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NOTE TO THE INSTRUCTOR -- 6e SOLUTIONS MANUAL

At the beginning of each chapter of the solutions manual, the instructor will find "solutions" for the "b" problems. After the "b" problem solutions in each chapter, the solutions to the other problems in the chapter are presented.

The "b" problems are more basic problems written to "encourage" the student to read the textbook. The basic problems are generally short answer, some requiring definitions, although some are involved in helping to analyze and understand patents.

The problems and solutions not designated with a "b" are generally analytical in nature. If a "D" appears in the problem number the problem usually involves design and requires problem solver (student) decision-making.

The solutions manual serves both the needs of the print and electronic formats for the 6th edition.

SOLUTIONS MANUAL
to accompany

FUNDAMENTALS OF MACHINE COMPONENT DESIGN

Sixth Edition

Chapter 1 "b" Problems

1.1Db, 1.2Db, 1.3Db, 1.6Db, 1.7Db, 1.8Db, 1.14D, 1.31D, 1.32b, 1.36b, 1.43b, 1.44b, 1.45b, 1.46b, 1.49b, 1.51b, 1.66Db

1.1Db Write definitions of the words *safety, imagination, ingenuity, ecology,* and *ergonomics* using a dictionary and compare with the ways in which these words are used in Section 1.2-1.5.

SOLUTION 1.1Db:

Safety --the condition of being protected from or unlikely to cause danger, risk, or injury ... "they should leave for their own safety"

Imagination. -- Imagination, also called the faculty of imagining, is the creative ability to form images, ideas, and sensations in the mind without direct input from the senses, such as seeing or hearing

Ingenuity -- the quality of being clever, original, and inventive

Ecology -- the branch of biology that deals with the relations of organisms to one another and to their physical surroundings

Ergonomics. -- the study of people's efficiency in their working environment

Comment: Also see Section 1.2-1.5 and/or a Webster dictionary at www.merriam-webster.com. The remainder of this problem is left as an exercise for the student to "encourage" them to read the textbook.

1.2Db The Segway two-wheeled-self-balancing electric vehicle invented by Dean Kamen and used for short distance personnel transportation reportedly travels at 12.5 mph. The vehicle is controlled and powered with computers and electric motors. Lean forward, you move forward. Lean back and you go backward. Lean the handlebars to the left or right and you turn in that direction—see www.youtube.com for a video. When you need to brake, the motor acts as a dynamometer. Review several articles written about the Segway and address the following statements that appeared recently and written by Jordan Golson, a technology and automotive reporter based in Durango, Colorado. Email: jlgolson@gmail.com Twitter: @jlgolson. He states that the Segway "has found a measure of success in industrial and fleet applications where employees are on their feet or moving around a lot." But he also states that the Segway "as a personal transporter, the Segway was a near complete failure" and he also says that "for a device that was said to have cost more than $100 million in research and development, it's impossible to call the Segway anything but a dud." Review several articles written about the Segway, list the articles you reviewed, and discuss (pro and con) the statements written by Jordan Golson.

Background: Wikipedia, the free encyclopedia, in an article dated September 4, 2010, entitled "Segway PT," presents a comprehensive review of the history, sales, technology, uses, operation, and safety of the Segway vehicle. In what follows, we present segments from the Wikipedia article:

1. <u>History</u>: The product was unveiled December 3, 2001, in Bryant Park on the ABC News morning program *Good Morning America*.

2. <u>Sales</u>: The product was unveiled December 3, 2001, in Bryant Park on the ABC News morning program *Good Morning America*. In a March 2009 interview, company official said the firm "has shipped over 50,000" Segways.

3. <u>Technology</u>: The dynamics of the Segway PT are identical to a classic control problem, the inverted pendulum.

The side effect of this balancing system is that as the Segway PT balances itself the entire unit changes position in the direction it has moved to restore balance. (For example, if the rider leans forward, the entire Segway PT will move forward from its original position, until the rider restores an upright position on the unit.) This is precisely how the Segway PT is controlled - the balancing and movement is essentially one combined system.

The Segway PT features a governor (speed limiting) mechanism. When the Segway PT approaches the maximum speed allowed by the software, it intentionally begins to tilt slightly backwards. This moves the platform out in front, and leans the handlebars backwards towards the rider, eventually nudging the rider to lean back slightly and slow the Segway PT down. If not for the governor, riders would be able to lean farther than the motor could ever compensate for. The Segway PT also slows or stops immediately if the handlebar of the unit (or forward bag) nudges into any obstacle.

4. <u>Uses</u>: Segways perform best in areas with adequate sidewalks, curb cuts at intersections, and ramps. They are used in cities for tours and in theme parks by visitors and employees. The special police forces trained to protect the public during the 2008 Summer Olympics used the Segway for mobility.

5. <u>Operation</u>: The original Segway models were activated using one of three keys:
Black Key: for beginners. Slowest speed (electronically limited to no more than 6 mph); slower turning rate.
Yellow Key: for intermediate users and/or pavements. Faster speed-up to 8 mph (13 km/h); faster turning rate.
Red Key: for more advanced users in open areas. Maximum speed-up to 10 mph (16 km/h) on p-Series and 12.5 mph (20.1 km/h) on i-Series; and max turning rate.

In September 2003, the Segway PT was recalled because if users ignored repeated low battery warnings on the PTs, it could ultimately lead them to fall. With a software patch to version 12.0, the PT would automatically slow down and stop in response to detecting low battery power. Any units sold before September 2003 with a label 12.0 have the upgraded software.

In August 2006, Segway discontinued all previous models and announced second-generation designs. The Gen II PT, marketed under the two product lines, i2 and x2, allows users to steer by leaning the handlebars to the right or left, which matches the intuitive nature of leaning forward and backward to accelerate and decelerate.

6. Safety: Because the Segway can reach speeds over 20 km/h (12 mph), the Bicycle Helmet Safety Institute recommends that all riders wear helmets when using Segways. The US Consumer Product Safety Commission does not have Segway-specific recommendations but does say that bicycle helmets are adequate for "low-speed, motor-assisted" scooters.

SOLUTION 1.2Db: The student is asked to address the following statements:

(a) the Segway "has found a measure of success in industrial and fleet applications where employees are on their feet or moving around a lot."

(b) "as a personal transporter, the Segway was a near complete failure"

(c) "for a device that was said to have cost more than $100 million in research and development, it's impossible to call the Segway anything but a dud."

This exercise is left for the student.

Comment 1: The title of Jordan Golson's article is: ***"Well, That Didn't Work: The Segway is a Technological Marvel. Too Bad it Doesn't Make Any Sense."*** For the article, please search www.wired.com under heading "GEAR" for JORDAN GOLSON, Segway, 01.16.15.

Comment 2: The Segway invented by Dean Kaman, a brilliant engineer, is indeed a technological marvel. For additional information about Dean Kaman and his many accomplishments, please see Wikipedia.

1.3Db A hands-free self-balancing two-wheeled board or scooter also sometimes referred to as a hover board is described in Wikipedia as a portable, rechargeable battery powered scooter having a wheel on each side of a platform on which a rider stands. Review several videos at www.youtube.com and address the question as to whether the hands-free board is a "reasonable safe design" using the following categories:

(a) The usefulness and desirability of the product

(b) The availability of other and safer products to meet the same or similar needs

(c) The likelihood of injury and its probable seriousness

(d) The obviousness of the danger

(e) Common knowledge and normal public expectation of the danger (particularly for newer versus established products)

(f) The avoidability of injury by care in use of the product (including the effect of instructions and warnings)

(g) The ability to eliminate the danger without seriously impairing the usefulness of the product or making it unduly expensive.

SOLUTION 1.3Db: We are asked to address the question as to whether the hands-free self-balancing two-wheeled board or scooter also sometimes referred to as a hover board is a "reasonable safe design"

Background: Additional information can be obtain from various web sites such as:

http://hands-free-skooter.com
See section: 8: Frequently Asked Questions and Answers

https://www.cnet.com/news/why-are-hoverboards-exploding-and-catching-fire/
www.cnet.com, search gadgets for the articles titled "hoverboard". One of several articles found was titled: "Here are the reasons why so many hoverboards are catching fire"

An analysis would involve an objective review of items (a) to (g) as listed in problem 1.3Db and repeated below:

(a) The usefulness and desirability of the product

Product helps promote … for users. Allows users to … Product is desirable, as…

(b) The availability of other and safer products to meet the same needs

There are currently personal transporters with more... No other skooter has a safer … design incorporating tamper resistant screws, guard interlocks, motor guard warnings and/or owners manual holders.

