

Step-by-Step Problem-Solving Guide for Physics

Prepare

1. **Recognize the topic of the problem (landscape recognition).** Begin by identifying the central topic or concept (e.g., diffusion, proportional reasoning, motion in 1D, etc.). This helps activate relevant ideas and connect the problem to similar ones you have already solved.
2. **List all given quantities and convert them to SI units (bookkeeping).** Write down every known quantity:
 - its physical symbol (e.g., t , v , D , etc.)
 - its numerical value (magnitude)
 - its unit (e.g., s, m/s, m²/s)

This step keeps your work organized and makes the next steps straightforward.

3. **Identify what is being asked (define the goal).** Clearly determine the quantity you are asked to find. Write down its physical symbol and the expected unit so you know what your final answer should look like.

Solve

4. **Choose the appropriate formula (copy and track).** Go to the section of the formula sheet that matches the topic from Step 1. Look for all equations that include the unknown quantity. Select the one that involves only quantities you already know from Step 2. Write this formula clearly underneath your list of known variables.
5. **Rearrange for the unknown (apply mathematics).** Use algebra to isolate the unknown variable. Move it to one side of the equation and place all known quantities on the other, following proper mathematical rules. Double-check that your rearranged equation is *dimensionally consistent* — this is the magic that often helps you find your own mistakes.
6. **Substitute and calculate (apply numbers).** Substitute each known value—with its unit—into your rearranged equation. Perform the calculation carefully and record your result with the correct number of significant figures.

Finalize

7. **Check your result (use physical intuition).**
 - *Magnitude:* Does the number make sense? Is it roughly what you expected based on the physical situation?

- *Units:* Are the resulting units correct for the quantity you calculated?

A quick mental check can often reveal arithmetic or conceptual errors before you move on.

8. **State your final answer clearly (presentation and credit).** Write your final result neatly, including both magnitude and unit. Copy it into the answer box on the front cover of your midterm. Clarity and correct units are essential for receiving full credit.

See a worked example on the next page!

Example Application of Solution Guide

Problem: Ciprofloxacin is an antibiotic that blocks bacterial DNA replication by binding enzymes in the nucleoid. After crossing the cell membrane, the drug must diffuse through the cytoplasm to reach the DNA. Assume the following: the effective step size in cytoplasm is 0.4 nm, the step (collision) time is 2.0×10^{-8} s, the motion occurs in 3 dimensions ($m = 3$) and the distance to DNA (half the bacterial diameter) is $0.8 \mu\text{m}$. Estimate the number of steps n required for a ciprofloxacin molecule to diffuse from the membrane to the DNA.

Step 1. Recognize the topic: This is a **diffusion problem** involving random motion in 3D. The mean square displacement formula will apply.

Step 2. List known quantities and convert them to SI units:

$$d = 0.4 \text{ nm} = 4.0 \times 10^{-10} \text{ m}$$

$$\tau = 2.0 \times 10^{-8} \text{ s}$$

$$m = 3$$

$$r_{\text{rms}} = 0.8 \mu\text{m} = 8.0 \times 10^{-7} \text{ m}$$

Step 3. Identify what is asked: We are asked to find the number of diffusion steps n .

Step 4. Select the appropriate formula: For a random walk in m dimensions:

$$r_{\text{rms}} = d\sqrt{mn}$$

Step 5. Rearrange for the unknown n :

$$n = \left(\frac{r_{\text{rms}}}{d\sqrt{m}} \right)^2$$

(Always check that the expression is dimensionally consistent — both sides are dimensionless here.)

Step 6. Substitute and calculate:

$$n = \left(\frac{8.0 \times 10^{-7}}{4.0 \times 10^{-10} \sqrt{3}} \right)^2$$

$$n \approx (1155)^2 \approx 1.33 \times 10^6$$

Step 7. Check the result: A few million random steps is reasonable for molecular diffusion inside a bacterial cell (the motion is microscopic and highly random).

Step 8. State your final answer:

$$n \approx 1.3 \times 10^6 \text{ steps}$$