**PHY240 Thermodynamics and Modern Physics**

**Fall 2012 Exam I (Chapters 1 – 3) September 30 2012**

**Total 50 points**

| **Due October 3, 2012** |
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## Chp 1: First Law of Thermodynamics (5 points)

**Question 1(a)** A 5-gallon container of water (approximately 20 kg) having a temperature of 212°F is added to a 50-gallon tub (approximately 200 kg) of water having a temperature of 50°F. What is the final equilibrium temperature (in °C) of the mixture?

a. 54
b. 36
c. 18
d. 66
e. 14

ANS: C

**Question 1(b) (15 points)**

**30.** A gas is taken through the cyclic process described in Figure P20.30. (a) Find the net energy transferred to the system by heat during one complete cycle. (b) **What If?** If the cycle is reversed—that is, the process follows the path *ACBA*—what is the net energy input per cycle by heat?

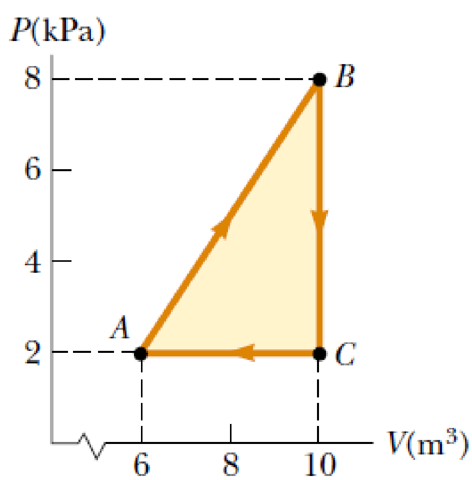


**Figure P20.30** Problems 30 and 31.

P20.30 (a) $Q = -W =$ Area of triangle

$$Q = 1/2\,(4.00\ \text{m}^3)(6.00\ \text{kPa}) = 12.0\ \text{kJ}$$

(b) $Q = -W = -12.0$ kJ

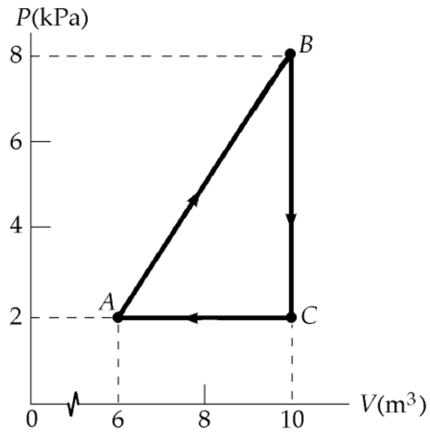


FIG. P20.30

## Chp 2: Kinetic Theory of Gases (15 points)

**34.** A certain molecule has f degrees of freedom. Show that an ideal gas consisting of such molecules has the following properties: (1) its total internal energy is fnRT/2; (2) its molar specific heat at constant volume is fR/2; (3) its molar specific heat at constant pressure is (f +2)R/2; (4) its specific heat ratio is = $C_P/C_V = (f + 2)/f$.

**35**. In a crude model (Fig. P21.35) of a rotating diatomic molecule of chlorine ($Cl_2$), the two Cl atoms are $2.00 \times 10^{-10}$ m apart and rotate about their center of mass with angular speed w = $2.00 \times 10^{12}$ rad/s. What is the rotational kinetic energy of one molecule of $Cl_2$, which has a molar mass of 70.0 g/mol?

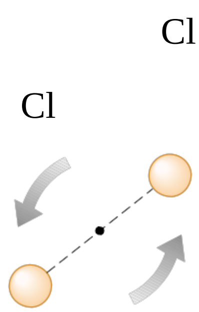


**Figure P21.35**

**P21.34** (1) $E_{\text{int}} = Nf\left(\frac{k_B T}{2}\right) = f\left(\frac{nRT}{2}\right)$

(2) $C_V = \frac{1}{n}\left(\frac{dE_{\text{int}}}{dT}\right) = \frac{1}{2} fR$

(3) $C_P = C_V + R = \frac{1}{2}(f+2)R$

(4) $\gamma = \frac{C_P}{C_V} = \frac{f+2}{f}$

**P21.35** Rotational Kinetic Energy $= \frac{1}{2} I\omega^2$

$I = 2mr^2$, $m = 35.0 \times 1.67 \times 10^{-27}$ kg, $r = 10^{-10}$ m

$I = 1.17 \times 10^{-45}\ \text{kg}\cdot\text{m}^2$ $\omega = 2.00 \times 10^{12}\ \text{s}^{-1}$

$\therefore K_{\text{rot}} = \frac{1}{2} I\omega^2 = \boxed{2.33 \times 10^{-21}\ \text{J}}$

## Chp 3: Entropy and Second Law of Thermodynamics (15 points)

**20.** A 20.0%-efficient real engine is used to speed up a train from rest to 5.00 m/s. It is known that an ideal (Carnot) engine using the same cold and hot reservoirs would accelerate the same train from rest to a speed of 6.50 m/s using the same amount of fuel. The engines use air at 300 K as a cold reservoir. Find the temperature of the steam serving as the hot reservoir.

**Solution:**

**P22.20** The work output is $W_{eng} = \frac{1}{2} m_{train} (5.00 \text{ m/s})^2$.

We are told $e = \frac{W_{eng}}{Q_h}$

$$0.200 = \frac{1}{2} m_t \frac{(5.00 \text{ m/s})^2}{Q_h}$$

and $$e_C = 1 - \frac{300 \text{ K}}{T_h} = \frac{1}{2} m_t \frac{(6.50 \text{ m/s})^2}{Q_h}.$$

Substitute $Q_h = \frac{1}{2} m_t \frac{(5.00 \text{ m/s})^2}{0.200}$.

Then, $$1 - \frac{300 \text{ K}}{T_h} = 0.200 \left( \frac{\frac{1}{2} m_t (6.50 \text{ m/s})^2}{\frac{1}{2} m_t (5.00 \text{ m/s})^2} \right)$$

$$1 - \frac{300 \text{ K}}{T_h} = 0.338$$

$$T_h = \frac{300 \text{ K}}{0.662} = \boxed{453 \text{ K}}$$