List of All Rubrics

Scientific Literacy

Students will have a basic understanding of major scientific concepts and processes required for personal decision-making, participation in civic affairs, economic productivity, and global stewardship.

Students use evidence-based reasoning to form testable hypotheses about the natural world

At an introductory level, students are not yet prepared to fully design and execute effective experiments. But having simple steps to follow with machine-like obedience will do nothing to develop a sense of the investigation and discovery so vital to scientific advancement. These three rubrics aim to have students think about the reasons for each action taken during lab.

	No Effort	Progressing	Expectation	Scientific
SL.A.a Is able to analyze the experiment and recommend improvements. Labs: 1, 2, 5, 10, 11	No deliberately identified reflection on the efficacy of the experiment can be found in the report	Description of experimental procedure leaves it unclear what could be improved upon.	Some aspects of the experiment may not have been considered in terms of shortcomings or improvements, but some are identified and discussed.	All major shortcomings of the experiment are identified and reasonable suggestions for improvement are made. Justification is provided for certainty of no shortcomings in the rare case there are none.

This task is to be completed at the end of a lab, but taking notes throughout the lab when you have thoughts on how something is inadequate to your needs will certainly help. If you were performing an experiment of your own design to investigate a matter of interest to you, then all of your time and energy would be devoted to making certain you are getting the best results possible with appropriate equipment and methods.

No experiment ever provides flawless knowledge. What we believe to have measured accurately can be found to be seriously flawed when the same measurement is performed with better tools or with a different approach. The idea is to think about the experiment you performed and all the tools you used, and determine any way in which your data could have been more accurate or the experiment could have better reflected the phenomena of interest.

It is always possible to find minor improvements, but the true objective is to identify those things which are most easily changed for the greatest impact. Each piece of equipment should be considered for the role in the experiment and how it could perform better (for example, a ruler could instead have been a caliper, allowing sub-millimeter accuracy). Then those potentials for improvement should be considered for how large of an impact they could have on the experiment. Finally, some mention should be made of how to improve, or an explicit statement of having attempted to think of a better approach and failing. It is also acceptable to discuss personal shortcomings for this rubric: If the group failed to understand instructions or had problems performing the tasks required for the experiment.

Progressing is assigned when a student is unable to explain what shortcomings there are in a manner the reader can comprehend or when no discussion of how to improve on the shortcomings is presented. Scientific is assigned when a student identifies all shortcomings which have a significant impact on the experimental outcomes and has a reasonable discussion on how to improve the experiment in a realistic manner.

	No Effort	**Progressing**	**Expectation**	**Scientific**
SL.A.b Is able to identify the hypothesis for the experiment proposed Labs: 3, 4, 6, 7, 9, 12	No deliberately identified hypothesis is present in the first half page or so of notes	An attempt is made to state a hypothesis, but no clearly defined dependent and independent variable, or lacking a statement of relationship between the two variables	A statement is made as a hypothesis, it contains a dependent and independent variable along with a statement of relationship between the two variables. This statement appears to be testable, but there are some minor omissions or vague details.	The hypothesis is clearly stated and the direct link to the experiment at hand is apparent to any reasonably informed reader.

A hypothesis is a proposed statement of a relationship between two variables. One variable is the independent variable – a value which we can control through choices in setting up each experimental trial – and the other one is the dependent variable – a value which we will measure as a result of each experimental trial.

Forming this hypothesis absolutely must be done prior to running any experimental trials, as your hypothesis informs you what to change between trials (the independent variable), and what to measure during them (the dependent). Knowing how the two values are related is not an important part of the hypothesis. You make a speculation based on your prior knowledge if they are proportionally or inversely related (both increase in tandem, or as one increases the other decreases), or even if there is no relationship at all (changing the independent won't have any reliable impact on the value of the dependent). Then through experimentation you will determine what the relationship truly is.

As we often deal with far more than two variables in a given lab, you will often have more than a single hypothesis during a lab.

Typically in science you seek to use your experiment to prove that your hypothesis is not correct, as even if you show something to be true a dozen times you cannot say if it is always true, but if you show it to be false just one time you know for certain that it is not true.

