A Guide to "Physics-ing"

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1 Who and What this guide is for

This document is meant as a guide to help you succeed in your physics courses. Specifically, it explains good practices in doing physics problems and demonstrates a generally reliable approach to solving them. It is intended primarily for students who are new to the study of physics, though the advice in this document is applicable for problems encountered in a wide range of physics courses.

2 What is Physics?

For a lot of students, the phrase "nightmare" comes to mind when thinking about physics, at least initially. This, of course, is not what physics actually is. It is difficult to define exactly what physics is, but much of it can be described as the study of matter and energy. Physics is both broad and deep - it includes mass, energy and interactions between them; electromagnetism; gravity; time; everything from planets to subatomic particles; and many other things. However, while physics as a whole is intricate, complex, and not easily definable, *doing* physics is actually much simpler. Essentially, the act of doing physics is an extensive exercise in *reasoning* and *problem solving*. Physics is, of course, not the only area where these skills are applied; where physics differs from many other areas where problem solving and reasoning are applied is that physics uses mathematics extensively.

3 So How do I do Physics?

To someone who is not accustomed to thinking like a physicist, the process of solving a physics problem can seem like madness – especially for those who find math frustrating – but there is a method to it. This method is sometimes referred to as the "ICE" method: Identify/Illustrate,

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Compute/Calculate, and Evaluate/Explain. The closely related “I SEE” method (Identify, Set Up, Execute, Evaluate) is used in Ref. [1]; the two describe essentially the same process to take in solving a physics problem, apart from how they group the process into steps that are easily remembered. In this document the ICE method will be used.

One source of difficulty for learning physics is that the problem statements are often very dense – there is a lot of crucial information expressed in a small number of words. This information needs to be identified and implications drawn from it. Thus, one should be prepared to read a physics problem carefully and possibly several times over.

Take the following problem as an example:

> Problem: a car is traveling around a level, circular highway off-ramp with a radius R. Given that the coefficient of static friction between the tires and the road is μ_s, what is the maximum speed v_{max} that the driver can have on this off-ramp without losing traction and sliding?

Now let's unpack this problem using the ICE method.

3.1 Identify/Illustrate:

The first part of doing physics is knowing what the problem is – this means we need to know what the situation in the problem is and what is to be solved for. The situation consists of all the known information in the problem, including pieces of information that are stated explicitly and implicitly. The thing we are to solve for is almost always some quantity (e.g. mass of a certain object or time between two events) related to the situation.

In the Identify/Illustrate section, first we identify this information. Next, we draw a diagram – drawing a diagram is always helpful, as it serves as a visual link between the problem being solved and the math used to solve it. Finally, we make assumptions which allow us to apply the formulas that are valid under those assumptions.

Identifying the information in the problem

We now extract the given information in our problem. Note that something being known does not necessarily mean we have an exact value for it. It could mean, as it does in the following case, that the quantity will be treated as if we had an exact value for it. Once the variable to solved for is expressed in terms of only numbers and known variables, the problem is solved.

In this example problem we seek to determine v_{max}, the maximum velocity that the car can obtain on the circular path before sliding off. The following information is given:

R, the radius of the circle (which the car travels around),

μ_s, the coefficient of static friction (between the tires and the road).

Additionally, we are given the following information (explicitly or implicitly):

- the car is in uniform circular motion (this is very important { it a ects many aspects of the problem, in ways which will be shown later in the process of solving this problem)
- air resistance against the car is considered negligible (this is always assumed unless otherwise stated in the problem)

Friction plays a crucial role in this problem, so it is useful to review it. The coefficient of kinetic friction is a characteristic of the materials that are in contact and the way the are being moved against each other. For any two materials under normal circumstances, they will either be slipping against each other (kinetic friction, μ_k), not moving relative to each other (static friction, μ_s), or (at least) one will be rolling on the other (rolling friction, μ_r). Here, we wish to find $v_{\max}$ such that the tire does not *slip* or *slide* away from the car's circular path; this is different from rolling. Pushing a car sideways, one would have to overcome static friction; pushing a car forwards, one would have to overcome rolling friction. Rolling friction certainly occurs between the car's tires and the road surface; however, it does not serve to keep the car moving along a circular path. Therefore, static friction is relevant to this problem whereas kinetic and rolling friction are irrelevant.

