Thermodynamique

Expériences : Premier principe

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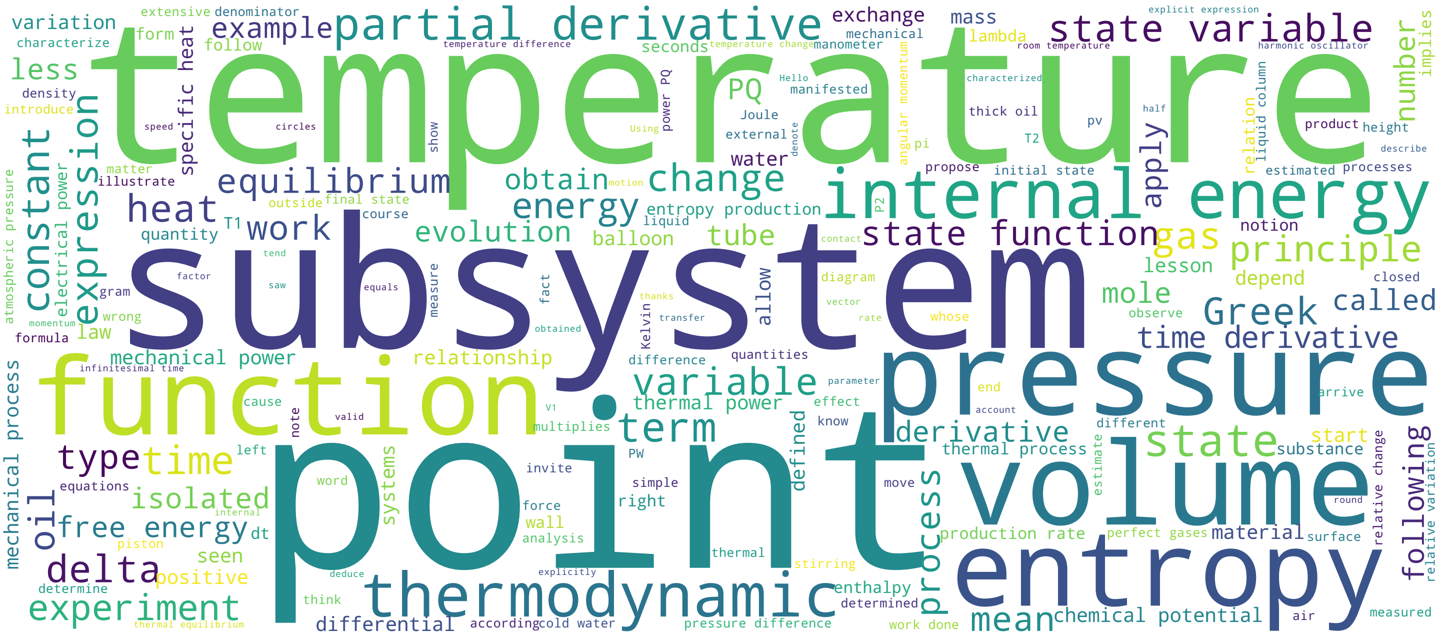
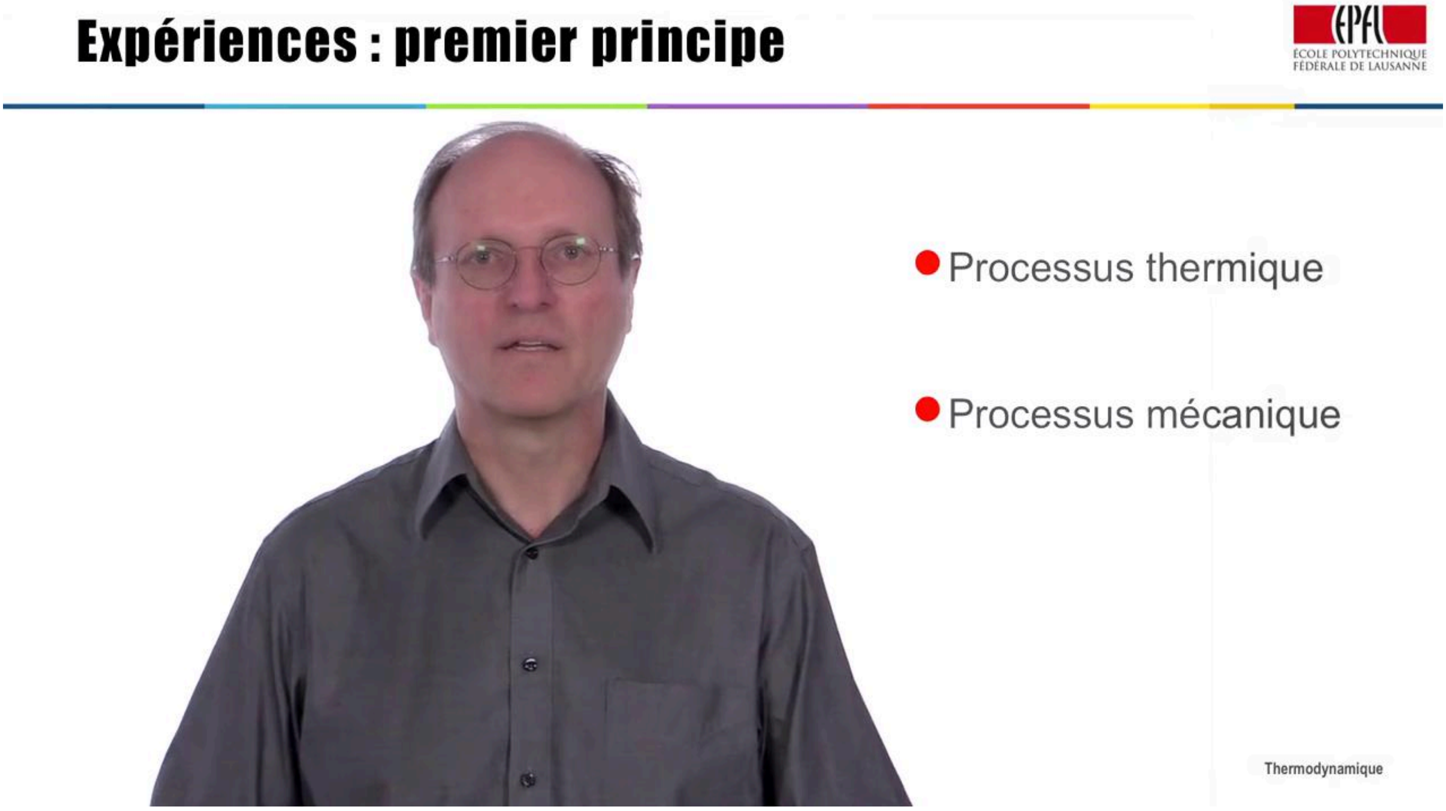
Joule