Progressing is assigned when it is unclear which two variables are being discussed, or even just unclear which variable is controlled and which is measured, and when there is no attempt to make an initial statement as to the relationship between the variables. Scientific is assigned when the hypothesis makes it clear which variables are being considered, how they will come in to play in the experiment, and what results are anticipated.

	No Effort	Progressing	Expectation	Scientific
SL.A.c Is able to determine hypothesis validity Labs: 3, 4, 6, 7, 9, 12	No deliberately identified attempt to use experimental results to validate hypothesis is present in the sections following data collection.	A statement about the hypothesis validity is made, but it is not consistent with the data analysis completed in the experiment	A statement about the hypothesis validity is made which is consistent with the data analysis completed in the experiment. Assumptions which informed the hypothesis and assumptions not validated during experimentation are not taken into account.	A statement about the hypothesis validity is made which is consistent with the data analysis and all assumptions are taken into account.

You form your hypothesis before the experiment ever begins, but you make a statement about the validity of the hypothesis after the experiment has concluded. When formed, the hypothesis included a statement of the relationship between the independent and dependent variables. The experiment tested that relationship. And so when the experiment is done you go back and reflect on your hypothesis with your new knowledge.

No experiment can ever *prove* any hypothesis. Your experiment can disprove the hypothesis (shows a case where the relationship absolutely is not what you stated it would be), or it can *support* the hypothesis (you did your best to disprove the hypothesis and failed). Disproving your hypothesis does not prove the opposite of your hypothesis any more than failing to disprove your hypothesis would prove that initial statement. But when you do disprove your hypothesis you should consider the experiment from that point out as an attempt to now disprove the inverse of your hypothesis (so if you said when an object is dropped it flies up to the ceiling, and then found one case where it instead fell to the floor, you would know that the hypothesis that objects fall up is not true, and would now seek to check if the inverse hypothesis that things fall down can be disproven as well. If you managed to disprove both cases, then your experiment would be one which supports the *null hypothesis*, a statement that there is no relationship between these two variables.

Of course, it is always possible that other factors were important besides those which we paid attention to. In mechanics friction is unavoidable, but often ignored. This is an assumption that friction has only a minor contribution to the outcome of the experiment. Unless the actual impact of friction is measured, any statement about the impact from it is just an assumption. We also assume things like a table being flat, or an experiment being unaffected by the amount of light in a room.

A large part of science is learning how to determine what assumptions are being made, and which ones may be relevant to the experiment.

Progressing is assigned when a student fails to understand their own data and makes an incorrect statement about the validity of the hypothesis. Scientific is assigned when a student correctly interprets their data and considers the assumptions which informed the design and outcome of the experiment.

Students demonstrate understanding of key concepts or basic principles in the discipline

Physics explains that natural world through discovery and explanation of patterns. We discover these patterns with careful observation and precise measurement via appropriate tools. These three rubrics ask you to consider how we measure the world, to understand the patterns observed in the world, and to acknowledge the differences between measured values and real values.

	No Effort	Progressing	Expectation	Scientific
SL.B.a Is able to explain operation and limitations of measurement tools Labs: 1, 2, 5, 10, 11	At least one of the measuring tools used in lab lacks a clear identification of precision/limitation	All measuring tools are identified with mention of the precision/limitation of each tool, but no details on how measurements are performed	All measuring tools identified with precision/limitation of each tool listed. Description of how to measure using some tools may be incorrect/vague, or precision may not be adequately justified.	All measuring tools are identified with proper precision values and thorough discussion of limitations. Descriptions on how to make measurements are complete and could be understood by readers with no prior familiarity with the measuring tools.

Measuring things reduces the complexity of the object to a simple number. This is phenomenal for allowing us to handle a lot of information quickly, but can lead to blind spots. It is vital to understand precisely what you are measuring and how accurately you are doing so. If I use a ruler to measure the length of a book, but I place the ruler across the book at an angle, then calling the resulting number the length of the book is incorrect. If I ask a dozen people to use a 12 inch ruler to measure the width of a hair or the length of a football field, I will find that the answers do not agree with one another at all. Each tool used to make measurements has limitations in what it can measure, and must be used in specific ways for the measurement to be valid. In many cases your lab manual will ask you to find values without mentioning what tools to use for measurement. You must select the appropriate tool and use it properly, while keeping in mind the limitations of the tool. Even when told what instrument to use and how to use it, taking the time to describe the measurement can help focus the mind on proper procedures.