(c) The likelihood of injury and its probable seriousness

The likelihood of injury from riding ... The seriousness of the injury is very high with great probability of serious but not life threatening injury ...

(d) The obviousness of the danger

The danger of a … and the … is open and obvious. Everyone knows that … and … can cause harm

(e) Common knowledge and normal public expectation of the danger
(Particularly for established products)

People see hoverboards as ... I believe the public knows that you can fall from a … and then be injured from the ... The public may also be aware of … My thought is that the public would see … as slightly more dangerous than … the major cause of injury. I do not believe the public is aware of the danger of the …

(f) The avoid ability of injury by care in use of the product
(Including the effect of instructions or warnings)

The ability to avoid injury is … when the users keeps … Warnings on the … may prevent the accident by discouraging … It is less likely that a warning placed … would prevent the accident … the location of the warning would have to be placed. Normal use of the product … would avoid all potential of the user from being …. If the owner's manual instructions were followed then the accident would …

(g)j The ability to eliminate the danger without seriously impairing the usefulness of the product or making it unduly expensive

The danger is easy to eliminate by ... The usefulness is not hampered in any way by … and does not add a significant cost. The … could serve a useful cosmetic purpose. The guard could be … that would discourage unauthorized access. But this would introduce additional parts that could fail and/or make the … more difficult to maintain. Also, there is no apparent additional means to remove the danger of the …

1.6Db A machine – see Figure P1.6Db -- for testing and comparing chains and sprockets of various geometries and materials comprising four sprockets and two chains and having a pneumatic cylinder for loading one chain against another is shown in FIG. 1 and FIG. 2 in a side view and top view. A motor drives a rotatable fixed shaft which is mounted in two pillow block bearings. This shaft contains two sprockets. A second rotatable shaft is journalized in two pillow blocks mounted on a movable platform. Means are provided for applying a predetermined load through the movable platform to the second shaft and means are also provided for measuring the total cycle to chain-sprocket system failure. Means are also provided for determining chain load, for measuring chain and sprocket temperatures, for lubrication of the chains and sprockets, for cooling the test chamber, and for automatic machine shut off at failure. For additional information, see Ross, et al, patent number 4,413,513.

Search the OSHA regulations at http://www.osha.gov and review the section related to machine guarding. List the general methods that could be used to guard known machine hazards in the chain and sprocket test machine. Is there a specific condition for this machine where a guard is not needed?

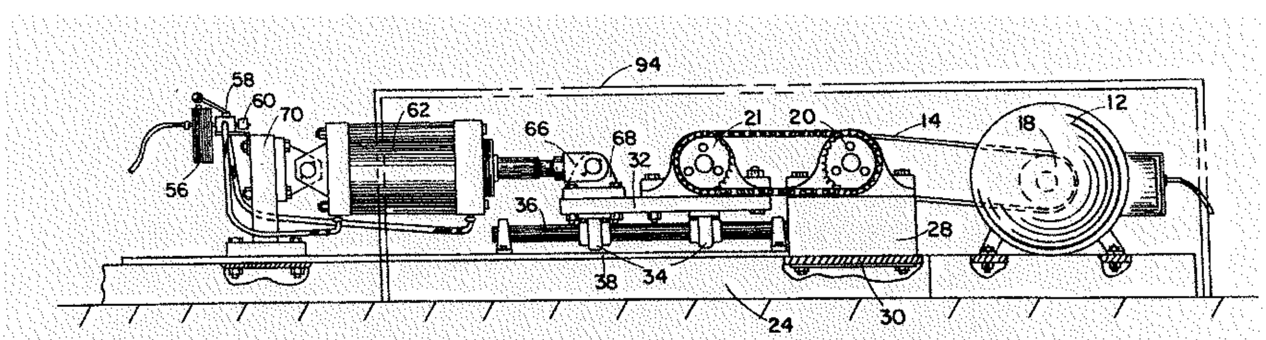


FIG. 1

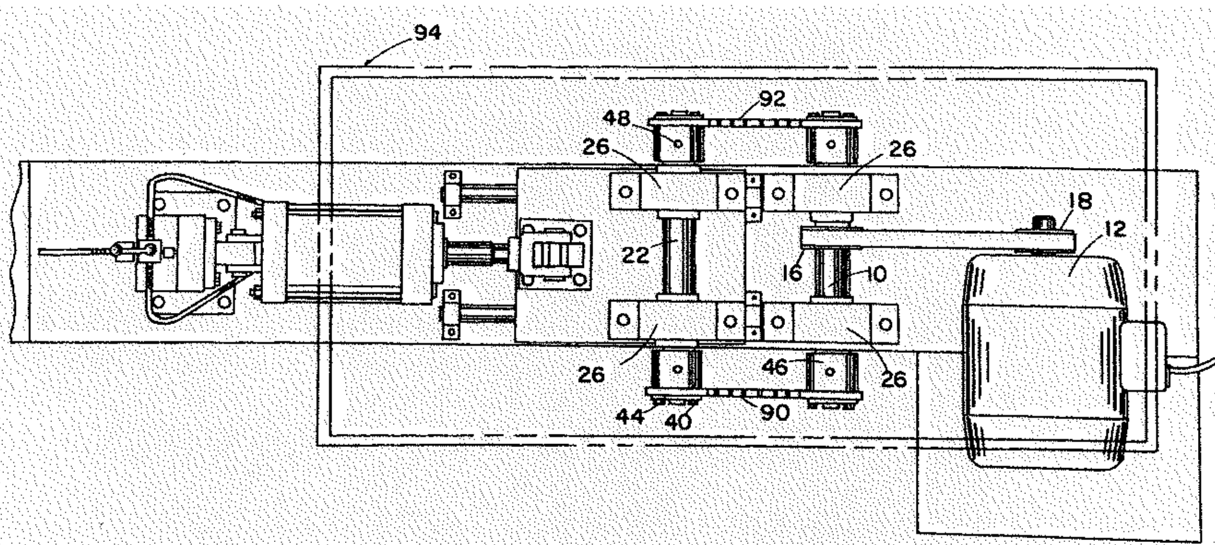


FIG. 2

SOLUTION 1.6Db: We are asked to (1) search the OSHA regulations at http://www.osha.gov, (2) review the section related to machine guarding, and (3) list the general methods that could be used to guard known machine hazards in the chain and sprocket test machine.

The OSHA regulations are found at **http://www.osha.gov**.

The Code of Federal Regulations, Title 29--Labor, § 1910.212 lists general requirements for all machines:

(a) *Machine guarding*

(1) *Types of guarding*. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

(2) *General requirements for machine guards*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

(3) *Point of operation guarding*.

(i) Point of operation is the area on a machine where work is actually performed upon the material being processed.

(ii) The point of operation of machines, whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

(iii) Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

(iv) The following are some of the machines that usually require point of operation guarding:

(a) Guillotine cutters.
(b) Shears.
(c) Alligator shears.
(d) Power presses.
(e) Milling machines.
(f) Power saws.
(g) Jointers.
(h) Portable power tools.
(i) Forming rolls and calenders.

(4) *Barrels, containers, and drums.* Revolving drums, barrels, and containers shall be guarded by an enclosure which is interlocked with the drive mechanism, so that the barrel, drum, or container cannot revolve unless the guard enclosure is in place.

(5) *Exposure of blades.* When the periphery of the blades of a fan is less than seven feet above the floor or working level, the blades shall be guarded. The guard shall have openings no larger than one-half (1/2) inch.

(6) *Anchoring fixed machinery.* Machines designed for a fixed location shall be securely anchored to prevent walking or moving. ■

Comment 1: Relative to the above discussion about machine guarding, in the machine for testing chains and sprockets – see Fig 1 and Fig 2, the instant machine has a barrier guard enclosing the top and all four sides – see Ross, '513 and #94 in the patent drawings. The guard protects the operator and others from ingoing running nip points, moving chains, rotating sprockets, motor shaft, coupling, and timing belt pulleys as well as from possible flying chains and sprocket parts. The guard did not offer an accident hazard in itself (unless you lifted and moved it and dropped it on your toes).

Comment 2: The OSHA regulations are given at http://www.osha.gov. The regulations for *General requirement for all machines*, are given at 29 CFR 1910.212; *The control of hazardous energy (lockout/tagout)* is found at 29 CFR 1910.147, and 29 CFR 1910.145, presents *Specifications for accident prevention signs and tags.* Lockout/tagout is used when performing maintenance or trouble shooting on a machine. Accident prevention signs and tags relate to warnings and instructions.

