NTNU – Trondheim
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Department of Physics

Examination paper for FY2290 Energy Resources

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Examination time (from-to): 9-13
Permitted examination support material: calculator, non-graphing, no spreadsheet program

Other information:

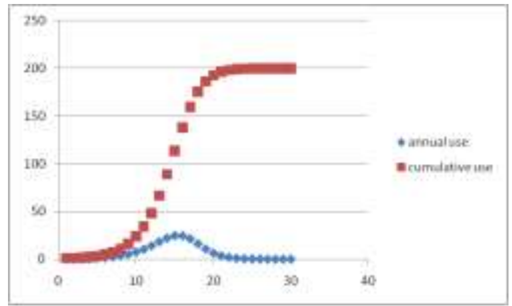
Language: English and Bokmål
Number of pages:
Number of pages enclosed

Checked by:

Date Signature

FY2290 Energy Resources
REMEMBER - to get full credit, you must show your work (set up the equation you will put into your calculator, e.g.) and give appropriate units.

PART 1 - Short answer questions - ANSWER ALL OF THESE



1)What is the physics definition of "work"? (in words, not an equation)
Motion against a force

2)List three of the four fundamental forces
Gravity, electricity/magnetism, strong nuclear, weak nuclear

3)Are the cumulative and annual usages shown at the right plotted on the same scale? Justify your answer.yes – the peak annual use is ~25, which is the same as the increment in total use

4)Why is wood generally not the first choice as a transportation fuel? The energy density is too low.

5)What is the purpose of the Hubbert model and similar mathematical formulations?they help predict when resources will be depleted

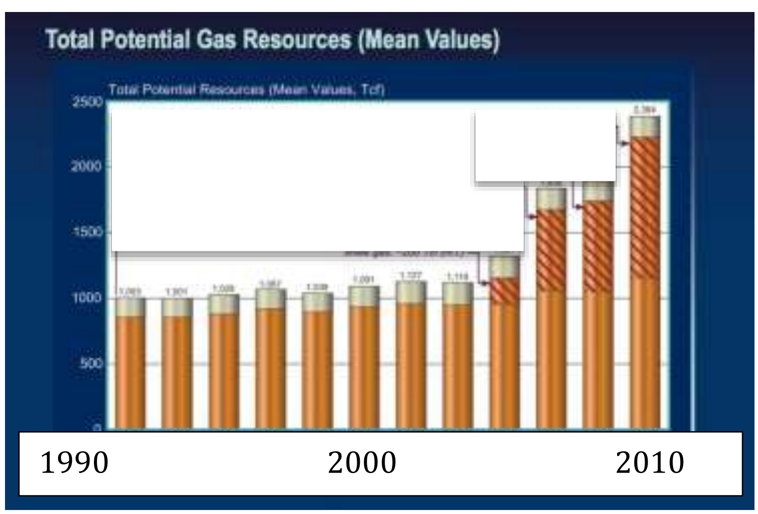
6)What does it imply if an R/P ratio stays constant or rises over a period of time?
New resources have been discovered.

7)List two energy vectors (radiation, electricity, wind)

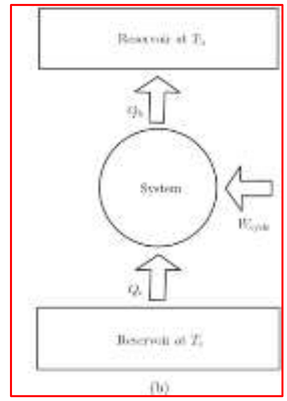
8)List four major regions of the atmosphere from **highest to lowest**, and indicate whether the temperature increases or decreases as you **descend** through each of them. Thermosphere – decreases; mesosphere – increases stratosphere – increases troposphere – increases

9)List one environmental problem for each resource associated with the extraction and transport of oil, gas and coal
(oil – tanker tanks, well blowouts, pipelines; gas- leakage during extraction; coal – landscape damage, water pollution)

10)In the graph below, what does the gold and red striped area portion represent?
Shale gas



11)Make a sketch of a generic heat pump including sources, sinks and work, and give the expression for the performance. $T_{hot}/(T_{hot}-T_{cold})$



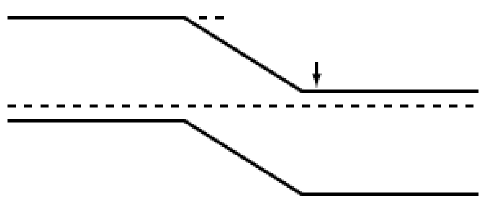
12) Charges are the source of electric fields; what are the sources of magnetic fields? electrical currents