Discussions of how to perform measurements included in your lab notebook should assume that the reader does not have access to the lab manual, and so cannot benefit from instructions provided in the manual for how to set up equipment. Much of the descriptions which satisfy this rubric can be prepared in advance of attending lab.

Progressing is assigned when students make no mention of the details for how they will perform measurements (ie - "we will use a meter stick to find the height." instead of "We will measure from the floor straight up to the bottom most point of the object"), scientific is assigned when students are completely clear on details involved in measurement and limitations of the tool precision.

	No Effort	Progressing	Expectation	Scientific
SL.B.b Is able to explain patterns in data with physics principles Labs: 1, 2, 5, 8, 10, 11	No attempt is made to explain the patterns in data	An explanation for a pattern is vague, OR the explanation cannot be verified through testing, OR the explanation contradicts the actual pattern in the data.	An explanation is made which aligns with the pattern observed in the data, but the link to physics principles is flawed through reasoning or failure to understand the physics principles.	A reasonable explanation is made for the pattern in the data. The explanation is testable, and accounts for any significant deviations or poor fit.

Physics relies heavily on observing patterns to describe the world around us. But finding a pattern alone is not sufficient to improve your understanding of physics. Being able to link patterns you observe to formula you work with in the lecture course is the aim of this rubric item.

Progressing is assigned when students are unable to understand their data or attempt to provide blanket proposals. Scientific is assigned when students demonstrate a clear understanding of the connection between physics formulas and experimental results.

	No Effort	Progressing	Expectation	Scientific
SL.B.c Is able to explain steps taken to minimize uncertainties and demonstrate understanding through performance where able. Labs: 3, 4, 7-9, 11	No explicitly identified attempt to minimize uncertainties and no attempt to describe how to minimize uncertainties present	No explicitly identified attempt to minimize uncertainties is present, but there is a description of how to minimize experimental uncertainty.	An attempt is made and explicitly identified for minimizing uncertainty in the final lab results, but the method is not the most effective.	The uncertainties are minimized in an effective way.

Any measurement we make includes some degree of interpretation by the observer. If you are using a ruler to measure a length and the object falls between two markings on the ruler, you have to decide what value to use for your final decimal place in the recorded measurement. When an object is not a true rectangle, but you are asked to find the surface area through measuring length and width you must decide which length and width to measure and how to handle the abnormal shape. Many other cases like these will come up regularly in your experiments. At other times there are practical limitations, like if you use a stopwatch to time something, then your reaction speed will dictate how long after the event actual ends you manage to stop the timer.

Progressing is assigned when students mention possible approaches to reduce uncertainties but do not make it clear to the reader that they have done so during the experiment. Scientific is assigned when students clearly explain how to reduce uncertainties and demonstrate that they have followed their own procedures throughout the experiment.

Critical Thinking Rubrics

Students will use reason, evidence, and context to increase knowledge, to reason ethically, and to innovate in imaginative ways.

Students identify and evaluate the key evidence underlying scientific theories

In these four rubrics, students carefully record their observations and evidence gathered in each experiment, and pay attention to why they record specific information and why they do not record the rest of what is observed. All science starts and ends with observations of either the physical reality before us or of the possibilities left open by combining various established explanations of that reality.

	No Effort	Progressing	Expectation	Scientific
CT.A.a Is able to compare recorded information and sketches with reality of experiment Labs: 2-7, 9, 12	No sketches present and no descriptive text to explain what was observed in experiment	Sketch or descriptive text is present to inform reader what was observed in the experiment, but there is no attempt to explain what details of the experiment are not accurately delivered through either representation.	Sketch and descriptive text are both present. The sketch and description supplement one another to attempt to make up for the failures of each to convey all observations from the experiment. There are minor inconsistencies between the two representations and the known reality of the experiment from the week, but no major details are absent.	Sketch and description address the shortcomings of one another to convey an accurate and detailed record of experimental observations adequate to permit a reader to place all data in context.

