RLP-PHYB · RLP Physics B — Energy, Thermal Physics, Electromagnetism and Waves

Unit 2: Thermal Energy and the Second Law

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 2.1 — Why a Dark Roof Gets Hotter: Temperature, Thermal Energy and Heat

FLUENCY

1. Convert 25 m/s to km/h.

2. Convert 25 kPa to atm.

3. Convert 60 g to kg.

4. How much energy warms 1.5 kg of water from 20 °C to 80 °C?

5. 50,000 J goes into 0.80 kg of aluminum (c = 900 J/(kg·K)). By how much does its temperature rise?

6. How much energy does a 1.2 kg cast-iron pan need to go from 25 °C to 200 °C ($c = 452$ J/(kg·K))?

APPLICATION

7. A 120 m^2 roof receives 950 W/m^2 of sunlight. Compare the power absorbed by a dark roof (absorbs 85%) and a cool roof (absorbs 25%), illustrative values.

8. On a 42 °C (108 °F) St. Louis afternoon, the July 2012 heat-wave peak, versus a 15 °C morning, by what factor is the average kinetic energy of air molecules larger?

9. A metal bench and a wooden bench sit in the same shade at 25 °C. Explain why the metal one feels colder to touch.

CHALLENGE

10. A 2.0 L pot of water at 15 °C sits on a 1,200 W electric burner that transfers 70% of its power into the water. How long until the water reaches 100 °C?

REVIEW

11. Find the kinetic energy of a 0.5 kg object moving at 5 m/s.

12. Find the kinetic energy of a 1000 kg object moving at 8 m/s.

Lesson 2.2 — Specific Heat by the Method of Mixtures

FLUENCY

1. Convert 300 mL to L.

2. Convert 100 mL to L.

3. Convert 60 mL to L.

4. 0.30 kg of water at 70 °C is mixed with 0.50 kg of water at 10 °C in an insulated cup. Find the final temperature.

5. Predict the final temperature when 0.250 kg of aluminum at 90 °C is dropped into 0.200 kg of water at 20 °C.

6. Which has the larger heat capacity: 0.30 kg of steel or 0.050 kg of water?

APPLICATION

7. A 0.200 kg copper sample at 95.0 °C is dropped into 0.150 kg of water at 21.0 °C; the mixture settles at 27.4 °C. Find the measured specific heat of copper and the percent difference from 387 J/(kg·K).

8. For the copper trial, redo the calculation with T_f = 27.3 and 27.5 °C. What range of c does a ±0.1 °C reading error produce?

9. A group's measured specific heat is consistently too low. Name the most likely source of error and explain the direction.

CHALLENGE

10. How much ice at 0 °C must be added to 0.300 kg of water at 25 °C to cool it to 5 °C? (L_f = 334,000 J/kg; the meltwater warms to 5 °C.)

REVIEW

11. A device takes in 1200 J and delivers 196 J of useful energy. What is its efficiency, and where did the rest go?

12. A device takes in 2000 J and delivers 1416 J of useful energy. What is its efficiency, and where did the rest go?

Lesson 2.3 — Why Heat Flows Downhill: The Second Law and Engine Limits

FLUENCY

1. A device takes in 1200 J and delivers 852 J of useful energy. What is its efficiency, and where did the rest go?
2. A device takes in 1200 J and delivers 854 J of useful energy. What is its efficiency, and where did the rest go?
3. A device takes in 2000 J and delivers 1647 J of useful energy. What is its efficiency, and where did the rest go?
4. What is the Carnot efficiency of an engine between 550 °C and 30 °C?
5. An engine takes in 5,000 J of heat per cycle and is 32% efficient. How much work does it do and how much heat does it reject?

6. 2,000 J flows from a reservoir at 400 K to one at 300 K. Find the total entropy change.

APPLICATION

7. A geothermal plant uses steam at 180 °C and cooling water at 35 °C (illustrative). What is its maximum possible efficiency? Why is it low?

8. An inventor claims an engine running between 400 K and 300 K with 40% efficiency. Evaluate the claim.

9. A student says: "When hot and cold water mix, energy conservation already predicts they reach the same temperature, so no second law is needed." Rebut this.

CHALLENGE

10. A power plant with 38% efficiency delivers 500 MW of electricity. How much heat does it reject each second, and what does that mean for the river or ocean that cools it?

REVIEW

11. A motor does 12000 J of work in 30 s. What is its power output?

12. What net force gives a 5 kg object an acceleration of 1.5 m/s^2?

Lesson 2.4 — Particles, Pressure, Heat Pumps and Insulating Materials

FLUENCY

1. A balloon holds 2.0 L at 0 °C. At constant pressure, what is its volume at 100 °C?

2. A gas at 101.3 kPa and 25 °C occupies 5.0 L. What volume does it occupy at 202.6 kPa and 77 °C?

3. A gas at 101.3 kPa and 25 °C occupies 10.0 L. What volume does it occupy at 80.0 kPa and 0 °C?

4. Find the pressure of 2.0 mol of an ideal gas in 24.5 L at 298.15 K (R = 8.314 L·kPa/(mol·K)).

5. A tire reads 230 kPa (gauge) at 15 °C and warms to 45 °C at constant volume. What does the gauge read?

6. Find the conduction rate through a 1.5 m^2 single-pane window 4.0 mm thick (k = 0.84 W/(m·K)) with a 25 K difference (slab model).

APPLICATION

7. A foam cooler wall (k = 0.033 W/(m·K), area 0.30 m^2, 3.0 cm thick) has 30 K across it. Find the heat flow and explain the role of the foam's structure.

8. What is the ideal coefficient of performance of a heat pump warming a house to 20 °C from 5 °C outdoor air?

9. Find the rms speed of nitrogen molecules (4.65×10^{-26} kg) at body temperature, 310 K.

CHALLENGE

10. A real heat pump with COP 3.2 delivers 9.0 kW of heat. How much electrical power does it use, and how much heat does it pull from the outdoor air?

REVIEW

11. Find the gravitational potential energy gained when a 70 kg object is lifted 10 m ($g = 9.8\ \text{m/s}^2$).

12. Find the gravitational potential energy gained when a 55 kg object is lifted 3 m ($g = 9.8\ m/s^2$).

Unit 2 checkpoint

1. Temperature measures
   A. the total thermal energy
   B. the average kinetic energy of particles' random motion
   C. the heat an object contains
   D. the mass of an object
2. Warming 0.50 kg of water by 30 K takes _____ J.
3. 25 °C is _____ K.
4. True or false: In a calorimeter, if energy leaks to the room, the measured specific heat of the metal comes out too high.
5. Why does a small mass of water barely change temperature when hot metal is dropped in?
   A. Water is a conductor
   B. Water's specific heat is large
   C. Metal has no thermal energy
   D. The metal cools instantly
6. The Carnot efficiency between 600 K and 300 K is _____%.
7. True or false: A refrigerator moving heat from cold to hot violates the second law.
8. Which is the best evidence for the second law from the mixing lab?
   A. Energy was conserved
   B. Temperatures always converged; the metal never got hotter while the water cooled
   C. The cup was foam
   D. The thermometer read 0.1 °C
9. A gas at 300 K and 100 kPa is heated to 360 K at constant volume. Its pressure becomes _____ kPa.
10. True or false: Foam insulates mainly because trapped still gas conducts poorly and cannot circulate.
11. In the Keep It Cold task, 'costs less than $5' is a
    A. criterion
    B. constraint
    C. hypothesis
    D. variable
12. Melting 0.10 kg of ice at 0 °C absorbs _____ J.