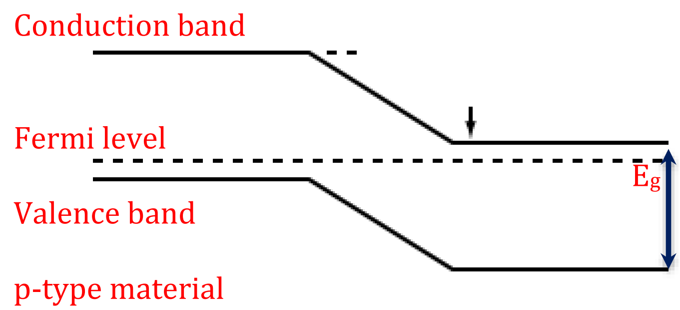
13) Why are root mean square values used for calculations of AC power? Because the sine wave average power is one-half of the dc value

14) List three significant sources of methane release affected by human activity rice, farm animals, gas/oil drilling

15) How are phase change materials used in passive solar systems? They are used to level out the temperature by melting around 20C .

16) Label in the figure: a) E_g b) valence band c) conduction band d) p-type material e) Fermi energy



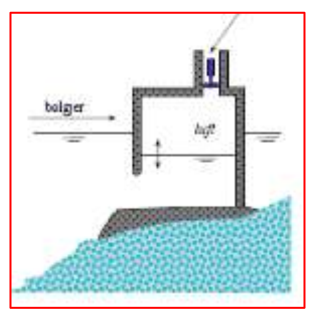


17) What causes the internal electric field in a p-n junction? Electrons from the n-type material move in to fill the holes near the junction, which leaves ionized positive impurities behind. The spatial separation of + and – charges results in an electric field.

18) What are the two main methods to utilize tidal flow for energy production? Barrage systems and in-flow turbines

19) What is the relationship between water wave speed and frequency? Low frequency waves have a higher group velocity

20) Describe the operation of an oscillating water column generator, including a sketch. Waves make the level in the chamber go up and down, driving air through the turbine, attached to a generator.



21) What is the relationship between half-life and the decay constant λ?

PART II

From the presentations: Answer **three** of the questions below, based on the presentations:

a) What are the input fuels and output products of Integrated Gasification Combined Cycle processing?hydrocarbons, CO+H2

b) Give an example of each of these categories of nuclear waste: Low, Intermediate and High levels low- discarded packaging, paper, clothing; Intermediate – casings of fuel rods, refrigerants, construction materials; High – spent fuel

c) What is the ratio of the PV subsidized to market price of electricity in the Czech republic? 10

d) What is the height above ground of wind turbines used in Switzerland? 140m

e) What country is a net exporter of bioethanol? Brazil

f) What part of Germany has the largest wind energy resources? The north (the Baltic)

g) What are the units of each of the terms in the triple product $T\tau n$? K,sec,atoms/cm^3

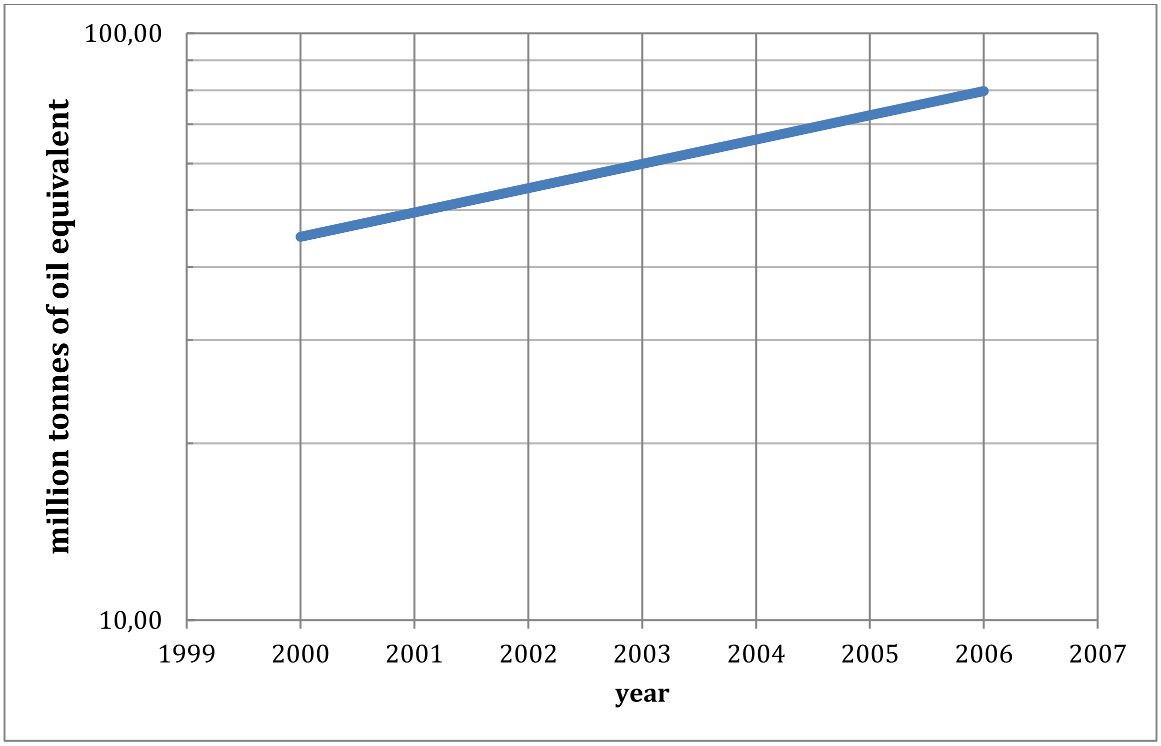
h) What is the energy source in an RTG? Nuclear decay, radioactivity