3.2 Compute/Calculate:

Newton's second law tells us that

$$\vec{F} = m\vec{a}; \tag{3}$$

and by definition, the net force is the sum of all forces acting on an object, so in this problem

$$\vec{F} = \vec{F}_{\mathrm{N}} + \vec{F}_{\mathrm{g}} + \vec{F}_{\mathrm{f}}: \tag{4}$$

The net force, as with any vector, can be expressed in terms of its components

$$\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath} + F_y\hat{k}; \tag{5}$$

where $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$ are the usual Cartesian basis vectors corresponding to the Cartesian coordinate system in Fig. 1. As described previously, there is no acceleration in the y direction or the z direction, so Eqn. 3 tells us that the net force is purely in the x direction

$$\vec{F} = F_x\hat{\imath}; \tag{6}$$

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We can combine this with Eqn. 8 to give

$$\mu_s F_N = \frac{m v_{max}^2}{R}. \qquad (11)$$

We can now apply Eqn. 4 to the y components. Recalling that the acceleration vector has no y component, Eqns. 3 and 5 imply that

$$F_y = F_{N,y} + F_{g,y} + F_{f,y} = 0. \qquad (12)$$

As can be seen in Fig. 1, the friction force has no y component, the normal force is perpendicular to the road surface in the positive y direction, and the gravitational force is perpendicular to the road surface in the negative y direction, so

$$F_N - F_g = 0 \quad \rightarrow \quad F_N = mg, \qquad (13)$$

where we have used $F_g = mg$. Finally, the z components of all of the forces in Fig. 1 are zero, so the z component version of Eqn. 4 does not provide any useful information.

At this point, we collect all the equations we have found and combine them to get an equation or system of equations which relates what we know with what we want to find, which in this case is v_{max}. Notice that we earlier combined several of the equations we found to create new equations. This means most of our work is done already.

First, we substitute Eqn. 13 into Eqn. 8, which gives

$$\mu_s mg = \frac{m v_{max}^2}{R}. \qquad (14)$$

Solving this for v_{max} gives us our final answer:

$$\boxed{v_{max} = \sqrt{\mu_s g R}}. \qquad (15)$$

3.3 Evaluate (does your answer pass the "sniff test"?)

The last step is to evaluate the answer: Is it plausible? Does it make sense? There are several ways, which work well for many physics problems, to check whether your answer is reasonable.

Dimensional Analysis

Physics deals with quantities that can be measured. In mechanics, all quantities can be expressed in terms of length, time and mass, each of which is called a *dimension* and has its own unit. Equations must be dimensionally consistent, which means that the units on both sides must be the same. We can apply this to Eqn. 15: do the units of the expression on the left hand side match the units of the expression on the right hand side?

- The units on the left hand side are speed units, which in SI units are m/s.

- In order to determine the units on the right hand side, recall that μ_s has no units, g has units of m/s^2, so the right hand side has units of $\sqrt{\mathrm{m} \ldots}$ [illegible]

physics problems. The last step is to apply this method to your own assignment and enjoy the resulting stream of \A+"s!

If you are ever stuck, there are tutors available to help you in the UFV Academic Success Centre, room G126 (Abbotsford campus) or A1212 (CEP). In addition, do not hesitate to ask your instructor: everyone in the physics department loves to help students learn physics!

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References

[1] Young, H. D. & Freedman, R. A. (2014) *Sears and Zemansky's University Physics with Modern Physics* (13th ed.). 1301 Sansome Street, San Fransisco, CA: Pearson Education, Inc.

[2] http://www.engineeringtoolbox.com/friction-coe cients-d_778.html