General Tips on How to Do Well in Physics Exams

1. **Establish a good habit in keeping track of your steps**.

For example, when you use the equation

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

to solve for d_i, you should first rewrite it as

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}, \qquad (1)$$

and then begin to put in numbers, such as:

$$\frac{1}{d_i} = \frac{1}{5\,\text{m}} - \frac{1}{6\,\text{m}} = \frac{1}{30\,\text{m}}. \qquad (2)$$

Then you'll know that what you have just got is not yet d_i, but is only $1/d_i$. So you must still do one more step to find that

$$d_i = 30\,\text{m} \qquad (3)$$

as the final answer. Now if you don't have a good habit, you would write only

$$\frac{1}{5} - \frac{1}{6} = \frac{1}{30}, \qquad (4)$$

without saying what it is really equal to. You would then forget that you have one more step to do, and simply give your answer as

$$d_i = \frac{1}{30}\,\text{m}. \qquad (5)$$

Comparing the correct answer (3) with the wrong answer (5), I hope you can now see where you are likely to make mistakes. It all boils down to the bad habit of omitting the step given as Eq. (1), and also being lazy in not paying attention to units in Eq. (4), and not explicitly noting that it is actually $1/d_i$ you have calculated there, not yet d_i. That is, you should have written Eqs. (1) and (2) instead of Eq. (4). Writing Eq. (4) instead of Eqs. (1) and (2) means that you have a bad habit, and you are lazy. You can not blame others if you get wrong answers this way.

(2) If you are to draw a figure to help you figure out the answer, avoid putting into the figure information that is not given by the problem. For example, if an angle is involved, avoid making it a right angle, or 45°, or 30°, or 60°, unless the problem says so. These are special angles with special properties which are not shared by a general angle. If the problem did not say that you have such a special angle, then you should not draw such a special angle. That is, in your drawing, you should avoid drawing any such special angles. Another example is: If a rectangle is involved in the problem, you should avoid drawing it as a square (unless it is a square). It should clearly be a rectangle. In fact, you should avoid drawing it in such a way that one side appears to be twice, or three times, etc., as long as the other side. Their ratio should not be a simple integer. It can mislead you into thinking that you have this extra information in the problem that you really don't have. Now these are just examples. I can not point out all things you are likely to do. The general guideline here is that you should avoid doing things to fool yourself into thinking that you have things you really don't have.

(3) **Do not improvise.** Physics laws do not allow you to modify them. For example, in optics, there is the equation for double-slit interference:

$$d \sin \theta = m\lambda . \qquad (*)$$

If you are given one *m* and one *d*, but two different λ's, then using the first λ, you can find the first θ, and using the second λ, you can find the second θ, but you can not put in the difference in λ, and hope to directly compute the difference in θ. That would be a misuse of the formula. That is what I mean by "improvise"! A formula does not allow you to use it in a way that it really doesn't allow. On the other hand, in the example formula given, when *d* is much larger than λ, so you know that both θ's are very small, then you can approximate sin θ by θ in radians. We then have $d\theta_1 = m\lambda_1$ and $d\theta_2 = m\lambda_2$, so taking the difference of the two equations does give you

$$d(\theta_1 - \theta_2) = m(\lambda_1 - \lambda_2) \quad \text{or} \quad \mathrm{d}\Delta\theta = m\Delta\lambda .$$

So in this case, you can indeed put in the difference of λ , and obtain directly the difference in θ . But this is an exception. It can be done in this case only because both λ and θ enter the equation linearly. This is not true with the original equation (*)! If the change in λ and θ are very small, then you can differentiate both sides of the original equation, and obtain

$$d \cos\theta \, \mathrm{d}\theta = m \, \mathrm{d}\lambda \, .$$

From this equation, you can indeed put in the very small quantity $\mathrm{d}\lambda$, and obtain directly the very small quantity $\mathrm{d}\theta$, and vice versa. But notice that it has cos θ in it, whereas the original equation has sin θ.

Another example is the equation for Doppler shift of a sound wave frequency when the source is moving with the speed v_{S}, and the listener is moving with the speed v_{L}:

$$f_{\mathrm{L}} = \frac{v - v_{\mathrm{L}}}{v - v_{\mathrm{S}}} f_{\mathrm{S}} \ ,$$

where v is the speed of sound, f_{S} is the actual frequency of the sound emitted by the source, and f_{L} is the apparent frequency of the sound heard by the listener. When solving such problems, you can not work with a relative speed, as if you are moving with the source, so only the listener is moving with the speed v_{L} - v_{S}, or moving with the listener (who is not you), so only the source is moving with the speed $v_{\mathrm{S}} - v_{\mathrm{L}}$. If you do that, you must also change v, because v is defined with respect to stationary carrier of the wave, and if you are moving with respect to the stationary carrier of the wave, then the sound speed is no longer v. If you don't take care of this point, and still work with a relative speed, then you are improvising, since you have changed the content of the equation.

If the problem is about the Doppler shift of a light wave, then the formula changes to:

$$f_{\mathrm{R}} = \sqrt{\frac{c - v}{c + v}} \, f_{\mathrm{S}} \, ,$$

where c is the speed of light, and $v \equiv v_{\mathrm{L}} - v_{\mathrm{S}}$ is the relative speed. That is, only the relative speed matters in this equation. This point actually has very sophisticated reasons behind it, and is the great discovery of Einstein. Namely, light is moving at the same speed of light no matter how fast you are moving. It also has to do with the fact that light waves have no carrier, so you can't move with respect to that non-existent carrier to change its speed.

