AP Physics

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Force Diagrams and Newton's Laws
(Problem Solving Guide)

Part 1: Draw the Force Diagram

Step 1: Draw a box and place an **m** inside to represent the object's mass. Think about the forces that act on the object. What types of forces are they and in what direction do they act on the object?

Step2: Attach an arrow to the box; one for each force that acts on the object. Each arrow must show the correct direction of the force and must also have a symbol that indicates the type of force it is: $\mathbf{F_g}$ (Gravity/Weight), $\mathbf{F_n}$ (Normal), $\mathbf{F_a}$ (Applied), $\mathbf{F_f}$ (Friction). Be certain to use different subscripts for forces of the same type but which have different values.

Step 3: Next to the mass, but not attached to it, draw arrows with symbols (**a** and **v**) to show the direction of the object's velocity and acceleration.

Step 4: Near the mass, but not attached to it, draw an arrow with a plus sign that indicates the direction which you have chosen to be the positive direction. This direction will be compared to the direction of each force to determine if that force will be positive or negative in Newton's 2nd Law equation.

Part 2: Apply Newton's 2nd Law

Step1: Begin by writing Newton's 2nd Law equation $\mathbf{F_{Net} = ma}$.

Step 2: Substitute terms from the force diagram for $\mathbf{F_{Net}}$. The sign (+ or -) of the term is determined by comparing the direction of that force to the direction that was chosen to be positive in the force diagram. If the directions are the same the term gets a positive sign (+) in the equation, if the directions are opposite the term gets a negative sign (-) in the equation.

Step 3: If the acceleration **a** is not given directly, a substitution using Galileo's Equations of Motion may be required; replacing **a** in Newton's 2nd Law equation with quantities of motion from Galileo's Equations.

Step 4: Any gravity/weight $\mathbf{F_g}$ may be expressed by **mg**, since the $\mathbf{F_g = mg}$.

Step 5: Complete by algebraically solving the equation for the required quantity. Box the answer and be certain to include its correct symbol and unit.

Problem-Solving Strategy

Newton's Laws

You will need to work problems in order to deepen your understanding of the laws of motion. Developing your skills for problem solving requires practice. To help you solve problems, we summarize here the problem-solving guidelines from Chapter 1 as they apply to problems involving Newton's laws.

1. Read the entire problem carefully. Then read it again, focusing on what you are being told.
2. Draw and label a diagram of the physical situation. Draw a free-body diagram where appropriate. Choose a coordinate system and indicate it on your drawing. Include units, such as meters or kilograms, with the quantities. The diagram is more than a simplified picture, it is part of the solution. In complicated situations, drawing several free-body diagrams separates the problem into manageable pieces so that you can find the appropriate equations.
3. After you understand what is given and after you have labeled the diagram, then tackle the question. Briefly restate the question, perhaps in symbols, on your paper. It may help to make a list of the known quantities given in the problem as well as the unknown quantities being sought.
4. State the basic principles or concepts that apply. Find a mathematical relationship between the known and unknown quantities and write it in the form of an equation, or perhaps several equations.
5. Solve the equation for the unknown quantity (or quantities) so that you have an equation with only the unknown on the left-hand side of the equals sign and all of the known quantities and constants on the right-hand side.
6. Now substitute the numerical values into the equation if the problem has a numerical solution. Include both the numerical value *and* the units for each quantity. Then compute the numerical answer.
7. As a final check you should ask whether your answer is reasonable.

Problem-Solving Strategy

Free-body Diagrams

Free-body diagrams show all of the forces acting on an object. When there is more than one object involved, use of free-body diagrams helps us to isolate the forces acting on each object separately. Thus, the free-body diagram becomes a very useful tool for analyzing the motion of a physical situation. The following three steps illustrate the method.

1. Choose the object you wish to isolate and draw it along with whatever geometry and dimensions are important to solving the problem. Show objects as simple particles or blocks and keep your diagrams simple and uncluttered.
2. Draw all forces acting on the object as vector arrows, in approximately correct size and direction. Label all forces clearly.
3. Indicate a coordinate system and show the positive direction of displacement, velocity, or acceleration, depending on the problem. If you resolve vectors into components, mark out the original vector so that you don't count it twice.