

Physics 173, Physics of Sustainable Energy
Homework 1
Due: 1pm Tues Sept 3, 2024

Please upload your answers at the Canvas website as a PDF file. Please ensure that the PDF presents the text in the correct orientation.

Regular question

When you write out your response, please circle or underline the final answer to each part of the question. This will make it clearly visible to the grader.

Remember to give justification for all your answers, and whenever the answer is a number always show the units, e.g. “200 J”, “0.5 kg”.

1. The current price of crude oil is about \$75/barrel. A barrel of crude oil is 42 gallons and weighs about 300 lbs.
 - (a) What is the current price of crude oil in dollars per liter?
 - (b) What is the density of crude oil in kg/liter?
 - (c) An oil refinery buys crude oil from an oil company and extracts fuels that can be sold (gasoline, kerosene, etc). From each barrel the refinery gets about 30 gallons of fuel. What is the refinery paying to the oil company per gallon of fuel produced?
 - (d) The density of medium crude oil is about 850 kg/m^3 . If an oil tanker carries 100 tons of crude oil, how many barrels is it carrying?

{8 points}

Multiple choice questions

{2 points each}

Each question has one correct answer, unless the question specifies otherwise. You do not have to show your working, but it may help the grader. You may look up online any quantities that are needed but not supplied in the question or in lecture materials. If you hand-write your answers please use capital letters.

1. Which of the following sentences uses incorrect units?
 - (A) A grand piano weighs about half a ton
 - (B) The Caspian sea has an area of over $100,000 \text{ mi}^3$
 - (C) An oil tanker carries about 10^7 liters of oil
 - (D) A one meter ruler is about 40 inches long
2. A “cord” is a unit of volume used in the U.S.A. for firewood. One cord is 128 cubic feet. Which of the following volumes of firewood would be one cord?
 - (A) a pile 10 feet long, 8 feet high, and 2 feet deep
 - (B) a pile 8 feet long, 8 feet high, and 8 feet deep
 - (C) a pile 10 feet long, 4 feet high, and 8 feet deep
 - (D) a pile 8 feet long, 2 feet high, and 8 feet deep

3. Human beings are mostly made of water. Which of these is the best estimate of the volume of a typical person?
(A) 17 liters (B) 70 liters (C) 270 liters (D) 400 liters
4. The gas tank of a car is 80 cm long, 30 cm wide, and 20 cm high. When it is full, roughly how much does the gasoline in it weigh?
(A) 24 kg (B) 12 kg (C) 48 kg (D) 36 kg
5. A 2010 Ford Mustang's engine capacity is 244 cubic inches. What is that in liters?
(A) 2.3 liters (B) 4.0 liters (C) 4000 liters (D) 5.7 liters
6. The Antarctic ice cap weighs about 24 million gigatons. How many cubic kilometers of ice does it contain?
(A) 24 million km³ (B) 24 billion km³ (C) 24 trillion km³ (D) 2.4×10^9 km³
7. The density of compressed hydrogen is 0.023 g/ml. If a hydrogen powered car needs to be able to store about 12 kg of hydrogen, how big would its compressed hydrogen fuel tank have to be?
(A) 80 cm by 80 cm by 80 cm (B) 1 foot by 1 foot by 1 foot
(C) about the same as a gasoline car's fuel tank (D) 0.5 m by 0.4 m by 0.3 m
8. The fact that energy is conserved means that
(A) the total thermal energy of a system always stays the same
(B) processes that create energy are irreversible
(C) energy is never created or destroyed
(D) when something burns, its chemical energy increases by the same amount
9. Suppose you ride your bicycle from the bottom of a hill to the top, and you stop there. At that point, which of the following is true?
(A) your bicycle has electrical energy that was converted from its gravitational potential energy
(B) chemical energy in food you have eaten has been converted to gravitational potential energy of you and the bicycle
(C) thermal energy in food you have eaten has been converted to gravitational potential energy of you and the bicycle
(D) you and the bicycle have kinetic energy that came from the chemical energy of the food you had eaten
10. The energy stored in a battery is in the form of
(A) gravitational potential energy
(B) electrical energy
(C) kinetic energy
(D) chemical energy
11. When someone is catching a ball (e.g. what the catcher does in baseball) the main form of energy conversion that is occurring is
(A) kinetic energy to potential energy
(B) thermal energy to kinetic energy
(C) chemical energy to kinetic energy
(D) kinetic energy to thermal energy