Video



As agreed, I'll meet you to illustrate this lesson with some experiments. The first principle. Implies that if the energy of a system changes. A process acts on this system. There are two types of processes thermal and mechanical processes. In this video, I will show you two experiments to illustrate these two types of processes. We will start with a process and then we will see a mechanical process.

Notes

Summary

0m 05s

Let's start with a thermal process. Here we have a glass balloon containing air. We measure the pressure of the gas in the flask thanks to a U-tube containing a colored liquid. At the beginning of the experiment, the pressure in the worm balloon is equal to the ambient atmospheric pressure. The balloon is then immersed in cold water. The gas cools down. It is a thermal process. We observe that the pressure decreases. Then, we plunge it in hot water and we observe that the pressure increases. Now let's move on to a mechanical process. We have here a small experiment that imitates the calorimeter that Joule had designed to study what was then called the equivalence of work and heat. Our arms are a thick oil with a stirrer that is driven by a motor electrical power is measured. We see that it takes about 28 electrical watts to.

Notes

Summary

0m 47s

You might object that even when empty, a certain amount of electrical power is required to drive the motor. You are right, let's measure that power.

Notes

Summary

2m 05s

We can see that nine watts are needed at no load. We can therefore conclude that a good part of of the difference, i.e. 18 watts, contributes to the mechanical work done on the oil. The temperature of the oil can then be measured under the effect of stirring. It can be seen that, in 120 seconds, the oil has increased in temperature by 3.4 Kelvin.