A significant requirement of your lab notebook is to give the reader the sense that they know what happened during your experiment to a degree that they would be able to repeat what you have done, but would not feel the need to do so. This means providing a clear picture in both words and literal pictures to the reader to capture as many details as you can without causing undue distraction. Carefully recording your observations and being honest about the limitations of your records is important here. Often times a quick drawing will not have items in the proper locations or will fail to maintain proper scale. This is only a problem if the reader is left to believe that the drawings are more accurate than they really are. And written descriptions can be incredibly detailed, but leave readers completely confused due to excessive details or poor writing practices. Analogies are frequently used in discussing science concepts, but without a discussion of how the analogy begins to fail, such discussions can cause more harm than good. Thus having both a written description and a sketch is the ideal approach.

Progressing is assigned when students provide a description and/or sketch with flaws in it and make no attempt to figure out those flaws on their own. Scientific is assigned when a sketch is present along with a description of finer details not captured accurately through the sketch alone.

	No Effort	**Progressing**	**Expectation**	**Scientific**
CT.A.b Is able to identify assumptions used to make predictions Labs: 3, 4, 6, 7, 9, 12	No attempt is made to identify any assumptions necessary for making predictions	An attempt is made to identify assumptions, but the assumptions stated are irrelevant to the specific predicted values or apply to the broader hypothesis instead of the specific prediction	Relevant assumptions are identified regarding the specific predictions, but are not properly evaluated for significance in making the prediction.	Sufficient assumptions are correctly identified, and are noted to indicate significance to the prediction that is made.

There is a very important distinction between a prediction and a hypothesis. A hypothesis states two variables and a relationship between them which will be tested in the course of experimentation, but a prediction states as accurately as possible an exact outcome of a specific trial set. Thus a prediction starts from the hypothesis and any data already acquired in earlier trial runs, and then through a few assumptions you decide on a numerical range as small as possible in which you anticipate the measurements in your trial to land. As you perform more experimental trials, your predictions for each one should become more accurate, as you will begin to refine the assumption used in each prediction. These assumptions can be formal things like assuming that the Conservation of Energy applies, or informal things like the magnitude of impact from air resistance. Stating precisely what assumptions you are making is important, as well as stating exactly how these assumptions will influence your predicted value range.

Progressing is assigned here when students fail to identify assumptions which have an actual impact on the value being measured. Scientific is assigned when students identify relevant assumptions and accurately state the nature of their impact on the measurement.

	No Effort	Progressing	Expectation	Scientific
CT.A.c Is able to make predictions for each trial during experiment Labs: 3, 4, 6, 7, 9, 12	Multiple experimental trials lack predictions specific to those individual trial runs.	Predictions made are too general and could be taken to apply to more than one trial run. OR Predictions are made without connection to the hypothesis identified for the experiment. OR Predictions are made in a manner inconsistent with the hypothesis being tested. OR Prediction is unrelated to the context of the experiment.	Predictions follow from hypothesis, but are flawed because relevant experimental assumptions are not considered and/or prediction is incomplete or somewhat inconsistent with hypothesis or experiment.	A prediction is made for each trial set in the experiment which follows from the hypothesis but is hyper-specific to the individual trial runs. The prediction accurately describes the expected outcome of the experiment and incorporates relevant assumptions.

After figuring out what assumptions need to be made in order to predict an accurate range in which you anticipate your measurements to occur, you must then state what that predicted range is. This should be done every time that the equipment is adjusted since those adjustments should result in different measurement ranges, or those adjustments are being made to test that they are not relevant, in which case you must explicitly state that you predict no change from your previous measured ranges. As stated in CT.A.b, the predictions should be informed by the hypothesis, but should be specific values which are only relevant for this precise set up of your experiment.

Progressing is assigned here when predictions are too broad or have no justification. Scientific is assigned when predictions are made for every trial run with narrow ranges that accurately encompass the actual measured values.

	No Effort	Progressing	Expectation	Scientific
CT.A.d "Is able to identify sources of uncertainty " Labs: 3, 4, 7-9, 11 No attempt is made to identify experimental uncertainties.	descworst	An attempt is made to identify experimental uncertainties, but many sources of uncertainty are not addressed, described vaguely, or incorrect.	Most experimental uncertainties are correctly identified. But there is no distinction between random and experimental uncertainty.	All experimental uncertainties are correctly identified. There is a distinction between experimental uncertainty and random uncertainty.