Physics 173, Physics of Sustainable Energy
Homework 2
Due: 1pm Tues Sept 10th, 2024

Please upload your answers at the Canvas website as a PDF file. Please ensure that the PDF presents the text in the correct orientation.

Regular question

When you write out your response, please circle or underline the final answer to each part of the question. This will make it clearly visible to the grader. Remember to give justification for all your answers, and whenever the answer is a number always show the units, e.g. “200 J”, “0.5 kg”.

1. In this question we will step through the process of calculating how much it costs to heat the water in a traditional Japanese *ofuro* bathtub. You can search online if you want to see what these tubs look like.
 - (a) An *ofuro* bathtub is a vertical-sided circular tub with a diameter (distance across the inside) of 43 inches. Suppose you fill it with water to a depth of 30 inches. What volume of water (in liters) is used to fill the tub?
 - (b) How much energy, in Calories, is needed to heat one liter of water from 10° C (cold water from a faucet) to 40° C (typical *ofuro* temperature)?
 - (c) How much energy, in Calories, would it take to heat all the water in the bathtub from cold to the typical *ofuro* temperature?
 - (d) How much is that in kiloWatt-hours (“kWh”)?
 - (e) How much (in dollars or cents) would this much energy cost, if it was obtained by burning natural gas at a cost of 3¢ per kiloWatt-hour?
 - (f) Roughly how much would it cost if the heater was electrical?
 - (g) How does the cost of an *ofuro* bath compare to the cost of a 10 minute shower? Explain why one costs more than the other.

{14 points}

Multiple choice questions

{2 points each}

Each question has one correct answer, unless the question specifies otherwise. You do not have to show your working, but it may help the grader. You may look up online any quantities that are needed but not supplied in the question or in lecture materials. If you hand-write your answers please use capital letters.

1. To within 20% accuracy,
 - (A) a Calorie is the same as a Watt-hour
 - (B) a British Thermal Unit is the same as a kiloWatt-hour
 - (C) a Watt-hour is the same as a British Thermal Unit
 - (D) a kiloJoule is the same as a kiloWatt-hour

2. Which of the following is a true statement about ways to store energy:
- (A) batteries have a higher energy density than butter
 - (B) alcohol has a higher energy density than hydrogen
 - (C) gasoline has a higher energy density than batteries
 - (D) coal has about the same energy density (to within 20%) as an explosive like TNT
3. Batteries are a popular way to store energy because
- (A) they provide electrical energy which is convenient to use
 - (B) they provide thermal energy which is convenient to use
 - (C) they have a high energy density compared to food or fuel
 - (D) they have a low energy density compared to food or fuel
4. When someone says “the energy density of gasoline is about 10 Calories per gram”, what they mean is
- (A) when a gram of gasoline is oxidized to carbon dioxide and water, it gives out 10 Cal of energy
 - (B) it takes 10 Cal of energy to extract a gram of gasoline from crude oil
 - (C) when a gram of gasoline evaporates, it gives out 10 Cal of energy
 - (D) in order for a gram of gasoline to evaporate, it must absorb 10 Cal of energy
5. A cup of water cools from an unknown initial temperature to room temperature (20 C), losing 15 Cal of thermal energy in the process. What was its initial temperature?
- (A) 50 C (B) 60 C (C) 80 C (D) 90 C
6. An iPad battery can store about 40 Watt-hours (Wh) of energy. How much gasoline would store about the same amount of energy as an iPad battery?
- (A) 3 kg (B) 50 g (C) 860 g (D) 3 g
7. Which of the following is a major advantage of electric cars compared to gasoline cars?
- (A) batteries have a lower energy density than gasoline
 - (B) electric motors are more efficient than gasoline engines
 - (C) electric energy cannot easily be converted to kinetic energy
 - (D) in terms of price per kWh, electrical energy is much cheaper than gasoline
8. The current price of gasoline in China is about \$1.20 per liter. How much are Chinese motorists paying for each kiloWatt-hour of chemical energy when they buy gasoline?
- (A) \$2/kWh (B) 4 ¢/kWh (C) 40 ¢/kWh (D) 14 ¢/kWh