i) What percentage of Australian electricity is derived from coal? 30

j) At what temperature must steam be extracted from a geothermal site to be practical for electricity generation? 150C

Problems

1) Shown below is a graph of natural gas production over a period of 5 years



a) What was the annual production in 2004, in exajoules?
production was 66 Mtoe = 2.8 EJ
b) What was the growth constant during 2000-2003?
ln(u/a)= kt; k is slope of log graph (ln(60)-ln(45))/3= 0.1
c) Assuming the growth continues as shown in the graph, when will annual production reach 400 MT oil equivalent?
t=(ln(400/45))*10 = 22 years; production would reach this value in 2022
d) List two ways that could be used in Excel to generate the sort of data shown in the graph above; the expression may be an approximation or an exact representation.
Line 1: 45 45
Line2 =(cell above)*1.1 (recursive) or = 45+ exp(0.1*T-2000)

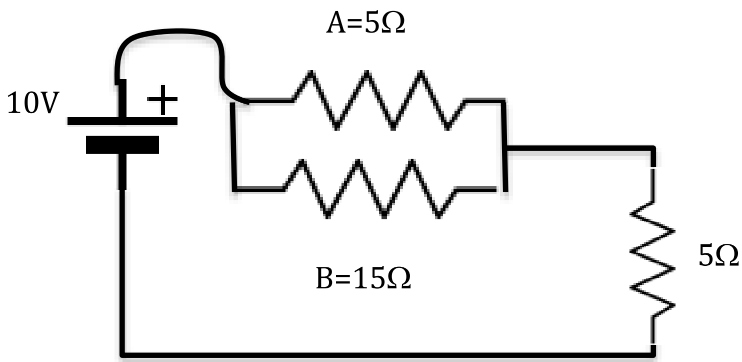
2) Electricity
a) How is energy stored (in what form) in a conventional AA battery ?
It is chemical (electromagnetic) energy
b) A simple capacitor can be made by placing two metal foils close to each other; to get a large area, the foils are separated by an insulator .05mm thick, and rolled into a "jelly-roll" cylinder with at total area of $300 cm^2$. If a 1.5 V battery puts 3 coulombs of charge on the plates, how much energy is stored in the capacitor?
Energy is charge*voltage = 4.5 Joules
c)What is the electric field between the plates?
E=V/d= 1.5/5E-5= 3E4 V/m
d) if the capacitor is connected to a 25 ohm resistor, what is the initial current that flows?

I=V/R =1.5/25=0.06 amps

e) A car battery is typically 12 V and has a capacity of 125 amp hours and weighs 30 kg. How much gasoline (~46 MJ/kg) has the same amount of energy?

E=12*125*3600= 5.4MJ; gasoline equivalent = 5.4MJ/(46MJ/kg) = .12kg

f) If solar panels with a 10 V output are connected to two loads as shown below, what will the current flow in load (resistor) A be?



Parallel resistance is given by 1/R=1/5+1/15=> 3.75 ohms +5 ohms in series, current = 1.14 Amps. voltage across parallel = 10- (1.14*5)= 4.3 V; I=4.3/5= .86 amps

3) A house in New Jersey, 3120 degree (°F) days) consists of the following: 200ft^2 of windows, 400 ft^2 of walls with an R value of 16.3 hr•°F•ft^2/Btu, 320 ft^2 of brick walls that are 13 inches thick, and 1300 ft^2 of roof with an R-value of 20 hr•°F•ft^2/Btu. The R-value of the windows is 1 and the R-value of the brick is 0.14 per inch (in the same units). Neglecting the losses though the slab and due to air infiltration, and the gain due to solar radiation, calculate the number of Btu required to heat this house for one season.

