Physics 6B
Sample Midterm 1 – Solutions

1.1 **(b)**
The entropy of the system + environment cannot decrease, so the entropy of the environment must increase when the entropy of the system under observations decreases.

1.2 **(d)**
You need to know how the pressure is changing as the volume increases in order to know how the temperature changes (think about all the possible paths from one volume to another on a p,V diagram).

1.3 **(a)**
The upward buoyancy force is equal to the weight of the displaced water (call it F_w). The downward force is the weight of the object; because the density of the object is three times that of water we know that that is a downward force of $3F_w$. The net force is therefore $2F_w$ downwards.

1.4 **(c)**
Both argon and helium are monatomic, so in both cases the average kinetic energy per particle is $3kT/2$. The argon atoms have lower speeds than the helium atoms, but the same kinetic energy.

1.5 **(a)**

$$\begin{aligned} p_1 + \frac{1}{2}\rho v_1^2 + \rho\, g y_1 &= p_2 + \frac{1}{2}\rho v_2^2 + \rho\, g y_2 \\ p_2 - p_1 &= \frac{1}{2}\rho(v_1^2 - v_2^2) + \rho\, g(y_1 - y_2) \end{aligned} \tag{1}$$

Because the pipe is getting wider, and $\rho v A$ must be constant, we know $v_2 < v_1$. We also know that $y_2 < y_1$, so both terms on the right hand side of the equation above are positive, so $p_2 > p_1$.

2A. Since the ice starts at 0 deg, the heat needed to melt it is the latent heat times the mass:

$$Q = L_{\text{fusion}} \times m_{\text{ice}} = (334)(20) = 6680J$$

2B. The change in the water temperature is related to the mass of the water and its specfic heat.

$$Q = m_{\text{water}} c_{\text{water}} \Delta T \quad \Longrightarrow \quad -6680 = 1000(4.184)\Delta T \quad \Longrightarrow \quad \Delta T = -1.6^\circ\text{C}$$

The temperature in the water drops to $100 - 1.6 = \mathbf{98.4}$°C

2C. You have 1000g of water at 98.4°C and 20g of water at 0°C.

$$T_{\text{eq}} = \frac{m_1c_1T_1 + m_2c_2T_2}{m_1c_1 + m_2c_2} = \frac{1000(4.184)(98.4) + 20(4.184)(0)}{1000(4.184) + 20(4.184)} = \mathbf{96.5}°\text{C}$$

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3A. The volume of half the dish is: $Ah = (20)(4) = 80\,\text{cm}^3$. The density of water is $1\text{g}/\,\text{cm}^3$ so the mass of the displaced water is **80g**.

3B. The dish will sink when $M_{\text{sinkers}} > 160\,\text{g}$ since $160\,\text{g}$ is the maximum amount of water the dish can displace, which has a weight of $(10)(.16) = 1.6\,\text{N}$. **The dish will float with 5 sinkers** ($1.5\,\text{N}$) but sink with 6 ($1.8\,\text{N}$).

4. Two things happen as the system is heated from 0°C to 100°C. The temperature of the gas rises (which will increase the pressure), and the volume of the cylinder shrinks because the plunger is pushed further in as aluminum rod expands (which will also increase the pressure).
Looking at the volume change first:

$$\frac{\Delta L}{L} = \alpha\,\Delta T \quad \Longrightarrow \quad \begin{aligned} \frac{\Delta L}{10} &= (2.5 \times 10^{-5})(100) \\ \Delta L &= (2.5 \times 10^{-5})(100)(10) = 2.5 \times 10^{-2}\,\text{m} = 2.5\,\text{cm} \end{aligned} \quad .$$

The depth of the cylinder of gas has changed from 10 cm to 7.5 cm, so the volume has changed from $V_1 = Ah = (0.1\,\text{m}^2)(0.1\,\text{m}) = 0.01\,\text{m}^3$ to $V_2 = (0.1\,\text{m}^2)(0.075\,\text{m}) = 0.0075\,\text{m}^3$.
Comparing before and after, p, V, T have all changed, but the amount of gas has stayed constant:

$$\begin{aligned} \frac{p_1V_1}{T_1} &= nR = \frac{p_2V_2}{T_2} \\ \frac{T_2V_1}{T_1V_2} &= \frac{p_2}{p_1} \\ \frac{373 \times 0.01}{273 \times 0.0075} &= \frac{p_2}{0.5\,\text{atm}} \\ \frac{373 \times 0.01}{273 \times 0.0075} &= \\ 1.82(0.5) &= p_2 \qquad \Longrightarrow \qquad \mathbf{p_2 = 0.91\,atm} \quad . \end{aligned}$$