As discussed in SL.B.a out measurement tools have limitations in how accurately they can make measurements. When we use measurements which are not absolutely accurate (and none are), then the values we find by using those measurements in equations are also not absolutely accurate. In addition to that, we are measuring real world values, and there are numerous factors which can influence the results of our experiment beyond those which we have control over. These factors should be addressed in our assumptions, and include things like friction, wind, and variations in material quality. These sort of uncertainties contribute to the fact that we get different measurements even when we believe that two trial runs were set up the same. This is why our predictions must be ranges and not single values.

In this rubric, you are meant to describe what contributes to the uncertainty in your measurements. Ideally you can make a distinction between random uncertainties (things you cannot control nor predict) and experimental uncertainties (things which could be less uncertain with better procedures or tools).

Progressing is assigned when students are unable to identify relevant uncertainties with any precision. Scientific is assigned when a student makes it clear precisely what contributes to the uncertainty in their experiment and properly identifies those uncertainties as random or experimental.

Students demonstrate understanding of the role of controlled experiments in the scientific process OR Students test hypotheses using appropriate methods involving data collection and analysis, and make valid inferences from results

This rubric category is at the heart of experimentation, and many of the rubrics could be assigned here as well as in the categories where they exist now. The two rubrics included in this category look for students to distill the experiment to the purpose and the most important data.

	No Effort	Progressing	Expectation	Scientific
CT.B.a Is able to describe physics concepts underlying experiment Labs: 1, 2, 5, 8, 10, 11	No explicitly identified attempt to describe the physics concepts involved in the experiment using student's own words.	The description of the physics concepts underlying the experiment is confusing, or the physics concepts described are not pertinent to the experiment for this week.	The description of the physics concepts in play for the week is vague or incomplete, but can be understood in the broader context of the lab.	The physics concepts underlying the experiment are clearly stated.

This should be completed before coming to lab each week. Through research in your text book or various online sources, you should arrive at lab understanding the physics involved in the experiment for the week with a solid idea of what will be happening during lab.

Knowing what you expect to do and what results should be observed will inform your development of a hypothesis and of individual predictions. It will help you to decide what assumptions are being made, and determine what limitations the equipment force upon your experiment. The title of the lab alone should give students a clear indication of what to focus their preparation on, and the manual will illustrate how lab will proceed.

Search YouTube for "The Monkey Business Illusion" for a clear example of why you cannot properly observe an event without knowing what to expect in advance. This is another reason why coming to lab fully prepared for the material is important, because you can easily be distracted by irrelevant details if not properly prepared.

Be especially mindful of plagiarism in this rubric, as copying directly from your sources does not show you understand the material, and is a violation of the WSU Academic Honesty policy.

Progressing is assigned here when students show that they are still uncomfortable with the physics concepts for the week, and hopefully students will realize this problem and ask questions at the start of lab to supplement their understanding. Scientific is assigned when students demonstrate a clear understanding of physics concepts involved in the lab by stating them in their own words.

	No Effort	Progressing	Expectation	Scientific
CT.B.b Is able to identify dependent and independent variables Labs: 1, 2, 5, 11	No attempt to explicitly identify any variables as dependent or independent	Some variables identified as dependent or independent are irrelevant to the hypothesis/experiment, or some variables relevant to the experiment are not identified	The variables relevant to the experiment are all identified. A small fraction of the variables are improperly identified as dependent or independent.	All physical quantities relevant to the experiment are identified as dependent and independent variables correctly, and no irrelevant variables are included in the listing.

This rubric also should be compelted before you arrive at lab for the week. Knowing what values you can control in an experiment and which ones you need to measure is critical to performing any experiment. It is also relevant to how you present your data to a reader. In most of our labs we explicitly inform you which variables are important, and the procedures make it clear which ones you have control over. But the lab notebook is intended to be recorded for a reader to understand without access to the lab manual. Building the habit of explicitly identifying your controlled and measured variables will improve your presentation of information in the future.

Progressing is assigned when students are unable to clearly state all values involved in the experiment. Scientific is assigned when students identify appropriate which variables are independent and which are dependent.