(4) Use dimensional analysis to help you find some of your mistakes. For example, in wave theory, we have $\lambda f = c$. That is, the wave-length of the wave times the frequency of the wave is equal to the speed of the wave. The dimension, or unit, of λ is meter, or m. The dimension, or unit, of f is Hz, or 1/s. Hence the product on the left hand side of the equation has the dimension, or unit, of m/s, which is precisely the unit of the wave speed c. Now suppose you carelessly put it as $\lambda = cf$. You should be able to find this mistake easily by looking at the dimension, or unit, on the two sides of the equation. The dimension, or unit, of λ is m. But the dimension, or unit, of cf is (m/s)×(1/s) = m/s^2, which is not what you have on the left hand side of the equation, Therefore it must be wrong. As a matter of fact, this dimensional analysis immediately suggests to you that the correct formula should be $\lambda f = c$, and not $\lambda = cf$. Every formula in physics allows you to analyzing it this way, and the dimension, or unit, must be the same on its two sides.

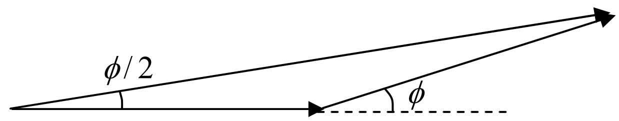
(5) Many formulas allow you to have some feeling on why certain quantities are in the numerator, and why certain other quantities are in the denominator. Take the formula for the speed of transverse wave on a string.

$$v = \sqrt{\frac{F}{\mu}}$$

where F is the tension in the string, and μ is the linear mass density of the string. In this formula, it is not difficult to see why F is in the numerator, and μ is in the denominator, and not the other way around. It is because increasing F can clearly make v larger, because neighboring molecules in the string can influence each other more easily when F is larger, and increasing μ will clearly make v smaller, because now neighboring molecules in the string will have a harder time to influence each other when μ is larger, because larger μ

means larger inertia. So you can now see that you should never write it as $v = \sqrt{\mu / F}$. (As to why there is a square root sign, dimensional analysis can help you see it.)

(6) If possible, you should use a figure to help you get things straight. For example, take the formula $I = I_0 \cos^2(\phi/2)$. You should remember the phasor diagram associated with it:



This phasor diagram not only let you see why it is $\phi/2$ and not just ϕ, as the argument of the cosine function, it also let you see that this formula is associated with the interference of two narrow light beams with a phase difference of ϕ between them, so it can't be used for the diffraction of a single wide slit, nor the diffraction of *N* narrow slits with $N > 2$. You will then not use it in the wrong place. On the other hand, you will also be able to see that you can also use this formula for the interference of two sound or radio waves generated at two point sources A and B, when the receiver is at distance d_1 form source A, and d_2 from source B. Then all you need is to also see that in this case, $\phi = 2\pi(d_1 - d_1)/\lambda$. On the other hand, if two light beams are interfering in phase to begin with, and a thin glass plate with index of refraction n and thickness t is inserted into one beam perpendicular to the beam, leaving the other beam undisturbed, then the above formula can also be used, except that now

$$\phi = 2\pi\left(\frac{t}{\lambda/n} - \frac{t}{\lambda}\right) = 2\pi(n-1)\frac{t}{\lambda},$$

because it is the <u>change</u> of phase of one beam (that is, a new phase, ,$2\pi[t/(\lambda/n)]$ minus an old phase, $2\pi[t/\lambda]$), with the phase of the other beam unchanged. So it is also the difference between the phases of the two beams after the glass plate has been inserted, if they are in phase before the glass plate is inserted. Note that in all these cases when the formula can be used, there are always two narrow beams of some wave interfering while there is a phase difference between them.

Many formulas allow you to understand them using some sort of figures. So you should learn such formulas this way, and not try to just memorize them.

(7) If the problem gives you a quantity, and you did not use it to get your answer, then you should ask yourself the following question: Should the answer be independent of this quantity? Assuming that it is true, then you should be able to change the value of this quantity to, say, zero, or infinity (if allowed). But the correct answer for these cases might be very easy to see. If it disagrees with your answer, then you know that your answer must be wrong, and the correct answer should depend on this quantity. For example, take the problem of inserting a glass plate into one beam, and you are asked the intensity change when it is interfering with another beam. If your answer does not depend on the thickness t of the glass plate, then you should see that it has to be wrong, since for t equal to zero, we have no glass plate, and the phase shift must be zero! So how can you find a non-zero answer that is independent of t?

(8) Even when a quantity does enter your solution, you can still ask whether it has entered correctly. Let us again take the glass-plate-insertion problem as an example. If you give the phase shift as

$$\phi = 2\pi\left(\frac{t}{\lambda / n}\right) = 2\pi n\frac{t}{\lambda},$$

then you can ask whether n has entered correctly. Well, you can look at the case when n =1. The glass plate has been replaced by a layer of air. That is, nothing is now inserted into the beam path. The phase shift should clearly be zero in that case. But is your answer zero in that case? It is not if ϕ is given by the above equation. So you know it has to be wrong! It immediately reminds you that you forgot to subtract the phase due to a layer of air of the same thickness. That is, you did not compute the change.

Of course, if you know nothing about what is a phase, all these remarks are useless to you. You must learn the general concepts first.