Physics 173, Physics of Sustainable Energy
Homework 3
Due: 1pm Tues Sept 17, 2024

Please upload your answers at the Canvas website as a PDF file. Please ensure that the PDF presents the text in the correct orientation.

Short report **{20 points}**

Write a short critical summary (about 300 words) of a recent published article which is related to the topics covered so far the course, namely energy storage, different types of car, fuels, etc. You can choose the article but first read the instructions for writing the report which are on the course web page in the “Materials” tab. For the report, text-based PDF (produced by “Export as PDF” in most apps) is preferred over an image since it is easier to annotate.

Using AI tools such as ChatGPT: You are allowed to use an AI tool to help you with your short report; if you do that, please provide additional information as described in the instructions.

Piazza: If you are unsure about your choice of article or use of AI tools or have other questions, you can post on the Piazza page,
<https://piazza.com/class/lvy8oqrzxjr1ln>

Multiple choice questions **{2 points each}**

Each question has one correct answer, unless the question specifies otherwise. You do not have to show your working, but it may help the grader. You may look up online any quantities that are needed but not supplied in the question or in lecture materials. If you hand-write your answers please use capital letters.

1. A Tesla electric car has a battery that holds 80 kWh of energy, whereas the gas tank of a conventional car holds about 500 kWh of energy. If the conventional car has a range of 300 miles on one full tank, what do you expect is the range of the Tesla car on a full charge?
(A) 50 mi (B) 100 mi (C) 200 mi (D) 400 mi
2. In regenerative braking,
(A) gravitational potential energy \rightarrow kinetic energy
(B) kinetic energy \rightarrow gravitational potential energy
(C) kinetic energy \rightarrow chemical energy
(D) chemical energy \rightarrow kinetic energy
3. Roughly what volume of liquid hydrogen stores the same amount of energy as a liter of gasoline?
(A) 4 gallons (B) 4 liters (C) 1/3 gallon (D) 1/3 liter
4. Which of the following is a significant advantage of hydrogen-powered vehicles over gasoline-powered vehicles?
(A) hydrogen is not explosive when mixed with air
(B) we can mine naturally-available liquid hydrogen

- (C) hydrogen fuel tanks will be smaller than gasoline tanks
(D) one can use a variety of energy sources to create the hydrogen
5. Blue hydrogen is
(A) made from natural gas, releasing CO_2 in to the atmosphere
(B) made from natural gas, producing CO_2 which is stored underground
(C) extracted from natural underground deposits of hydrogen gas
(D) made from water using energy from low-carbon sources
6. The energy density of methanol is about half that of gasoline. Using your knowledge of the efficiency of fuel cells versus gasoline engines, how many miles would you expect a methanol-powered car could travel on a gallon of methanol? (The density of methanol is similar to gasoline)
(A) 50 miles (B) 20 miles (C) 5 miles (D) 1 mile
7. A methanol powered car produces CO_2 when it runs. Does that mean it is contributing to global warming?
(A) No, if the methanol was produced from recently living biomass
(B) Yes, if the methanol was produced from recently living biomass
(C) Yes, if the methanol was produced from solar power
(D) No, if the methanol was produced from natural gas.
8. Which of the following is included in the marginal cost of making 1 kWh of electrical energy from coal?
(A) Just the cost of the coal burned
(B) The cost of the coal burned and the wages of the plant workers
(C) The cost of building the plant and the cost of the coal burned
(D) The cost of building the plant and decommissioning it when it shuts down.
9. Based on the numbers given in the “Marginal cost of energy” lecture slide, how much coal does it take to generate 1 kWh of electricity?
(A) 100 lb (B) 5 kg (C) 1 lb (D) 50 g
10. Suppose your electric bill for a whole year is \$1200. Assuming your electricity comes from burning coal, how much coal was burned to supply you with electricity for a year?
(A) 600 kg (B) 1.5 tons (C) 5 tons (D) 16 tons