Quantitative Reasoning Rubrics

Students will solve quantitative problems from a wide variety of authentic contexts and everyday life situations.

Without the data experimentation doesn't exist. Knowing how to work with your data is vital to being able to understand what the data is telling you.

	No Effort	Progressing	Expectation	Scientific
QR.A Is able to perform algebraic steps in mathematical work. Labs: 2-4, 6-12	No equations are presented in algebraic form with known values isolated on the right and unknown values on the left.	Some equations are recorded in algebraic form, but not all equations needed for the experiment.	All the required equations for the experiment are written in algebraic form with unknown values on the left and known values on the right. Some algebraic manipulation is not recorded, but most is.	All equations required for the experiment are presented in standard form and full steps are shown to derive final form with unknown values on the left and known values on the right. Substitutions are made to place all unknown values in terms of measured values and constants.

We deal with quite a few formula throughout physics, and seeing letters in an equation doesn't always mean you are looking at variables since we also deal with units to identify which values measure what variables. In addition, many times we need to apply the same formula to multiple sources of information, and will denote this through subscript notation, which adds even more letters which are not actually variables to equations. As with CT.B.a and CT.B.b, this should be compelted before you come to lab each week.

It is absolutely vital to form a habit of manipulating your equations without inserting any known values until you have a final form of the equation ready.

Progressing is assigned here if students fail to identify all equations required for the experiment. Scientific is assigned when students identify all equations required in their standard form, and show all algebra and substitutions involved in setting up final forms of the equations for use in the experiment.

	No Effort	Progressing	Expectation	Scientific
QR.B Is able to identify a pattern in the data graphically and mathematically Labs: 1, 2, 5, 8, 10, 11	No attempt is made to search for a pattern, graphs may be present but lack fit lines	The pattern described is irrelevant or inconsistent with the data. Graphs are present, but fit lines are inappropriate for the data presented.	The pattern has minor errors or omissions. OR Terms labelled as proportional lack clarity - is the proportionality linear, quadratic, etc. Graphs shown have appropriate fit lines, but no equations or analysis of fit quality	The patterns represent the relevant trend in the data. When possible, the trend is described in words. Graphs have appropriate fit lines with equations and discussion of any data significantly off fit.

If you want to show a relationship between two variables, you need to use a graph. Tables are great for showing a large list of single value variables and discussing how they all interact, but to get a pattern to show or to establish a relationship you want to use a graph and focus on two variables at a time. Once you have a graph of your data, you need to be able to identify the pattern displayed as accurately as possible. This is done with finding a fit line, and including the equation for that line.

In the event your data contradicts known physics principles, you still need to explain the pattern which does show up in your data. You will likely want to also discuss why you believe that your data conflicts with known physics. This explanation would be needed by rubrics CT.B.a and CT.A.d anyway. Failing to find a pattern which aligns with physics principles will make your discussion for rubric SL.B.b quite a bit more interesting as well, and should lead to many ideas for SL.A.a

Due to uncertainties and data measurements happening in ranges, finding these patterns can be difficult, especially if the data taken was not taken well. This rubric focuses on how well you work with the data you have, while other rubrics have dealt with how good of data you acquire. Remember whenever you present a graph to place the independent variable (the one you control) on the X axis (horizontal) and the dependent variable on the Y axis. Also do not leave lines connecting your data points, as a line implies that anywhere you add a point along that line is as valid as data which was collected. This is not the case in our labs, as we did not gather data for those specific values of our independent variable, and our uncertainties mean we cannot say what the actual data point would be. The fit line accounts for the uncertainties in each reading and includes a term to explain how far off of the line new data is expected to be.

Progressing is assigned when an improper fit line is used in a graph or a written description of a pattern is incorrect. Scientific is assigned when both a written description and a graph are present with a proper fit line and equation for the fit line.

	No Effort	Progressing	Expectation	Scientific
QR.C Is able to analyze data appropriately Labs: 1-12	No attempt is made to analyze the data.	An attempt is made to analyze the data, but it is either seriously flawed, or inappropriate.	The analysis is appropriate for the data gathered, but contains minor errors or omissions	The analysis is appropriate, complete, and correct.

