The Safety Professionals Handbook

TECHNICAL APPLICATIONS

INSTRUCTORS' GUIDE

Joel M. Haight, Editor
THE PENNSYLVANIA STATE UNIVERSITY

American Society of Safety Engineers
Des Plaines, Illinois, USA

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Applied Science and Engineering: Electrical Safety

Steven J. Owen

End-of-Chapter Questions

1. The three hazards associated with electricity are shock, _____, and blast.
   A) arc
   B) equipment failure
   C) short circuit
   D) overload

2. Shock normally occurs in one of three ways. Which one of the following ways is not considered to be one of the three ways?
   A) Contacting one of the wires of a circuit and ground
   B) Contacting both wires of a circuit
   C) Contacting an energized metal part
   D) Contacting an energized part with insulated gloves

3. The skin is composed of three layers. The outer layer of skin is made of a protein known as _____.
   A) keratin
   B) ginseng
   C) Merkel
   D) pacinian

4. The severity of shock depends on all but which of the following?
   A) Length of time of contact
   B) Amount of current
   C) The AIC rating of the overcurrent device protecting the circuit
   D) The path of current flowing through body

5. An electrical arc can reach temperatures as high as _____.
   A) 7000° F
   B) 14,000° F
   C) 35,000° F
   D) 700° F

6. OSHA, in 29 CFR 1910, Section 1910.300, defines a "qualified person" as one who _____.
   A) has a statewide electrical license
   B) has a city or county electrical license
   C) has permission from the employer to perform specific job-related tasks
   D) is familiar with the construction and operation of the equipment and the hazards involved. This is for specific equipment related to the employee's job task.

7. Examples of increased or additional hazards include which of the following?
   A) Removal of illumination from an area
   B) Deactivation of emergency alarm systems
   C) Interruption of life support equipment
   D) All the above

8. Lockout/tagout devices should be standardized by which of the following?
   A) Color
   B) Shape
   C) Type
   D) All of the above

9. Lockout/tagout devices must warn against hazardous conditions. Which of the following warnings is not generally used?
   A) Do not start.
   B) Do not close.
   C) Do not energize.
   D) Do not clean.

10. One of the most important elements of proper development of detailed switching procedures is _____.
   A) advice from a consultant
   B) licensed electricians
   C) safety electrical one-line drawings
   D) supervisor's consent

11. All but which of the following pieces of personal protective equipment are required for safe electrical switching procedures?
   A) Gauntlet-type electrical insulated gloves of the proper rating
   B) Safety glasses with side shields
   C) A Class 2, type E nonconductive hard hat
   D) Steel-toe work shoes

12. All grounding cables, clamps, and ferrules used to construct grounding cables must meet the requirements of _____.
   A) ANSI Z-535
   B) NFPA 233B
   C) OSHA 1910.404
   D) ASTM F 855-80

13. What is the minimum size conductor permitted to be used as a personal protective ground cable?
   A) #2 AWG
   B) #1/0 AWG
   B) #2/0 AWG
   C) No requirement

14. Which is the first and last connection made when applying personal protective grounds?
   A) Ground-end clamp
   B) Positive end of clamp
   C) The middle of the cable
   D) Either end, as it does not matter

15. All but which of the following items is considered to be an effective method of improving electrical safety in the workplace, with respect to equipment?
   A) Use finger-safe electrical components when possible.
   B) Specify the use of copper-clad aluminum bus when possible.
   C) Specify the use of insulated bus in motor control centers and switchgear.
   D) Use current-limiting fuses and circuit breakers where possible.

16. Which NFPA standard is applicable for the safety of personnel working on or near exposed energized electrical circuits, conductors, and equipment?
   A) NFPA 70
   B) NFPA 70E
   C) NFPA 70B
   D) NFPA 79

17. What are the three requirements of an effective ground-fault current return path as described in the "Grounding and Bonding Notes" section?
    A) Metal raceway, ground rods, and Class H fuses
    B) Permanent and continuous, sufficient current-carrying capability, and low impedance
    C) Copper conductors, solid connection, and bonding jumpers
    D) There are no rules regarding ground-fault current paths.

18. What is listed as the number one rule for establishing an employers electrical safety program?
    A) To make personnel aware of rules, responsibilities, and procedures
    B) To demonstrate the employer's commitment to comply with the law
    C) To document general requirements and guidelines
    D) To encourage employee participation

19. With respect to the responsibilities of the "electrical safety authority," what needs to be done following an electrical safety incident?
    A) Nothing
    B) Call OSHA immediately
    C) Reprimand employee(s) involved
    D) Issue summaries and "lessons-learned"

20. What has to be provided for electrical personnel and nonelectrical personnel who work on or around energized parts of electrical equipment and/or systems?
    A) Employee representation
    B) Tools and equipment
    C) Training
    D) There are no requirements; let an employee perform any task.

21. Planning a job would include which of the following?
    A) Reviewing one-line safety electrical drawings
    B) Determining which employees are authorized to perform job tasks
    C) Reviewing equipment manuals and procedures to work on the equipment
    D) All of the above

22. Anticipating unexpected events would include which of the following?
    A) An unplanned company meeting
    B) A contractor coming to the job site
    C) The possibility of the equipment having an arcing burndown
    D) The job being canceled at the last minute

23. Isolating the equipment generally means _____.
    A) a transformer
    B) permitting a person to work alone, unsupervised
    C) lockout/tagout
    D) moving the equipment to another location

24. Protecting the person would include _____.
    A) insulated gloves of the proper voltage rating
    B) nonconductive, nonmetallic, Type 2, Class E hard hat
    C) safety glasses
    D) all of the above

25. Using the right tool for the job, on or near energized parts, would include which tool?
    A) A 1000-volt insulated screwdriver
    B) Klein non-insulated tools
    C) Metallic tools
    D) Needle-nose pliers

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Applied Science and Engineering: Permit-to-Work Systems

David Dodge

End-of-Chapter Questions

1. You have just been appointed head of safety at a brand new, state-of-the-art manufacturing facility that will open for production in about a month. In regard to permit-to-work systems, what is your first step?
2. You have just been appointed head of safety for an older, established manufacturing facility that has not had someone in charge of safety for several years. A permit-to-work system is in place, but you find that it was last reviewed three years ago. In regard to the permit-to-work safety system, what is your first step?
3. When is a risk assessment performed, and by whom?
4. A subcontractor shows up on the work site and can provide no evidence of a permit-to-work system for a roofing operation. What do you do?
5. A worker is assigned a task within a space that is not accessed very often. How will the worker know if it is a confined space?
6. Who establishes the acceptable flammability and toxicity ranges for material within a confined space?
7. A permit is submitted asking permission to perform nonroutine work on an elevated system. What should be the first safeguard considered?
8. A contractor erects a scaffolding on which your employees are to work. Is a permit to work required?

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Applied Science and Engineering: Basic Safety Engineering

John Mroszczyk

End-of-Chapter Questions

1. What is a *hazard*?
2. What is *risk*?
3. What is a *safe* design? What is a *defective* design?
4. What is *designing for safety*?
5. What are the steps involved in designing for safety?
6. What information should be in a warning label message panel?
7. It is desired to measure the SCOF of a dry floor surface using a drag sled. The sled weighs 5 pounds. The horizontal force to move the sled is measured with a force gauge. Five readings are taken: 2.84, 2.88, 2.76, 2.60, and 2.68 pounds. What is the SCOF?
8. The average velocity in a duct is measured as 50 fps. The air is standard air with a weight density of 0.075 lbs/ft^3. What is the velocity pressure? What is the velocity pressure in inches of water?
9. The duct from Problem #8 is serving a hood. The loss factor has been obtained from the manufacturer as 2.1. What is the total loss associated with the hood?
10. A fan is operating at 1500 rpm and 1200 cfm. What will be the new flow rate if the fan rotation rate is increased to 2000 rpm?
11. The unweighted sound pressure level from noise generated by a machine is measured as 60 dB at 125 Hz. What is the A-weighted sound level?
12. An untreated room is 20 feet long, 16 feet wide, and 10 feet high, and has an untreated surface with an average absorption coefficient of 0.01. The sound level in the room is 90 dB when all sources of sound are turned on. It is desired to reduce the sound level in the room to 80 dB by carpeting the floor. What should the absorption coefficient of the carpet be?
13. A safety mat is to be used as a presence-sensing device. The response time of the machine brake and the control circuit is 0.150 seconds. The brake monitor is set for 0.200 seconds. The safety mat has a response time of 29 milliseconds. How far should the outside edge of the mat be placed from the nearest machine hazard?
14. What are the components of an industrial truck training program?
15. What is the minimum clearance between an AGV and its load and a fixed object?

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Cost Analysis and Budgeting

Mark Friend

End-of-Chapter Questions

1. Explain the role of the safety professional in the organization.
2. Explain the concept of zero-based budgets.
3. Explain the concepts of fixed costs and variable costs.
4. What are the elements of a loss exposure?
5. List six methods of identifying loss exposures.
6. Arrange an appointment with a company financial officer. Ask what criteria are used to determine budget priorities. How do these relate to the material discussed in this chapter?
7. Talk to at least three different individuals charged with safety responsibilities. Ask them if they believe it is possible to eliminate all accidents from a given workplace and why. If their responses differ from one another, why do you think that is? Do you think their responses are based on knowledge or supposition?
8. Look around your workplace. Are there risks that can be avoided? Transferred? Insured? Are these wise financial decisions or not?

Case Study

You are asked to review three investment decisions on the part of the safety department. Each will cost the company $10,000.

