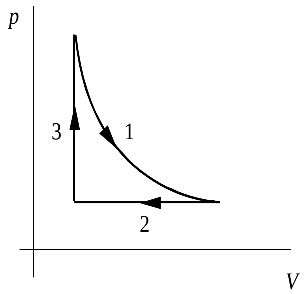
9. 1: isothermal expansion; 2: isobaric compression; 3: isometric pressure increase.



10. This is an adiabatic compression. When the plunger is pushed in, the work done goes into increasing the internal energy of the air. The increase in internal energy increases the temperature of the air and causes the paper to catch fire.

16. $Q = \Delta U + W$, ☞ $W = Q - \Delta U = -6.5 \times 10^5\text{ J} - (-1.2 \times 10^6\text{ J}) = \boxed{5.5 \times 10^5\text{ J}}$.

21. (a) From the ideal gas law, $pV = nRT$, $T \propto pV = 2p_1(V_1/2) = p_1V_1$. So the initial and final temperatures are the same, therefore $\Delta T = 0$. Therefore the overall change in the internal energy is $\boxed{\text{(2) zero}}$.

(b) $W_{\text{isobar}} = p\Delta V = 2p_1(V_1/2 - V_1) = \boxed{-p_1V_1\text{ (on the gas)}}$.

(c) $Q = \Delta U + W = 0 + (-p_1V_1) = \boxed{-p_1V_1\text{ (out of the gas)}}$.

$\boxed{22}$. Work equals the area under the curve.

From 1–2, $W = \boxed{0}$; from 2–3, $W = (0.50 \times 10^5\text{ Pa})(0.50\text{ m}^3) = \boxed{2.5 \times 10^4\text{ J}}$;

from 3–4, $W = \boxed{0}$; from 4–5, $W = (1.00 \times 10^5\text{ Pa})(0.25\text{ m}^3) = \boxed{2.5 \times 10^4\text{ J}}$.

$\boxed{25}$. (a) It is an $\boxed{\text{(2) isobaric}}$ process (expansion), because the pressure is maintained at 1.00 atm.

(b) $\Delta U = Q - W = Q - p\Delta V = Q - pA\Delta x = 420\text{ J} - (1.01 \times 10^5\text{ Pa})(\pi)(0.120\text{ m})^2(0.0600\text{ m}) = \boxed{146\text{ J}}$.

26. (a) For a monatomic ideal gas, $\gamma = 1.67$.

$$p_1V_1^{\gamma} = p_2V_2^{\gamma}, \quad ☞ \quad p_2 = p_1\frac{V_2^{\gamma}}{V_1^{\gamma}} = p_1\left(\frac{V_1}{V_2}\right)^{\gamma} = (1.00 \times 10^5\text{ Pa})\left(\frac{240}{40}\right)^{1.67} = \boxed{1.99 \times 10^6\text{ Pa}}.$$

(b) $$W_{\text{adiabatic}} = \frac{p_1V_1 - p_2V_2}{\gamma - 1} = \frac{(1.00 \times 10^5\text{ Pa})(240 \times 10^{-3}\text{ m}^3) - (1.99 \times 10^6\text{ Pa})(40 \times 10^{-3}\text{ m}^3)}{1.67 - 1} = \boxed{-8.30 \times 10^4\text{ J}}.$$

28. (a) The work done equals the area under the curve (the area of the trapezoid). The work is $\boxed{\text{(3) negative}}$ for compression.

(b) $W = \frac{1}{2}(2.0 \times 10^5\text{ Pa} + 5.0 \times 10^5\text{ Pa})(0.50\text{ m}^3 - 1.0\text{ m}^3) = \boxed{-1.8 \times 10^5\text{ J}}$.

(c) From the ideal gas law, $pV = nRT$,

$$\Delta T = \frac{\Delta(pV)}{nR} = \frac{p_2V_2 - p_1V_1}{nR} = \frac{(2.0 \times 10^5\text{ Pa})(0.50\text{ m}^3) - (5.0 \times 10^5\text{ Pa})(1.0\text{ m}^3)}{(1\text{ mol})(8.31\text{ J/K·mole})} = \boxed{-4.8 \times 10^4\text{ K}}.$$

37. (a) The change in entropy is $\boxed{\text{(1) positive}}$, because heat is added in the process (positive heat).

(b) $$\Delta S = \frac{Q}{T} = +\frac{mL_f}{T} = +\frac{(1.0\text{ kg})(3.3 \times 10^5\text{ J/kg})}{273\text{ K}} = \boxed{+1.2 \times 10^3\text{ J/K}}.$$

43. (a) The entropy of the gas will $\boxed{\text{(1) increase}}$, because $Q > 0$. For isothermal, T = constant so $\Delta U = 0$. In an expansion, the work done by the gas is positive, so $Q = \Delta U + W = W$.

(b) $Q = \Delta U + W = W = 3.0 \times 10^3$ J. So $\Delta S = \frac{Q}{T} = +\frac{3.0 \times 10^3\text{ J}}{273\text{ K}} = \boxed{+11\text{ J/K}}$.