Comment 3: For a machine, the general rule is: "If a danger exists design it out, if you can not design it out, guard against it, and if you can not guard against it, warn about it."

Comment 4: To find the contact information for the OSHA Federal or State Program office nearest you, see the OSHA Regional and Area Offices map. For a publication that provides a general overview see: **https://www.osha.gov/Publications/osha3142.pdf**

Comment 5: Those not covered by the OSH Act include: self-employed workers, immediate family members of farm employers, and workers whose hazards are regulated by another federal agency (for example, the Mine Safety and Health

Administration, the Department of Energy, or Coast Guard).

1.7Db A machine for testing and comparing chains and sprockets of various geometries and materials is described in Problem 1.6Db. At issue are (a) whether the chain and sprocket test machine contained proper warnings, (b) whether the test machine was properly guarded, and (c) whether the machine should be allowed to "coast down" to a stop or the sprockets should stop rotating immediately once the machine electrical power is "turned off." Search the OSHA regulations http://www.osha.gov and specifically review the regulations 29 CFR 1910.212, General requirement for all machines, 29 CFR 1910.147, The control of hazardous energy (lockout/tagout), and 29 CFR 1910.145, Specifications for accident prevention signs and tags. Write several paragraphs explaining how each regulation would apply to a chain and sprocket test machine.

SOLUTION 1.7Db: We address the question of how the following regulations apply to a chain and sprocket test machine such as the one pictured in P1.6Db.

The OSHA regulations are found at http://www.osha.gov. The regulations are:
29 CFR 1910.212, *General requirement for all machines*,
29 CFR 1910.147, *The control of hazardous energy (lockout/tagout)*, and
29 CFR 1910.145, *Specifications for accident prevention signs and tags*.

•The Code of Federal Regulations, 29 CFR 1910.212, ***General requirement for all machines*** (Title 29--Labor, § 1910.212 lists general requirements for all machines), that is

(a) *Machine guarding*

(1) *Types of guarding*. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

(2) *General requirements for machine guards*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

(3) *Point of operation guarding*.

(i) Point of operation is the area on a machine where work is actually performed upon the material being processed.

(ii) The point of operation of machines, whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

(iii) Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

(iv) The following are some of the machines that usually require point of operation guarding:

(a) Guillotine cutters.
(b) Shears.
(c) Alligator shears.
(d) Power presses.
(e) Milling machines.
(f) Power saws.
(g) Jointers.
(h) Portable power tools.
(i) Forming rolls and calenders.

(4) *Barrels, containers, and drums*. Revolving drums, barrels, and containers shall be guarded by an enclosure which is interlocked with the drive mechanism, so that the barrel, drum, or container cannot revolve unless the guard enclosure is in place.

(5) *Exposure of blades*. When the periphery of the blades of a fan is less than seven feet above the floor or working level, the blades shall be guarded. The guard shall have openings no larger than one-half (1/2) inch.

(6) *Anchoring fixed machinery*. Machines designed for a fixed location shall be securely anchored to prevent walking or moving. ■

•The Code of Federal Regulations, 29 CFR 1910.147, ***The control of hazardous energy (lockout/tagout)***, discusses the procedure of lockout/tagout for machines or equipment.

Indeed, when service or maintenance is being preformed on a machine or equipment it should be locked and tagged out. These service or maintenance activities include lubrication, cleaning, or unjamming of a machine or equipment and making adjustments or tool changes, where the employee may be exposed to the unexpected energization or startup of the equipment or release of hazardous energy. A lockout device, either a key lock or combination lock, must be placed on the energy isolating device locking it into the safe position so that the equipment being controlled cannot be operated until the lockout device is removed. The tagout device should be placed on the isolating device, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

•The Code of Federal Regulations, 29 CFR 1910.145, ***Specifications for accident prevention signs and tags.***

Specifications for danger and caution signs are found in 29 CFR 1910.145, which can be located at the website **http://www.osha.gov**.

1. Danger signs are to be used only where an immediate hazard exists. Caution signs are to be used only to warn against potential hazards or to caution against unsafe practices.

2. Warning tags may be used to represent a hazard level between "caution" and "danger," instead of the required "caution" tag, provided that they have a signal word of "warning," an appropriate major message, and otherwise meet the general tag criteria. ■

Comment: The exercise of writing several paragraphs explaining how each regulation applies to a chain and sprocket test machine is left for the student.

1.8Db Referring to Problem 1.6Db:

(a) Sketch a chain and sprocket test machine and label a guarding device, power source, point of operation, and danger zone.

(b) List general methods used to guard known chain and sprocket hazards.

(c) Write a paragraph explaining the procedure of lockout/tagout for the chain and sprocket test machine.

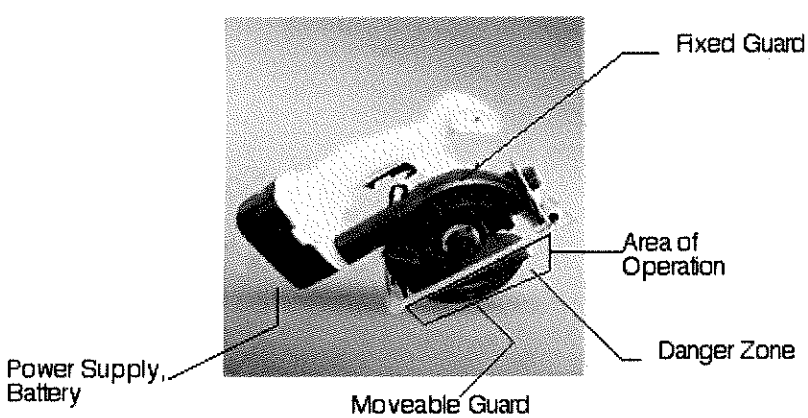
(d) Develop a warning sign/label(s) that could be applied to the chain and sprocket test machine. Where should warning signs be located?

SOLUTION 1.8Db:

(a) Sketch a chain and sprocket test machine and label a guarding device, power source, point of operation, and danger zone.

As a helpful introduction we present an example problem of a battery powered circular saw wherein we label a guarding device, power source, point of operation, and danger zone.

Analysis:



Comment: The exercise of similarly labeling the chain and sprocket test machine is left as an exercise for the student.

(b) List general methods used to guard known chain and sprocket hazards.

General methods used to guard known machine hazards are listed in 29 CFR 1910.212 which contains general requirements for all machines. The Code of Federal Regulations, Title 29--Labor, § 1910.212 lists the following general requirements for all machines:

(a) *Machine guarding*

(1) *Types of guarding*. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

(2) *General requirements for machine guards*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

(3) *Point of operation guarding*.

(i) Point of operation is the area on a machine where work is actually performed upon the material being processed.

(ii) The point of operation of machines, whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

(iii) Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

(iv) The following are some of the machines that usually require point of operation guarding:

(a) Guillotine cutters.
(b) Shears.
(c) Alligator shears.
(d) Power presses.
(e) Milling machines.
(f) Power saws.
(g) Jointers.
(h) Portable power tools.
(i) Forming rolls and calenders.

(4) *Barrels, containers, and drums*. Revolving drums, barrels, and containers shall be guarded by an enclosure which is interlocked with the drive mechanism, so that the barrel, drum, or container cannot revolve unless the guard enclosure is in place.

(5) *Exposure of blades*. When the periphery of the blades of a fan is less than seven feet above the floor or working level, the blades shall be guarded. The guard shall have openings no larger than one-half (1/2) inch.

(6) *Anchoring fixed machinery.* Machines designed for a fixed location shall be securely anchored to prevent walking or moving. ■

(c) Write a paragraph explaining the procedure of lockout/tagout for the chain and sprocket test machine.

•The Code of Federal Regulations, 29 CFR 1910.147, ***The control of hazardous energy (lockout/tagout)***, discusses the procedure of lockout/tagout for machines or equipment.

Indeed, when service or maintenance is being preformed on a machine or equipment it should be locked and tagged out. These service or maintenance activities include lubrication, cleaning, or unjamming of a machine or equipment and making adjustments or tool changes, where the employee may be exposed to the unexpected energization or startup of the equipment or release of hazardous energy. A lockout device, either a key lock or combination lock, must be placed on the energy isolating device locking it into the safe position so that the equipment being controlled cannot be operated until the lockout device is removed. The tagout device should be placed on the isolating device, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

(d) Develop a warning sign/label(s) that could be applied to the chain and sprocket test machine. Where should warning signs be located?

