1 Two values of specific heat capacity

If you google "specific heat capacity of air" you will find two values:

$$c_p = 1.00 \text{ kJ/kg} \times \text{K, at } T = 293 \text{ K, } P = 1 \text{ atm} \tag{1}$$
$$c_v = 0.72 \text{ kJ/kg} \times \text{K, at } T = 293 \text{ K, } P = 1 \text{ atm} \tag{2}$$

The first value, c_p, refers to the heat required to the raise the air temperature while holding pressure constant. The second value, c_v, refers to the heat required to raise air the air temperature while holding volume constant. The goal of this question is to compare these published values to the physics we've learned so far. To simplify the question, treat the air as if it were pure nitrogen gas (the main component of air). Nitrogen gas has a density of 1.17 kg/m^3 at $T = 293$ K and atmospheric pressure. The equation of state is $pV = Nk_BT$. The internal energy of the gas is $\frac{5}{2}Nk_BT$.

(a) On a pV diagram, mark the initial state of the nitrogen gas (assume 1 kg of gas at 1 atm). On this same diagram, show how the state of the gas would change if heat was added while (i) keeping volume constant or (ii) keeping pressure constant.

(b) For the constant volume process, how much heat (in Joules) does it take to raise the temperature by 1 K? (Answer this question with 3 sig. fig. precision. When constructing your solution, don't refer to the published values of c_p or c_v).

(c) For the constant pressure process, how much heat (in Joules) does it take to raise the temperature by 1 K? (Answer this question with 3 sig. fig. precision. When constructing your solution, don't refer to the published values of c_p or c_v).

(d) Sensemaking: Do your calculations agree with published values?

2 Thermal energy in the earth's atmosphere

Thermal energy is stored in all materials on Earth, including the air, water and rocks. The air is composed mostly of diatomic molecules such as N$_2$ and O$_2$.

(a) Use Google to look up the mass of the earth's atmosphere. Now, exercise some skepticism and make sure that Goggle's answer is consistent with other facts about the earth: Air pressure at sea level is about 100 kPa and the radius of the earth is about 6400 km. The air pressure at sea level (force per unit area) is caused by the downward force of gravity acting on the atmosphere directly above a unit area. The thickness of the atmosphere is much much less than the radius of the earth. Give your argument supporting or refuting the internet's value for the mass of the earth's atmosphere.

(b) We know that between 1955 and 2010, the temperature of the top 2000 meters of the ocean rose by about 0.05 C. Given this fact, assess the validity of the following statement:

> "If the same amount of heat that has gone into the top 2000 meters of the ocean between 1955-2010 had gone into the lower 10 km of the atmosphere, then the atmosphere would have warmed by about 20°C (36°F)."

Is this statement reasonable, or ridiculous? Show your calculations that support your conclusion. Your starting assumptions will include the specific heat capacity of air and water, and a reasonable guess regarding the fraction of the earth's surface that is covered with ocean.