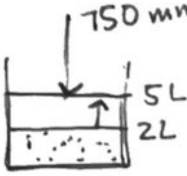
Key

Pressure-Volume Work Problems

1. How much work is done by a gas that expands from 2.00 liters to 5.00 liters against an external pressure of 750. mmHg?

750 mmHg ⇒ constant



→ work is done by system on surroundings

$w = -P\Delta V = (.9868\ atm)(3.00\ L) = -2.96\ atm \cdot L = \boxed{-300.\ J}$

$\frac{2.96\ atm \cdot L}{1} \times \frac{101.3\ J}{1\ atm \cdot L} = 299.8\ J$ →

2. How much work is done by 0.540 moles of a gas that has an initial volume of 8.00 liters and expands under the following conditions: 30.0˚C and 1.30 atm?

ΔV?

P_{ext} → constant

$n = .540\ mol$

$T = 30.0°C = 303\ K$

$P = 1.30\ atm$

$PV = nRT$

$V = \frac{(.540)(.08206)(303)}{1.30} = 10.3\ L$

$\Delta V = 10.3 - 8.00 = 2.3\ L$

$w = -P\Delta V$

$= -(1.30\ atm)(2.3\ L)$

$= -3.0\ L \cdot atm = \boxed{-303\ J}$

3. How much work is done by a gas that expands against an external pressure of 1.80 atm if the final pressure and volume of the gas are 1.70 atm and 1.56 liters?

$P_{initial}$

$P_f V_f = P_i V_i$

$(1.70\ atm)(1.56\ L) = (1.80\ atm)(V_i)$

$V_i = 1.47\ L$

$\Delta V = 1.56 - 1.47 = .09\ L$

$w = -P\Delta V$

$= -(1.80\ atm)(.09\ L)$

$= -.162\ L \cdot atm$

$= \boxed{-16.4\ J}$

4. A small high-performance internal combustion engine has six cylinders with a total nominal displacement (volume) of 2.40 liters and a 10:1 compression ratio (meaning the volume of each cylinder decreases by a factor of 10 when a piston compresses the air-gas mixture inside the cylinder prior to ignition). How much work in joules is done when a gas in one cylinder of the engine expands at constant temperature against an opposing pressure of 40.0 atm during the engine cycle? Assume the gas is ideal, the piston is frictionless, and no energy is lost as heat.

$\frac{2.40\ L}{6\ cyl} = \boxed{.400\ L/cyl}$ (Total vol. of 1 cyl) →

10 : 1

.400 L : .0400 L

$\Delta V = .400 - .0400 = .360\ L$

$w = -P\Delta V$

$= -(40.0\ atm)(.360\ L)$

$= -14.4\ L \cdot atm$

$= \boxed{-1460\ J}$

5. Breathing requires work, even if you are not aware of it. The lung volume of a 70 kg man at rest changed from 2200 mL to 2700 mL when he inhaled, while his lungs maintained a pressure of approximately 1.0 atm.

A. How much work in liter-atmospheres and in joules was required to take a single breath?

$$\Delta V = 2.700\,L - 2.200\,L = .500\,L$$

$$W = -P\Delta V$$

$$= -(1.0\,atm)(.500\,L) = -.50\,L\cdot atm$$

$$= \boxed{-51\,J}$$ Resting

B. During exercise, his lung volume changed from 2200 mL to 5200 mL on each in-breath. How much additional work in joules did he require to take a breath while exercising?

$$\Delta V = 5.200\,L - 2.200\,L = 3.000\,L$$

$$W = -P\Delta V$$

$$= -(1.0\,atm)(3.000\,L) = -3.0\,L\cdot atm$$

$$= \boxed{-300.\,J}$$ Exercising

C. While exercising, the man takes 1 breath every 3 seconds. How many calories does he burn in one minute just from breathing?

$$\frac{1\,min}{1} \cdot \frac{60\,s}{1\,min} \cdot \frac{1\,breath}{3\,s} \cdot \frac{300\,J}{1\,breath} \cdot \frac{1\,calorie}{4.184\,J} = 1430\text{ calories}$$

$$\frac{1430\text{ calories}}{1} \times \frac{1\text{ Calorie}}{1000\text{ calories}} = 1.4\text{ Calories}$$ → "Food Calorie"

1.4 kcal