Notes

Summary

2m 21s

Expériences : premier principe

- Effet mécanique d'un processus thermique
- Effet thermique d'un processus mécanique

Thermodynamique

In summary, we have seen a thermal process which was manifested by a change in pressure. Then, we saw a mechanical process which was manifested by a change in temperature.

Notes

Summary

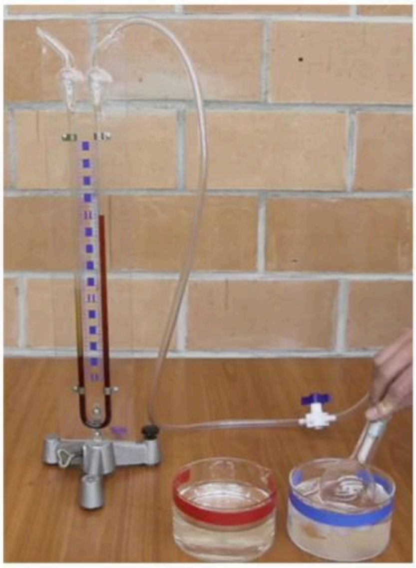
3m 00s

Ordres de grandeurs : processus thermique

$h = 17$ cm $\quad \rho \approx 1000$ kg / m^3 $\quad p_0 \approx 101'325$ Pa

$|\Delta p| = \rho g h \quad \frac{|\Delta p|}{p_0} = \approx 0.016$

$\frac{|\Delta p|}{p_0} = \frac{|\Delta T|}{T_0} \approx 0.016 \quad \Delta T \approx -5$ K



Thermodynamique

I now propose to you to conduct a quantitative analysis of these two experiments. You can follow me if you have some basic notions of thermodynamics. Otherwise, I invite you to review this passage when you have followed the word to the fifth lesson. Taking the experience of the process the pressure gauge indicates a difference of height in liquid columns of 17 cm. The atmospheric pressure is given here in pascals. And the pressure difference represented by the manometer is equal to the density times HG of the earth acceleration. Times the height of the liquid column. We do not know exactly the density of this liquid, but it must be very close to water. So we'll take 1000 kilos per meter cube and therefore we have a relative change in pressure of about one point 6 %. If we apply the law of perfect gases pv rt. The volume being constant, we have the relative variation of pressure which is equal to the relative variation of the temperature, which implies a temperature change of about five Kelvin. Frankly, I think it's too little. I doubt the preparer went to the trouble of making a cold water mixture, that it is just five degrees cooler or warmer than the ambient temperature.

Notes

Summary

3m 18s

Ordres de grandeurs : processus thermique

$h = 17$ cm $\quad \rho \approx 1000$ kg / m^3 $\quad p_0 \approx 101'325$ Pa

$$|\Delta p| = \rho g h \qquad \frac{|\Delta p|}{p_0} = \approx 0.016$$

$$\frac{|\Delta p|}{p_0} = \frac{|\Delta T|}{T_0} \approx 0.016 \qquad \Delta T \approx -5 \text{ K}$$

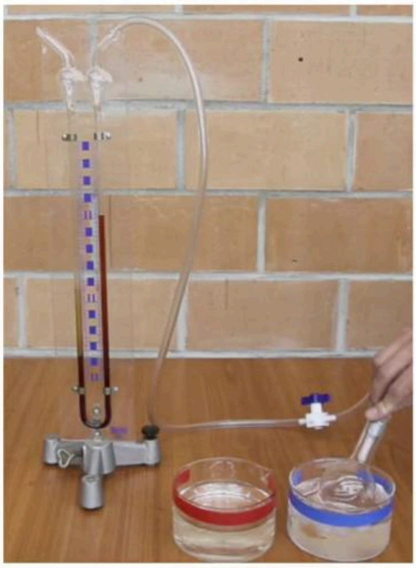
A : ballon dans l'eau, B : tube à température ambiante

$$N_A R T_A = p_A V_A$$

$$N_B R T_B = p_A V_B$$

$$N = N_A + N_B = \frac{p_0(V_A + V_B)}{R T_0}$$

$$\left(1 - \frac{T_A}{T_0}\right) = \frac{(p_0 - p_A)(1 + \frac{V_B}{V_A})}{p_0 + (p_0 - p_A)\frac{V_B}{V_A}}$$



