Survival Guide to Concourse Physics

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Introduction

The purpose of this document is to give you a clear picture of what we expect from you in Concourse Physics. When I was a Concourse student, very little of this was written down anywhere. I picked some things up by talking to the course staff, but I had to learn a lot by trial and error. I wrote the original version of this document in the fall of 1997 as an email to the Concourse '01 class, after I graded their first problem set and realized that they were confused about many of the same issues that had confused me during my own freshman year. I have since rewritten it, added more examples, and included several new pieces of advice that I have found myself dispensing frequently over the past few years. The guide is a bit long, but that's because I have tried to make it as clear as possible. I hope you will find it helpful.

The Prose Requirement: How to Get Credit for Your Solutions

The course syllabus emphasizes that your solutions to problems in the course are to be written up in coherent English. This "prose requirement" is one of the defining characteristics of Concourse physics, and we take it very seriously.

This idea will be new for most of you, because it contrasts sharply with most high school physics classes. In high school, the objective was simply to get the answer (usually by randomly throwing equations at the problem until you find one that "works"). Here at MIT, the objective is to demonstrate to the grader that you understand how to solve the problem. You may assume that the grader is reasonably intelligent and knows physics. However, the grader cannot read your mind, so you must show your work and write prose to explain anything that is not clear about how you solved the problem. The grader should never look at your paper and wonder how you got from step 3 to step 4 – if it is not clear, then you are not doing your job properly.

Sample Problem

A box of mass 2 kg is pushed along a frictionless table with a force of 10 N. Find the acceleration of the box.

Acceptable Answer #1

By Newton's Second Law, the acceleration of the box is $\frac{\text{force on box}}{\text{mass of box}}$. Thus $a = \frac{10\text{ N}}{2\text{ kg}} = 5\frac{\text{m}}{\text{s}^2}$

This is actually more prose than you need for a problem like this one, but it illustrates the kind of thing you might write in order to clarify how you went about solving the problem.

Acceptable Answer #2

$a = \frac{F}{m} = \frac{10\text{ N}}{2\text{ kg}} = 5\frac{\text{m}}{\text{s}^2}$

This is a more efficient solution to the same problem. It contains no actual English prose at all, but since the first step $\left(a = \frac{F}{m}\right)$ is a well-known equation of physics, anyone reading the solution can easily tell that the problem is being solved using Newton's Second Law. No further explanation is necessary, because nothing is unclear.

An Insufficient Answer

$a = \frac{10\ \text{N}}{2\ \text{kg}} = 5\frac{\text{m}}{\text{s}^2}$

Here, it is not clear how the problem is being solved. A grader can justifiably ask, "How do you know that $a = \frac{10\ \text{N}}{2\ \text{kg}}$? Where did you get that from?" Of course, in a simple problem such as this one, a grader could easily use his or her own problem-solving skills to figure out where that equation came from, but the point is that the grader should never have to figure out what you did; it should be obvious from reading your solution.

Distinguishing Physics from Mathematics

From our physics-centric point of view, mathematics is a tool (actually, a large collection of tools) that we use to help us solve physics problems. The solution to a physics problem usually involves three distinct phases:

1. Translate the problem from physical language (physical quantities, verbal descriptions of what's happening in the problem, pictures, etc) to mathematical language (variables and equations).
2. Use mathematics to manipulate the equations and solve for the values of any unknown variables.
3. Translate the answer from mathematical language (the value of a variable) back to physical language (a verbal statement about the physical situation).

Phase 2 of this process involves only mathematics; it does not contain any physics at all. All of the physics happens in phases 1 and 3. This doesn't mean that you won't spend a significant amount of time on phase 2; in fact, for many problems you'll spend most of your time on phase 2. What it does mean is that you need to make a conscious effort to really pay attention to what goes on in phases 1 and 3 and try to understand it; the art of problem solving is subtle, and many students allow themselves to get so bogged down in the details of the mathematics that they completely lose sight of the physics. Try not to let this happen to you.

Please note that the prose requirement does not require you to explain every mathematical step of your solution – only the steps that require logical clarification. We assume that you understand algebra by now, and it would be a colossal waste of everyone's time (yours and the grader's) to have you write out prose fragments such as "now multiply both sides of the equation by 3." Once you have written down an equation, you may algebraically transform it as much as you like without any further explanation. Just be sure that you adequately explain how you got the *first* equation; that's the physics part of the problem.

Example

A boulder is falling from a high cliff (neglect air resistance). At time t = 0, its velocity is 7 m/s downward and it is 500 m above the ground. Find the time t at which the boulder is 150 m above the ground.

Solution

Let y be the height of the boulder above the ground.

$$y = y_0 + v_0 t + \frac{1}{2}at^2 \tag{A}$$

$$(150\ \text{m}) = (500\ \text{m}) + (-7\ \tfrac{\text{m}}{\text{s}})t + \frac{1}{2}(-9.8\ \tfrac{\text{m}}{\text{s}^2})t^2 \tag{B}$$

$$t = 7.8\ \text{s} \tag{C}$$

So the boulder is 150 m above the ground at time t = 7.8 seconds.

First we write down the general form of the equation we want to use as our mathematical model (A). Next, we incorporate the details of the physical problem into the model (B). Using algebra, we solve this equation for the variable that represents the quantity we're interested in (C). Finally, we translate our mathematical solution into a physical statement that answers the question posed by the problem.

You've probably noticed that this solution does not include any of the intermediate algebraic steps needed to get from (B) to (C). Including these intermediate steps in your own solutions is probably a good idea, because it will greatly reduce the frequency of careless mistakes in your answers; however, the omitted steps are not strictly necessary from a physics point of view, so the sample solution is acceptable as written.

When you use a more advanced mathematical technique, such as taking a derivative or an integral, we do not expect you to explain the details of how you calculated the derivative or integral, but your reason for doing it in the first place should be clear (for example, "now we use calculus to find the time when the height of the cannonball is at a maximum").

Defining variables and coordinate systems

Before you write down an equation containing a bunch of variables such as x, y, v_1, v_2, and a, make sure that the reader will understand what these variables represent. Don't forget to define reference points for quantities that need them (knowing that a car is at position $x = 5$ doesn't tell you very much if you don't know where the origin of coordinates is). For example:

Let x = position of car, measured from starting line.
Let v_1 = velocity of car
Let y = height of boulder above ground
Let v_2 = velocity of boulder
Let a = acceleration of boulder

If there's only one moving object in the problem, you can generally get away with using v, a, and x or y to represent that object's velocity, acceleration, and position *without* having to write out explicit definitions; this is a standard physics convention. Also, unless you state otherwise, we will assume by convention that the "positive directions" of your coordinate system are upward (for vertically-oriented quantities), to the right (for horizontally-oriented quantities), outward (for radially-oriented rotational quantities), and counterclockwise (for tangentially-oriented rotational quantities).

Clarifying Graphs

The same philosophy of clarification that applies to other problems also applies to drawing graphs, but there are a few extra things to be aware of. Whenever you draw a graph, you should explain the important features of your graph and the reasoning behind them, and label any points of special interest. This allows us to evaluate your solution based on what you *meant* to draw, instead of relying on your artistic skills (which vary widely from person to person). You must also label each axis of your graph with the physical quantity (or variable) that it represents.

Example

A bucket on a rope is being lowered into a well with constant speed. At time t_0, the rope is cut and the bucket begins to fall freely (neglect air resistance). Qualitatively sketch a graph showing the height of the bucket as a function of time.