44. (a) It would be $\boxed{\text{(3) negative}}$, because 1000 J of heat will never flow from the cold reservoir to the hot reservoir spontaneously. It is a violation of the second law of thermodynamics.

(b) $\Delta S_h = \dfrac{Q_h}{T_h} = \dfrac{1000\text{ J}}{373\text{ K}} = 2.68\text{ J/K}$, $\Delta S_c = \dfrac{-1000\text{ J}}{273\text{ K}} = -3.66\text{ J/K}$.

$\Delta S = \Delta S_h + \Delta S_c = 2.68\text{ J/K} - 3.66\text{ J/K} = \boxed{-0.98\text{ J/K}}$.

47. (a) The heat transfer from state 2 to state 3 is $\boxed{\text{(2) zero, } \Delta S = 0}$.

(b) From state 1 to state 2, $\Delta S_1 = 200\text{ J/K} - 100\text{ J/K} = 100\text{ J/K}$.
From state 2 to state 3, $\Delta S_2 = 0$. The total change in entropy is $\Delta S = \Delta S_1 + \Delta S_2 = 100\text{ J/K}$.

$\Delta S = \dfrac{Q}{T}$, ☞ $Q = T\Delta S = (273\text{ K})(100\text{ J/K}) = \boxed{2.73\times 10^4\text{ J}}$.

52. (b). Because $\varepsilon = 1 - \dfrac{Q_c}{Q_h}$, $\dfrac{Q_c}{Q_h}$ determines the thermal efficiency of a heat engine.

58. (a) $\varepsilon = \dfrac{W_{net}}{Q_h}$, ☞ $W_{net} = \varepsilon Q_h = 0.28(2000\text{ J}) = \boxed{5.6\times 10^2\text{ J}}$.

(b) $Q_c = Q_h - W_{net} = 2000\text{ J} - 5.6\times 10^2\text{ J} = \boxed{1.4\times 10^3\text{ J}}$.

63. (a) $E = 2(3.3\times 10^8\text{ J}) = \boxed{6.6\times 10^8\text{ J}}$.

(b) In one hour, $W = Pt = (25\times 10^3\text{ J/s})(3600\text{ s}) = 9.0\times 10^7\text{ J}$. So $\varepsilon = \dfrac{W_{net}}{Q_h} = \dfrac{9.0\times 10^7\text{ J}}{3.3\times 10^8\text{ J}} = \boxed{27\%}$.

69. $\text{COP}_{ref} = \dfrac{Q_c}{W_{in}}$, ☞ $W_{in} = \dfrac{Q_c}{\text{COP}_{ref}} = \dfrac{1.0\times 10^7\text{ J}}{2.75} = 3.64\times 10^6\text{ J}$.

So $P = \dfrac{W}{\Delta t} = \dfrac{3.64\times 10^6\text{ J}}{(20\text{ min})(60\text{ s/min})} = \boxed{3.0\text{ kW}}$.

71. $\varepsilon = 1 - \dfrac{Q_c}{Q_h}$, ☞ $Q_h = \dfrac{Q_c}{1-\varepsilon} = \dfrac{1.50\times 10^6\text{ J}}{1 - 0.250} = 2.00\times 10^6\text{ J}$. This is the heat input in one hour. The net work output in one hour is then $W_{net} = Q_h = -Q_c = 2.00\times 10^6\text{ J/h} - 1.50\times 10^6\text{ J/h} = 5.0\times 10^5\text{ J/h}$.

So the time required is $t = \dfrac{3.0\times 10^6\text{ J}}{5.0\times 10^5\text{ J/h}} = \boxed{6.0\text{ h}}$.

75. (a), because $\varepsilon = 1 - \dfrac{T_c}{T_h}$.

83. (a) $\varepsilon_C = 1 - \dfrac{T_c}{T_h} = 1 - \dfrac{(273+5)\text{ K}}{(273+25)\text{ K}} = \boxed{6.7\%}$.

(b) $\boxed{\text{Probably not}}$ at the moment, due to low efficiency and still relatively cheap fossil fuels.

101. First calculate the net work output of the engine for each gallon (gal) of gasoline consumed.

$\varepsilon = \dfrac{W_{net}}{Q_{in}}$, ☞ $W_{net} = \varepsilon Q_{in} = (0.25)(1.3\times 10^8\text{ J}) = 3.25\times 10^7\text{ J}$.

From the definition of power, $P = \dfrac{W}{\Delta t}$, we can calculate the time one gallon of gasoline lasts.

$\Delta t = \dfrac{W}{P} = \dfrac{3.25\times 10^7\text{ J}}{(45\text{ hp})(746\text{ W/hp})} = 968\text{ s} = 0.269\text{ h}$.

At 75 mi/h, in 0.269 h, the car will travel a distance of $v\Delta t = (75\text{ m/h})(0.269\text{ h}) = 20\text{ mi}$.

Therefore the answer is $\boxed{20\text{ mi/gal}}$.