Thermodynamique

I invite you to take a break and try to see what was wrong with my analysis. I think what's wrong with my analysis. This is because the volume of gas in the tube that connects the balloon to the manometer was ignored. This gas remains at room temperature. To analyze the effect of this residual gas, I propose the following approach. We will note a sub-system of the balloon and b the air subsystem in the tube. We will apply the law of perfect gases in the subsystem A and in the subsystem B, the sum of the moles A and B. It can be determined if we know the total volume by a measurement made at room pressure and room temperature. Then we have three equations and we have three unknowns. An a nb was at. You will notice that in these equations I have put the same pressure, not in the balloon and in the tube as it should be. After some algebraic manipulations. We arrive at the following formula for the relative change in temperature as a function of pressures and volumes. In this formula. In the denominator, we have the pressure difference p0 at least p.a which comes next to a P0. We have just determined that this pressure difference is very small.

Notes

Summary

4m 53s

Ordres de grandeurs : processus thermique

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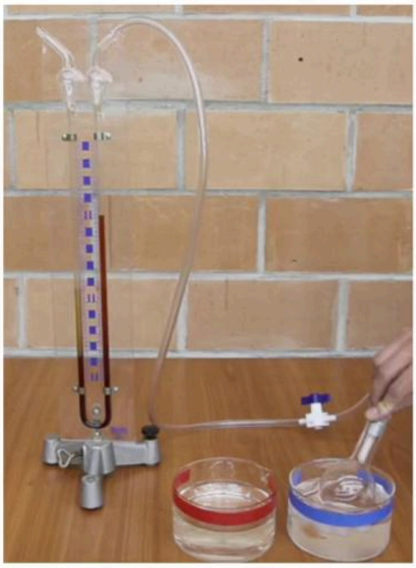
$$\frac{|\Delta p|}{p_0} = \frac{|\Delta T|}{T_0} \approx 0.016 \qquad \Delta T \approx -5 \text{ K}$$

A : ballon dans l'eau, B : tube à température ambiante

$$N_A R T_A = p_A V_A$$
$$N_B R T_B = p_A V_B$$
$$N = N_A + N_B = \frac{p_0 (V_A + V_B)}{R T_0}$$

$$\left(1 - \frac{T_A}{T_0}\right) = \frac{(p_0 - p_A)(1 + \frac{V_B}{V_A})}{p_0 + (p_0 - p_A)\frac{V_B}{V_A}} \approx \left(1 - \frac{p_A}{p_0}\right)(1 + \frac{V_B}{V_A})$$



Thermodynamique

We will therefore neglect this term in the denominator and we arrive at the following beautiful formula. Or we see now a corrective factor in addition VB will monitor. If by chance the volume of gas in the tube was approximately equal to the volume of gas in the balloon, we have a factor of two. So we have a temperature difference of ten kelvins, which seems reasonable to me.

Notes

Summary

6m 46s

Ordres de grandeurs : processus thermique

observés : $P_W = 19$ W; $\delta t = 120$s; $\Delta T = 3.4$ K

$\Delta U = m c_V \Delta T$ $\quad$ $c_V \approx 2.2$ J / (g K) $\quad$ $m \approx 200$g

$$\dot{U} = P_W$$

$$\dot{U} \approx \frac{\Delta U}{\delta t} \approx 12 \text{ W}$$

Thermodynamique

Now let's move on to the experiment. Or we heated oil while stirring. So with a mechanical process. I remind you here the experimental data. We had estimated the electrical power. The oil was stirred for 120 seconds and a temperature change of 3.4 Kelvin was obtained. If we use the notion of specific heat, the internal energy change of the oil can be calculated. With this formula M cvf delta tai M the mass of the oil cv, the specific heat per unit mass of this oil. By going to look at typical values for very thick oils, I estimated that the reasonable value was 2.2 joules per gram. And by what film? And we have about 200 grams of oil. I can now apply this law of evolution that we discussed with the first principle. For the internal energy of the equal point, the mechanical power. And here the point, I can estimate it. In the following way I have the Delta U thanks to my estimate of the specific heat and the delta is 120 seconds I find. Twelve watts is less than the 19 watts of electricity, but it's not far off. There is a lot of uncertainty about all these parameters. And more, the engine could very well have an efficiency of about seventy.

Notes

Summary

7m 13s