Problem 1: (C)

Definition of absolute temperature T: $\frac{1}{2} m\langle v^2\rangle = (3/2)\, kT$

Problem 2: (A)

Wien law: $\lambda_{max} \propto 1/T$

Problem 3: (C)

Adiabatic processes: PV^{γ} = constant ; ideal gas law: PV/T = constant

Derivation:
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 $nC_PdT - nRdT = nC_VdT$, $C_P - C_V = R$.
Adiabatic expansion: $dU = - PdV = nC_VdT$, $dT = -PdV/(nC_V)$.
Ideal gas law: $PdV + VdP = nRdT = -nRPdV/(nC_V) = -(C_P - C_V)PdV/C_V$.
$(C_p/C_V)PdV + VdP = 0$, $(C_p/C_V)dV/V + dP/P = 0$.
Integrate: $(C_p/C_V)\ln V + \ln P = 0$. PV^{γ} = constant, $\gamma = C_p/C_V$

Problem 4: (C)

Buoyant force: $\rho_{block}Vg = ¾*(1000\ kg/m^3)Vg + ¼*(800\ kg/m^3)Vg$

Problem 5: (C)

Kinetic theory: $\frac{1}{2} m\langle v^2\rangle = (3/2)\, kT$
At a fixed T we have $\langle v^2\rangle \propto 1/m$. The average time between collisions $\propto 1/v_{rms}$.

Problem 6: (A)

Equation of continuity and Bernoulli's equation:
$v_1A_1 = v_2A_2$, $P_1 + \rho gh_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho gh_2 + \frac{1}{2}\rho v_2^2$
Here $v_1 = v_0$, $v_2 = 4v_0$, $P_2 = P_1 – (15/2)\rho v_0^2$

Problem 7: (C)

Kinetic theory: $\Delta U = (3/2)nR\Delta T$, $C_P - C_V = R$
constant volume: $\Delta U = nC_V\Delta T = Q$, $Q = (3/2)nR\Delta T$
constant pressure: $\Delta U = nC_p\Delta T = nC_V\Delta T + nR\Delta T = Q + (2/3)Q = (5/3)Q$

See derivation under problem 3.

Problem 8: (B)

Second law of thermodynamics: $Q_1/T_1 = Q_2/T_2$
Heat pump: $COP = Q_{high}/(Q_{high} - Q_{low}) = Q_{high}/W = T_{high}/(T_{high} - T_{low}) = 300/20$
$W = (15000\ J)*20/300 = 1000\ J$

Problem 9: (D)

Work done by a gas: $W = \int_{V1}^{Vf} P dV$

$W = \int_{V1}^{Vf} [RT_0/(V-b)]dV - \int_{V1}^{Vf} (a/V^2)dV$

Problem 10: (B)

Entropy: $dS = dQ/T$

For each body: $dQ/T = c\, m\, dT/T$, $\Delta S = c\, m \ln(T_f/T_i)$

$\Delta S_{total} = c\, m \ln(300/500) + c\, m \ln(300/100) = c\, m \ln(9/5)$

Problem 11: (E)

Second law of thermodynamics:

Heat cannot, of itself, flow from a cold to a hot object is one way of stating the 2nd law.

Problem 12: (D)

Definition of absolute temperature T: $\frac{1}{2} m\langle v^2\rangle = (3/2)\, kT$

$$v_{rms} = \sqrt{\frac{3kT}{m}} \qquad \frac{v_{He}}{v_{Ar}} = \sqrt{\frac{m_{Ar}}{m_{He}}} = \sqrt{10} \approx 3$$

Problem 13: (E)

First law of thermodynamics: $\Delta U = \Delta W + \Delta Q$

Here $\Delta W = 0$, $\Delta Q = 0$.

For a real gas the internal energy is the sum of kinetic and the potential energy, since the molecules can have long range interactions. If the distance between the molecules is changing, then the potential energy may change. Therefore the kinetic energy and the temperature can change.

Problem 14: (A)

Phase diagrams: At lower pressure the substance freezes at a higher temperature.

Problem 15: (E)

Stefan-Boltzmann law: $P_{rad} \propto T^4$