Safety in Physics Education

AAPT American Association of Physics Teachers

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by the
American Association of Physics Teachers
Apparatus Committee

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Preface

Educators have a moral, ethical, and legal obligation to provide safe activities for students. Are any physics activities hazardous? This is difficult to answer; little hard data exists and most minor accidents go unreported. More extensive accidents occasionally are filed with the local Safety Office, where they become buried in the school's overall accident-report files. People tend to make judgments based on a few well-publicized, spectacular accidents.

There is no systematic record of physics accident data. You might infer then that physics is a rather safe activity. While there are many standard activities that have been performed for years without accident, this should not create a sense of complacency. Science by its very nature can never be completely risk-free. Further, one should not form a limited definition of safety. Usually, the dangers we confront are not threats to life, but threats to the quality of life. The few well-publicized life-threatening incidents that have occurred should not overshadow the wide variety of welfare-threatening microrisks that can affect one's everyday life. Safety is a broad, all-encompassing concept. Just as a physicist can look at an equation and systematically classify it, a physicist responsible for educational activities should be able to systematically identify safety issues. This protects us legally, morally, and ethically. More importantly, it protects our students and audiences.

Most people receive little, if any, formal exposure to physics in their lifetime, so it is prudent to make the limited opportunities they do have safe and enjoyable. Being aware of and observing safety measures can have additional benefits. They will hopefully instill an awareness for safety that students can take with them to the workplace. For educators, safety awareness helps us to focus on the sometimes questionable assumptions and generalizations made in designing activities.

This manual is intended for a broad audience in the physics teaching community. It can be used across the spectrum of experimental and demonstration activities – from elementary to advanced undergraduate laboratories. Because of this broad range, it cannot specifically address the variety of specialized activities that exist, especially at the advanced lab level. It does seek to provide a framework that educators can use in assessing the risk in their own activities and provide guidance for some of the more common hazards. Not all of the hazards discussed will be applicable to every level but some concession to completeness is necessary. The ultimate goal of this manual is to create an awareness of safety, to encourage safe habits, and to teach respect for potential safety hazards. The intent is not to discourage the use of apparatus, but to develop an awareness of the risks involved in teaching physics and the steps to take to protect students as well as educators.

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An Introduction to Risk and Risk Management

An Introduction to Risk and Risk Management

Safety in physics begins with an understanding of risk and risk management. Choices made in life contain risks, which can be minimized, but are not unavoidable. Even innocent actions have risks because of unforeseen events.

Therefore, keep in mind the following three principles:

1. Risk arises in some form in virtually all of life's activities.
2. It is important not to ignore risk or be frightened by it.
3. Systematic methods to assess and handle risk can be developed.

To deal with risk, assess the risks present and then find ways to address them in everyday procedures. Remember that addressing risk is a gamble — it implies an uncertainty and inability to control the outcome or consequences of an action. However, to do nothing could lead to much greater risk.

Conducting an objective risk assessment is easier if there is a history of similar situations. If there is no such history, make a subjective determination based on experience, expertise, and common sense. Typically, situations are a mix of the two types; but since there is little hard data on physics accidents, physics risk assessments are more likely to be subjective.

The aim of this section is to provide a framework for assessing risk, i.e., to examine the process of risk management.

Risk Management

Risk management is part of everyday life and is an effort to avoid unpleasant surprises. The practice of risk management creates policies and procedures that restrict behavior. Learning is based on growth and innovation, which typically necessitates risk. This philosophy of education is inconsistent with risk management, leading to potential but not insurmountable difficulties. Risk management means anticipating unsafe scenarios and developing controls against their occurrence. Fortunately, because physics course activities are well established, this is easier. Risk plays a bigger role in new activities or when educators become complacent.

The **risk management** process is divided into four stages:

1. IDENTIFICATION of risk.
2. EVALUATION of the risks identified.
3. SELECTION of management and engineering controls.
4. IMPLEMENTATION and periodic review of the selected controls.

Identification

Risks may be static or dynamic. A **static risk** is statistically constant — it is *predictable*. Static risks are associated with objective risk assessments, meaning there is a lot of evidence to support them. Discovery of static risks is accomplished by use of checklists, personal inspections, and audits and reviews of policies and procedures. **Dynamic risk** arises from change itself. Discovery of dynamic risks requires anticipation, education, and creative analysis. Knowledge of federal, state, and local regulations is also helpful.