- Decision 1 will save the company $15,000 the first year but will result in no further savings afterward.
- Decision 2 will save the company $2000 per year for each of the next 8 years but yield no savings thereafter.
- Decision 3 will save the company $1000 for each of the next 20 years but yield no savings thereafter.

1. With no additional information, can you make an informed decision as to which of the decisions is the most attractive from a financial perspective? If not, what additional information do you need?
2. Assuming a discount rate of 10%, which of the proposals is the most financially attractive?

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Benchmarking and Performance Criteria

Brooks Carder and Pat Ragan

End-of-Chapter Questions

1. The numbers in Table 1 represent the number of recordable accidents in a plant for 36 consecutive months. Each month represents 200,000 person hours of work. Plot a control chart of the accidents. Based on the chart, do you see any problems with the plant's recording of incidents?

TABLE 1

Recordable Accidents

Month	Accidents	Month	Accidents
1	3	19	3
2	3	20	1
3	3	21	3
4	3	22	1
5	3	23	3
6	3	24	3
7	1	25	3
8	2	26	0
9	2	27	3
10	3	28	3
11	1	29	3
12	2	30	3
13	1	31	3
14	3	32	1
15	3	33	3
16	3	34	1
17	3	35	3
18	3	36	1

2. You have an opportunity to benchmark one of the following companies:

   Company A is in your industry. It has a recordable accident rate of 1.6. The company is not a quality leader in the industry. The CEO is famous as a disciplinarian and cost-cutter who drives numbers relentlessly.

   Company B is also in your industry. It is the quality leader. It has a recordable accident rate of 2.4, which is better than your company's rate. You have no idea who the CEO is.

   Company C is an American company with its plant in Mexico. It is the low-cost leader in your industry. It also has a recordable rate of 2.4.

   What are your thoughts about which company to choose for benchmarking the safety training of supervisors? What else would you like to know about these companies to help you in making a decision?
3. Many accident reports list "operator error" as the sole cause. Even if the operator did indeed make an error, what is wrong with this designation? How would you explain to senior management that this was not sufficient?

4. Given that safety surveys represent only the opinions of the workforce, why should we take them seriously?
5. Describe the process you would use to establish the reliability and validity of an audit process used by your company.
6. You are asked to lead a safety benchmarking team. How would you choose the team? What players would be critical?
7. In Table 2 are the scores given by three independent auditors for ten plants. Each auditor was instructed to use the same protocol. What can you say about the reliability of the audit process?

TABLE 2

Scores Given by Three Auditors on Ten Plants

	Auditor 1	Auditor 2	Auditor 3
Plant 1	96	92	84
Plant 2	85	91	62
Plant 3	77	82	87
Plant 4	87	83	80
Plant 5	80	76	62
Plant 6	55	54	52
Plant 7	88	92	78
Plant 8	80	84	88
Plant 9	66	60	81
Plant 10	73	81	90

8. In Table 3 is a set of scores from ten plants: the score from a recent audit by a corporate team, the recordable rate for the past two years, and a recent score on a safety survey. All of the plants are relatively similar in size and conduct very similar manufacturing operations. The plants have between 40 and 75 employees. Please comment on the validity of the instruments. Do the data suggest anything else?

TABLE 3

Scores for Ten Plants on Audit, Recordable Accident Rate, and Safety Survey

	Audit Score	Recordable Accident Rate	Survey Score
Plant 1	93	1.45	88
Plant 2	72	4.23	68
Plant 3	85	4.07	82
Plant 4	71	5.21	67
Plant 5	62	6.11	68
Plant 6	91	1.6	92
Plant 7	84	3.68	76
Plant 8	87	3.78	93
Plant 9	82	3.47	77
Plant 10	57	2.74	62

SECTION 1

RISK ASSESSMENT AND HAZARD CONTROL

Best Practices

Stephen Wallace

End-of-Chapter Questions

1. What is the most critical phase in identifying risks?
2. What are the five elements of inherent safety?
3. What are the differences between passive and active safety systems?
4. What is the disadvantage of adding too many alarms to a process?
5. What is the purpose of isolation valves?
6. Why should fire-water equipment be separated from process water?
7. Along with the personnel safety, what is another reason that building design is critical in a manufacturing plant?
8. What is the definition of a critical instrument?
9. Which OSHA standard lays out the regulations for confined space entry?
10. What are the general steps involved with conducting a security vulnerability analysis?

SECTION 2
EMERGENCY PREPAREDNESS

Regulatory Issues

Jon J. Pina

End-of-Chapter Questions

1. List the types or variety of emergencies that may be encountered in the workplace.
2. Describe the role of the safety, health, and environmental (SH&E) professional in the development of an emergency action plan as required in 29 CFR 1910.38/1926.35.
3. What is the role of the LEPC and SERC? Which CFR would one access to establish their reporting requirements?
4. What is HAZWOPER? What is the difference between HAZMAT and HAZWOPER?
5. What is the role of NFPA concerning emergency response preparedness?
6. What is the role of NRC concerning emergency response preparedness?
7. What is the role of FEMA concerning emergency response preparedness?
8. What is the purpose of the National Response Center concerning emergency response preparedness planning?

Suggested Projects

1. Design an emergency action plan following 29 CFR 1910.38 for a facility you are familiar with.
2. Develop a list of the training requirements for emergency response preparedness for a facility you are familiar with taking into consideration OSHA, EPA, DOT, NFPA, NRC, and FEMA.
3. Develop a mock disaster scenario and describe what actions you would take in chronological order.

SECTION 2
EMERGENCY PREPAREDNESS

Cost Analysis and Budgeting

Pam Ferrante

End-of-Chapter Questions

1. Research the fines levied under Title III of the Superfund Amendments and Reauthorization Act of 1986. List your findings.
2. Use the emergency planning document found at the Federal Emergency Management Agency (FEMA) Web site to complete a Shelter-in-Place Plan for your organization. Make sure that you address warning systems that will used, plans for dealing with visitors, people with disabilities, and persons with limited comprehension of English, if applicable. Determine who will be in charge of the head count and be certain to develop a method for performing practice drills. (http://www.ready.gov/business/plan/shelterplan.html).
3. Use the OSHA confined space regulations found at 29 CFR 1910.146 to develop an equipment and supplies list for a 5-member rescue team. Be sure to include equipment and supplies that are needed for the annual drill.
4. Using the example comparison in the text of the use of a sole-source contract with a built-in price guarantee versus a competitive bid contract with yearly price increases, determine how many years it will take for the sole-source contract with a price increase to be a better value than the competitive bid contract.
5. Assuming a 7 percent rate of return for the organization, use the same formula as in Question 4 to compare the following:
   - the time value of a 5-year sole-source contract with a cost of $70,000 for the first three years and a price increase of 5 percent taken at Year 4 and held constant for Year 5
   - the time value of a 5-year competitive bid contract that starts at $75,000 the first year and has a built-in annual price increase of 3 percent.
6. Use the equations in the text to calculate the return on investment (ROI) and a break-even point that assumes an annual cost savings generated by the expense of $3,000.00. Would you recommend this expenditure based upon these calculations? Why or why not?
7. Calculate the ROI and break-even point for the training budget seen in Figure 5 for the second year of implementation. Assume an annual cost savings generated by the expense of $20,000. Would you recommend this expenditure based upon these calculations? Why or why not?

SECTION 2

EMERGENCY PREPAREDNESS

Benchmarking and Performance Criteria

Bruce J. Rottner

End-of-Chapter Questions

These questions may have more than one answer or they may not have any answer. They are provided to stimulate thought. Additionally, they are intended to require readers to think past the obvious solution and expand the scope of their understanding of emergency response issues. Questions such as these must be answered by the individual organization before an emergency occurs, and the answers should be included as policy and/or procedures established in the written plan.

1. A growing fire next to a 55-gallon-drum storage area is causing the drum contents to heat and expand. Most of the drums contain flammable liquids, but some contain a material poisonous to local species of fish. Downwind from the facility is a nursing home, and behind the facility is a stream that empties into a lake that is popular for fishing and recreation. As Incident Commander (IC), establish incident goals and objectives for this scenario.
2. You have modeled a chemical release from your facility and have determined that there is a potential for the plume to cover the railroad tracks used for commuter trains. How would you shut down rail operations in the event of an emergency?
3. To resolve one type of emergency at your facility, a specific piece of equipment is needed, and the correct use of this equipment requires significant training. Would you purchase the equipment and donate it to the local community emergency response organization? Would you purchase the equipment and train personnel at your facility? Would you handle the situation using a different option from the two listed above?
4. Your emergency response plan requires trained personnel to return to the facility during off-hour emergencies. During an emergency response exercise, you determine that local law enforcement has been instructed by the public IC to stop all traffic to your facility. How will you ensure that your emergency responders will get through the traffic checkpoint? How will local law enforcement be able to identify emergency response personnel from the press or others just wanting to get closer to the emergency event?
5. You are the emergency coordinator for a large metropolitan hospital and have signed a memorandum of understanding (MOU) with an ambulance service in case you need to evacuate the hospital. The ambulance service is the largest in the city, but it has signed similar agreements with four other hospitals in

the same city. During a city-wide emergency, no ambulances respond to your requests. Identify resources that will be required for a long-term (one week) situation where patients will need to remain at the hospital during the emergency.

6. A small coal-mining company has hired you to develop an emergency response plan. Identify hazards associated with this operation.
7. During an emergency, the press has arrived at your facility to cover the incident. They represent all media, such as television, radio, and newspapers. Your company has a spokesperson who is stationed at the corporate office in another city. Company policy prohibits you from speaking to the press. How would you handle this situation?