•The Code of Federal Regulations, 29 CFR 1910.145, ***Specifications for accident prevention signs and tags.***

Specifications for danger and caution signs are found in 29 CFR 1910.145, which can be located at the website **http://www.osha.gov**.

1. Danger signs are to be used only where an immediate hazard exists. Caution signs are to be used only to warn against potential hazards or to caution against unsafe practices.

2. Warning tags may be used to represent a hazard level between "caution" and "danger," instead of the required "caution" tag, provided that they have a signal word of "warning," an appropriate major message, and otherwise meet the general tag criteria. ■

Comment: The exercise of writing several paragraphs explaining how each regulation applies to a chain and sprocket test machine is left for the student

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1.14Db Describe the BP (referred to in the press as the former British Petroleum) oil spill and answer the questions (1) when did the oil spill occur, (2) how much oil was spilled in the Gulf of Mexico, (3) what was the "cost" of the oil spill, and (4) what role did engineering play in this spill from a *safety*, *ecological*, and *sociological* standpoint. Your write-up should reflect the professional appearance expected of an engineer.

SOLUTION 1.14Db:

References:

Interim Report on Causes of the *Deepwater Horizon* Oil Rig Blowout and Ways to Prevent Such Events, National Academy of Engineering and National Research Council of the National Academies, November 16, 2010.

Deep Water, The Gulf Oil Disaster and the Future of Offshore Drilling, Report to the President (0bama), National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling Final Report (Released 01/11/2011) – recently found at cybercemetary.unt.edu.

Comment 1: Every student should read these reports.

Comment 2: President Barack Obama in an address to the nation stated that … "this oil spill is the worst environmental disaster America has ever faced. And unlike an earthquake or a hurricane, it's not a single event that does its damage in a matter of minutes or days. The millions of gallons of oil that have spilled into the Gulf of Mexico are more like an epidemic, one that we will be fighting for months and even years."[1]

[1] President Barack Obama, "Remarks by the President to the Nation on the BP Oil Spill" (June 15, 2010) http://www.whitehouse.gov/the-press-office/remarks-president-nation-bp-oil-spill].

Comment 3: And this was most probably an understatement of the ecological and sociological damage done. This exercise is left for the student as every student and faculty member should read and remember the "BP Oil Spill", "Deepwater Horizon Oil Spill", "Macondo Well-Deepwater Horizon Blowout", "Deep Water, The Gulf Oil Disaster"… explosion, fire, severe injuries, death, massive oil spill, devastating environmental pollution … disaster.

1.31Db Investigate the web site http://wallaceracing.com that provides calculators to evaluating and estimating racing performance. Select a specific calculator, and verify if possible that the calculator will provided correct results. Write a short paragraph on how you verified that the calculator was "correct." What would increase your confidence in the calculator given on the web site?

SOLUTION 1.31Db: We start this problem by discussing a previous problem where we investigated the web site www.analyticcycling.com which provides technical methods for evaluating and estimating cycling performance. In the previous problem, we were asked to verify that the conversion calculator provided on the web site would convert units correctly for speed (mph to km/hr), temperature (F to C), and force (lb to N. Here is what we stated:

1. Speed, temperature, and force calculations were verified using several range points that covered the span of conversions most likely to be used. This also includes the

identity conversions for each unit transformation. For example, in temperature the Celsius points -273°C, 0°C, 100°C can be quickly used to verify the accuracy of a conversion program to Fahrenheit degrees.

2. Confidence in a conversion calculation would generally be improved by (a) disclosure of the algorithm and/or method employed, (b) a self check of the algorithm/method, (c) a statement by the author of the conversion calculator of its accuracy and range of use, and (d) disclosure by the author of intended uses, misuses or other issues.

In the present problem we are asked you to investigate the web site http://wallaceracing.com that provides calculators to evaluating and estimating racing car performance. The answers in paragraphs 1 and 2 above should provide guidance.

Comment: A more exhaustive discussion on this topic of "conversion and calculation verification" is left for the instructor. ■

1.32b Check the dimensional homogeneity of the following equations: (a) (1.1a), (b) (1.1b), and (c) (1.1c)

SOLUTION 1.32Db: (a), (b), and (c) are all dimensionally homogeneous

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1.36b A block has a mass of 10 kg. Determine its weight in Austin, Texas, in (a) English Engineering units, (b) British Gravitational units, and (c) SI units.

SOLUTION 1.36b: Answers: (a) 22.042 lbs, (b) 22.05 pounds, (c) 98 N

Analysis:

(a) English Engineering units

$F = ma/g_c$[Eq. (1.1a)]

where

$$m = \left(\frac{10\ \text{kg}}{1}\right)\left(\frac{1\ \text{slug}}{14.6\ \text{kg}}\right) = 0.685\ \text{slug}$$

or,

$$m = \left(\frac{0.685\ \text{slug}}{1}\right)\left(\frac{32.2\ \text{lbm}}{1\ \text{slug}}\right) = 22.1\ \text{lbm}$$

$$a = \left(\frac{9.81\ \text{m}}{\text{s}^2}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right) = 32.2\ \text{ft/s}^2$$

$g_c = 32.2$ ft·lbm/lb s^2

Thus,

$$F = \frac{(22.057\ \text{lbm})(32.2\ \text{ft/s}^2)}{(32.2\ \text{ft·lbm/lb s}^2)} = 22.1\ \text{lb}$$ ■

(b) British Gravitational units

$F = ma$ [Eq. (1.1b)]

$F = (0.685\ \text{slug})(32.2\ \text{ft/s}^2) = 22.1\ \text{slug·ft/s}^2 = 22.1\ \text{lb}$ ■

(c) SI units

$F = ma$ [Eq. (1.1c)]

$F = (10\ \text{kg})(9.81\ \text{m/s}^2) = 98.1\ \text{kg·m/s}^2 = 98.1\ \text{N}$ ■

Comment: The answers in (a) and (b) are equivalent to the answer in (c), since $(98.1\ \text{N})\left(\frac{1\ \text{lb}}{4.448\ \text{N}}\right) = 22.1\ \text{lb}$

1.43b A block weighing 1500 lb slides on a flat surface at an initial velocity of 88 feet per second where the coefficient of friction is 0.7. Determine the friction force causing the block to slow. How far does the block travel in slowing to a stop? How many seconds does it take for the block to come to rest? How much work was done to stop the block? What was the initial kinetic energy of the block?

SOLUTION 1.43b:

Analysis:

1. The friction force to slow the block is given by $F = \mu W = (0.7)(1500\ \text{lb}) = 1050\ \text{lb}$.

2. Newton's Second Law gives, $F = (1/g_c)\ ma$, where $F = 1050$ lb, $m = 1500\ \text{lb}_m$, $g_c = [(32.2\ \text{lb}_m\cdot \text{ft}) / (\text{lb}_{f.}\ \text{s}^2)]$, and a = acceleration in ft/s^2.

3. Solving for a gives, $a = [(1050)(32.2)/(1500)] = 22.54\ \text{ft/s}^2 = 0.7g$ (where $g = 32.2\ \text{ft/s}^2$.

4. $t = V_{initial}/a = [88\ \text{ft/s}^2] / [22.54\ \text{ft/s}^2] = 3.904$ s

5. $S = ½\cdot at^2 = ½\ (22.54)(3.904^2) = 171.78$ feet

6. Work is force times applied distance, $W = F\ S$. In this case, the force is the sliding friction force over the distance of 171.78 feet. Thus, $W = F\cdot S = (1050\ \text{lb})(171.78\ \text{feet}) = 180{,}369$ ft-lb.

7. The initial kinetic energy of the block is given by $KE = ½\cdot(1050\ \text{lbm}/32.2)\cdot(88\ \text{ft/s})^2 = 180{,}369$ ft-lb. ■

Comment 1: The deceleration of the block is equal to 0.7g; i.e., the coefficient of friction in g's. ■

Comment 2: The block will slide until the friction force does enough work (that is converted to heat energy) to dissipate the initial kinetic energy of the block. That is KE = Work = F * S where F is the sliding friction force. We note that the surface is flat so there is no change in potential energy. ■

1.44b A small car weighing 1500 lb tows a single axle two-wheel trailer weighing 750 lb at 60 mph. There are no brakes on the trailer, and the car, which by itself can decelerate at 0.7g, produces the entire braking force. Determine the force applied to slow the car and trailer. Determine the deceleration of the car and the attached trailer. How far do the car and trailer travel in slowing to a stop? How many seconds does it take to stop?