In QR.A you were asked to perform all algebraic manipulation before inserting any known values. Now you are being instructed to insert the units of your values without the numbers so that you can focus on making sure that your units make sense. Unit analysis can show you when a unit conversion is needed (like converting millimeters to meters) and it can show you when terms are missing from your equation (it is not possible to add two variable sets with different units, and units should be the same on both sides of an equal sign). Attempting to evaluate units and numbers at the same time can cause quite a mess in larger equations, so even in simple equations it is good to work on developing good habits of treating the units apart from the numerals.

Progressing is assigned when units are not placed in SI form or appropriately converted from SI form to the scale appropriate to the lab work, or when there are clear conflicts in the treatment of units in the equations. Scientific is assigned when students use unit analysis to verify equations are accurate throughout the lab.

Information Literacy Rubrics

Students will effectively identify, locate, evaluate, use responsibly, and share information for the problem at hand.

Your existing information literacy skills are going to be vital for arriving at lab prepared for the experiment each week. I advise you to check out OpenStax, MIT OpenCourseWare, EdX, and Coursera. Other resources exist, such as Khan Academy and Hyper Physics. Just be sure to validate any information you find by checking it against at least one other known reliable source.

But in this category the information literacy we are focusing on developing purposefully during lab are about pulling information from the real world and recording it to share with others.

	No Effort	Progressing	Expectation	Scientific
IL.A Is able to record data and observations from the experiment Labs: 1-12	"Some data required for the lab is not present at all, or cannot be found easily due to poor organization of notes. "	"Data recorded contains errors such as labeling quantities incorrectly, mixing up initial and final states, units are not mentioned, etc. "	Most of the data is recorded, but not all of it. For example measurements are recorded as numbers without units. Or data is not assigned an identifying variable for ease of reference.	All necessary data has been recorded throughout the the lab and recorded in a comprehensible way. Initial and final states are identified correctly. Units are indicated throughout the recording of data. All quantities are identified with standard variable identification and identifying subscripts where needed.

This rubric is all about recording information to share with others. If your reader cannot make sense of the information you have recorded, then that information is useless. That means numbers written on the page need to be linked to a variable and a unit. Variables should be identified through subscripts to keep initial and final states or different objects distinct from one another.

Progressing is assigned when some data is recorded poorly or the reader is unable to figure out how it is intended to be understood, but it appears that data was being recorded throughout the lab. Scientific is assigned when all data from the lab is presented clearly and legibly.

	No Effort	Progressing	Expectation	Scientific
IL.B Is able to construct a force diagram Labs: 1-12	No force diagrams are present.	Force diagrams are constructed, but not in all appropriate cases. OR force diagrams are missing labels, have incorrectly sized vectors, have vectors in the wrong direction, or have missing or extra vectors.	Force diagram contains no errors in vectors, but lacks a key feature such as labels of forces with two subscripts, vectors are not drawn from the center of mass, or axes are missing.	The force diagram contains no errors, and each force is labelled so that it is clearly understood what each force represents. Vectors are scaled precisely and drawn from the center of mass.

Force diagrams are a phenomenal tool for understanding how to properly assemble equations in mechanics. Every time an object moves in a new direction it is worth your time to draw up a force diagram for that object. This can help you identify assumptions as well. These simplified diagrams of forces also lend an understanding of motion to any other sketches of your experiment for a reader who understands Newton's Laws.

Progressing is assigned when force diagrams are present but so poorly completed that the reader cannot make sense of them. Scientific is assigned when it is possible to understand the outcome of an experiment through the force diagrams alone.

Writing and Communication Rubrics

Students will communicate successfully with audiences through written, oral, and other media as appropriate for the audience and purpose.

This final set of rubrics includes more specific guidance in various elements of your lab manual which are required to fulfill other rubrics.

	No Effort	Progressing	Expectation	Scientific
WC.A Is able to create a sketch of important experimental setups Labs: 1, 3, 4, 6, 7, 10-12	No sketch is constructed.	Sketch is drawn, but it is incomplete with no physical quantities labeled, OR important information is missing, OR it contains wrong information, OR coordinate axes are missing.	Sketch has no incorrect information but has either a few missing labels of given quantities, or subscripts are missing/inconsistent. Majority of key items are drawn with indication of important measurements/locations.	Sketch contains all key items with correct labeling of all physical quantities and has consistent subscripts. Axes are drawn and labeled correctly. Further drawings are made where needed to indicate precise details not possible in the scale of initial sketch.