SECTION 2
EMERGENCY PREPAREDNESS

Best Practices

Philip E. Goldsmith

End-of-Chapter Questions

1. Distinguish among the four phases of the emergency management life cycle.
2. Describe the benefits of scalability, standardization, and common terminology to an emergency management program.
3. Identify the uses of hazard-driven models and event-driven models in emergency management planning.
4. Explain the use of the risk matrix in identifying and prioritizing the exposures to be dealt with in an emergency management plan.
5. Describe the type of emergency management program that might best be organized around the elements of:
   - NFPA 1600
   - The DRII/DRJ Best Practices document
   - The National Incident Management System/The National Response Plan

SECTION 3

FIRE PREVENTION AND PROTECTION

Applied Science and Engineering: Fire Dynamics

David G. Lilley

End-of-Chapter Questions

1. A hole of diameter 1/16 inch develops in a liquid line from a propane tank at 120 °F. Calculate
   (a) exit velocity
   (b) volume flow rate
   (c) heat release rate if ignited
2. A fire grows from size zero to a size of 6 MW in 300 seconds. Considered as a t^2-fire, calculate the growth parameter α in kW/s^2 and growth time t_g in seconds.
3. A round puddle of gasoline of diameter 1.5 m is burning in a large room. Calculate
   (a) the heat release rate $\dot{Q}$ in kW
   (b) the flame height L in m
   (c) the radiation heat flux level 3 m away in kW/m^2
   (d) The ventilation factor $A\sqrt{H}$ required to sustain combustion in $m^{5/2}$
4. Using the criterion of
   (a) Babrauskas
   (b) Thomas

   estimate the energy release rate required for flashover of a typical compartment (length 5 m, width 3 m, height 2.4 m) with a single open window 1.5 m wide and 2 m high.
5. Ethane (C_2H_6) burns continuously under constant pressure conditions in a controlled heater combustion chamber. What is the adiabatic flame temperature, assuming 100% excess air in the reaction and assuming the products of combustion have a mean specific heat at constant pressure of $C_p = 1250\ J/kg \cdot K$?
6. Gasoline is stored in an above-ground tank to a depth of 10 feet. The exit piping from the bottom of the tank develops a leak of area equal to that of a round hole of diameter 0.2 inches.
   (a) Calculate the exit velocity of leaking fuel.
   (b) Calculate the volume flow rate.
   (c) Calculate the heat release rate in kW if the fuel burns.
7. (a) Calculate the heat release rate in kW for a 0.1 m-diameter pool fire of heptane (C_7H_{16}) using appropriate tabular data as needed. Do not include any reduction in burning rate (on a per-unit surface area basis) because of the diameter's small size—take $\dot{m}'' = \dot{m}''_\infty$ in usual notation.
   (b) Estimate the flame height for the pool fire of part (a).
   (c) Estimate the radiative fraction of the pool fire of part (a).
   (d) Using a simple inverse square distance law, determine the minimum distance away from the pool fire of part (a) that easily ignitable items would have to be for safety.

8. (a) Calculate the heat release rate in kW for a 1-m-diameter pool fire of gasoline, using appropriate tabular data as needed.
   (b) Estimate the flame height for the pool fire of part (a).
   (c) Estimate the radiative fraction of the pool fire of part (a).
   (d) Using a simple inverse square distance law, determine the minimum distance away from the pool fire of part (a) that the following would have to be for safety.
      (1) easily ignitable items
      (2) normal items
      (3) difficult-to-ignite items
   (e) Estimate the maximum temperature and maximum upward velocity on the centerline in the plume above the pool fire of part (a).
9. On a calm, clear night, an emission of 20 kg/s of butane occurs continuously from a ground level release point. The wind speed is 5 m/s. Calculate the mean concentration (in volume percent) of butane at 100 m downwind, in the wind direction.

   Assume the gas is neutrally buoyant and omit consideration of the dense gas situation.

   If a small pilot flame is located at this location, is ignition likely to occur or not? Discuss.
10. An arsonist pours an ignitable liquid on furniture in a room in such a way that the fire growth after ignition is found to obey the equation

    $$\dot{Q} = \beta t^{3/2}$$

    with $\dot{Q}$ in kW, t in seconds and $\beta = 0.1925$ kW/s$^{3/2}$.
    (a) How long does it take for the fire heat release rate to reach 2 MW?
    (b) If the only opening is a window 2.2 m wide and 1.4 m high, what is the maximum fire size that can be supported?
    (c) How long does it take for the specified fire to reach this maximum supportable size?
11. (a) After how many seconds will flashover occur in a typical room 3 m wide, 4 m long, and 2.4 m high subjected to a so-called "fast" t^2-fire with an incubation period of 100 seconds? Take the room to have a single window opening 2 m high and 1 m wide.
    (b) Whose theory are you using, how accurate is it likely to be, what alternative theories are available, and what obvious parameters affecting flashover are omitted from the theory used in your answer?
    (c) What is the maximum fire size in kW that can be supported in an enclosure with a single rectangular window opening 2 m high and 1 m wide in one of the walls?
12. A three-seater couch with polyurethane interior padding is furiously burning in a room with a single square opening.
    (a) Estimate the total heat output rate and the radiation heat output rate, in kW.
    (b) What is the minimum size of the square opening required to support this amount of burning?
    (c) How close to the fire can you expect to venture before the skin pain threshold alerts you to depart?
    (d) What is the minimum distance away that easily ignitable material would have to be for safety?
13. Kerosene is stored in a large above-ground tank to a depth of 15 feet. The exit piping from the bottom of the tank develops a leak of area equal to that of a round hole of diameter 0.25 inches.
    (a) Calculate the exit velocity of leaking fuel.
    (b) Calculate the volume flow rate.
    (c) Calculate the heat release rate in Btu/hour and kW if the fuel burns.
14. (a) After how many seconds will flashover occur in a typical room 3 m wide, 4 m long and 2.5 m high subjected to a so-called "fast" t^2-fire with an incubation period of 100 seconds? Take the room to be a single opening 1.5 m wide and 0.5 m high.

(b) Whose theory are you using, how accurate is it likely to be, what alternative theories are available, and what obvious parameters affecting flashover are omitted from the theory used in your answer?

(c) What is the maximum fire size in kW that can be supported in an enclosure with a single rectangular opening 1.5 m wide and 0.5 m high in one of the walls?

15. (a) Calculate the heat release rate in kW for a 0.5-m-diameter pool fire of methanol, using appropriate tabular data as needed.

(b) Estimate the flame height for the pool fire of part (a).

(c) Estimate the radiative fraction of the pool fire of part (a).

(d) Using a simple inverse square distance law, determine the minimum distance away from the pool fire of part (a) that easily ignitable items would have to be for safety.

16. Ethanol burns continuously under constant pressure conditions in a controlled heater combustion chamber. What is the adiabatic flame temperature, assuming 50% excess air in the reaction and assuming the products of combustion have a mean specific heat at constant pressure of $C_p = 1250$ J/kg · K?

17. (a) Calculate the heat release rate in kW for a 2-m-diameter pool fire of polypropylene, using appropriate tabular data as needed.

(b) Estimate the flame height for the pool fire of part (a).

(c) Estimate the radiative fraction of the pool fire of part (a).

(d) Using a simple inverse square distance law, determine the minimum distance away from the pool fire of part (a) that the following would have to be for safety.

(1) easily ignitable items

(2) normal items

(3) difficult-to-ignite items

18. A fire grows from size zero to a size of 3 MW in 500 seconds. Considered as a t^2-fire, calculate the growth parameter in kW/s^2 and growth time t_g in seconds. How would you categorize this fire—slow, medium, fast or ultrafast?

19. Using the criterion of

(a) Babrauskas

(b) Thomas

estimate the energy release rate required for flashover of a typical living room (length 6 m, width 5 m, height 2.4 m) with a single open window 3 m wide and 2 m high.

20. (a) At standard pressure and temperature, what is the heat content of 1 ft^3 of

(1) methane

(2) propane

(3) butane

(b) Assume that each of the following gases obeys the ideal gas law

$p = \rho RT$ where $R = \bar{R}/\text{MW}$

What is the density in lbm/ft^3 when the gage pressure is 30 psig and the temperature is 100 °F for the following gases:

(1) methane

(2) propane

(3) butane

SECTION 3

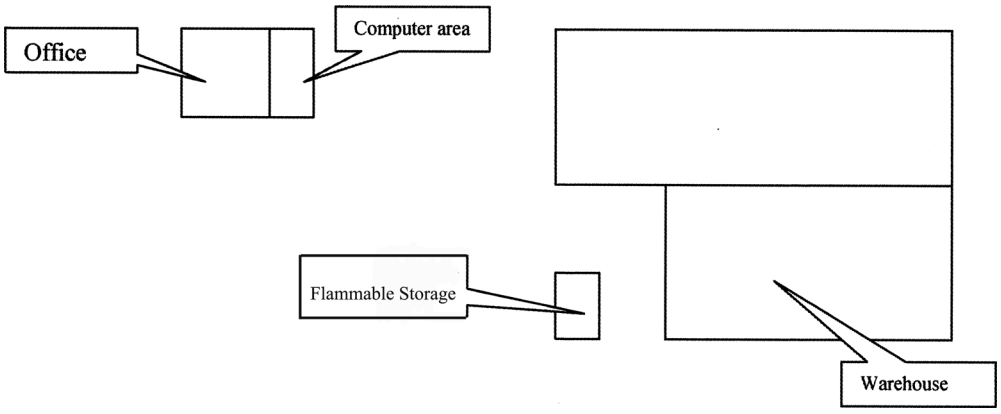
FIRE PREVENTION AND PROTECTION

Applied Science and Engineering: Fire Suppression and Detection

Dick Decker

End-of-Chapter Questions

1. Select the fire detection method best suited for an outdoor flammable liquid processing area.
   a. Ionization
   b. Rate-of-rise heat detector
   c. Ultraviolet
2. Name the stages of fire development.
3. Detectors should never be placed closer than ____ feet from fans, supply diffuser or other strong sources of drafts.
4. Fire alarm and annunciation systems should be designed in accordance with
   a. NFPA 13
   b. NFPA 230
   c. NFPA 72
5. A fire alarm circuit configuration that operates up to a single fault (open-circuit or ground-fault condition) is a
   a. Class A circuit
   b. Class X circuit
   c. Class D circuit
   d. Class B circuit
6. A small industrial plant has four buildings: an office with a central computer processing area, a machine shop, a warehouse, and a flammable liquid storage building, arranged as follows:



Assume that the office, machine shop and warehouse are protected by sprinkler systems and that the flammable liquid storage building is protected by a carbon dioxide system. Also assume that the computer area has an early-warning smoke detection system.

a. Make a schematic sketch of a fire alarm system for the plant showing what signals need to be collected; classify the circuits.
b. Specify detectors for the computer room.
c. Because the warehouse is not heated, what type of sprinkler will be provided? What signal monitoring is needed?

7. List the classes of fires that would be anticipated at the plant discussed in the previous question.
8. What quantity of carbon dioxide is needed to protect the 8 × 10 × 8-foot-high flammable liquid storage building? Assume a 40% design concentration.
9. Create a conceptual design of a sprinkler system for the machine shop assuming it to be 60 × 100 feet with open steel truss construction forming 20-foot bays. The building has a flat roof. Determine the hazard class, water density, and most remote sprinkler branch line arrangement. Calculate flow and pressure demand at the end of the branch line. Specify sprinklers and spacing. What temperature rating and color code would apply to the sprinklers?
10. Determine a hydraulically equivalent 8-inch C = 120 for a 6-inch C = 100 pipe 200 feet long.

SECTION 3

FIRE PREVENTION AND PROTECTION

Best Practices

Craig A. Brown

End-of-Chapter Questions

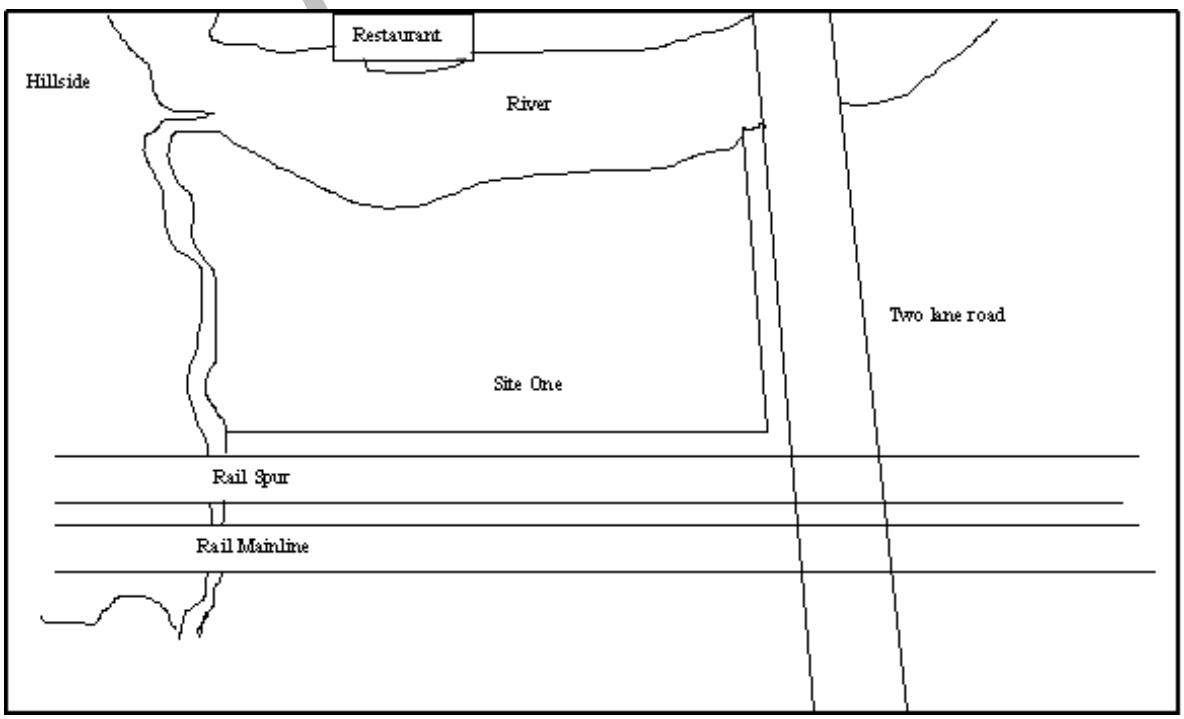
The following provide review questions to challenge understanding of the concepts and practices presented above.

1. Facility Siting Exercise

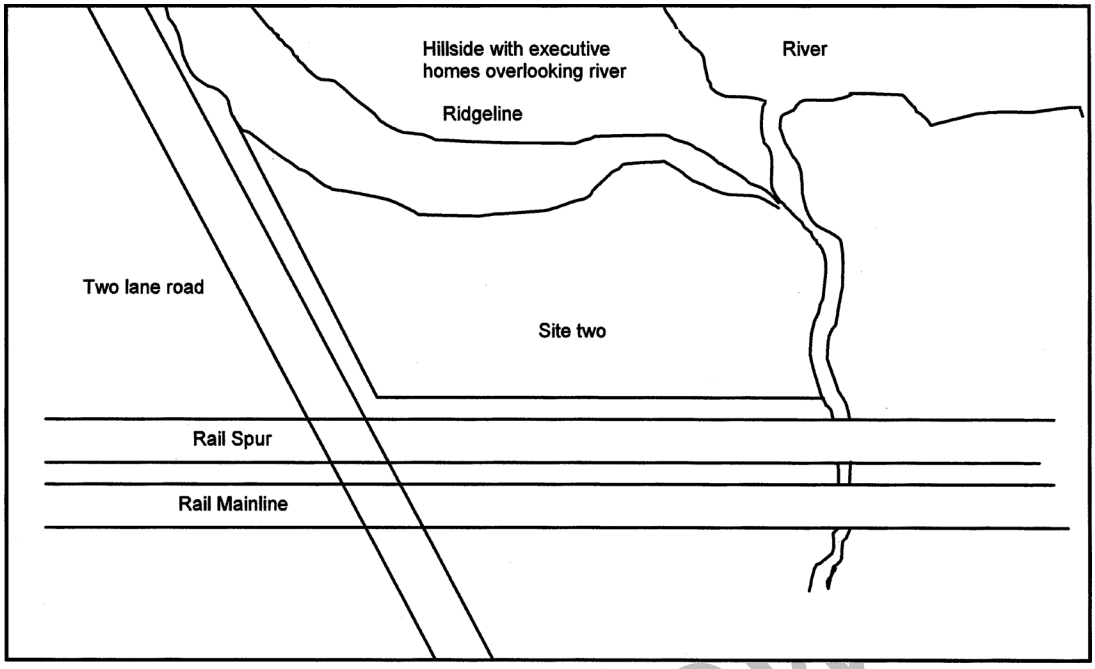
Design Objective: Two parcels of land within a new business park are available for the use of a small liquefied petroleum gas distributor. Assume that both parcels of land meet the distributor's cost restraints and that the only considerations are related to siting and general facility layout.

Design solution: Using the reading, consider the two sites presented and lay out a bulk storage vessel (a horizontal vessel 10 feet in diameter by 40 feet long), a truck loading area for one semi-tractor–trailer delivery vehicle and up to two simultaneous-loading local bobcat trucks (smaller vehicles used for local delivery), and a small office (20′ × 20′) with a parking lot for four employees and a single-bay (8′ × 12′) workshop with welding equipment and light-duty automotive repair equipment (floor jack, parts cleaning facility).