SOLUTION 1.44b: We assume the following:

1. The car and trailer are stable during deceleration.

2. The deceleration of the car and trailer does not change the 1500 lb car tire force on the pavement.

Analysis:

1. The friction force to slow the car is given by F = μW = (0.7)(1500 lb) = 1050 lb.

2. Newton's Second Law gives, F = $(1/g_c)$ ma, where F = 1050 lb, m = (750 lb_m + 1500 lb_m) = 2250 lb_m, g_c = [(32.2 $lb_m \cdot$ ft) / (lb_f s^2)], and a = acceleration in ft/s^2.

3. Solving for a gives, a = [(1050)(32.2)/(2250)] = 15.03 ft/s^2 = 0.467g (where g = 32.2 ft/s^2.

4. t = $V_{initial}$ /a = [88 ft/s^2] / [15.03 ft/s^2] = 5.855 s

5. S = ½ at^2 = ½ (15.03)(5.855^2) = 257.62 feet

Comment: The deceleration of the car and attached trailer is 0.467g. The car by itself, decelerating at 0.7g, can stop in 171.78 feet rather that in 257.62 feet. ■

1.45b A small car weighing 1500 lb, traveling at 60 mph, decelerates at 0.70g after the brakes are applied. Determine the force applied to slow the car. How far does the car travel in slowing to a stop? How many seconds does it take for the car to stop?

SOLUTION 1.45b: We assume that the car decelerates uniformly at 0.70g until the vehicle stops.

Analysis:

1. The friction force to slow the car is given by $F = \mu W = (0.7)(1500\ lb) = 1050\ lb$.

2. Newton's Second Law gives, $F = (1/g_c)\ ma$, where $F = 1050\ lb$, $m = 1500\ lb_m$, $g_c = [(32.2\ lb_m \cdot ft) / (lb_f \cdot s^2)]$, and a = acceleration in ft/s^2.

3. Solving for a gives, $a = [(1050)(32.2)/(1500)] = 22.54\ ft/s^2 = 0.7g$ (where $g = 32.2\ ft/s^2$.

5. $t = V_{initial} /a = [88\ ft/s^2] / [\ 22.54\ ft/s^2] = 3.904\ s$

6. $S = ½\ at^2 = ½\ (22.54)(3.904^2) = 171.78$ feet

Comment: The deceleration of the car is equal to 0.7g; i.e., the coefficient of friction in g's. ■

1.46b A jump rope is made from an elastic cord with two hollow plastic handles attached to each end. Two boys, instead of using the rope for jumping, decide to use it for a tug-of war. Each boy pulls on an end of the rope. When the elastic cord is stretched, energy is stored in the elastic cord. One boy lets go of his handle; the other boy holds his end and is almost immediately struck in the eye by the sharp end of the released handle. The rope and handle weighed 2 oz. A force of 9 lb applied to each handle will stretch the rope about 10 in.

Address the question as to whether the jump rope as described above conceptually is a "reasonably safe design" using the following categories:
(a) The *usefulness and desirability* of the product
(b) The *availability* of other and safer products to meet the same or similar needs
(c) The *likelihood* of injury and its probable seriousness
(d) The *obviousness* of the danger
(e) Common *knowledge and normal public expectation* of the danger (particularly for established products)
(f) The *avoidability* of injury by care in use of the product (including the effect of instructions and warnings)
(g) The ability to *eliminate* the danger without seriously impairing the usefulness of the product or making it unduly expensive

SOLUTION 1.46b:

General background: The incident occurred in Texas, and resulted in injury to a six-year-old boy. The incident product was an eight-foot jump rope made of a rubber-like cord and injection molded plastic handles. The jump rope was distributed by a Texas manufacturer in a contest sponsored by the American Heart Association.

On the day of the incident, the six-year-old boy was using the incident product with his six-year-old friend. While playing with the jump rope, the handle of the jump rope struck the boy in the eye, and he sustained injury due to the impact of the handle with his eyeball.

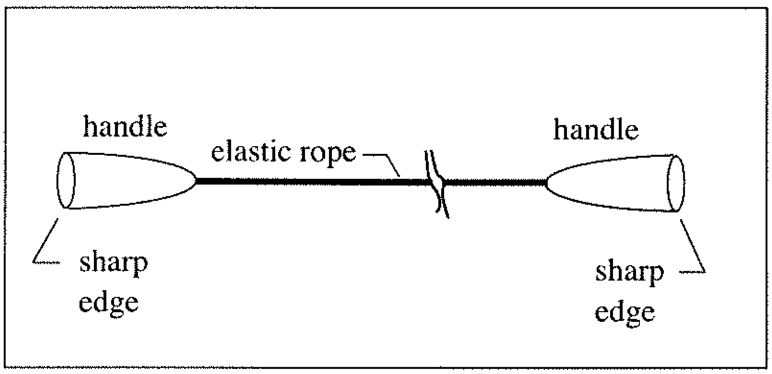
An evaluation of two different jump ropes was conducted. One exemplar jump rope and one jump rope made of cotton with wooden handles were tested to determine the spring constant and the handle projectile speed. The mechanism of injury when using the incident rope was studied.

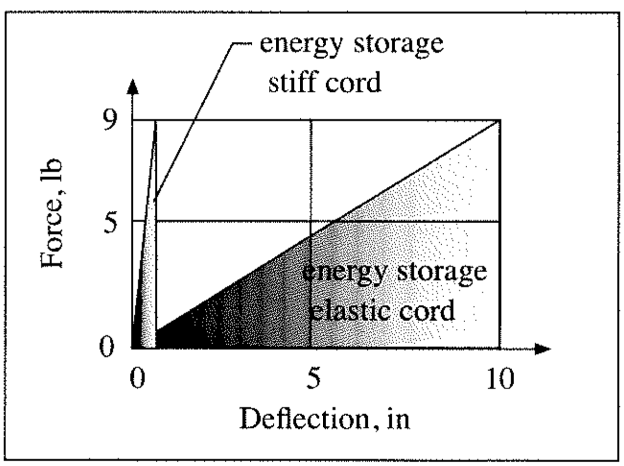
An analysis of handle speed when it stuck the boy's eye

Known: A jump rope is made from an elastic cord. Two hollow hard plastic handles are attached to each end of the cord as shown in the figure below. Two boys each pull on an end of the rope with a force of 9 lb, stretching the elastic rope 10 inches. Then one boy lets go of his handle. The rope and handles weigh 2 ounces.

Find: What was the approximate speed of the handle when it struck the boy's eye?

Schematic and Given Data:





Assumptions:
1. The potential energy stored in the rope is all converted to kinetic energy.
2. The rope/handle is a concentrated mass of two ounces.
3. The force of air drag can be neglected.

Analysis:

1. The potential energy stored by the stretched rope is calculated with PE = Work = ½ F • S where F = 9 lb, and S = 10 inches.

2. The kinetic energy of rope is given by KE = ½ $m_{rope}V^2_{rope}$ = ½ F • S where m_{rope}= 0.125 lb_m.

3. Solving one of the above equations gives $V^2_{rope} = (F \cdot S)/m_{rope}$ =

   $(9\ lb)(10\ in)(32.2\ lb_m \cdot ft/lb \cdot s^2)[12\ in/ft]/(.125\ lb_m) = 1932\ ft^2/s^2$.

4. Solving gives V_{rope} = 43.95 ft/s = 29.96 mph.

Comment: An experiment with an elastic cord could be conducted, and the speed of the cord and/or handle estimated from a videotape of the release jump rope – see the next section.

An experimental investigation of a jump rope handle impact speed and location

The problem was to determine the handle impact velocity and/or impact location for two jump ropes when a handle was released with the rope horizontal and under a static tensile load.

Figure 1 illustrates the apparatus used to determine the impact speed and impact location of a jump rope handle. Table 1 lists equipment used in estimating jump rope handle impact speed and location.

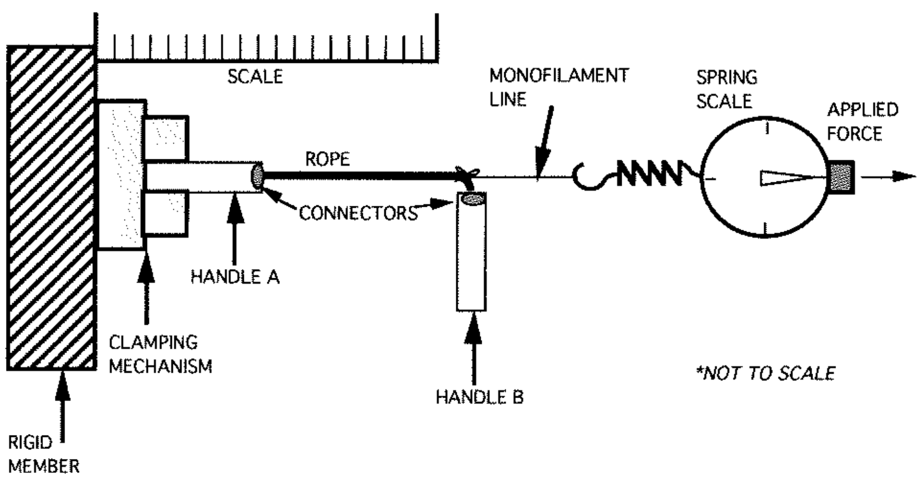


Figure 1 Schematic of the apparatus used to measure impact speed and impact location of a jump rope handle.

