Homework #1 - due Thursday, 9/10 by 4:00 pm
bonus problems - due Tuesday, 9/15 by 4:00 pm

Readings for this homework assignment and upcoming lectures

1. Read lecture notes:
   - Part 1. Introduction to Energy
   - Part 2. Energy Perspectives
   - Part 3. Growth Rate and Hubbert’s Peak

2. Watch the sequence of videos on Prof. Bartlett’s lecture on Arithmetic, Population, and Energy; the link to the videos is on the course website and on Canvas.
   [link to Prof. Bartlett’s Lectures]

Homework Submission

For this first assignment, the homework is to be worked and submitted individually either in class or by dropping off at my office (room 831).

If you use EES for this assignment, then archive the EES files and any pdf output files in a .zip format and email the single, zipped file to jstallen@mtu.edu. Use the following naming convention for the zip file: MEEM4200_HW01_firstname_lastname.zip. PLEASE include the course number (MEEM4200 -or- MEEM5290) in the subject line of any email correspondence.

References


**Homework #1** – Thursday, 9/10 by 4:00 pm

1. 1.21 from Weston

2. Explain why is the magnitude of $g_c$ equal to 1 for all of the common engineering unit systems except the English Engineering system? What is another unit system for which $g_c$ does not have a magnitude equal to 1.

3. What is the Btu equivalent of 1 bbl crude oil? [cite your sources of information]

4. What is the Btu equivalent of 1 hp-hr? [cite your sources of information]

5. What is the quad/yr equivalent of a million barrels of oil per day (Mbd)? [cite your sources of information]

6. What is the GJ equivalent of 1 toe (tonne oil equivalent)? [cite your sources of information]

7. What is the therm equivalent of 1 bbl of crude oil? [cite you sources of information]

8. What is the therm equivalent of 1 bbl of crude oil? [cite you sources of information]

9. Determine the short tons of coal that could be saved per year in the U.S. if all of the undeveloped potential for hydropower were utilized. Assume electrical conversion efficiencies of 36% and 84% for coal and hydropower, respectively. Use an average higher heating value (HHV) of 28,000 kJ/kg for the coal. Be sure to explain any assumptions and equivalencies. (Hint: Look for the 2004 hydropower resource assessment conducted by the Idaho National Lab; Appendix B is most useful.)

10. The following quote is from the DOE Energy Star FAQ:

> If every home in America replaced just one incandescent light bulb with an ENERGY STAR qualified CFL, in one year it would save enough energy to light more than 3 million homes. That would prevent the release of greenhouse gas emissions equal to that of about 800,000 cars.

Making reasonable engineering assumptions, evaluate if this is a legitimate claim or a gross exaggeration. Support your conclusion using data from the Annual Energy Review.

11. A 2013 television commercial makes the following claim:

> The amount of wood and paper we throw away each year would heat 50 million homes for 20 years.

Making reasonable engineering assumptions, evaluate if this is a legitimate claim or a gross exaggeration. Support your conclusion using data from the Annual Energy Review.

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1 as posted in June 2010
12. Determine the energy and power equivalent of gasoline: [cite your sources of information]

(a) Calculate the energy in 21 gallons of gasoline in terms of kJ, Btu’s, and tons of TNT. Use the average API gravity in your calculation. Gasoline has an average API (American Petroleum Institute) gravity of 70 °API. (Hint: You will need to determine the conversion between °API gravity and specific gravity.)

(b) If it takes 6 minutes to fill an empty 21 gallon tank with gasoline. What is the equivalent power during tank filling in terms of kW and hp?

13. A proposed solution for the supply of electrical energy to a house involves the use of a windmill to pump water from a depth of 36 meters with a reversible water pump-turbine. The pumped water is then stored in a tank for use when there is no wind. The windmill shaft is not only connected to the water pump-turbine but it is also directly connected to an electrical generator. If the average household consumes 140 kW-hr/day, determine:

(a) the size of storage tank, in gallons, required to store water for a 3-day period of no wind. Assume that the combined mechanical-electrical conversion efficiency of the water turbine and generator unit is 60 percent, and

(b) the dimensions of the cylindrical storage tank if the diameter is equal to the height.

14. A 2400-MW_e power plant has the following power demand for a given day:

<table>
<thead>
<tr>
<th>Time</th>
<th>Power (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-5 a.m.</td>
<td>850</td>
</tr>
<tr>
<td>5-7 a.m.</td>
<td>1250</td>
</tr>
<tr>
<td>7-8 a.m.</td>
<td>1840</td>
</tr>
<tr>
<td>8-9 a.m.</td>
<td>1960</td>
</tr>
<tr>
<td>9-12 a.m.</td>
<td>2150</td>
</tr>
<tr>
<td>12-1 p.m.</td>
<td>2040</td>
</tr>
<tr>
<td>1-4 p.m.</td>
<td>2400</td>
</tr>
<tr>
<td>4-5 p.m.</td>
<td>2500</td>
</tr>
<tr>
<td>5-6 p.m.</td>
<td>2430</td>
</tr>
<tr>
<td>6-8 p.m.</td>
<td>1850</td>
</tr>
<tr>
<td>8-10 p.m.</td>
<td>1500</td>
</tr>
<tr>
<td>10-12 p.m.</td>
<td>1150</td>
</tr>
</tbody>
</table>

Find the total power output in:
(a) MW_e-days/day, (b) kW_e·h/day, (c) MeV_e/day, (d) J_e/day, and (e) Btu_e/day.