Option Site One

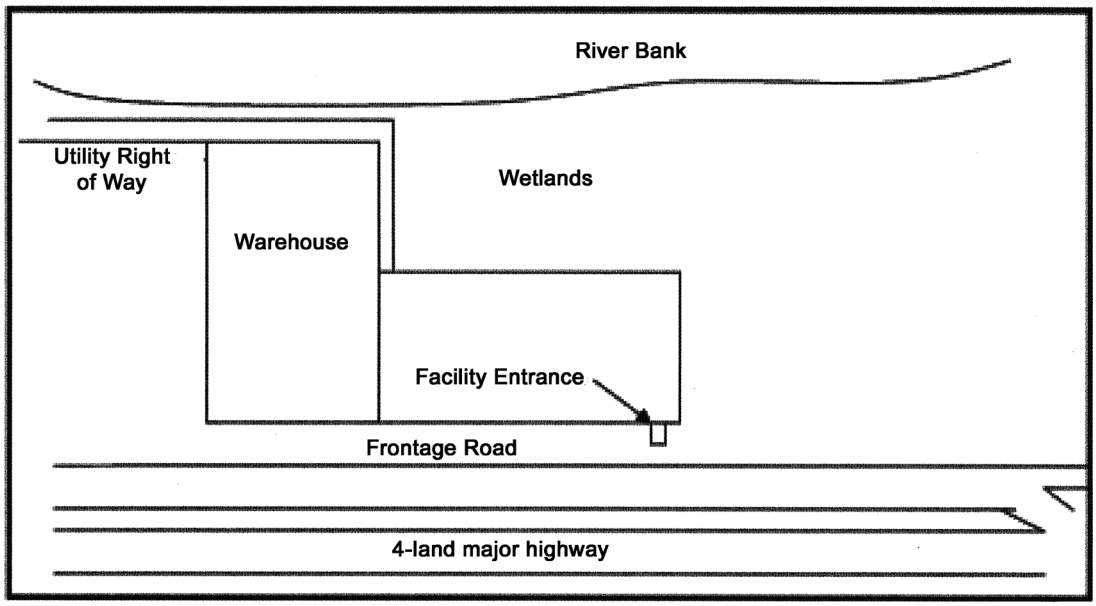


Option Site Two

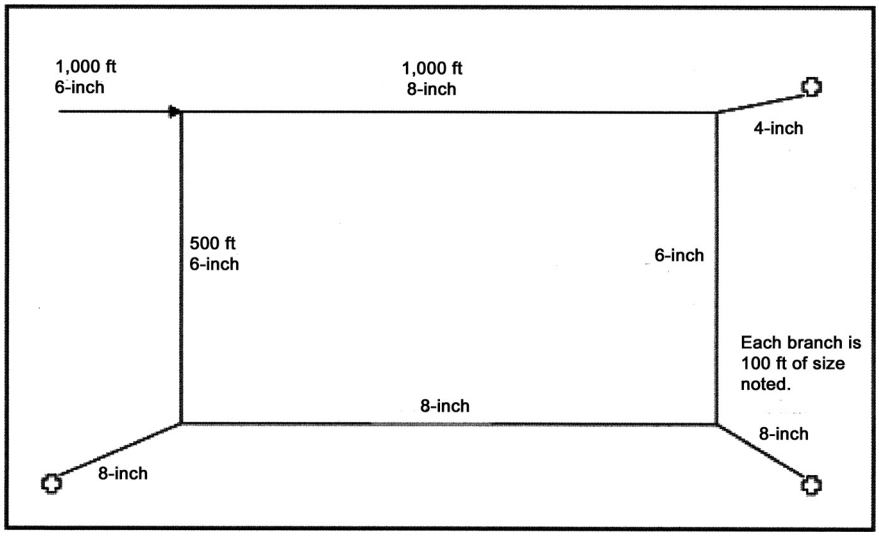


2. Facility Evacuation

Design Objective: An existing facility has only one method of evacuation, the entrance. The facility is along a roadway and is in an isolated area. Provide a proposed alternate evacuation route should the primary route become blocked. Consider response equipment in laying out the evacuation route. Detail in a short statement reasons for selecting the route and what considerations need to be included in designing the route.



3. Fire Water Loop System



Review the above sketch of an existing system and offer an opinion as to the suitability of the system to provide 1000 gpm of fire water through any one hydrant. The client is not interested in taking time to calculate the flow potential, being interested merely in trying to understand whether this system is salvageable or not. The client has indicated they may want to replace it but needs to understand what the main considerations are. The system has used brackish water in the past.

4. Liquefied Petroleum Gas Spheres

There are 3 liquefied petroleum storage gas spheres, each 100 feet in diameter. Calculate the volume of fire water required. Provide sketches of the fire water ring main and detail special considerations such as drainage, deluge valve location, and access. Assume access is not an issue and that the area is on a large open plot of land.

5. Drainage

The owner of a small bulk oil storage facility (class IIA liquid) has recognized the need to improve drainage following heavy rain in the region. Review the site, noting that the four 30-foot diameter tanks are spaced per NFPA 30. A low earthen berm surrounds the site and the tanks each sit on a foundation 6 inches above the surrounding grade. It appears they are all level and at the same elevation. A small stream runs next to the facility about 50 feet from the tanks. Prepare a sketch of the facility and note the drainage paths. List additional considerations for assuring a safe, code-compliant (NFPA 30) design.

6. Computer Room

Develop a plan to address the fixed Halon 1301 system installed in a computer facility whose owner has made substantial changes to it, recognizing the need to consider other solutions to the use of Halon. The owner is concerned about the cost of relying on the system.

1. The system was installed in 1981.
2. The facility is 15,000 ft^2 of open area.
3. There is a 16-inch-high raised floor with underfloor power cabling in steel conduit. Communications cabling is fire-rated to the latest code requirements because of recent equipment upgrades.
4. About half the floor area is now used for cubicle office space.
5. Equipment is composed of servers and mass storage devices in the operational area, as well as of standard office desktop computers.
6. An area of about 500 ft^2 is used for three large high-speed plotters and two high-capacity color printers.
7. The owner estimates the room has about $5 million dollars worth of office hardware and furniture.
8. The facility is staffed around the clock; shifts are staffed about equally.
9. A new loading dock has been installed to handle the added function the room now has in relation to printing operations. The staff bundles jobs for shipment about every 4 hours and has about twenty carts' worth of printout per batch. These carts are staged near the doors to the loading dock.

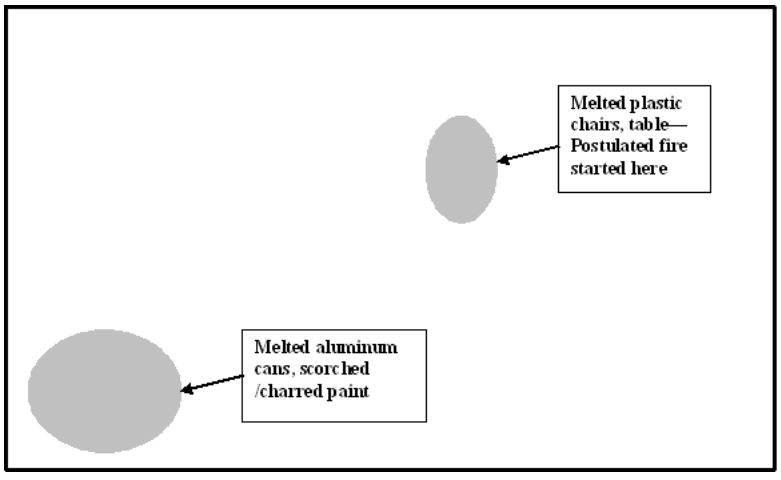
Develop a plan that can be presented in a short presentation to the owner.

7. Extinguisher Maintenance Program

A facility uses stored pressure water, CO_2, dry chemical, and Halon extinguishers. Recommend a program, as well as a checklist for each of the extinguisher types. Comment about any specific considerations that the owner should be aware of regarding the selection and use of extinguishers.

8. Fire Temperatures

A fire of questionable origin is under investigation. The local authority is convinced the fire started in one area, but evidence calls that into question. Using the table in the text dealing with temperature characteristics of materials exposed to flame, refer to the drawing and come to a conclusion.



9. Internet Search of Root Cause Analysis Vendors

Using an Internet search engine, identify two vendors of root cause software and compare and contrast their programs.

10. Fire Root Cause Analysis Report

Critique the report below and offer corrections.

Company	XZY Supply
Address	123 C Street
City	Centerville
Telephone	123-9876
Contact	Phredd Jaxon
Date	January 1, 2007

Event	Fire/Medical/Motor Vehicle (select one)
Event Description	Two fire fighters were burned when room fire flashed over.
Facility Type	Building electrical closet
Equipment Type	Electrical
Responders	Engine Company #54

Details of Event

At 2 am on January 1, 2001, fire fighters responded to an alarm from XYZ Supply. The source of the alarm was quickly identified as a fire in the electrical closet of the building. Fire fighters responded to the room and prepared to enter knowing flash over was a potential risk. Power to the facility was cut and after some difficulty due to blocked access ways, fire hoses and portable fire fighting equipment was brought to fight the fire.

Upon entering the room, the fire did flash over and the fire fighters (2) sustained minor injuries. Injuries where classified as 1st degree burns to wrists and neck of both fire fighters. They were provided first aid treatment by paramedics at the site and returned to their normal duties.

The fire was extinguished and an investigation into the event was begun. Fire Marshal working with building owner to ascertain cause.

Response

1. Alarm received at Engine Company #54 at 1:53 am, January 1, 2007
2. Engine Co responded to scene at 2 a.m.
3. Claxon siren sounding and smoke observed through windows.
4. Automatic alarm panel identified location as electrical closet
5. Two hose lines and two portable CO2 extinguishers routed to closet
6. Access blocked entrance to building slowing progress initially.

