Answers to selected problems from Essential Physics, Chapter 15

1. (a) 2 > 1 (b) 2 > 1 (c) 2 > 1

3. (a) All other factors being equal, we would expect system B to require more heat. In system B, some of the heat goes to doing work, and the rest goes to increasing the internal energy (increasing the temperature). In system A, all the heat added goes to increasing the internal energy. Thus, system B needs all the heat that A needs, plus an additional amount that goes into the work done by the gas. (b) A possible explanation for this result (that both systems actually require the same amount of heat) is that system B is a system of monatomic ideal gas, while system A is a system of diatomic ideal gas. The extra energy needed to change the internal energy of the diatomic ideal gas, compared to that of the monatomic ideal gas in system B, is exactly equal to the work done by the gas in system B.

5. (a) Yes, if the process is isothermal. All the heat added goes into doing work. One way to do this is to have a piston free to move in a cylinder. If mass is slowly and gradually removed from the piston, the piston will slowly expand at constant temperature. (b) Yes, this can be done with an adiabatic compression. An example is a bicycle pump, in which the gas is compressed quickly, with no time for heat to be transferred, resulting in a significant gain in the temperature of the gas. (c) Yes, if the work done by the system is larger than the heat transferred. This is essentially the process in a fridge, in which a gas expands and cools, with heat coming out of the inside of the fridge into the cool gas. The work done by the gas is generally larger than the heat transferred to it. (d) Yes. If such a system expands, it will cool, and if it contracts, its temperature increases.

7. (a) A > C > B (b) B > C > A (c) A > C > B (d) B > C > A

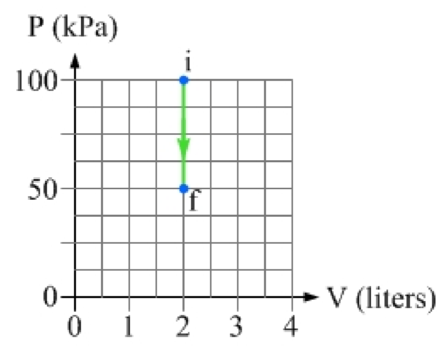
9. (a) A > B > C (b) A > B > C (c) C > B > A (d) A > B > C

11. (a) A > B > C (b) A = B = C (c) A > B > C (d) C > B > A

13. (a) Cylinder 1 has more heat removed from it. Cylinder 1 experiences a decrease of internal energy and negative work, while cylinder 2 only has a decrease in internal energy. (b) The changes in internal energy are the same, because the temperature difference is the same in both cases.

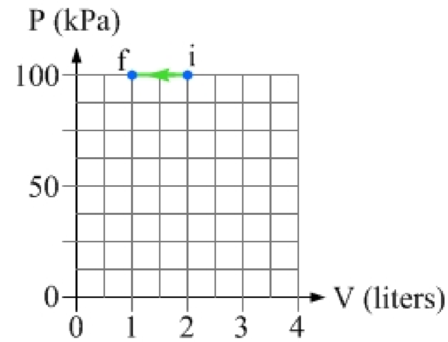
15. (a) W_A = 1920 J; W_B = 1440 J; W_C = 960 J (b) 5600 J in each case
(c) Q_A = 7520 J; Q_B = 7040 J; Q_C = 6560 J

17. (a)



(b) 0
(c) –250 J
(d) 250 J of heat was removed
(e) 250 J

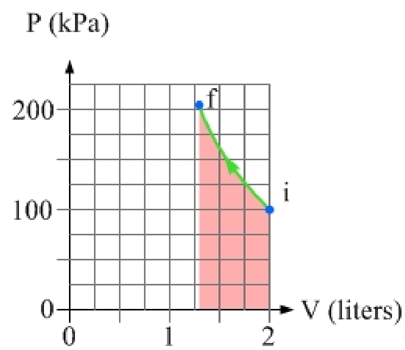
19. (a)



(b) –100 J
(c) –250 J
(d) 350 J of heat was removed
(e) 250 J

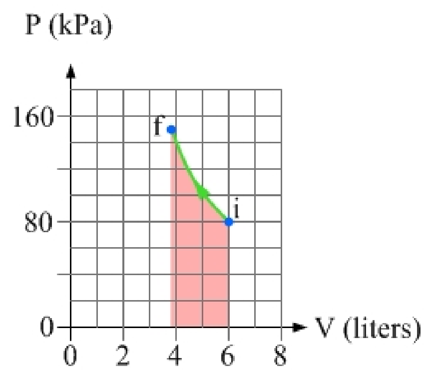
21. (a) +480 J (b) +1200 J

23. (a)



(b) 533 K (c) 1.3 L (d) 205 kPa

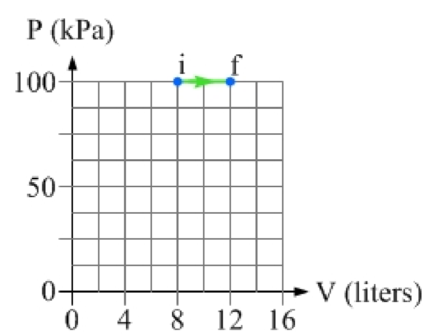
25. (a)



(b) 3.8 L (c) –236 J (d) 1.2 : 1

27. (a) 23.4 kPa (b) +259 J (c) 0.52

29. (a) +400 J (b) 600 K (c)

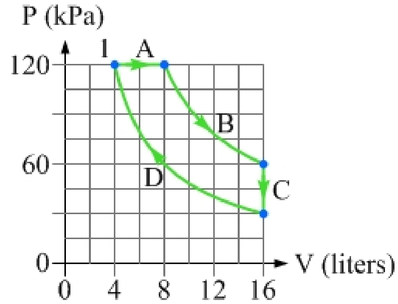


31. (a) +777 J
(b) +4800 J
(c) +5577 J

33.