Physics 173, Physics of Sustainable Energy
Homework 4

Due: 1pm Tues Sept 24th, 2024

Please upload your answers at the Canvas website as a PDF file. Please ensure that the PDF presents the text in the correct orientation.

Regular question

When you write out your response, please circle or underline the final answer to each part of the question. This will make it clearly visible to the grader.

Remember to give justification for all your answers, and whenever the answer is a number always show the units, e.g. “200 J”, “0.5 kg”.

1. The power produced by a person riding an exercise bicycle is about 0.15 horsepower.
 - (a) How much is that in kiloWatts?
 - (b) How much work (in Calories) is done by the person in half an hour of riding?
 - (c) How many grams of butter would you have to eat to provide that much energy? Remember to include the efficiency factor: your body is not 100% efficient at converting food to work.
 - (d) Suppose you used the exercise bicycle to power a light bulb (of the appropriate Wattage) for half an hour. By how many cents is your electric bill reduced, through using human power instead of plugging the light bulb in to the electricity supply?

{8 points}

Multiple choice questions

{2 points each}

Each question has one correct answer, unless the question specifies otherwise. You do not have to show your working, but it may help the grader. You may look up online any quantities that are needed but not supplied in the question or in lecture materials. If you hand-write your answers please use capital letters.

1. A large gasoline-powered truck with a filled 100 gallon fuel tank can go about 800 miles before it needs refuelling. If the truck were modified to be powered by compressed (not liquid) hydrogen fuel, via a fuel cell and electric motor, how big a fuel tank would it need to have the same range?
(A) 300 gal (B) 600 gal (C) 3000 gal (D) 1600 gal
2. When a car crashes into a brick wall, what is a good estimate of the power of the collision?
 - (A) The kinetic energy of the car
 - (B) The kinetic energy of the car divided by the amount of time for which the car had been driving
 - (C) The kinetic energy of the car divided by the mass of the car
 - (D) The kinetic energy of the car divided by the duration of the collision

3. Suppose your house is heated by electric heaters. In the winter, your electric bill for the heating is \$300 per month. According to the energy cost table shown in class, how much would you save per month if you switched to natural gas heating?
(A) \$30 (B) \$60 (C) \$120 (D) nothing
4. In terms of the total cost (“levelized cost”) per kiloWatt-hour, which of the following is the cheapest way to provide electrical energy?
(A) wind power
(B) coal
(C) solar panels on the roofs of houses
(D) nuclear power
5. A new hydroelectric power plant proposed for the Mississippi River near St. Louis is advertised as “delivering 438,000 megawatt-hours of renewable electricity to the region annually”. What is the average power output of the plant?
(A) 50 MW (B) 1.2 GW (C) 438 GW (D) 438 MW
6. A large animal’s body produces about 1 horsepower in the form of heat. Roughly how many food Calories does this require the animal to eat in a day?
(A) 60,000 Cal (B) 15,000 Cal (C) 8 million Cal (D) 20 Cal
7. A coal-fired power plant outputs 500 MW of electrical power. How many tons of coal does it consume per day?
(A) 5 tons (B) 500 tons (C) 5000 tons (D) 50 tons
8. In a year, roughly how much energy does the U.S. obtain from wind?
(A) 20 quads (B) 200 quads (C) 2 quads (D) 10^{17} J
9. How much power does China get from natural gas?
(A) 15 quads/year (B) 50 quads/year
(C) 30 quads/year (D) 160 quads/year
10. Which fuel provides the biggest share of electricity generated in the U.S.?
(A) nuclear (B) coal (C) natural gas (D) petroleum
11. Which of the following is a true statement about U.S. energy use?
(A) biomass is mostly used for generating electricity
(B) most of the natural gas that the U.S. consumes is used for residential heating
(C) most of the electricity we generate comes from burning coal
(D) more than half of the oil (petroleum) we use is for transportation