Table 1 List of Equipment
1. Jump rope
2. Spring scale
3. Clamping member

4. Rigid member (2 x 6 x 23 inch pine board)
5. Video camera
6. Monofilament line
7. Scissors
8. Linear scale

A clamping mechanism was attached to a rigid member to anchor handle A of the jump rope. Handle B of the jump rope was pulled with a spring scale. The spring scale provided a measure of the force being exerted on the jump rope.

Two jump ropes types were tested -- see Table 2. The first jump rope was manufactured in Texas and is comprised of a rubber-like rope material with plastic hollow open-ended handles attached with crimped metal connectors on the ends of the rope. The second jump rope was manufactured by Altus Athletic Mfg. Co. and is comprised of a woven cotton rope with solid wooden handles attached with metal coils to the ends of the rope.

Table 2 Identification of Jump Ropes

Jump rope 1	XYZ	Rubber like cord with hollow plastic handles
Jump rope 2	AA Mfg. Co.	Cotton rope with wooden handles

Once the rope was under the desired tensile load, the monofilament used to attach the end of the rope to the spring scale was cut to immediately release the end of the jump rope. A video camera was used to record the approximate motion of the jump rope, the location of impact, and to provide distance-time data needed to calculate the handle velocity. The rigid member located near handle A recorded, by deformation, the impact of the handle.

Procedure and experimental setup

The experimental setup used a clamping mechanism and rigid member to anchor one end of the jump rope. This clamping mechanism was used to simulate a person resisting with an equal and opposite force to that pulling the opposite end of the jump rope. The opposite end of the rope was pulled using the spring scale. The spring scale was used to measure the force. At a measured pull force of 9 lbf, the monofilament was cut, thereby releasing the handle initially toward the rigid member. The impact location was recorded on videotape. The videotape was used to estimate the handle velocity.

Results

Figure 2 shows an approximate handle path of travel for jump ropes 1 and 2.

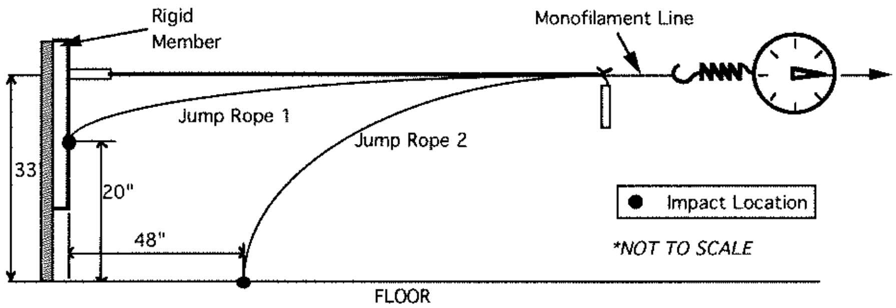


Figure 2 Approximate path of travel of for each handle after release.

The released handle for jump rope 2 landed on the floor. There was not enough energy stored in the cotton rope at a pull force of 9 lbf to accelerate the released handle to the rigid member. Indeed, the released handle impacted the floor approximately 4 feet from the rigid member, falling an approximate 33 inches from its release height -- see Figure 2.

As mentioned, jump rope 1 was tensioned to 9 lbf when the handle was released. The released handle traveled a path such that it impacted the rigid member approximately 13 inches below its starting position -- see Figure 2. The impact speed of the handle was calculated using "high" speed video.

The velocity of the handle was estimated from the videotape in several different ways:

1. using the time for the released handle to travel from the release point to the rigid member
2. using the time for the handle to travel the viewed distance to the rigid member
3. using the distance the handle travels in the last video frame (1/30th of a second) to the rigid member.

Table 3 gives three estimates of the handle velocity for jump rope 1. The handle velocities ranged from 14 to 34 mph.

Table 3 Handle Velocity

Estimate	Distance Traveled	Time (estimated range)	Velocity
1	116.15 in	.166 s to .233 s	58.08 fps to 41.48 fps (39.60 mph to 28.28 mph)
2	33 in	.066 s to .133 s	41.25 fps to 20.6 fps (28.13 mph to 14.05 mph)
3	10 in to 11 in	.033 s	25.00 fps to 27.50 fps (17.05 mph to 18.75 mph)

The distance traveled in estimate 1 was determined using a spring constant of 0.496 lbf/in to approximate the stretched length. The distance traveled for estimates 2 and 3 were approximated by extrapolating the linear measuring scale included in the viewing area. All of the times were based on a video speed of 30 frames per second.

Discussion

The most reasonable estimate of the handle velocity of jump rope 1 at the moment of impact is most probably in the range of estimate 2 in Table 3. Assuming that the handle was to travel at a constant velocity over the entire path up to impact, there would be a range of time from release to time of impact of .233 to .468 seconds. This means that the maximum amount of time from release to impact, with a 9 lbf pull and an estimated 116.15 inch stretched length of the jump rope, is only .468 seconds. From the experimental values, the minimum amount of time from release to impact would be .166 seconds.

The impact of the handle of jump rope 1 on the (wooden) rigid member left a noticeable dent in the board. The indentation is a physical manifestation/representation/realization of the force and speed of impact.

Conclusions

When jump rope 1 was pulled to a 9 lbf tensile force and one handle was released, the released handle accelerated through the air and impacted the rigid member at approximately 14 to 28 miles per hour leaving a dent in the rigid member surface. Under these conditions, there would be approximately a .166 to .468 second time delay from the release of the handle to the impact of the handle on the rigid member. Under the same conditions, the handle for jump rope 2 did not impact the rigid member.

Additional experiments:

Additional experiments were conducted on exemplar XYZ jump ropes. Nine tests were recorded on videotape. The equipment, procedure, and results were for all practical purposes made the basis of this case, identical to those described above in the report "An experimental investigation of a jump rope handle impact speed and location". The damage to the impacted member by the released handle was consistent with the first test, and 9 of 10 times leaving an identifiable semi-circular groove in the rigid member ((2 x 6 x 23 inch pine board).

Based on the information and analysis the following could be opined:

1. The incident jump rope was most probably being stretched longitudinally by forces exerted on each handle just prior to the release of one handle.

2. As the incident jump rope was stretched longitudinally, the released handle traveled toward the other handle at a high velocity.

3. The handles were hollow with rounded hollow cylindrical shaped ends. Contact of the hollow cylindrical shaped ends could create high stresses when impacting other objects.

4. The high velocity of the handle resulted because of the (a) force exerted on each handle, (b) stretching of the jump rope, (c) light weight of the handle, (d) light weight of the rope, and (e) high potential (internal) energy storage capabilities of the jump rope.

5. The high velocity of the handle -- caused by (a) the light weight of the handle and rope, and (b) the high potential (internal) energy storage capabilities of the jump rope -- and the hollow end shape of the handle created an unreasonable danger and therefore represent a manufacturing and/or a design defect.

6. The incident jump rope did not contain a warning concerning its ability to store energy whereby the release of one handle would cause high handle projectile velocities.

7. A producing cause of the accident was the high handle projectile velocity and the hollow end shape of the handle.

8. A producing cause of the accident may have been that the six-year old boy and his six-year old friend were not adequately instructed in the proper use of a jump rope.

9. A producing cause of the accident may have been the lack of a warning with and/or on the jump rope.

With the above additional information, left an exercise for the student is the question as to whether the jump rope as described above conceptually is a "reasonably safe design" using the following categories:

(a) The *usefulness and desirability* of the product
(b) The *availability* of other and safer products to meet the same or similar needs
(c) The *likelihood* of injury and its probable seriousness
(d) The *obviousness* of the danger
(e) Common *knowledge and normal public expectation* of the danger (particularly for established products)
(f) The *avoidability* of injury by care in use of the product (including the effect of instructions and warnings)
(g) The ability to *eliminate* the danger without seriously impairing the usefulness of the product or making it unduly expensive

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1.49b The shaft to a motor rotates at 2000 rpm and transmits a power of 40 kW. Determine the torque on the motor output shaft, in N. m.