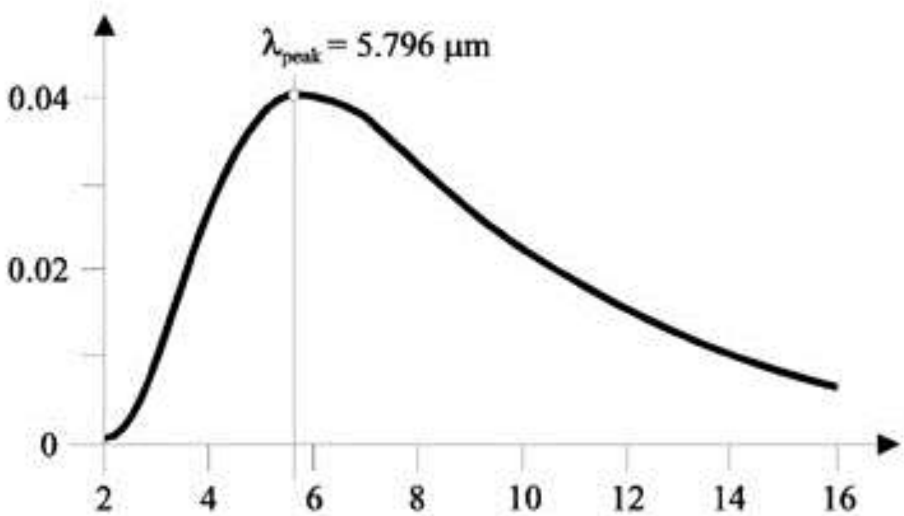
heat loss (□ΔQ) per year = 24*degree days* A/R

= 3120*24°F•hr * [(200ft^2/(1°F•hr•ft^2/Btu)+400/(16.3)+320/(13*.08)+1300/20]

□≈3120*24* (200 + 24.5 + 307.7 +15) = 41 E6 Btu

4) Greenhouse effect

a) label the axes of the blackbody radiation curve below with appropriat e units.



b) What is the temperature of this object at the instant that the spectrum above is taken?

λ_m=2.8972 E6 nm-K/T; T=2.9E6nm K/5.8E3nm = 500K

c) What is the radiated intensity at the surface?

I= 5.67E-8 $Wm^{-2}K^{-4}$ T^4= 3543 W/m^2

d) Assume this (spherical)object is heated by receiving radiation with an average intensity over the surface of 1.5 kW/m^2 between the wavelengths of 500-800 nm (no internal source of energy). Calculate the equilibrium temperature.

I_{in}=I_{out} at equilibrium so T= $(1.5E3/5.67E\text{-}8)^{1/4}$ =403 K

e) What could be done to increase the equilibrium temperature without changing the incoming radiation intensity?

Add an atmosphere that transmits visible light and blocks the infrared

f) What could be done to decrease the equilibrium temperature without changing the incoming radiation intensity?

Increase the albedo (reflectance)of the surface.

5) Water vs. wind

a)A tidal plant has a 20MWe turbine. Assume water is falling through an average distance of 4.0 m, that the density of salt water is 1.02 x $10^3 kg/m^3$ and that the efficiency of conversion from gravitational potential energy to electricity is 95%. What is the volume of water flowing through the turbine per second?

$20x10^6 Jsec^{-1}$/.95=mgh=Volume*1.02 x $10^3kg/m^3$*9.8 m/s^2*4m

V= $20x10^6Jsec^{-1}$/(.95*1.02 x $10^3kg/m^3$*9.8 m/s^2*4m)= 526.5 m^3 each second

b) If a wind farm with 6 turbines is to equal this output(20 MWe),, how long would the turbine blades have to be, assuming a 10m/sec wind, and an efficiency (conversion to electricity) of 85% of the theoretical maximum?

P= $20x10^6Jsec^{-1}$ =(0.85*0.59)*A/2* $(10m/s)^3$*1.2kg/m^3

total A= $40x10^6Jsec^{-1}$ /(.85*.59*1.2*1000m^3/s^3)= 66467; each turbine would need an area of 11077, so the blades would need to be ~60 m long.

Appendix/Vedlegg

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	$8.6\text{x}10^{-5}$
1 calorie (cal)	4.184	1.16×10^{-6}	$3.97\text{x}\ 10^{-3}$	$1\text{x}\ 10^{-10}$
1 British thermal unit (Btu)	1055	2.93×10^{-4}	1	2.5×10^{-8}
1 Electron volt (eV)	$1.6\text{x}\ 10^{-19}$	$4.45\text{x}\ 10^{-26}$	1.52×10^{-22}	3.8×10^{-30}

Equations

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

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

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

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

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

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

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

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

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

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

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

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

$$P = I^2 R$$

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

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

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

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

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

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

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

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

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

$$R = 1/k$$

$$Q = mC\Delta T$$

$$m = \rho V$$

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

$$V = IR$$

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

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

Storage material	MJ per kilogram	MJ per liter (litre)
Deuterium–tritium	330 000 000	0.14 [2]
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