In identifying risks, it is essential to be unbiased. What seems obvious to the assessor may not be at all obvious to a student. If possible it is better to get a variety of opinions and expertise.

Evaluation

Before evaluating risks, decide what *level* of risk is appropriate for the course. Those involved must decide if they are risk takers or risk averters in the educational process. Think carefully about this. Extreme risk aversion can lead to a very static educational process — lecturing, writing on the board, and nothing else. Extreme risk taking can unnecessarily endanger students for little or no pedagogical advantage. Once the level of risk is established, the pedagogical benefit of individual activities, experiments, and demonstrations must be determined. Is this level of risk commensurate with the consensus decision? If there is a significant disparity, then re-evaluate or eliminate the activity.

In carrying out risk assessment, there are two areas to consider — the categories of hazards and the basic causes of accidents. The categories are:

1. **Physical:** hazards associated with an object.
2. **Mechanical:** hazards associated with the operation of an object.
3. **Electrical:** hazards that might interfere with neuro-muscular function or could lead to coagulation, charring, and incineration.
4. **Radiation:** ionizing may disrupt cellular or subcellular components and functions; nonionizing may adversely affect tissue or organs due to thermal absorption.
5. **Pressure:** hazards related to the use of vacuums.
6. **Chemical:** hazards created by use of specific chemicals, compressed gases, or cryogenics.
7. **Noise:** hazards that may be sufficient to cause hearing loss.
8. **Thermal:** hazards that may cause inflammation, coagulation, charring, and incineration.
9. **Biological:** hazards due to exposure to specimens, tissues, cultures, or bodily fluids.

Each of these categories (except for biological hazards) will be discussed in detail in subsequent sections.

The basic causes of accidents have been categorized[1] as follows:

1. Failure to give adequate instructions or inspections.
2. Failure to properly plan or conduct the activity.
3. Improper design, construction, or layout.
4. Failure to provide protective devices, equipment, or tools.
5. Failure to use provided protective devices, equipment, or tools.
6. Failure to follow safety rules or instructions.
7. Presence of a physical handicap.
8. Lack of knowledge or poor mental attitude.
9. Use of defective apparatus (either knowingly or unknowingly).

Selection

Addressing the risks that survive the evaluation stage requires some effort. What controls can be implemented to lessen the risks? Gathering the necessary information might take time. If the pedagogical benefits make the risk acceptable, then what alternatives are available? Can a different approach, equipment modification, or different materials achieve the same objective with less risk?

An important point must be considered at this stage. When deciding on ways to eliminate risk, be careful to avoid **risk substitution** – eliminating one risk but having it be replaced by another equally or more dangerous risk. This is another reason to have several parties involved in the risk management process.

The relationship between these elements is summarized in Table 1.

Table 1. Relationship between phases of risk assessment process and components of risk.[2]

Phases of the risk assessment process	Components of Risk Magnitude of potential loss	Chances of potential loss	Exposure to potential loss
Identify risks	What losses are possible?	What are the sources of uncertainty?	What is open potential loss and to what extent?
Evaluate risks	Are the possible losses bearable and worth assuming?	Are the chances worth taking?	Is the exposure acceptable?
Adjust risks; gain control	How can potential losses be moderated?	How can uncertain events be prevented or made less likely?	How can risks be shared or spread?
Gain information	How much can be lost?	How likely is the potential loss?	Are options available for spreading risk?
Gain time	Can delay reduce loss?	Can delay reduce uncertainty?	Can delay reduce exposure?

Implementation

The final step is to implement the solutions. The solutions should be reviewed and updated as the nature of the risks, activity, or laws and regulations change.

Barriers to Risk Assessment

There are many factors that prevent effective risk evaluations. Psychologically, people tend to use hidden rules[3] that might distort risk perceptions. While there is some overlap between them, look at the assessment from both the students' and the assessors' point of view.

From the students' perspective:

- Imposed risks loom larger than voluntary ones — students forced to do a particular activity may see greater hazards than those in an activity they choose to do.
- Risks that seem unfairly shared are seen as more hazardous — if students perceive no benefit from an activity, it is more objectionable.
- Controllable risks are more acceptable than uncontrollable ones — students with options or the ability to control will perceive less risk.
- Natural risks are less threatening than man-made ones — radiation from a piece of uranium ore is less threatening than radiation from a commercially produced source with less activity.
- Risks from exotic technologies create more fear than familiar ones, even though the probability of risk is higher in the familiar case.

