Introduction to Solving Physics Problems

Physics 2211/2212 IPLS

Physics is a complex, highly mathematical subject. Because of this, it often appears impenetrable to many students, something to be survived rather than enjoyed. However, physics provides a rich set of tools for describing myriad natural phenomena in a way that no other subject can, thus making the beauty of nature's order readily apparent. The promise of a physics course is to learn how to apply these tools and to solve problems, not merely learn a set of disconnected facts and equations to memorize. Here, we try to distill the problem-solving process into an almost algorithmic approach composed of eight steps that should help you get started on almost any problem.

1) Read the question
2) Organize the information
3) Check for coherent units
4) Draw a diagram
5) Identify the principle at work
6) Consider the formulas
7) Solve (symbolically)
8) Verify result(s)

Let us look at these steps in the context of a problem from 2211C; this problem comes from the lab quiz covering pressure. This example will help illuminate some of the steps and provide a skeleton for further problem solving.

Example Procedure

Question:

The window of a skyscraper measures 2.0 m by 3.5 m. If a storm passes by and lowers the pressure outside the window to 0.997 atm while the pressure inside the building remains 1 atm, what is the net force pushing the window out?

$$1\,\text{atm} = 1.013 \times 10^5\,\text{Pa} \textbf{ and } 1\,\text{Pa} = 1\,\text{N/m}^2$$

Read the question & Organize the information

The first things you want to do are read the question thoroughly and identify any information that may be pertinent to solving the problem. We then take this information and organize it into a list. The information provided in the problem is highlighted in blue and the question is highlighted in red.

Q: The window of a skyscraper measures 2.0 m by 3.5 m. If a storm passes by and lowers the pressure outside the window to 0.997 atm while the pressure inside the building remains 1 atm, what is the net force pushing the window out?

- $l_{\text{window}} = 2.0$ m
- $w_{\text{window}} = 3.5$ m
- $P_{\text{out}} = 0.997$ atm
- $P_{\text{in}} = 1.0$ atm
- $F_{\text{net}} \stackrel{?}{=}$

Check for coherent units

Next, you should always verify that your units are consistent. In this case, pressure is given in terms of atmospheres (atm), which **do not** correspond to the International System of Units (SI) unit of pressure (Pascal, or Pa). Thus, you should convert atm to Pa because (1) it is generally safer to use SI throughout and (2) this will ensure that the units of pressure and the dimensions of the window are compatible. Provided in the original question statement are the conversions for atm to Pa. As a general rule, it is better to know common unit conversions rather than rely on them being provided in the question statement; that being said, we will usually provide them.

Q: The window of a skyscraper measures 2.0 m by 3.5 m. If a storm passes by and lowers the pressure outside the window to 0.997 atm while the pressure inside the building remains 1 atm, what is the net force pushing the window out?

$$1\text{ atm} = 1.013 \times 10^5\text{ Pa } \textbf{and } 1\text{ Pa} = 1\text{ N/m}^2$$

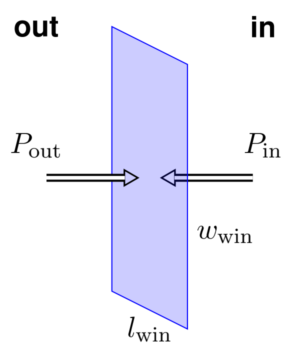
- $l_{\text{window}} = 2.0$ m
- $w_{\text{window}} = 3.5$ m
- $P_{\text{out}} = 0.997\text{ atm} \times \frac{1.013\times10^5\text{ Pa}}{1\text{ atm}} = 100996.1\text{ Pa}$
- $P_{\text{in}} = 1.0\text{ atm} \times \frac{1.013\times10^5\text{ Pa}}{1\text{ atm}} = 101300\text{ Pa}$
- $F_{\text{net}} \stackrel{?}{=}$

Draw a picture & Identify the principle at work

This step, perhaps the most critical of all, will organize the information in a way that text and equations cannot. "Free-body diagrams", for instance, allow one to quickly relate magnitudes and directions of forces acting on an object at a single glance. Furthermore, you can make your pictures as simple or elaborate as you need - you do not need to be an artist! Below, we are given the window dimensions and the pressure on either side of the window.