Assume that the plant burns coal with a heating value (energy content) of 26,400 kJ/kg with an overall efficiency of 32%. Determine (f) the total mass of coal, in short tons consumed during the day’s operation, and find (g) the maximum design coal rate, in short tons per hour, required for proper operation of the unit. Also evaluate (h) the heat rate of the unit in Btu/kWh, (i) the capacity factor of the unit for one day’s operation, and (j) the load factor for the same period of operation.

15. Determine the area of solar cells required to drive a commuter electric car if the overall conversion efficiency of the propulsion system, including the electromagnetic-electric-mechanical conversion is 13 percent. Assume that the car requires 24 hp and that the average gross solar input is 650 W/m². If the system can store energy while sitting in the parking lot and is storing energy at a rate of 4 hours for each hour of operation, find the required area of the solar-cell array. Assume the storage efficiency of the batteries is 60 percent.
16. Locate and download the Department of Energy’s most recent Annual Energy Review from the DOE website. What is the URL address for this document? Using data from the AER, answer the following questions:
   (a) What was the primary source of energy consumed in the United States in 1920? In 1970?
   (b) In 2012, what percentage of non-fuel petroleum was used to produce asphalt?
   (c) In 2012, what percent of crude oil was used for transportation?
   (d) To whom does the US export coal?
   (e) What are the top 5 crude oil producing countries in 2012?
   (f) What are the top 5 coal reserves countries in 2012?
   (g) What are the top 5 coal producing countries in 2012?
   (h) What are the top 5 coal consuming countries in 2012?
   (i) What are the top 5 CO$_2$ producing countries in 2012?

Homework #1 – 5290 only

17. 1.8 from Weston

18. 1.15 from Weston

19. A 2007 Associated Press article states that Ann Arbor will replace street lights with Light-Emitting Diodes (LED’s). The article states:
   (a) LED technology uses half the energy of traditional bulbs,
   (b) the change could save Ann Arbor $100,000 per year,
   (c) lighting consumes 22% of the electricity in the United States,
   (d) Ann Arbor’s lighting conversion will reduce the city’s production of carbon dioxide and gases that contribute to global warming in an amount equal to taking 400 cars of the road.

Making reasonable engineering assumptions, evaluate if these are legitimate claims or a gross exaggerations. [cite your sources of information]

20. What would the diameter of a 2-m-long copper wire have to be in order to keep the wire temperature below 70°C during an electrical power transfer equivalent to that in problem 12(b). Since this is a short time for power transfer, neglect convective heat transfer around the wire and only consider Joule heating and thermal mass. [cite your sources of information]
bonus problems – Tuesday, 9/15 by 4:00 pm

21. The world’s nuclear arsenal has been estimated to be 13,000 megatons of TNT. Determine the minutes of equivalent sunshine that would yield the same amount of energy to the earth. Also evaluate the length of time this stockpile could supply one hundred 1000-MW\(_e\) power reactors with a thermal efficiency of 34 percent and a capacity factor of 70 percent.

22. It is proposed to power an automobile with a hybrid mechanical-electrical drive system. The prime mover is a 50-hp, external combustion steam engine with a thermal efficiency of 30 percent. The steam engine drives an alternator with an overall thermal efficiency of 60 percent. Power from the alternator is either stored in a lead-acid battery system or fed directly to an electric traction motor with an electromechanical efficiency of 80 percent. The storage-battery efficiency, including charging, discharging, and storage losses, is around 65 percent. Find the power delivered to the drive wheels, in kW, and the overall conversion efficiency of the system when:

(a) The storage batteries are bypassed.
(b) The storage batteries are not bypassed.

23. If the world’s supply of fossil fuels is uniformly consumed over a 10-year period, find the ratio of the fossil-fuel energy release to the amount of solar energy absorbed by the earth for the same time period. In the determination of the amount of solar energy received by the earth, use the “solar constant” of 1395 W\(_{em}\)/m\(^2\) as the incident energy flux at the earth’s orbital position. Assume that the earth receives solar energy as a disk and that 30\% of the incident energy is reflected. The diameter of the earth is 12,756,000 m and the distance from the sun to the earth is 1.49 \times 10^{11} m. Using these values, also determine the rate at which the sun is converting mass into energy.