PHYSICS 1012 — Problem Set 6

Total – 62 marks — due April 10, 2022

For surely the atoms did not hold council, assigning
order to each, flexing their keen minds with
questions of place and motion and who goes where.
But shuffled and jumbled in many ways, in the course
of endless time they are buffeted, driven along,
chancing upon all motions, combinations.
At last they fall into such an arrangement
as would create this universe ...

Lucretius (95 - 55 BC) from *De Rerum Natura (On the Nature of Things)*

As always, in the following you need to show how you got an answer – i.e., show your work. If you don't you will get 0 marks for the problem.

1. (2 marks) What's the specific heat of a material if it takes 7.5 kJ to increase the temperature of a 1 kg sample by 3.0°C?

2. (4 marks) An 8.0 by 12.0 m house is built on a concreate slab 27 cm thick. Find the heat-loss rate through the floor if the interior is at 27°C while the ground is at 10°C. The thermal conductivity, κ, of concrete is 1 W/m·°K.

3. (4 marks) You've got a 2.33 kg aluminum skillet on a hot stove burner, and the skillet is at a sizzling 286°C. You plan to plunge the skillet inot 25° water to cool it. What's the minimum amount of water that will keep the equilibrium temperature below 40°C? Recall that specific heats of aluminum and water are 900 and 4184 J/kg·°K, respectively.

4. (4 marks) A circular lake 1.0 km in diamter is uniformly 10 m deep. Solar energy is incident on the lake at an average rate of 200 W/m^2. If the lake absorbs all this energy and does not exchange heat with its surroundings, how long will it take to warm from 10°C to 20°C?

5. (3 marks) You arrive for a party on a night when it's 8°C outside. Your hosts meet you at the door and say the party may need to be cancelled because the heating system has failed and they don't want to discomfort their guests. "Not so fast!" you say. A total of 40 people are expected, the average power output of a human body is 100 W, and the house loses energy at t he rate 320 W/°C. Will the house remain comfortable?

6. (3 marks) If it takes 840 kJ to vaporize a sample of liquid oxygen, how large is the sample? You'll need to look up the latent heat of vaporization for oxygen and also O_2 is approximately 32 g/mol.

7. (3 marks) A helium balloon occupies 8.0 L at 20°C and 1.0 atm pressure. The balloon rises to an altitude where the air pressure is 0.65 atm and the temperature is -10°C. What's its volume when it reaches equilibrium at the new altitude?

8. (6 marks) The recommended treatment for frostbite is rapid heating in a water bath. Suppose a frostbitten hand with mass 120 g is immersed in water that conducts energy into the hand at the rate of 800 W. Treating the hand as essentially water, initially frozen solid, how long will it take for it to thaw and return to body temperature (37°C)?

9. (4 marks) A bowl contains 16 kg of punch (essentially water) at a 25°C. What's the minimum amount of ice at 0°C needed to cool the punch to 0°C?

10. (5 marks) In a closed but insulated container, 500 g of water is shaken violently until the temperature rises by 3.0°C. The mechanical work done in the process is 9.0 kJ. (a) How much heat is transferred to the surroundings during the shaking? (b) How much mechanical energy would have been required if the container had been perfectly insulated?

11. (4 marks) Nitrogen gas ($\gamma = 1.4$) at 18°C is compressed adiabatically until its volume is dreduced to one-fourth of its initial value. By how much does its temperature increase?

12. (6 marks) An ideal gas with $\gamma = 1.4$ occupies 8.26 L at 335°K and 89.2 kPa pressure. It's compressed adiabatically to one-third of its original volume, then cooled at constant volume back to 335°K. Finally, it's allowed to expand isothermally to its original volume. How much work is done on the gas.

13. (6 marks) A gas sample undergoes the cyclic process $ABCA$ as shown in Figure 5, where AB is an isotherm. The pressure at A is 60 kPa.

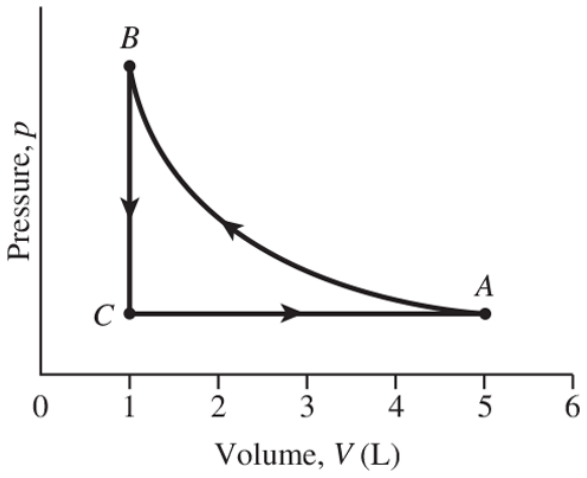

Figure 1: Figure for question 26

(a) (2 marks) What is the pressure at B?

(b) (4 marks) What is the net work done on the gas?

14. (8 marks) An ideal gas with $\gamma = 1.67$ starts at point A in Figure 6, where its volume and pressure are 1.00 m^3 and 250 kPa, respectively. It undergoes an adiabatic expansion that triples its volume, ending at B. It's then heated at constant volume to C and compressed isothermally back to A.

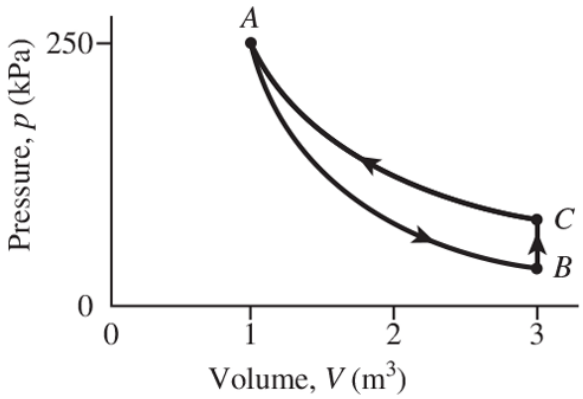

Figure 2: Figure for question 27

(a) (2 marks) What is the pressure at B?

(b) (2 marks) What is the pressure at C?

(c) (4 marks) What is the net work done on the gas?