SOLUTION 1.49b: We assume that the motor is operating at steady state conditions.

1. From Eq. (1.2), $\dot{W} = \dfrac{2\pi\, n\, T}{60{,}000}$ or $T = \dfrac{60{,}000\, \dot{W}}{2\pi\, n}$

2. For the motor shaft, $T = \dfrac{60{,}000(40)}{2\pi\,(2000)} = 191.0$ N·m

Comment: The efficiency of the motor (and the second law of thermodynamics) would suggest that the input power supplied to the motor would be greater than the shaft output power, with energy losses accounted for through heat energy transfer eventually to the surroundings.

1.51b An electric motor draws a constant current of 6 A, with an applied voltage of 110 V, for 100 h. Determine the total amount of energy supplied to the motor by electrical work, in kW·h.

SOLUTION 1.51: We assume that the voltage and current are constant with time. Then

1. $\dot{W} = IV = (6\text{ A})(110\text{ V}) = 660\text{ W} = 0.66\text{ kW}$

2. Total energy = electrical work = $\int \dot{W}dt = (0.66\text{ kW})(100\text{ hr}) = 66\text{ kW·h}$ ■

1.66Db Search online at www.linengineering.com for common stepper terminology and step motor basics. For step motors, define rotational speed, torque, speed and torque curves, current and voltage, efficiency, microstepping, and reducing resonance. List typical step motor applications.

SOLUTION 1.66b: See the web site:
http://www.linengineering.com/contents/stepmotors/pdf/Step_Motor_Basics.pdf

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SOLUTION (1.1D)
Known: Definitions of the words science, engineering, and design are given in Section 1.1.

Find: Write definitions of the above words using a dictionary and compare with those given in Section 1.1.

Analysis:

1. According to Webster's Ninth New Collegiate Dictionary, science is the knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method. According to Section 1.1, science is concerned with uncovering basic knowledge.

2. According to Webster's Ninth New Collegiate Dictionary, engineering is the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people in structures, machines, products, systems, and processes. According to Section 1.1, engineering is an applied science, in the sense that it is concerned with understanding scientific principles and applying them to achieve a designated goal utilizing the resources and laws of nature to benefit humanity.

3. According to Webster's Ninth New Collegiate Dictionary, art is a skill acquired by experience, study, or observation. (Also, art is defined as the conscious use of skill and creative imagination, especially in the production of aesthetic objects.)

4. According to Webster's Ninth New Collegiate Dictionary, design is an act of devising for a specific function or end. According to Section 1.1, mechanical engineering design deals with the conception, design, development, refinement, and application of machines and mechanical apparatus of all kinds. ■

SOLUTION (1.2D)
Known: The Segway two-wheeled-self-balancing electric vehicle invented by Dean Kamen and used for short distance personnel transportation reportedly travels at 12.5 mph. The vehicle is controlled and powered with computers and electric motors. Lean forward, you move forward. Lean back and you go backward. Lean the handlebars to the left or right and you turn in that direction – see www.youtube.com for a video. When you need to brake, the motor acts as a dynamometer.

Find: Review the design of the Segway and address the question as to whether the Segway conceptually is a "reasonable safe design" using the following categories:
(1) The usefulness and desirability of the product.

(2) The availability of other and safer products to meet the same or similar needs.

(3) The likelihood of injury and its probable seriousness.

(4) The obviousness of the danger.

(5) Common knowledge and normal public expectation of the danger (particularly for established products).

(6) The avoidability of injury by care in use of the product (including the effect of instructions and warnings).

(7) The ability to eliminate the danger without seriously impairing the usefulness of the product or making it unduly expensive.

Schematic and Given Data:

Analysis: Wikipedia, the free encyclopedia, in an article dated September 4, 2010, entitled "Segway PT," presents a comprehensive review of the history, sales, technology, uses, operation, and safety of the Segway vehicle.

Comment:

In what follows, we present segments from the Wikipedia article:

1. History: The product was unveiled December 3, 2001, in Bryant Park on the ABC News morning program *Good Morning America*.

2. Sales: The product was unveiled December 3, 2001, in Bryant Park on the ABC News morning program *Good Morning America*. In a March 2009 interview, company official said the firm "has shipped over 50,000" Segways.

3. Technology: The dynamics of the Segway PT are identical to a classic control problem, the inverted pendulum.

The side effect of this balancing system is that as the Segway PT balances itself the entire unit changes position in the direction it has moved to restore balance. (For example, if the rider leans forward, the entire Segway PT will move forward from its original position, until the rider restores an upright position on the unit.) This is precisely how the Segway PT is controlled - the balancing and movement is essentially one combined system.

The Segway PT features a governor (speed limiting) mechanism. When the Segway PT approaches the maximum speed allowed by the software, it intentionally begins to tilt slightly backwards. This moves the platform out in front, and leans the handlebars backwards towards the rider, eventually nudging the rider to lean back slightly and slow the Segway PT down. If not for the governor, riders would be able to lean farther than the motor could ever compensate for. The Segway PT also slows or stops immediately if the handlebar of the unit (or forward bag) nudges into any obstacle.

4. Uses: Segways perform best in areas with adequate sidewalks, curb cuts at intersections, and ramps. They are used in cities for tours and in theme parks by visitors and employees. The special police forces trained to protect the public during the 2008 Summer Olympics used the Segway for mobility.

5. Operation: The original Segway models were activated using one of three keys:
Black Key: for beginners. Slowest speed (electronically limited to no more than 6 mph); slower turning rate.
Yellow Key: for intermediate users and/or pavements. Faster speed-up to 8 mph (13 km/h); faster turning rate.
Red Key: for more advanced users in open areas. Maximum speed-up to 10 mph (16 km/h) on p-Series and 12.5 mph (20.1 km/h) on i-Series; and max turning rate.

In September 2003, the Segway PT was recalled because if users ignored repeated low battery warnings on the PTs, it could ultimately lead them to fall. With a software patch to version 12.0, the PT would automatically slow down and stop in response to detecting low battery power. Any units sold before September 2003 with a label 12.0 have the upgraded software.

In August 2006, Segway discontinued all previous models and announced second-generation designs. The Gen II PT, marketed under the two product lines, i2 and x2, allows users to steer by leaning the handlebars to the right or left, which matches the intuitive nature of leaning forward and backward to accelerate and decelerate.

6. Safety: Because the Segway can reach speeds over 20 km/h (12 mph), the Bicycle Helmet Safety Institute recommends that all riders wear helmets when using Segways. The US Consumer Product Safety Commission does not have Segway-specific recommendations but does say that bicycle helmets are adequate for "low-speed, motor-assisted" scooters.

A more exhaustive discussion on the question of whether conceptually the Segway is a “reasonable safe design” is left for the student and/or the instructor. ■

SOLUTION (1.3D)

Known: An accident occurred at a gym where a woman was injured while exiting a hack squat machine after completing a set of lifts. The woman was operating the incident hack (slide) squat) machine when the machine fell on her leg. She had entered the machine, completed one set of reps, and then placed the handle latches down on the machine. She released the carriage weight from her legs and felt the weight being supported. She then stepped her left foot from the footplate to the floor inside the machine and stood up. Then the machine's carriage assembly fell on the rear of her leg (left calf). Her left leg was pinned under the carriage. She was trapped and had to have the machine raised off her leg before she could move.

Find: From your viewpoint, address the issue of whether the latching system on the incident squat machine created an unreasonable danger. (Alternatively, address the question as to whether a specific hack squat machine (equipment) is a "reasonably safe design" and whether a safer alternative design exists.)

Assumption: An inspection of a specific hack squat machine would probably be necessary to work on this problem.

Analysis: An analysis would begin by attempting to better understand the accident event. Once the sequence of the accident event is known one can then address the issues of whether the incident hack squat machine was reasonably safe and not unreasonable dangerous.

A. <u>In the instant case, it was determined that the accident took place in the following manner:</u>

1. The operator was using the incident hack squat machine.

2. The operator completed one set of repetitions (her feet on the foot plate) with the incident hack squat machine.

3. After finishing her first set, the operator placed the handle latches down on the machine.

4. To do this she had to move her feet down the footplate and place herself on her toes to get the latches to secure.

5. She then released some of the carriage weight from her legs and felt the weight being supported.

6. The operator moved her left foot from the footplate to the floor and stood up.

7. The carriage of the machine dropped and struck the calf area of her left leg.

B. <u>Additional facts in this case are as follows:</u>

1. The incident hack squat machine allows the user to do weighted incline squats and was being used by the operator at the time of her injury.