Q: The window of a skyscraper measures 2.0 m by 3.5 m. If a storm passes by and lowers the pressure outside the window to 0.997 atm while the pressure inside the building remains 1 atm, what is the net force pushing the window out?

- $l_{\text{window}} = 2.0$ m
- $w_{\text{window}} = 3.5$ m
- $P_{\text{out}} = 100996.1$ Pa
- $P_{\text{in}} = 101300$ Pa
- $F_{\text{net}} \stackrel{?}{=}$



After drawing a diagram, we can identify the principle at work, e.g., conservation of energy (initial energy is equal to final energy), static equilibrium (sum of the forces is zero), etc. For this problem, while there is an "initial" and a "final" state, the question is only referring to the final state. Thus, it is a simple matter of defining the **unknown** force in terms of the **known** quantities (pressure and area).

Consider the formulas & Solve symbolically

This component is the most traditionally "physics" step in this entire procedure. Up until this point, you should have effectively organized the **known** information and determined the principle at work. This principle usually has a set of associated equations, e.g., $\sum \vec{F} = 0$ for static equilibrium. Now you must determine how to find the **unknown** variable. From the example, we are asked to find the net force pushing the window out. We also know that we are seeking this information because of our list in steps 1 & 2. Based on the definition of pressure, we know that it is force per unit area: $P = F/A$. This is our starting point. Try to solve symbolically **before** plugging in any numbers .

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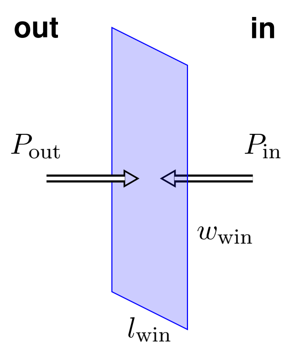

$$\Delta P = \frac{F}{A_{\text{win}}}$$

Rearrange & solve for the unknown F.

$$F = \Delta P \, A_{\text{win}}$$

The area of the window is $l \times w$.

$$F = \Delta P \, (l_{\text{win}} \times w_{\text{win}})$$

$$\Delta P = P_{\text{in}} - P_{\text{out}}$$

$$F = (P_{\text{in}} - P_{\text{out}}) \, (l_{\text{win}} \times w_{\text{win}})$$

Only now plug in numbers for the known quantities.

$$F = (101300 \text{ Pa} - 100996.1 \text{ Pa}) \, (2.0 \text{ m} \times 3.5 \text{ m})$$

$$\boxed{F = 2127.3 \, \text{N}}$$

Verify the result

Once you have the answer, you may think you are done - not true! Far too many times, people will either plug values into their calculator incorrectly, fail to convert units accordingly, or even make an incorrect substitution. One of the simplest ways to verify is to check that the units of your answer agree with what you expect. For example, in this problem, the unknown quantity is a force; therefore, your answer should be in Newtons (assuming you're using SI units). Furthermore, a little bit of intuition goes a long ways during verification. For example, you perform a calculation that results in the speed of an electron being faster than the speed of light, a clear impossibility and an indication that you've done something wrong. By having carried out your work in such a methodical fashion, you can reassess your solution step by step to find where the error occurred. Shown below is a somewhat trivial, but still useful, example of starting from the first equation and effectively determining if the left-hand side is the same as the right-hand side.

Recall:

$$\begin{aligned}
\Delta P =& \frac{F}{A} \\
P_{\text{in}} - P_{\text{out}} =& \frac{2127.3\,\text{N}}{2.0\,\text{m} \times 3.5\,\text{m}} \\
(101300\,\text{Pa} - 100996.1\,\text{Pa}) =& \frac{2127.3\,\text{N}}{7.0\,\text{m}^2} \\
303.9\,\text{Pa} =& 303.9\,\text{N/m}^2
\end{aligned}$$

Well done! You've gone the the process of solving and verifying a physics problem! Because we know that 1 Pa = 1 N/m^2, the two sides of the equation are indeed equivalent. This pragmatic approach to problem solving effectively conveys your clear understanding of the problem at hand. Furthermore, this process aids a reader understand your procedures and the solution.