From the assessor's perspective:

- Familiarity breeds complacency (or carelessness) — just because something is obvious to the expert does not mean it is obvious to the amateur.
- Older people tend to perceive a greater degree of risk than younger ones.
- Highly publicized events create a greater perception of risk than ordinary events, even though risk is higher in ordinary events.
- Different personal value systems create different perceptions of risk.
- Risks that are additive (i.e., they depend on the occurrence of several preceding events) tend to be underestimated.

The fundamental point is that because of the variability of human nature, it is better to have several people perform risk assessments rather than one.

Summary

This outline can help in assessing apparatus and activities for hazards, being as anticipatory as possible (see *Legal Implications* section). Many causes of accidents can be immediately eliminated from consideration. While the entire assessment process may seem confusing and tedious, most instructors already perform an informal assessment when developing activities. This presentation merely provides a more comprehensive list of considerations. With practice, use of this process should become second nature.

Notes

1. N.V. Steere, ed., *CRC Handbook of Laboratory Safety*, 2nd ed. (CRC Press, Boca Raton, FL, 1971), pp. 5–6.
2. ibid., p. 28.
3. *The New York Times*, Feb. 1, 1994.

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N.V. Steere, ed., *CRC Handbook of Laboratory Safety*, 2nd ed. (CRC Press, Boca Raton, FL, 1971).

Legal Implications of Safety

Legal Implications of Safety

In addition to the regular concern for safety, there is also a legal side to the subject. Instructors, the physics department, the school, and the county or state can incur legal liability in several ways, only one of which is relevant to us: negligent behavior.

Quoting from a National Science Teachers Association publication:

> "In all states it is the teacher who is legally responsible for the safety of the pupils. However, the courts have held that a teacher is liable for damages only if it can be proven that the teacher has failed to take 'reasonable care' or has acted in an illegal manner. A teacher must foresee dangers, but only to the extent that any reasonably prudent person would. A teacher must perform assigned duties if he is to avoid being censured by the school district in which he is employed."[1]

Although this statement was written with pre-college teachers in mind, it applies equally to university instructors. In the following sections, torts and the concept of negligence as it applies to instructors will be examined.

Torts and Negligence

Negligent behavior comes under the torts category of law. A **tort** is a civil (i.e., private) noncontractual wrong. For a crime (a public wrong), the state prosecutes the wrongdoing individual; in a tort (a civil wrong) the injured person must bring a civil lawsuit against whoever was responsible. An example is an automobile accident. In a tort action, a person's rights are created by statute or, more commonly, by precedent. Under common law, a school district, as agents of county and state government, cannot be held liable for student injury. This principle does not apply to instructors, though, because they can be sued.

Of the three tort subdivisions (negligence, intentional, and constitutional), negligence is the most commonly litigated.[2] **Negligent** torts have fault rather than intent as their basis. To establish liability, four elements must be found: a legal duty of care; its breach; causation or proximate cause; and damage, or loss of harm. Breach and damages are usually not at issue; duty and cause typically must be established.[3]

Duty is the baseline recognized by law as the minimum acceptable standard of conduct. There can be a case of negligence only where there is a legal *duty* between the parties involved. The question of whether such a legal duty exists is a question of law and not subject to jury interpretation.[4] We will examine the duties of a teacher later.

Assuming that a legal duty exists, it must be established that the person acted below the prevailing standard of care for it to be ruled negligence. Negligence can be defined in a number of ways:

- Careless conduct.
- Failure to use the degree of care demanded by the circumstances at the time of the act; failure to act.
- Failure to use the care that an ordinary, prudent person would use under the same or similar circumstances to avoid causing injury to another or to protect another from injury.[5]
- A matter of recognizable danger or injury.
- Conduct that involves an unreasonably great risk of causing damage.
- Conduct, not a state of mind (i.e., no element of premeditation).

Please note that negligence is not the same as the **tort of negligence.** Recalling what we stated earlier, the tort of negligence occurs when a person's negligence proximately causes injury to another person's interest.[6]

A jury determines if a person was acting as "an ordinary, prudent person" would act under the same or similar circumstances based on facts presented by lawyers.[7] **Standard of care** is difficult to measure; typically there are no precise definitions and so it is often a matter of debate in a negligence trial. If the "standard of care" is not set by statute, then the standard used is reasonable care or ordinary prudence of "the reasonable person." An important aspect of how an ordinary, prudent person acts is **foreseeability** (anticipation). A prudent person is expected to be aware of human nature and be able to foresee (anticipate) ordinary events and, in some cases, extraordinary ones. As a result, reasonableness is decided in court based on the merits of the case. Lawyers may present expert witnesses or they can put together a fact pattern that speaks for itself (known in Latin as *res ipsa loquitor* — the thing speaks for itself).[8]

Breach is established once it has been shown that the accused acted below the established standard of care.