As mentioned in CT.A.a, a sketch is important for providing clarity to written descriptions. While it is hard to convey all information through sketches alone, developing good practices in designing your sketches will help inform the reader of important details and let them know how the sketch links to the written descriptions provided along with them.

Progressing is assigned here when the sketch lacks vital information about what is being shown or vital details which help connect the image to the written description. Scientific is assigned when sketches show great attention to detail and help guide the reader's attention to important aspects of the experiment.

	No Effort	Progressing	Expectation	Scientific
WC.B Is able to draw a graph Labs: 1, 2, 4-8, 10, 11	No graph is present.	A graph is present, but the axes are not labeled. OR there is no scale on the axes. OR the data points are connected.	"A graph is present and the axes are labeled, but the axes do not correspond to the independent (X-axis) and dependent (Y-axis) variables or the scale is not accurate. The data points are not connected, but there is no trend-line. "	The graph has correctly labeled axes, independent variable is along the horizontal axis and the scale is accurate. The trend-line is correct, with formula clearly indicated.

As discussed in QR.B, a graph is used to show a pattern in your data. Failing to provide graphs when they are needed will penalize you in QR.B, but short of including no graphs at all for the entire lab, you are evaluated in WC.B only on the graphs you do provide to see how well you construct those graphs. Graphs should be drawn to scale so that straight lines really do indicate linear relationships, and the graph should be labelled so that all values are understood and units are known. As stated in WC.B, make sure that any line on your graph can be properly interpreted to mean that all points on the line are expected to be appropriate values as if measurements were made for those specific values.

Progressing is assigned when critical information is missing from the graph, but the data is present. Scientific is assigned when the graph conveys all information acquired in the lab including the trendline and equation.

	No Effort	Progressing	Expectation	Scientific
WC.C Is able to construct a ray diagram Labs: Not used	No Ray Diagram is constructed.	Some Ray Diagrams are constructed, but not for all cases considered during the experiments. OR Rays drawn in the Ray Diagram do not follow the correct paths. Object or image may be located at the wrong position.	"Ray diagram is missing key features, but contains no errors. One example could be the object is drawn with the correct lens/mirror, but rays are not drawn to show image. Or the rays are too far from the main axis to have a small-angle approximation. Or the diagram was drawn without the aid of a straight-edge. "	"Ray diagram has object and image located in the correct spot with the proper labels. Rays are correctly drawn with arrows and contains at least two rays per object/image pair. A ruler was used to draw the images. "

Ray diagrams are useful tools to simplify geometric optics. In our simplified lab arrangements they do not offer much extra insight, but you are being presented simple arrangements now so that if you continue to work with optics you understand how to use ray diagrams to figure out more complicated optical arrangements.

Progressing is assigned when some ray diagrams are omitted or when the ones present are poorly rendered. Scientific is assigned when the ray diagram appropriately locates the image and is sharply presented.

	No Effort	Progressing	Expectation	Scientific
WC.D Is able to draw a circuit diagram Labs: Not used	No circuit diagram is drawn.	Components of the circuit are missing, or connected incorrectly. Components are not clearly labelled.	"Circuit diagram is missing key features, but contains no errors. It may be difficult to follow electrical pathways, but it can be determined which components are connected with sufficient scrutiny. "	Circuit diagram contains minimal connecting lines, components are neatly arranged to ensure labels are readily identified to appropriate components.

Circuit diagrams rarely look like the physical circuit we create with components and wires in real life. The reason for a circuit diagram is to make it trivial to figure out how the components connect to one another, and to establish labels for identification of each component. To assist with clarity, the number of connecting lines in a circuit diagram should be kept to a minimum, and lines should only cross one another when connected if at all possible. Even if the diagram for your circuit is provided in the manual for the experiment, you should always include a circuit diagram in your journal to ensure the reader understands the circuit being used.

Progressing is assigned when some details of the circuit diagram itself are incorrect. Scientific is assigned when the circuit diagram is completely legible and provides valuable information to the reader.

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