Event Sequence

1. 3 pm, December 31 Employee locks facility and leaves vehicle parked as directed at building entrance
2. 1:48 am January 1, the fire detection system indicates smoke in the electrical closet
3. 1:49 am cross zone detection goes into alarm.
4. 1:50 am claxon siren sounds
5. 1:50 am central supervisory system (BED Security and Safety) receives alarm.
6. 1:51 am operator notifies building owner that the alarm has sounded.
7. 1:53 am operator calls 911 and reports fire
8. 1:53 Engine Co #54 responds
9. 2:00 am Engine Co arrives scene
10. 2:02 am Engine Co identifies source of alarm – electrical closet
11. 2:04 am Engine Co hampered by access
12. 2:06 am power cut to building
13. 2:08 am two fire fighters access room, open door
14. 2:08 am fire flashes over (as expected), fire fighters receive minor burns
15. 2:10 am fire brought under control using one hose stream.
16. 2:15 am fire extinguished
17. 2:20 am fire fighters receive first aid treatment for 1st degree burns
18. 2:30 am building owner arrives

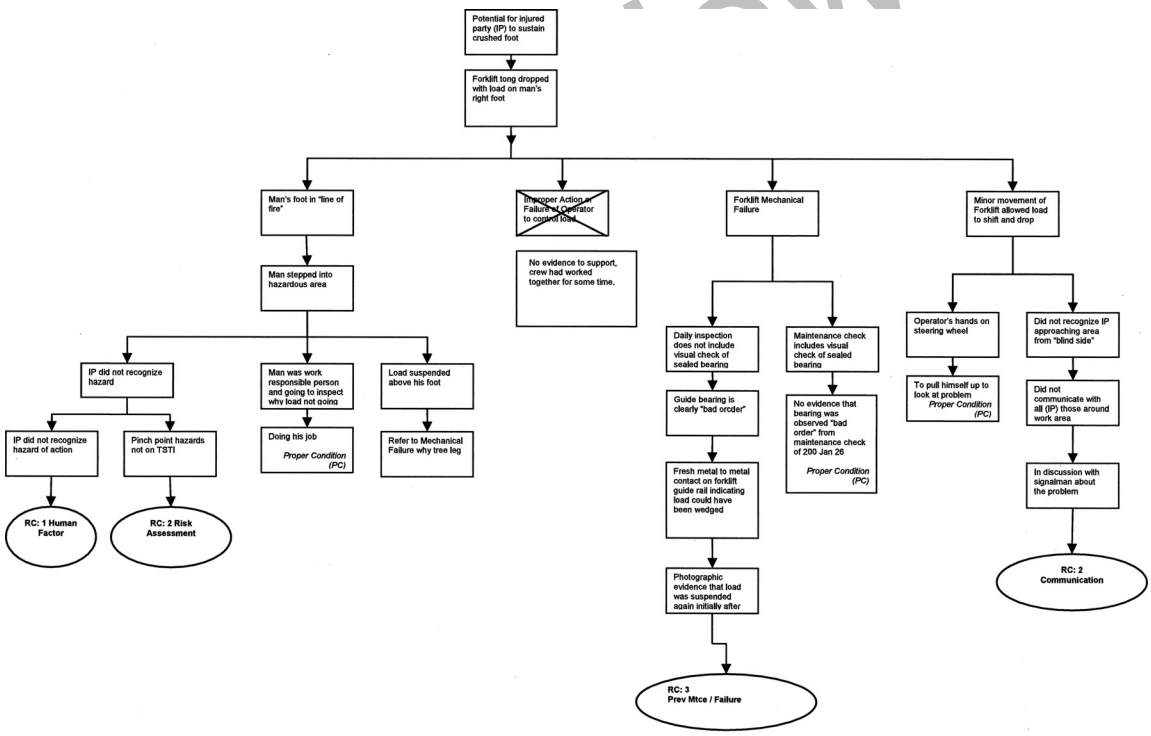
19. 3:15 Engine Co returns to station	
Root Cause	**Description**
1. Human Factor	Believed fire dampers did not need routine maintenance
2. Preventive Maintenance / Equipment Failure	No maintenance conducted on fire dampers as recommended by vendor
3. Design	No internal power cut off
4. Preventive Maintenance / Equipment Failure	No update of computer software, update available
5. Human Factor	Access blocked as driver in hurry to return home

Recommendations	**Person Responsible**	**Date Due**

Attachments	
Photographs	
Witness Statements	
Maintenance Records	
Medical Reports	
Procedures	
Job Safety Analysis	

Prepared By:

Root Cause Analysis Report



11. Fire Protection Checklist

Develop a series of checklists for an industrial facility after researching the types of fire protection concerns on the Internet and in the *NFPA Handbook*.

Please prepare checklists for the following reviews:

- Automotive repair workshop (both passenger and light-duty trucks)
- Welding workshop adjacent (and connected by an overhead door) to the automotive workshop
- Employee break room
- Small laboratory (including hydrocarbon, chlorine, and ammonia gases)

SECTION 4
INDUSTRIAL HYGIENE

Regulatory Issues

Gayla McCluskey

End-of-Chapter Questions

1. The first standard OSHA developed under full rulemaking was for:
   a. benzene
   b. hazard communication
   c. confined spaces
   d. asbestos
2. An Emergency Temporary Standard is effective:
   a. thirty days after it is published
   b. immediately on publication
   c. upon the date OSHA assigns
   d. sixty days after it is published
3. The Supreme Court decided in the review of which standard that OSHA must use quantitative measures to show significant risk?
   a. cotton dust
   b. asbestos
   c. respiratory protection
   d. benzene
4. What is the order of the hierarchy of controls?
5. The current permissible exposure limits are largely based upon the ACGIH threshold limit values that were published in:
   a. 1996
   b. 1985
   c. 1971
   d. 1968
6. List the industrial hygienists who have served as Assistant Secretary of OSHA.
7. Which other governmental agency shares responsibility for regulating occupational exposure to radiation?
8. The Environmental Protection Agency sets chemical exposure limits using authority from which Act of Congress?
9. Who is considered to be the founder of industrial medicine in the United States?
   a. Frances Perkins
   b. George Guenther
   c. Alice Hamilton
10. Samples are collected during an OSHA inspection and analyzed. When the sample result does not exceed the PEL but the UCL does exceed the PEL, or when the result exceeds the PEL but LCL is below the PEL, is this exposure:
    a. in compliance with the standard?
    b. in violation of the standard?
    c. a possible overexposure of the standard?

SECTION 4
INDUSTRIAL HYGIENE

Applied Science and Engineering: General Principles

Deborah Imel Nelson, Shery Milz, and Susan Arnold

End-of-Chapter Questions

1. What is the impact of integrating the risk-assessment and risk-management roles on risk-management decision making?
2. How is the precautionary principle impacting the risk-assessment paradigm?
3. Describe tools that a risk assessor can use to conduct qualitative, semiquantitative, and quantitative risk assessments.
4. What trade-offs are made in moving from one level of risk assessment to another? When and why would the risk assessor consider a simple, qualitative risk assessment? A more complex (and expensive) full, quantitative risk assessment?
5. How can models be used if all assumptions associated with the models are not valid for a given scenario?
6. What factors should be considered in designing a comprehensive exposure assessment strategy?
7. Differentiate between instantaneous and integrated monitoring.
8. Who should be sampled when exposure assessment is performed using a comprehensive strategy and a compliance strategy?
9. Differentiate between acceptable and unacceptable exposures.
10. How can an industrial hygienist ensure that sample results are meaningful?

SECTION 4

INDUSTRIAL HYGIENE

Applied Science and Engineering: Chemical Hazards

William Piispanen

End-of-Chapter Questions

1. In designing a ventilation system for a parts-solvent washing operation, what chemical parameters should be considered?
2. Inhalation is considered the most common route of chemical exposure in the workplace, but for particulate material, what factor determines the potential risk to unprotected workers?
3. A solvent with a STEL of 5 ppm, identified as a poison by ingestion and with a skin notation in the PEL table, a vapor density of 0.9, and an LEL of 40 percent, is being used in a chemical cleaning bath. What workplace controls would be considered for a task requiring removal of parts from the bath?
4. Describe how field-spraying of a pesticide using a handheld aerosol spray unit could contribute to an exposure of the worker to the product. What are the potential routes of entry? What information is necessary to assess the potential risk of exposure? How would this information be obtained? How would the worker receive training on methods for controlling the hazards? What monitoring method would assess the level of control achieved?

SECTION 4

INDUSTRIAL HYGIENE

Applied Science and Engineering: Physical Hazards

James C. Rock

End-of-Chapter Questions

1. Physical agents are distinguished primarily by the toxic effects they produce in living tissue—true or false?
2. What is the speed of sound in air:
   a. At sea level on a standard day with P = 101.325 kPa and 75°F?
   b. At 12,400 feet above sea level and 75°F on a day with barometric pressure = 29.8 inHg as reported by NOAA, assuming the effect of altitude is to reduce pressure by 1 inHg for each 1000 feet MSL?
3. What is the wavelength, in meters, for a 1250 Hz sinusoidal acoustic wave propagating through air at the speed of sound in air at a temperature of 75°F (297 K)?
4. The acoustic wave in Figure 2 was generated by vibrations in the flat panels of a machine enclosure. A low-mass accelerometer properly placed on that surface would provide the time history of its transverse acceleration, while a noncontact LASER interferometer would provide the time history of its transverse displacement. The equation for transverse displacement from Figure 2 is copied here for convenience. Note that t is time, x is the direction of propagation, and y is the transverse direction measured in μm.

$$y(x,t) = \sin 2\pi(x - vt)/\lambda + [\sin 4\pi(x - vt)/\lambda]/2 + [\sin 8\pi(x - vt)/\lambda]/4$$
$$= \sin 2\pi x/\lambda - \omega t + (1/2) \sin 4\pi x/\lambda - 2\omega t/2 + (1/4) \sin 8\pi x/\lambda - 4\omega t$$

Transverse velocity is the time derivative of transverse displacement:

$$v(x,t) = dy/dt$$
$$= -\omega \cos 2\pi x/\lambda - \omega t - \omega \cos 4\pi x/\lambda - 2\omega t - 2\omega \cos 8\pi x/\lambda - 4\omega t$$