The third step is to prove that the negligent conduct was the cause of the injury. Cause can be evaluated from two perspectives: whether it was the act or omission that was the "cause in fact," i.e., the direct, or **proximate**, cause of the injury.

There are two categories of proximate cause:

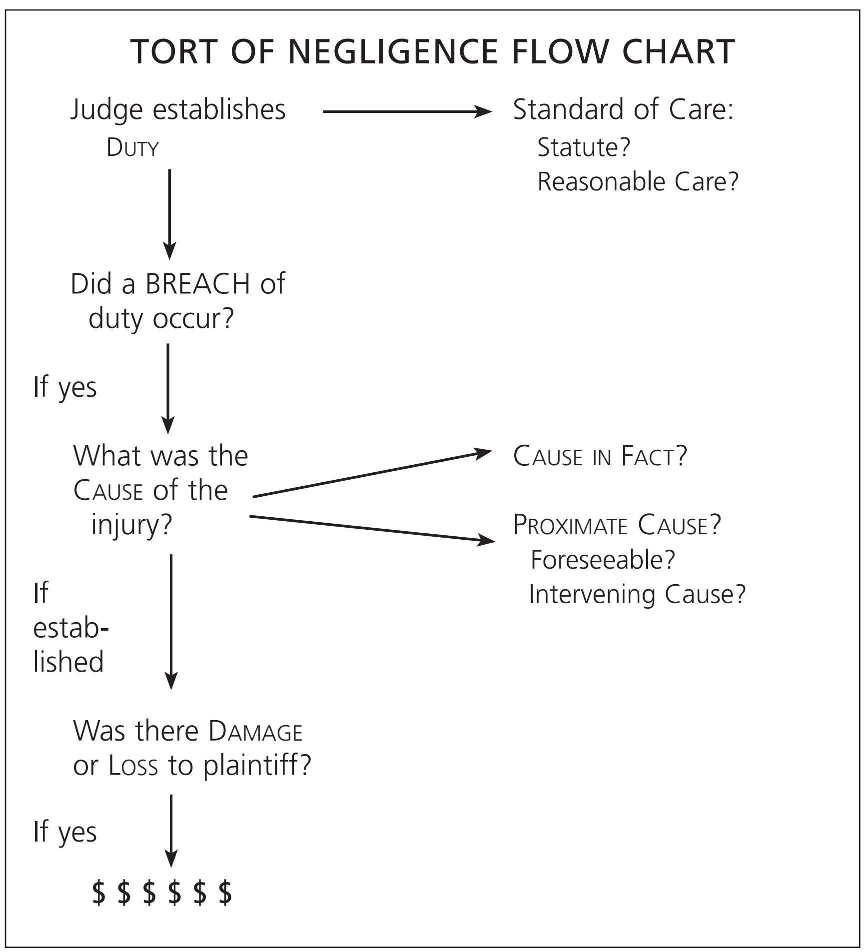
- Foreseeability, which is negligence founded on an inability to determine potential for harm that a "reasonably prudent person" would anticipate.
- Intervening cause, in which an act or event occurs subsequent to the defendant's act and before the injury.

Note that foreseeability and proximate cause are not interchangeable terms. Foreseeability of an injury due to negligence is an element in proximate cause.[9]

If the tort of negligence is proven, then the injured party may recover damages.[10] The amounts can be very substantial (on the order of millions of dollars, depending on the severity of the misconduct). The relationship between these elements is shown in the figure below.

The accused is not helpless in negligence torts. There are several defenses available, the most common of which are:

- *Denial:* the accused claims no responsibility for the cause of the loss.
- *Bar by statute of limitations:* an applicable statute of limitations has expired so the case cannot come to court.
- *Contributory negligence*: this is a narrowly applied defense because it is an affirmative one that requires the accused to prove that the accuser's own unreasonable behavior or conduct contributed to the proximate cause of the loss. Note that the accused is accepting at least some of the blame by using this defense.
- *Assumption of risk:* must be pleaded and proved by the accused; the basis of this defense is that the accuseds' negligence is excused due to the plaintiff's voluntary consent to encounter a danger resulting from that negligence. This is extremely hard to apply in the educational setting as students are considered a "captive audience" — the class is required so they must do the activities associated with the class.



