

PHYS 1220-02 Fall 2026 Quiz 1
Brief Solutions

1. Thermal equilibrium

Two bodies are in thermal equilibrium if they have the same temperature.

2. 77 K in Celsius

The conversion between Celsius and kelvin is that the kelvin temperature is 273.15 higher than the Celsius temperature. Thus, $77\text{ K} - 273.15 = -196.15^\circ\text{C}$.

3. Celsius boiling temperature difference

The kelvin and Celsius scales are only offset by 273.15. Differences between temperatures are the same in both scales. We know both boiling temperatures in kelvin: 77K and 300K. The difference is 223K, so the difference is also 223°C .

4. Thermal expansion of unobtainium

a. Coefficient of linear expansion

We are given the length at 20°C and the length increase upon raising the temperature to 140°C . The formula for linear expansion in terms of the coefficient α is $\Delta L/L_0 = \alpha\Delta T$. Thus

$$\alpha = \frac{L}{L_0\Delta T} = \frac{9 \times 10^{-3}\text{ m}}{(3.2\text{ m})(120^\circ\text{C})} = 2.34 \times 10^{-5}/^\circ\text{C}$$

b. Coefficient of volume expansion

The coefficient of volume expansion β is three times the linear expansion coefficient. That makes it $7.02 \times 10^{-5}/^\circ\text{C}$.

5. SI unit of heat

Heat is a type of energy transfer, and the SI unit of energy is the joule. Thus, the SI unit of heat is the joule.

6. Condition for heat transfer

There must be a temperature difference for any heat flow to occur. In this case of heat flowing from A to B, A must have the higher temperature.

7. Evaporative cooling

The hot iron transfers heat to the water, raising the water's temperature to 100°C and then boiling it away.

a. Heat released by the iron

Here we can directly plug-and-chug $Q = mc\Delta T$, where $m = 0.250 \text{ kg}$, $c = 490 \text{ J/(kg} \cdot \text{K)}$, and $\Delta T = -1100^\circ\text{C}$. This gives $Q = -134,750 \text{ J}$. The negative sign means that heat went away from the iron, but the question asked for the heat loss of the iron, which is a positive number, 135 kJ .

b. Mass of water evaporated

The water must be heated to the boiling temperature before it boils. There are two steps to the process of boiling the water away whose energy we must account for: heating the water to 100°C , requiring heat $Q_h = mc\Delta T$; and boiling the water at 100°C , requiring heat $Q_b = mL$. We were given the heat capacity of water $c = 4184 \text{ J/(mol} \cdot \text{K)}$ and the heat of vaporization of water $L = 2.26 \times 10^6 \text{ J/kg}$. Together,

$$\begin{aligned} Q &= Q_h + Q_b \\ &= mc\Delta T + mL = m(c\Delta T + L) \\ &= m \left(4184 \frac{\text{J}}{\text{kg} \cdot \text{K}} \cdot 70 \text{ K} + 2.26 \times 10^6 \text{ J/kg} \right) \\ &= m(0.293 \times 10^6 \text{ J/kg} + 2.26 \times 10^6 \text{ J/kg}) \\ &= m(2.55 \times 10^6 \text{ J/kg}), \end{aligned}$$

allowing us to solve for water mass m because we found the heat input Q in the previous part of the question.

$$m = \frac{Q}{c\Delta T + L} = \frac{135 \times 10^3 \text{ J}}{2.55 \times 10^6 \text{ J/kg}} = 0.0529 \text{ kg} = 53 \text{ g}.$$

8. Irradiance at a higher temperature

We are given the radiative power output of a tungsten filament at one temperature and asked to find the power output at a higher temperature. We know that the thermal radiation output is proportional to the fourth power of temperature: irradiance, the power output per area, is $I = \epsilon\sigma T^4$. Thus

$$\begin{aligned} I_1 &= \epsilon\sigma T_1^4; & I_2 &= \epsilon\sigma T_2^4 \\ \frac{P_2}{P_1} &= \frac{AI_2}{AI_1} = \frac{I_2}{I_1} = \frac{\epsilon\sigma T_2^4}{\epsilon\sigma T_1^4} = \left(\frac{T_2}{T_1} \right)^4 \\ P_2 &= P_1(T_2/T_1)^4 = (25 \text{ W}) \left(\frac{3000}{2700} \right)^4 = (25 \text{ W})(10/9)^4 = 25 \text{ W} \cdot 1.524 = 38 \text{ W} \end{aligned}$$

(Just to be clear: here, P is power, as distinct from pressure p .)

9. Heat loss through a window

The question asks for “heat current,” which is the rate of energy transfer, in watts. The formula is the Fourier heat conduction law $H = kA\Delta T/L$.

$$H = \left(0.85 \frac{\text{W}}{\text{m}^\circ\text{C}} \right) (0.800 \cdot 1.200) \text{ m}^2 \frac{35^\circ\text{C}}{0.004 \text{ m}} = 7140 \text{ W}$$

10. Ideal gas molecule characteristics

The signature properties of the molecules of an ideal gas are

- point masses
- not interacting with each other
- colliding elastically with surfaces they contact.

I also wanted students to say something about kinetic energy per mode of motion being $\frac{1}{2}kT$ per mode of motion, but nobody did that, and I concede that's not really a molecular property.

11. Moles of ideal gas

We are given volume, temperature, and pressure, which is everything we need to calculate the number of moles. Two conversions we need to keep in mind is that the equation of state $pV = nRT$ uses absolute (kelvin) temperature, and that the pressure was given in bar, which is 10^5 joules per cubic meter.

$$n = \frac{pV}{RT} = \frac{(1.01 \times 10^5 \text{ J/m}^3)(28 \text{ m}^3)}{(8.31441 \text{ J/(mol} \cdot \text{K)})(295.15 \text{ K})} = 1150 \text{ mol}$$