Transverse acceleration is the time derivative of transverse velocity:

$$a(x,t) = dv/dt$$
$$= -\omega^2 \sin 2\pi x/\lambda - \omega t - 2\omega^2 \sin 4\pi x/\lambda - 2\omega t - 4\omega^2 \sin 8\pi x/\lambda - 4\omega t$$

Answer the following questions by using the relations: $\omega = 2\pi f = 2\pi v/\lambda$.

a. Given an observed wavelength of λ = 23 cm, at a frequency of 3 kHz find the speed, v in m/s, and ω in rad/s for the elastic vibration wave in the panel.
b. Make a scaled sketch in the shape of the transverse displacement of the panel as a function of time at the point where $x = 0$. Show that the same sketch applies to x = 0.23 m, 0.46 m, . . . , $n \times 0.23$ m, where n is an integer.

c. Compare your sketch with the chart at the bottom of the page, which shows transverse displacement as a function of time (t) at a fixed position, x = constant.
d. Sketch the shape of the transverse velocity of the panel as a function of time at a fixed point along the x-axis, data that could be observed with a doppler LASER detector.
e. Sketch the shape of the transverse acceleration as a function of time at the point where $x = 0$. This is the waveform that could be observed by an accelerometer.
f. Estimate the peak values for the displacement, velocity, and acceleration functions for this illustrative example (these high frequencies would be unlikely in practice).

5. The acoustic spectrum for sound waves at a machine operator's location is measured with a narrow-band spectrum analyzer. In physical units, the peak reported sound pressures in octave band widths were {250 Hz, 2 Pa}, {500 Hz, 1 Pa}, {1 kHz, 1 Pa}, {2 kHz, 0.5 Pa}, and {4 kHz, 0.25 Pa}. Use the A- and C-weighting filter attenuation factors summarized in the table below (NIOSH 1998) to answer the questions that follow.
   a. Find the *rms* sound pressure and sound pressure level for each of its five harmonics.
   b. Find the sound intensity and sound intensity level that would be measured using a survey instrument with a flat frequency response on a standard day when L_P dB re 20 μPa is numerically equal to L_I dB re 1 pW/m^2.
   c. Estimate the C-weighted sound intensity level at this workstation by estimating the C-weighting attenuation for each harmonic, subtracting that from the flat-weighted sound intensity level for each harmonic, converting each harmonic L_I to intensity, summing the intensities, and converting the sum back to the total sound intensity level, L_I.
   d. Estimate the A-weighted sound intensity level at this workstation.
6. A pair of piezoelectric sensors has been used on a piece of steel pipe at a temperature of 95°F to discover that a standing wave sinusoid with an ultrasonic frequency of 35 kHz has a wavelength of 14.5 cm. What is its speed of propagation in the steel?
7. Find the speed of light in a medium where the permeability is $4\pi 10^{-7}$ V s/A m and the permittivity is $36 \times 10^{-9}/\pi$ (A s/V m).
8. A new ferrite material is advertised for use with an induction furnace. It is said to have a relative permittivity of 12 and a relative permeability of 1000 under operating conditions of T and P.
   a. What is the speed of light in the bulk of this material?
   b. What is the ratio of the vacuum speed of light to the ferrite speed of light?
   c. What is the free-field electromagnetic impedance of this material?
9. Find the frequency for an electromagnetic wave with a wavelength of 1 meter in a medium characterized by a speed of light = 2.2×10^8 m/s.
10. Wavelength increases and speed decreases when an EM wave passes from free space into a media with relative permeability or relative permittivity greater than unity—true or false?
11. An electromagnetic wave with a frequency of 10^9 Hz is propagating in the far field of a radar antenna with an *rms* electric field strength of 300 V/m.

A- and C-Weighting Filter Attenuation Factors

Frequency/Hz	31.5	63	125	250	500	1k	2k	4k	8k	16k
A-weight/dB	−39.4	−26.2	−16.1	−8.6	−3.2	0	1.2	1.0	−1.1	−6.6
C-weight/dB	−3.0	−0.8	−0.2	0	0	0	−0.2	−0.8	−3	−8.5

a. What is the free-field *rms* magnetic field strength in Tesla?
b. What is the power density of the EM field at this point?
c. Does this comply with the TLV?
d. What is the maximum E field strength that keeps power density < 1 mW/cm^2?

12. Express the electromagnetic fluxes in units of Volt, Ampere, second, and meter. Recall that electric flux $\Phi_E = E \cdot dA$ and magnetic flux $\Phi_B = B \cdot dA$.
13. Confirm that $E = c_0 B$ is consistent with the impedance of free space, $Z_0 = 376.7$ ohm, using the following steps:
    a. Find E in V/m, when $Bf = 1.0$ T (a very strong magnetic field).
    b. Find Hf in A/m from $Bf = \mu_0 Hf$.
    c. Find Z_0 as Ef/Hf.
14. Find the frequency in Hz and energy in eV of a photon with a vacuum wavelength = 10^{-8} m in a medium with a speed of light = 2.5×10^8 m/s.
15. A photon with f = 540 THz has the frequency near which the human eye has its maximal photopic sensitivity. Understanding that f has units of cycles per second and ν (nu) has units of radians per second,
    a. Find its frequency in radians per second, ν.
    b. Can its energy be calculated from either $E = hf$, or from $E = hbar\ \nu$?
    c. Express its energy in both J and eV.
16. Photon energy is often expressed in units of electron Volt rather than Joule. Convert 10^{-17} J to eV and decide whether a photon with this energy would be considered ionizing radiation.
17. The threshold for visual sensitivity for scotopic vision is remarkable. For a 20 ms pulse having a green light wavelength of 505 nm, the energy density threshold is approximately 10^{-32} J/m^2. Recall that the threshold for human hearing is approximately equal to a sound pressure level of L_P = 0.0 dB re 20 μPa or a sound intensity level of L_I = 0.0 dB re 1 pW/m^2 . Estimate the energy density of the auditory threshold of hearing and determine which sensory mode is more sensitive to delivered energy.
18. An LED with an on-axis intensity of 3 cd is shining onto a surface 2 m away. (David Gibson at www.caves.org.uk/led/foot3.pdf, *CREG Journal* (Sep. 1997) 27:9–10).
    a. Find the illumination at the center of the beam.
    b. If the beam illuminates a perfectly diffuse surface with a reflectance of 0.1, find the peak luminance of that surface.
19. It is important to understand the often confusing terminology associated with photometry and radiometry. Just as there are different units for physical and physiological acoustical measurements, there are different units for physical and physiological radiometric measurements. Answer true or false for each of the following questions:
    a. A radiometer measures EM parameters weighted by human physiological response.
    b. A photometer measures EM parameters weighted by human physiological response.
    c. Radiance is a property of a light source.
    d. Irradiance is a property of a light source.
    e. Radiance is a measure of intensity of light at the lens of the receiver.
    f. Irradiance is a measure of intensity of light at the lens of the receiver.
    g. Luminance is a property of a light source weighted by its relative spectral effectiveness.
    h. Illuminance is a property of a light source weighted by its relative spectral effectiveness.
    i. Luminance is a measure of light at the lens of the receiver, weighted by its relative spectral effectiveness.
    j. Illuminance is a measure of light at the lens of the receiver, weighted by its relative spectral effectiveness.
    k. Illuminance is weighted by the frequency response of a physiological system.
    l. Irradiance is weighted by the frequency response of a physiological system.
    m. Luminance is weighted by the frequency response of a physiological system.
    n. Radiance is weighted by the frequency response of a physiological system.

20. True or false? The WBGT index is a direct means for controlling core body temperature of workers.
21. Find the windchill temperature in an environment with a temperature of 5°C (41°F) and a windspeed of 22.37 mph.
22. Calculate the wet-bulb globe temperature inside a building with a measured wet-bulb temperature, WB = 79°F, globe temperature, GT = 110°F, and dry-bulb temperature, DB = 95°F. Write the work–rest schedule you would recommend for protection of lightly clothed workers in this environment.
23. Calculate the wet-bulb globe temperature outdoors when the WB = 79°F, GT = 110°F, and DB = 95°F.
24. The sound pressure level of 102 dB re 20 μPa corresponds to an *rms* sound pressure of _____.
    a. 102 Pa.
    b. 10.2 Pa.
    c. 2.52 Pa.
    d. 316,800 Pa.
25. The OSHA PEL-allowed duration of exposure and the ACGIH TLV-allowed duration of exposure to noise measuring L_P = 102 dBA re 20 μPa are:
    a. Duration (PEL) = _____.
    b. Duration (TLV) = _____.
26. What is the sound pressure level in a workplace where the measured *rms* sound pressure is 0.75 Pa?
27. What is the sound intensity level in a location where the measured sound pressure level is 96 dB re 20 μPa, the density of air is 1.0 kg/m^3, and the speed of sound is 270 m/s?
28. Consider a location where the temperature of air is T_{air} = 120°F and the station barometric pressure is 75 kPa.
    a. Find the sound intensity level if the measured sound pressure level is 96 dB re 20 μPa.
    b. If the altitude is 8000 feet, what barometric pressure would NOAA report for this location?
29. Point source problem: Consider a public address system for a newly designed arena. The speaker system will be placed at the center of a circular seating area 30 meters above the floor and at the center of the hemispherical roof (radius = 80 m). The inner surface of the roof is treated to minimize reflected sound (reflections are a remarkable –30 dB below incident acoustic energy to avoid reverberation). Estimate the sound power that needs to radiate from the speakers to produce sound intensity of 90 dB in the front row of seats (40 m from speakers), and find the intensity in the top row of seats. Use the point source equation and neglect all reflections. Coordinates for this problem, in meters, are: center of arena floor (0,0); speaker (0,30); front row (40,0); top row (80, 30). Find:
    a. the sound intensity in the front row from the given sound intensity level.
    b. the sound power radiating from a speaker into the arena air, and its sound power level.
    c. the sound intensity and sound intensity level in the back row.
30. Show that the ANSI reference quantities are internally consistent by calculating I_0 from P_0 and Z_0 using I_0 = 1 pW/m^2.
31. Estimate the mechanical pressure from a continuous LASER with spot size 0.05 mm based on its reported *rms*-averaged beam intensity. Assume a nonrealistic uniform spot illumination intensity. Proceed by finding the intensity of the EM field from the radiated power and spot size. Convert the intensity to spot pressure using the relation between intensity, speed of light, and pressure exerted on a target by an electromagnetic beam. Note that the pressure and force can be estimated from intensity without knowing the wavelength. Estimate pressure in the spot for two extreme types of surfaces: complete absorption or full reflection.
    a. 5 mW LASER
    b. 5 W LASER
    c. 5 kW LASER