Process	**Q (J)**	**W (J)**	**ΔE_{int} (J)**
1 → 2	+6720	+1920	+4800
2 → 3	–4800	0	–4800
3 → 1	–887	–887	0
Entire Cycle	+1033	+1033	0

35. (a)

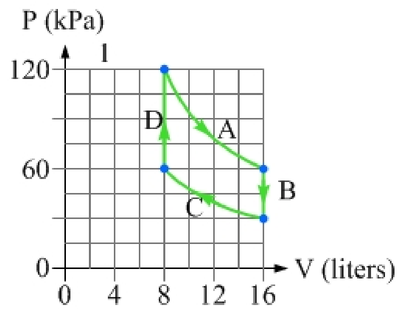


(b) +480 J

37. (a) The area represents both the net work done by the system in one cycle, as well as the heat added to the system in one cycle (these are always equal to one another, because the net change in internal energy for one cycle is zero). (b) 20 J (c) 8 boxes (d) +160 J

39. (a) +146.9 J/K (b) –141.9 J/K (c) +5.0 J/K

41. (a)



(b)

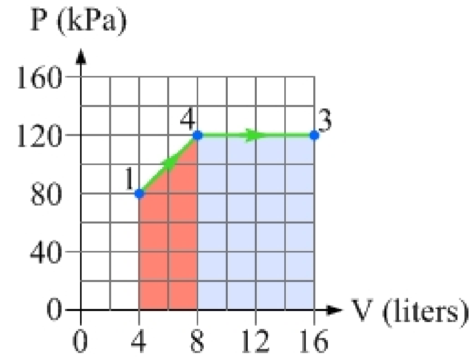
Process	Q	W	ΔE_{int}	ΔS
A	+	+	0	+
B	–	0	–	–
C	–	–	0	–
D	+	0	+	+
Cycle	+	+	0	0

43. (a) 0.56 (b) 1.0×10^6 J

45. (a) This air conditioner is not ideal. The coefficient of performance can be written as $COP = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$. If the air conditioner was ideal, then we can replace the heats in the equation by temperatures, like so: $COP = \frac{T_L}{T_H - T_L}$. If we work out the coefficient of performance using the absolute temperatures, we get 29.3, significantly higher than the value of 7.5 that is given. Thus, the air conditioner must be less than ideal (this is the case for all real-life air conditioners, of course).

(b) Yes, we would expect that an increase in the outside temperature would change the coefficient of performance. If the outside temperature increases, the air conditioner has to do more work to extract the same amount of heat from inside your house and release that heat, plus the work, outside. Thus, when the outside temperature increases, the coefficient of performance decreases.

47. (a) (in red) + (b) (in blue)

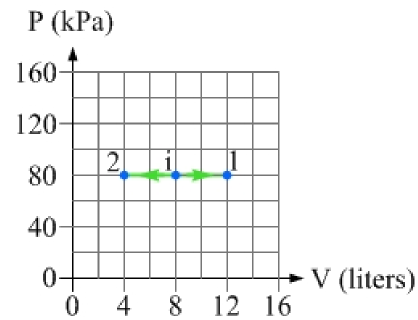


(c) $W_{1\rightarrow 4} = +400$ J ;
$W_{4\rightarrow 3} = +960$ J

49. (a) $\Delta E_{int,1\rightarrow 4} = +960$ J ;
$\Delta E_{int,\,4\rightarrow 3} = +1440$ J

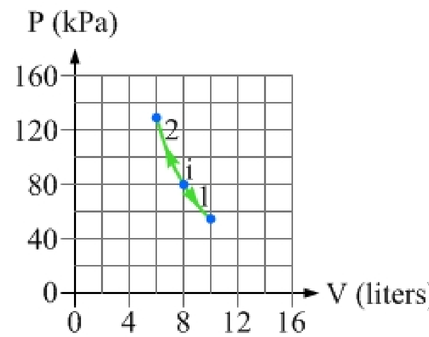
(b) $Q_{1\rightarrow 4} = +1360$ J ;
$Q_{4\rightarrow 3} = +2400$ J

51. (a)



(b) The magnitude of the work done by the gas is the magnitude of the area under the curve for the process on the P-V diagram. The two areas have the same magnitude, so the magnitude of the work done in case 1 is equal to the magnitude of the work done in case 2.
(c) –320 J

53. (a)



(b) The work done clearly has a larger magnitude for process 2 – the area under the curve for that process is larger than it is for process 1.
(c) –203 J

55. (a) The pressure is 150 kPa, and the volume is (32/3) L
(b) The pressure is 50 kPa, and the volume is 32 L

57. The entropy of the set of building materials decreases during construction, because a whole collection of items is assembled into a highly ordered structure by the time the house is done. This does not violate the second law, however, because the set of building materials is not a closed system. If you calculated the entropy of the system of building materials, all the light and heavy machinery involved in building the house, and all the people who worked on the house, the entropy of that system would increase.

59. (a) 11.3% (b) 880 MW (that's 880 million joules every second) (c) 780 MW

61. These students have some incorrect ideas. What is described here is an adiabatic process – no heat is transferred, because the system is so well insulated. However, this does not mean that the temperature remains the same – the temperature can change, with any change in internal energy being offset by the work.