

Eng 4en 140

Physics of Energy

- collected questions -

from  
(course book)

## 5.2 Practice Problems [answers posted on Canvas]

Worldwide energy production (WEP) in 1987 was 320 quadrillion ( $320 \times 10^{15}$ ) Btu (British thermal units; 1 Btu = 1.055 kJ = energy to heat 1 pound of  $H_2O$  from  $60^\circ$  to  $61^\circ$  F). By 1996, it had increased by 55 quadrillion Btu.

1. Determine the magnitude of energy production in 1996 in joules and the percentage increase from 1987. Calculate the average annual rate of increase in WEP between 1987 and 1996.
2. In 1996, the USA produced 73 quadrillion Btu, more than any other country. Calculate the contribution of the USA to WEP in 1996.
3. Only about 0.025% of the Sun's radiant energy that reaches Earth is captured by photosynthetic organisms. Calculate the magnitude of this energy (in  $\text{kJ} \cdot \text{s}^{-1}$ ), using the data provided in section 5.1.3 above. Find the ratio of  $\text{WEP}_{1996}$  to the Sun's energy captured by photosynthetic organisms.
4. Assuming that  $173,000 \times 10^{12} \text{ W}$  of the energy reaches Earth and is then either reflected or absorbed, calculate the total energy output of the Sun ( $1 \text{ W} = 1 \text{ J} \cdot \text{s}^{-1}$ ). (Diameter of Earth = 12,756 km; area of a circle =  $\pi \times (\text{diameter}/2)^2$ ; surface area of a sphere =  $4 \times (\text{diameter}/2)^2$ ; mean distance of Earth from Sun =  $149.6 \times 10^6 \text{ km}$ ).
5. Using your result from the previous problem, calculate the number of moles of  $^2\text{H}$  consumed when a heat this large is released. Calculate the energy equivalent of the Earth (mass =  $5.976 \times 10^{27} \text{ g}$ ). Compare the mass energy of Earth to the radiant energy of the Sun that reaches Earth in one year.

[from Haynie, D. T. 2008. Biological Thermodynamics. Cambridge University Press]

(2017 worksheet).

## The Physics of Energy – Worksheet 1

1. What country was responsible for driving the growth in energy consumption in 2015?
2. Convert the global annual energy consumption of 17.26 TW to Mtoe. 1 Mtoe = 11.63 TWh.
3. What percentage of the world energy production comes from renewable sources?
4. What percentage of NZ's energy production comes from renewable sources?
5. NZ uses less than half of the electricity of Norway, who consume 461 PJ in electricity each year. If Norway's population is 5.2 million, what is their electricity use (in kWh) per capita?
6. We used the Stefan-Boltzmann law to determine the radiant power of the Sun and the average temperature of the Earth, which was 281 K. How does this value compare to the actual temperature of the Earth and why is there a difference?
7. What fossil fuel produces the most carbon dioxide per unit energy, and why?
8. What is the unit of energy expressed in base SI units?
9. Show that kinetic energy and gravitational potential energy have dimensionally consistent base SI units.
10. What are the base SI units of force?
11. The USA produces 6,000 MMT (million metric tonne) of CO<sub>2</sub> as a by-product of combustion of fossil fuels. Let's assume that 30% of this CO<sub>2</sub> emission is from transportation and the combustion of petroleum. What is the amount of energy lost to heat due to the combustion of petroleum in transportation? The thermal efficiency of the average combustion engine is 25%. Carbon dioxide emission per unit energy for petroleum is 19 kg/GJ.
12. The radiant energy from the Sun that reaches the Earth is  $1.74 \times 10^{17}$  W. We know that 48% of this energy is absorbed by the land and sea, 35% is reflected by the clouds and 17% of this energy is absorbed by the atmosphere. Calculate the radiant energy that is absorbed by the atmosphere over one year.
13. There are many factors that influence the mechanical efficiency of a vehicle. In class we used some simple physics to understand the total energy budget of a car in an attempt to understand where all of the energy from the combustion engine was going. What is the largest contributor to the mechanical energy budget of a combustion engine vehicle and give a practical example of how this energy can be reduced.

Not covered

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ENERGY SECTION (TOTAL 60 MARKS)

Physics of Energy – 18 marks

- 21) Global energy use has steadily increased over the last 15 years, except for the last two years. This is surprising, given the continued increase in the world's population. What is the main cause of this 'plateau' in global energy consumption? (1 mark)

Answer: \_\_\_\_\_

- 22) Worldwide energy consumption in 2005 was 488 EJ (exa= $10^{18}$ ). In class we estimated 2015 worldwide energy consumption to be 13,000 Mtoe (1 toe =  $42 \times 10^9$  J). What has been the percentage increase in worldwide energy consumption in the last 10 years? (2 marks)

Percentage Increase: \_\_\_\_\_

- 23) Which of the following sectors is mainly responsible for the growth in NZ energy consumption over the last 15 years? (1 mark)
- A. Industrial
  - B. Residential
  - C. Transport
  - D. Commercial and Public Services
  - E. Agriculture, Forestry, and Fishing

Answer: \_\_\_\_\_

- 24) The radiant energy from the Sun that reaches the Earth is  $1.74 \times 10^{17}$  W. Approximately 52% of these photons are either reflected back to space, or absorbed by the atmosphere. We know that 0.025% of the energy that reaches the land is absorbed by photosynthetic organisms. Calculate the radiant energy that is converted by photosynthetic organisms over one year. (3 marks)

Radiant Energy: \_\_\_\_\_

Page Total: \_\_\_\_\_

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- 25) Using base SI units, show that the units for work are dimensionally consistent with the units of gravitational potential energy. (2 marks)

Answer:

- 26) The USA consumes 36 EJ (exa= $10^{18}$ ) of electricity each year, and 39% of this comes from the combustion of coal.

- a. Calculate the annual  $\text{CO}_2$  emissions of the USA from coal-based power plants. Assume the power plant has an efficiency of 33%.  $\text{CO}_2$  emissions from coal combustion = 24kg/GJ. (3 marks)

Annual  $\text{CO}_2$  emissions: \_\_\_\_\_

- b. If you worked for the Environmental Protection Agency in the USA and you cared about global warming and  $\text{CO}_2$  emissions, would you recommend the use of electric heaters or natural gas as a mechanism of providing heating in homes. Justify your answer. (2 marks)

Answer:

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- 27) Auckland's Sky Tower is 328m high. Determine whether the energy content of a 'Whopper' burger (from you-know-where) would be sufficient to fuel a person weighing 72kg to climb the Sky Tower. The nutrition information shows that on average a Whopper contains 2649kJ. Assume 20% efficiency in converting nutritional energy to mechanical energy.

(2 marks)

**Answer:**

- 28) Simple physics provides us with ideas for reducing our transport energy cost. The work required to overcome air resistance ( $W_{\text{air}}$ ) plays the biggest role in the total energy budget of a vehicle. The NZ Government are thinking about increasing the speed limit from 100 km/h to 110 km/h. What effect would this have on the percentage increase in fuel consumption?

(2 marks)

**Answer:**