Physics 173, Physics of Sustainable Energy
Homework 5
Due: 1pm Tues Oct 1st, 2024

Please upload your answers at the Canvas website as a PDF file. Please ensure that the PDF presents the text in the correct orientation.

Short report

{20 points}

Write a short critical summary (about 300 words) of a recent published article which is related to one of the topics covered in recent lectures: power, heat, kinetic energy, temperature, thermal expansion etc. You can choose the article but first read the instructions for writing the report which are on the course web page in the “Materials” tab. For the report, text-based PDF (produced by “Export as PDF” in most apps) is preferred over an image since it is easier to annotate.

Using AI tools such as ChatGPT: You are allowed to use an AI tool to help you with your short report; if you do that, please provide additional information as described in the instructions.

Piazza: If you are unsure about your choice of article or use of AI tools or have other questions, you can post on the Piazza page, <https://piazza.com/class/lvy8oqrzxjr1ln>

Multiple choice questions

{2 points each}

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1. A heater can heat a cup of water from room temperature (20 C) to boiling in 1 minute. What is the power of the heater?
(A) 3500 W (B) 1500 W (C) 6 kW (D) 80 kW
2. Based on the energy density table that we studied earlier in the course, estimate how fast the internal parts of an energy-storage flywheel are travelling.
(A) 500 mi/hr (B) 20 mi/hr (C) 100 mi/hr (D) 5 mi/hr
3. A baseball pitcher throws a ball at 80 mi/hr. The ball’s kinetic energy is measured as 90 J. What is the mass of the ball?
(A) 5 kg (B) 150 g (C) 70 g (D) 2500 g
4. Gasoline consists of molecules that typically contain about 8 carbon atoms and 18 hydrogen atoms. Estimate how many such molecules there are in a gallon of gasoline.
(A) 10^{19} (B) 10^{28} (C) 10^{16} (D) 10^{25}
5. Different isotopes of the same element have
(A) different numbers of protons in the nucleus
(B) the same number of neutrons in the nucleus
(C) the same total number of neutrons plus protons
(D) similar chemical properties

6. Absolute zero is the temperature at which
- (A) water freezes
 - (B) molecules fall apart into atoms
 - (C) an object contains no heat energy
 - (D) air becomes a liquid
7. When you heat water from just above its freezing point to just below its boiling point, the kinetic energy per molecule
- (A) increases by about 20%
 - (B) increases by about 40%
 - (C) doubles
 - (D) stays about the same
8. Which contains a larger amount of heat energy: one kilogram of boiling water, or two kilograms of ice at -100 C ?
- (A) there is significantly more heat energy in the one kilogram of water
 - (B) there is significantly more heat energy in the two kilograms of ice
 - (C) they have the same amount of heat energy to within 10%
 - (D) it is impossible to say from just this information
9. A nylon rod is 12 cm long at room temperature. When dropped in boiling water, how much does its length increase by?
(Nylon has a linear thermal expansion coefficient $\alpha = 10^{-4}\text{ C}^{-1}$.)
- (A) 0.1 mm (B) 0.3 cm (C) 3 mm (D) 1 mm
10. The linear expansion coefficient of water is 5×10^{-5} per C. If we take 1 liter of water in the ocean and heat it by 2.5 C (a reasonable estimate of the change due to global warming in a hundred years or so) by how much does the volume increase?
- (A) 0.05 ml (B) 2 ml (C) 0.12 ml (D) 0.4 ml