLEMS

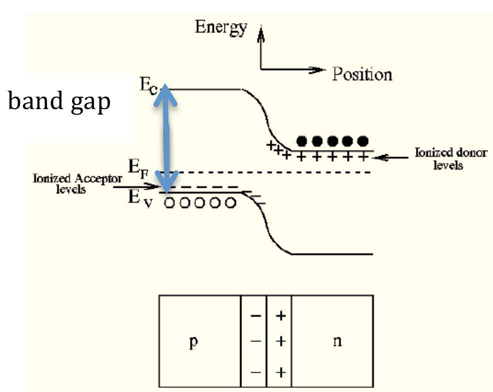
A) A refrigerator with a COP of 1.2 consumes 50kWh (1.8 MJ) of electrical energy while operating over a particular period of time. During this time,
a)5 How much heat energy is removed from the refrigerator
b)5 How much heat energy is removed (dissipated) by the condenser?

B)5 A tidal energy plant has one 20 MWe turbine. If operating at full power, what is the water flow per second, assuming the water change in height is 4 m, the water density is 1.02×10^3 kg/m^3, and the conversion efficiency is 95%?

C)5 *Thermal transport/efficiency*
A 2.5 cm thick layer of wood ($k=0.12$ W°C^{-1}m^{-1}) is glued to a 10 cm thick cement ($k=1.3$) wall as shown. The face of the wood is held at 30 C and the far side of the cement is held at 10 C. What is the power transmitted through each square meter of the wall, and what is the temperature at the cement/wood interface (T)?

D) Photovoltaics

a)5 Draw a sketch of the energy bands in a silicon p-n junction. Label the valence band, conduction band and the band gap.
b)6 Explain what happens when a photon is absorbed in the vicinity of the junction, and how this leads to electrical power generation.



Appendix

Energy conversion factors

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

Equations

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

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

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

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

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

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

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

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

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

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

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

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

$$P = I^2 R$$

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

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

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

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

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

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

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

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

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

$$R = 1/k$$

$$Q = mC\Delta T$$

$$m = \rho V$$

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

$$V = IR$$

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

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

Storage material	MJ per kilogram	MJ per liter (litre)
Deuterium–tritium	330 000 000	0.14
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 $x10^3 kg/m^3$
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)