Evaluation Tasks

1 What are they?

During a physics course, students are expected to identify, correct, and learn from their mistakes with the help of an instructor. This aid may come in many forms, such as when an instructor provides problem solutions to a class, or tutoring to an individual student. However, in each case the student relies upon an instructor (or sometimes a textbook) in order to determine whether, and how, their work is mistaken. Since the students are not given any other means with which to evaluate their work, the students come to see evaluation by external authorities as the only way for them to identify and learn from their mistakes. This dependence on external evaluation has several negative effects on students, detracting from their ability and desire for learning.

In order to evaluate information, one must have some criteria for judging the correctness of the information, and a strategy for performing the judgment. There are several sets of criteria and strategies which are commonly used by practicing physicists, and if we want physics students to become self-evaluators they too must value and use these strategies. Each of these strategies relies upon hypothetico-deductive reasoning [Lawson], whereby the information is used to create a hypothesis which is then tested. The logical sequence for this testing can be characterized as: If (general hypothesis) and (auxiliary assumptions) then (expected result) and/but (compare actual result to expected result), therefore (conclusion). For example, when evaluating an equation with dimensional analysis, the logical sequence is:
If the equation is physically self-consistent,
And I correctly remember the units for each quantity in the equation,
Then I expect the units for each term in the equation to be identical,
And/But the units for each term are/are not identical,
Therefore the equation is/is not physically self-consistent.

2 Why do you want to use them?

Evaluation plays a central role in learning since it incorporates strategies for:

1. Identifying and correcting mistakes (allowing students to self-regulate their knowledge)

2. Developing new connections between ideas

3. Integrating knowledge into a coherent structure

This claim is supported by research from such diverse areas as reading, writing, history, biology, mathematics, and physics education. The ability to evaluate ones thought and work has two major components:

1. An awareness that evaluating ones own thought and work is an important and beneficial process to engage in.
2. An understanding of several strategies for evaluating ones own thought and work.

Our tasks are designed to help students develop both components, and thereby help the students become self-correcting learners. This has the short-term benefit of improving their performance in physics class, and the long-term benefit of improving their general ability to learn.

3 How do you use them?

The use of the evaluation tasks may be adapted to suit particular needs, but there is a general method for which they are designed. This method engages the students in a process of activity, feedback, and reflection which may be iterated several times. I

1. Introduction: Instructor leads a general discussion introducing students to the format and goals of the task.
2. Preliminary Activity: Students work on a task (as individuals or groups). This may be done in lectures, recitations, workshops, or labs.
3. Preliminary Review: Students either self-assess their work using the provided rubrics, or an instructor assesses their work and provides feedback to the students to help them improve their performance. Students should then be given time to reflect on their work and any feedback theyve gotten, and to ask questions.
4. Follow-up Activity: Students work on a similar task (same physics topic, same type of task) in order to try learning from the feedback provided in step iii. This work may be included as part of their homework.
5. Follow-up Review: Student work on the follow-up activity is assessed, and time allowed for feedback and student questions.

Step (i) may be skipped after the students have had sufficient experience with these types of tasks and are familiar with the basic task formats and strategies. The evaluation tasks may also be included on exams, as a form of summative assessment.

4 What are some types?

There are several types of evaluation tasks, and each category has its own set of goals. However, the basic design of all evaluation tasks is the same: the students are asked to somehow evaluate a proposed problem solution.

1. *Evaluation by Comparison*: The goal of these tasks is to help make students aware of some common mathematical errors and conceptual misperceptions. The proposed solution that the students are asked to evaluate has a few typical mistakes in it, and the students must find the mistakes in the problem by solving it on their own and then comparing their solution with the provided solution. Another way to use this strategy is to evaluate consistency between different representations, for example by determining whether a given free-body diagram is consistent with a description of the situation.

2. *Evaluation by Dimensional Analysis:* The goal of these tasks is to help students learn how to use dimensional analysis as a strategy for checking their own work, and also to help them develop a deeper conceptual understanding of physics equations and quantities. The students are presented with a solution and asked to check the dimensions of the equation in order to determine whether it is self-consistent (all terms in the equation must have the same dimensions).

3. *Evaluation by Limit/Special-Case Analysis:* The goal of these tasks is to help students learn how to use limit/special-case analysis as a strategy for checking their own work, and also to help them better understand how different equations, ideas, and theories are related to one another. The students are presented with a proposed problem solution/model/conceptual claim and asked to determine whether it makes sense in certain limiting/special cases.

4. *Evaluation by Assumption Analysis:* The goal of these tasks is to help students learn how to identify and judge the assumptions which are often made when solving physics problems. The students are presented with a proposed problem solution and asked to identify and evaluate any assumptions which are required for the solution to give an accurate answer. Also, the students may be asked to identify factors which could cause the assumptions to be false.

5. *Evaluation by Estimation:* The goal of these tasks is to help students learn the typical magnitudes which different quantities have, and how to use this knowledge in order to check their own work. The students are presented with a proposed problem solution or model, and asked to evaluate it by comparing the magnitudes for various quantities in the equation (each side of the equation should have roughly the same order of magnitude). Each of these tasks can be extended by asking the students to modify and correct any solutions/models/claims that are incorrect.

5 How do you score them?

We have developed several rubrics which characterize the typical levels of performance on the different types of tasks, and which assign scores to each level of performance. The levels of performance reflect the different levels of ability development many students exhibit.

While the instructor should use the rubrics to assess student performance, the students themselves may also be given the rubrics. When the students are first given the rubrics, the instructor should explain what they are, and how they are used. This may best be done by providing the students with several different example solutions to an evaluation task, and explaining how each example solution would be assessed with the rubrics. After a few examples, the students may be given the opportunity to assess their own work on evaluation tasks administered during lectures or labs.

Example:
While studying for the physics exam, you come across the following equations which model the properties of a convex mirror:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad and \quad f = \frac{R}{2}$$

Do a limit-case analysis to evaluate this model. What relation do you get between d_o and d_i for that limiting case? Does this relation make sense? Explain why or why not.

Ideal Response:
When $R = \infty$, the convex mirror becomes a plane mirror (a circle of infinite radius is just a straight line). So we expect $d_o = -d_i$. In this limit case the focal length is infinite, so

$$\begin{aligned} \frac{1}{\infty} = \quad 0 \quad &= \frac{1}{d_o} + \frac{1}{d_i} \\ \frac{1}{d_o} &= \frac{-1}{d_i} \\ d_o &= -d_i \end{aligned}$$

This is what we expected, therefore the model makes sense in this limiting case.

Sample Response:
When R = the convex mirror becomes a plane mirror. We get

$$\begin{aligned} \frac{1}{\infty} = \quad 0 \quad &= \frac{1}{d_o} + \frac{1}{d_i} \\ \frac{1}{d_o} &= \frac{-1}{d_i} \end{aligned}$$

This makes sense.

Example of Scoring Using Scientific Abilities Rubrics

Scientific Ability	**0**	**1**	**2**	**3**
Is able to analyze a relevant limiting/special case for a given model, equation, or claim.	No attempt is made to analyze a relevant limiting/special case.	An attempt is made to analyze a limiting/special case, but the identified limiting/special case is not relevant.	An attempt is made to analyze a relevant limiting/special case, but the students analysis is flawed.	A relevant limiting/special case is correctly analyzed.

SCORE: 2

This is scored as a 2 according to the special/limiting-case analysis rubric, since the student identified a relevant limiting case but did not properly analyze it (they did not state their expectation for what the model should say in this limiting case, and this is why they did not give any explanation for why they believed their result to make sense).