Other protections should be available. The school district or institution should have liability coverage and legal assistance for instructors. However, there is an important point to remember. In such lawsuits, other people (supervisor, chair, dean, etc.) are typically included in the suit. If the district or institution has, e.g., a $1 million liability policy, the $1 million is typically split equally among all those named in the suit. What sounds like a significant amount of coverage suddenly becomes very diluted, and the accused will be liable for any difference. “Teachers” insurance is available from private insurance companies in the form of professional or business pursuits coverage. Typically rather expensive, this is a rider attached to your homeowners policy, and the cost depends on the amount of coverage selected.

Duties of a Teacher

To protect yourself against negligence actions, instructors should know what their duties are regarding teaching safely — the duty of instruction, the duty of supervision, and the duty of proper maintenance and upkeep of all equipment and supplies.[11]

In this context, instruction does not refer to teaching the subject material; it refers to the safe conduct of an activity or the safe use of apparatus. For activities containing hazardous apparatus, materials or procedures, the instructor cannot merely tell students to read the instructional materials and begin. Even if students are not directly involved in an activity, the instructor should point out hazards and what was done to minimize them because students sometimes try the demonstrations on their own with unfortunate results.

In general, give instruction on the safe operation, including proper startup and shutdown, of equipment. Include an explanation of the basic principle involved, suggestions on how to perform the activity, and any risks involved.[12] Following these suggestions will satisfy the duty of instruction with respect to the tort of negligence.

Along with failure to instruct properly, insufficient supervision is a direct cause of most accidents. This is straightforward: If the instructor is not present in the room and an accident occurs, there is proximate cause for an injury. The same is true if the instructor is in the room but not paying attention. When there are hands-on activities in progress, the instructor should be continuously circulating, observing the students at work. This is not only safer, it makes the instructor more available for questions.

The final duty is proper maintenance and upkeep of equipment. The instructor is charged with providing safe equipment and keeping it maintained. Even if a technician is available to do this work, the instructor is not relieved of this responsibility. If an apparatus is damaged, do not just leave it for the next instructor or student to use. Remove it from service and place it in an area where a repair person can get to it. There should always be enough apparatus and supplies for the number of students doing the activity. If these guidelines are not followed and an accident results, then there is proximate cause for a tort of negligence.

In general, when an instructor has been derelict in his duties and the dereliction is the proximate cause of an accident, then there are grounds for a tort of negligence and the injured party may recover damages.

A final note: Instructors also have a responsibility to keep themselves updated on any federal, state, or local regulations that may apply to their curriculum.

Conclusion

Instructors must be constantly aware of their duties as viewed by the courts. No student actions should be permitted without detailed instruction and supervision. To this end, the following list is provided as a guideline to aid in compliance with these duties and to minimize the chances of becoming involved in tort of negligence legal proceedings:

1. Instructors are expected to protect the health, welfare, and safety of their students.
2. Instructors must recognize that they are expected to foresee the reasonable consequences of their actions (or inactions).
3. Instructors must instruct their classes and laboratories and must give careful directions before allowing students to start working on their own.
4. Instructors must relate risks inherent in an activity, demonstration or laboratory experiment prior to beginning work.
5. Instructors should create an environment in which appropriate behavior is maintained.
6. Instructors should report all hazardous conditions to appropriate personnel immediately.
7. The instructor's continuous presence in the classroom or laboratory is required to assure adequate (safety) supervision.[13]

Notes

1. B.W. Brown and W.R. Brown, *Science Teaching and the Law* (National Science Teachers Association, Washington, DC, 1969), cited in Jack Gerlovich and Gary Downs, *Better Science Through Safety* (Iowa State University Press, Ames, IA, 1981), p. 9.
2. Joseph L. Frascona, *Business Law* (William C. Brown Co., Dubuque, IA, 1981), p. 59.
3. ibid., p. 59.
4. ibid., p. 59.
5. ibid., pp. 59–60.
6. ibid., p. 60.
7. ibid., p. 60.
8. ibid., pp. 60–61 .
9. ibid., p. 61.
10. ibid., p. G-6.
11. Jack Gerlovich and Gary Downs, *Better Science Through Safety* (Iowa State University Press, Ames, IA, 1981), p. 10.
12. ibid., p. 10.
13. ibid., p.13.

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