32. Estimate the mechanical pressure from a LASER used in the National Ignition Facility at Lawrence Livermore Laboratory (www.llnl.gov/nif/project/news_first_bundle.html). In December 2005, a bundle of eight LASERs achieved a 10 ns flat top pulse totaling 152.8 kJ. In final configuration, the NIF will have 192 such LASERs to cover the surface of a 1 mm–diameter fuel pellet. Find the pressure produced under the assumptions of uniform illumination, simultaneous ignition, and nonoverlapping spots.
    a. Find the power of the LASER beam during the pulse.
    b. Find the area of the spot on the surface of the absorbing spherical target.
    c. Find the average intensity over the surface of the spot.
    d. Find the average pressure over the surface of the spot.
    e. Find the force exerted by the spot on the target.
33. Another way to apply pressure to charged particles is with a magnetic field. The instantaneous pressure, in Pascal, is $B^2/2\mu$, with B in Tesla. Estimate the magnetic field, in Tesla, needed to produce a pressure of 225,000 atm in a region where the magnetic permeability is μ_0.
34. Answer true or false:
    a. LASER light in near IR to visible (1400–400 nm) is likely to damage the cornea.
    b. LASER light in near IR to visible (1400–400 nm) is likely to damage the lens.
    c. LASER light in near IR to visible (1400–400 nm) is likely to damage the retina.
    d. LASER light in UV (400–100 nm) is likely to damage the cornea.
    e. LASER light in UV (400–100 nm) is likely to damage the lens.
    f. LASER light in UV (400–100 nm) is likely to damage the retina.
    g. LASER light in far IR (10,600–1400 nm) is likely to damage the cornea.
    h. LASER light in far IR (10,600–1400 nm) is likely to damage the lens.
    i. LASER light in far IR (10,600–1400 nm) is likely to damage the retina.
35. A LASER with a radiated power level of 10 mW may be treated as a Class I LASER if two conditions are met. Those are:
    a. _____.
    b. _____.
36. LASERs operating in the visible light frequencies are considered safe for viewing for periods less than 1000 seconds if their radiated power level is smaller than
    a. 4 nW.
    b. 4 μW.
    c. 4 mW.
    d. 4 kW.
37. Consider a vibrating hand tool that has its energy concentrated in two narrow frequency bands, 16 Hz and 63 Hz. Orthogonal basicentric axes used here are x (pointing away from the palm), y (through knuckles), and z (along the forearm axis). For the first 3 hours of the shift, a repetitive task has measured triaxial accelerations of $\{ax,ay,az\} = \{0.1,1.5,2\}$ m/s^2 at 16 Hz and $\{0.1,0.05,2.5\}$ m/s^2 at 63 Hz. Later in the shift a 2-hour task is performed having measured accelerations of $\{0.05,0.25,2\}$ m/s^2 at 16 Hz and $\{0.1,0.5,4\}$ m/s^2 at 63 Hz. The shift ends with a 10-minute task measuring $\{0.05,5,0.5\}$ m/s^2 at 16 Hz and $\{0.1,0.1,5.1\}$ m/s^2 at 63 Hz. All measurements are expressed as *rms* time averages taken at the indicated frequencies.
    a. A transfer function that satisfies the ISO hand–arm frequency weighting criteria is:

$$wt(f) = \left(\frac{jf/4}{1 + jf/4}\right)^2 \left(\frac{1.4286}{1 + jf/16}\right)$$

    The italic "j" represents the square root of negative one. Find the weighting for 16 and 63 Hz by finding the magnitude of the complex function at these frequencies. Also, find the time-weighting coefficient for each task as the ratio of task duration to an 8-hour (480-minute) shift.
    b. For each of the three tasks—3-hour, 2-hour, and 10-minute—compute the

frequency-weighted total *rms* acceleration amplitude along each basicentric axis and compute the length of the weighted vector using the mathematical concept called "norm of a vector." Then use the time-weighting coefficients to compute the 8-hour TWA for each component and for the resultant vectors.

c. For the frequency-weighted measurements, compare the *x*-component, the *y*-component, the *z*-component, and the resultant vector to the TLV guideline—that the dominant frequency component should not exceed 6 m/s^2 over periods of 2–4 hours or 4 m/s^2 for periods of 4–8 hours; compare the frequency-weighted resultant vector to the European Union 8-hour standard of 5 m/s^2 and 8-hour action value of 2.5 m/s^2.

d. Repeat the calculations of part b with no frequency weighting. That is, find the components and length of the acceleration vector for each task directly from the frequency band measurements using the vector norm function to estimate resultant vectors, and use these to find the TWA acceleration vectors to compare with exposure guidelines.

e. Compare the unweighted 8-hr resultant TWA acceleration intensity received on this day relative to the European Union 5 m/s^2 8-hr guideline and to its 2.5 m/s^2 8-hr action value, using the frequency-weighted measurements.

f. Use Equation 36 to estimate the TLV for each task and for the 8-hour shift. Discuss how this affects your assessment of this work environment.

38. From the following choices, pick the electromagnetic frequency band that is most effective at depositing energy in the human body.
    a. 1–2 MHz
    b. 60–80 MHz
    c. 500–1000 MHz (= 0.5–1 GHz)
39. Which of the following frequencies is known to be very effective at heating tissue?
    a. 1–2 MHz
    b. 100–200 MHz
    c. 2–4 GHz
    d. 100–200 GHz
40. The worry about cancer associated with ELF exposures is unjustified because
    a. ELF wavelengths are too small.
    b. ELF wavelengths are too large to deposit much energy in tissue.
    c. ELF intensity is too small because it does not propagate.
    d. ELF near field is too small for a human to enter.
41. The averaging time for estimating nonionizing energy deposited in human tissue is:
    a. 24 hours.
    b. 8 hours.
    c. 15 minutes.
    d. 6 minutes.
42. The fields 10 m from a 13 kV power line have been measured on an *rms* basis to be as large as $E = 20$ V/m and $B = 1\ \mu$T (Tesla). Given that measurement, estimate the *E* and *B* fields at 5 m from the power line considered as a line source, neglecting the reactive near field.
43. The control of exposure to ionizing radiation involves repeated application of three overarching principles. Name them:
    a. _____
    b. _____
    c. _____
44. A new airport scanner is proposed that will use ultra wideband short-pulse radio-frequency technology as a technique for stimulating characteristic rf emissions from contraband materials. Its specifications call for pulses with 0.2 ns rise time and 40 ns dwell time at an intensity of 250 mW/cm^2. Find the maximum *prf* for continuous operation based on the TLV.
45. The following questions can be answered from this list of wavelengths: (100–180 nm), (305–700 nm), (380–1400 nm), (770–3000 nm), and (180–400 nm).
    a. Retinal thermal damage is primarily caused by light in the wavelength range

____ to ____ nm with a maximum hazard weighting, $R\lambda$, of ____ at λ = _____ nm.

b. Cornea and lens thermal damage is primarily caused by light in the wavelength range ____ to ____ nm with a maximum hazard weighting, $T\lambda$, of ____ at λ = _____ nm.

c. Aphakic eye retinal photochemical damage from blue light is primarily caused by light in the wavelength range ____ to ____ nm with a maximum hazard weighting, $A\lambda$, of ____ at λ = ____ nm.

d. Normal eye photochemical damage from blue light is primarily caused by light in the wavelength range ____ to ____ nm with a maximum hazard weighting, $B\lambda$, of ____ at λ = ____ nm.

e. UV light and damage to skin and cornea is primarily caused by light in the wavelength range ____ to ____ nm with a maximum hazard weighting, $S\lambda$, of ____ at λ = ____ nm.

f. These energetic far UV photons are able to ionize many biochemical molecules but are not listed among those posing a hazard to humans because they are so strongly absorbed in the air that a beam of them is extinguished within a few centimeters of its source. Their wavelength range is _____.

46. Answer shielding questions from the following elemental stable isotopes:

$$^{1}H_{1},\ ^{14}C_{12},\ ^{57}Fe_{26},\ ^{207}Pb_{82}$$

a. Neutrons are best shielded with _____.

b. X-rays used for imaging in medicine and nondestructive inspection are best shielded by _____.

47. OSHA allows how much external radiation per quarter for a healthy male worker?