Solutions

Common themes:
Theme 1: Radiation laws
Wien law: $\lambda_{max} \propto 1/T$
Stefan-Boltzmann Law: Radiated power = emissivity * σ * T^4 * Area

Theme 2: Thermodynamic processes (adiabatic, isobaric, isothermal and isometric)
The ideal gas law: $PV = Nk_BT = nRT$
First law of thermodynamics: $dU = dQ - dW$, $dW = PdV$

Theme 3: Second law of thermodynamics, entropy

Theme 4: Carnot Engines, Heat Engines

Problem 1:
(E) Thermodynamic processes (theme 2)

Problem 2:
(E) Radiation laws (theme 1)
The Stefan Boltzmann law: The total energy radiated per unit area per unit time is proportional to T^4.

Problem 3:
(A) Heat engines
max efficiency = $(T_1 - T_2)/T_1$ = 200/(727+273)
$W_{max} = Q_{high}$*200/1000 = (2000 J)/5. (theme 4)

Problem 4:
(B) Speed of sound
http://scienceworld.wolfram.com/physics/SpeedofSound.html
Or make a simple argument. Speed of sound should be proportional to speed of particles. E is proportional to T, v is proportional to $T^{1/2}$. (Note T is absolute temperature.)

Problem 5:
(D) Thermodynamic processes (theme 2)
The work is equal to the area under the PV diagram. It is positive if the path is clockwise, and negative if the path is counterclockwise.
$W = -\frac{1}{2}*2\ m^3 * 300*kPa = -300$ kJ.

Problem 6:
(E) Thermodynamic processes (theme 2)
PV = nRT. The work done by the gas is $W = \int_{V1}^{V2} PdV$.
For the isothermal process P = nRT/V with T constant.
For the adiabatic process P = nRT(V)/V. T(V) decreases as the volume increases, since the gas does work and its internal energy decreases.

Problem 7:
(C) Heat engines
If T_1 and T_2 are the temperatures of the source and sink respectively, the efficiency of the Carnot engine is given by $\eta = (T_1 - T_2)/T_1$.
Therefore, initially we have $1/5 = (T_1 - T_2)/T_1$ so that $T_2 = 4T_1/5$.
In the second case (when the temperature of the sink is reduced), we have
$2/5 = [T_1 - (T_2 - 100)]/T_1$.
Substituting for $T_2 = 4T_1/5$ in the above equation, we obtain $T_1 = 500$ K. (theme 4)

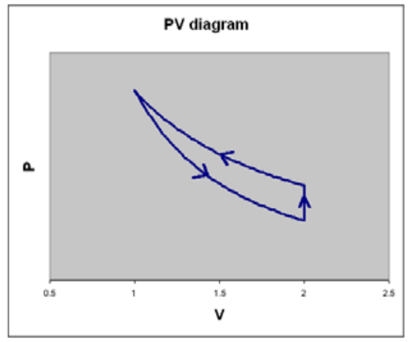
Problem 8:
(B) Changes of phase
Critical isotherm: A curve showing the relationship between the pressure and volume of a gas at its critical temperature. This temperature, above which the gas cannot be liquefied, is called the critical temperature.

Problem 9:
(B) Changes of phase
Vapor-liquid equilibrium is a condition or state where the rate of evaporation equals the rate of condensation.

Problem 10:
(C) Kinetic theory
The average energy associated with each translational degree of freedom of a molecule is ½kT, the average energy associated with each rotational degree of freedom of a molecule is ½kT, and the average energy associated with each vibrational mode is kT.
[The average kinetic energy of an oscillator mode is ½ kT (from the definition of the temperature T) and the average potential energy is equal to the average kinetic energy.]

Problem 11:
(C) Radiation laws
The Stefan Boltzman law: The total energy radiated per unit area per unit time is proportional to T^4. 16 times as much energy is delivered to the water. (theme 1)

Problem 12:
(A) Thermodynamic processes
All other answers are false.
Energy conservation: $dU = dQ - dW$.
For an ideal gas $PV = NkT$.
For an isothermal process PV = constant, $P \propto 1/V$.
For an adiabatic process $dU = -dW = -PdV$.
But we also have $U = N(1/2)m\langle v^2\rangle$.
Since $(1/2)m\langle v^2\rangle = (3/2)kT$, we have $U = (3/2)PV$,
$dU = (3/2)(PdV + VdP)$.
Equating our two expressions for dU we have
$-PdV = (3/2)(PdV + VdP)$,
$dP/P + (5/3)dV/V = 0$. $PV^{5/3} = C$ = constant, $P \propto 1/V^{5/3}$.



The reversible process is described by a counterclockwise path on the PV diagram.
(theme 2)

Problem 13:
(C) Entropy
We have reversible processes. In a reversible process the total entropy does not change.
(theme 3)

Problem 14:
(D) Maxwell speed distribution

Problem 15:
(A) Thermodynamic processes
at constant pressure: $dQ = nC_PdT$
at constant volume: $dQ = nC_VdT$
Energy conservation:
at constant pressure: $dU = dQ - dW = nC_PdT - PdV = nC_PdT - nRdT$
at constant volume: $dU = nC_VdT$
dU depends only on the change in temperature,
so $nC_PdT - nRdT = nC_VdT$, $C_P - C_V = R$. (theme 2)