2. The incident hack squat machine had carriage stops at one height. The carriage stops allow for securement from the user's position of the sliding carriage assembly.

3a. The apparent function of the carriage stops was to allow the user to lock the carriage and safely enter and depart from the operator's position.

3b. The operator was not warned that due to her height some machines might not be advisable for her to use.

3c. The operator was not warned that her height might affect her use of the incident machine or that she might need to take certain precautions.

4. The handles on the latch required that some users had to stand on their toes during part of the operation of the hack squat machine due to the location of the carriage stops on the machine.

5. The location of the carriage stops failed to consider the height of the user, the potential hazards of a downward sliding assembly carriage, and the associated pinch and crush "points".

6. Because the carriage stops were "high" relative to the footplate, it required the operator to stand on her toes to set the handle latches.

Comment:
A mechanical engineer working on this accident concluded the following:

1. The carriage of the hack squat machine was most probably set and stationary in a "latch position" at the time just prior to the accident.

2. The cause of the stationary "latch position" of the carriage was most probably the failure of the latching system to fully latch which allowed the carriage to fall.

3a. There was a failure to warn that certain persons would have difficulty engaging the latch, and there was a failure to warn that the latching system could falsely latch.

3b. The carriage latching system created an unreasonable danger and therefore represents a manufacturing, design, and/or warning defect.

4. The design defect most probably existed at the time of manufacture of the hack squat machine.

5. A safer alternative design existed that would most probably have prevented or significantly reduced the risk of the accident without significantly impairing the usefulness of the hack squat machine carriage latching system. ■

SOLUTION (1.4D)

Known: Definitions of the words brake, clutch, two-hand control device, die, foot pedal, pinch point, and point of operation are given in 29 CFR 1910.211, which can be located at the website **http://www.osha.gov**.

Find: Write definitions for the above words using 29 CFR 1910.211. Identify the defined words (features) on a picture of a power press.

Analysis:

1. Brake means the mechanism used on a mechanical power press to stop and/or hold the crankshaft, either directly or through a gear train, when the clutch is disengaged.

2. Clutch means the coupling mechanism used on a mechanical power press to couple the flywheel to the crankshaft, either directly or through a gear train.

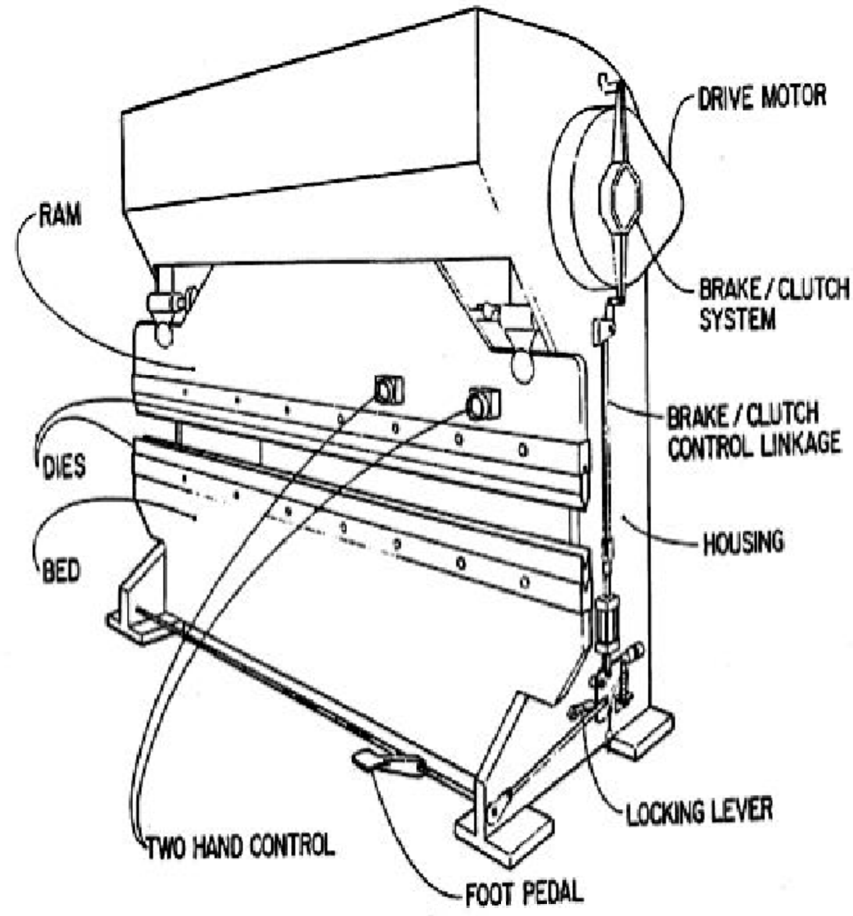
3. Two-hand control device means a two hand trip that further requires concurrent pressure from both hands of the operator during a substantial part of the die-closing portion of the stroke of the press.

4. Die means the tolling used in a press for cutting or forming material. An upper and a lower die make a complete set.

5. Foot pedal means the foot operated lever designed to operate the mechanical linkage that trips a full revolution clutch.

6. Pinch point means any point other than the point of operation at which it is possible for a part of the body to be caught between the moving parts of a press or auxiliary equipment, or between moving and stationary parts of a press or auxiliary equipment, or between the material and moving part or parts of the press or auxiliary equipment.

7. Point of operation means the area of the press where material is actually positioned and work is being performed during any process such as shearing, punching, forming, or assembling.



Comment: The document 29 CFR 1910.211 provides definitions for numerous power press terms. ■

SOLUTION (1.5D)
Known: 29 CFR 1910.212 contains the general requirements for all machines, and can be located at the website **http://www.osha.gov**.

Find: Print a copy of 29 CFR 1910.212 from the website, and locate a picture of a machine that you have used and has a machine guard to protect the operator or others from hazards.

Analysis:

SOLUTION (1.6D)
Known: The OSHA regulations are found at **http://www.osha.gov**.

Find: List methods used to guard machine hazards. Give conditions where guards should be used.

Analysis: The Code of Federal Regulations, Title 29--Labor, § 1910.212 lists general requirements for all machines:

(a) *Machine guarding*--(1) *Types of guarding*. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

(2) *General requirements for machine guards*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

(3) *Point of operation guarding*. (i) Point of operation is the area on a machine where work is actually performed upon the material being processed.

(ii) The point of operation of machines, whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

(iii) Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

(iv) The following are some of the machines that usually require point of operation guarding:

(a) Guillotine cutters.
(b) Shears.
(c) Alligator shears.
(d) Power presses.
(e) Milling machines.
(f) Power saws.
(g) Jointers.
(h) Portable power tools.
(i) Forming rolls and calenders.

(4) *Barrels, containers, and drums*. Revolving drums, barrels, and containers shall be guarded by an enclosure which is interlocked with the drive mechanism, so that the barrel, drum, or container cannot revolve unless the guard enclosure is in place.

(5) *Exposure of blades*. When the periphery of the blades of a fan is less than seven (7) feet above the floor or working level, the blades shall be guarded. The guard shall have openings no larger than one-half (1/2) inch.

(b) *Anchoring fixed machinery*. Machines designed for a fixed location shall be securely anchored to prevent walking or moving. ■

SOLUTION (1.7D)

Known: An incident occurred on a cattle ranch resulted in an injury to the operator of a tub grinder used to grind hay bales.

Find: Search the OSHA regulations http://www.osha.gov and specifically review the regulations 29 CFR 1910.212, *General requirement for all machines*, 29 CFR 1910.147, *The control of hazardous energy (lockout/tagout)*, and 29 CFR 1910.145, *Specifications for accident prevention signs and tags*. Write several paragraphs explaining how each regulation would apply to a tub grinder.

Analysis:

1. The OSHA regulations can be obtained by searching the key words: OSHA 1910.212, OSHA 1910.147, and OSHA 1910.145.

2. The exercise of writing several paragraphs on how each regulation applies to a tub grinder is left for the student.

Comment: For additional information about this incident, please see the information provided with the following solution. ■

SOLUTION (1.8D)

Known: Referring to Problem P1.7D, we know that an incident occurred on a cattle ranch resulted in an injury to the operator of a tub grinder being used to grind hay bales.

Find:

(a) Sketch a tub hay grinder and label a guarding device, power source, point of operation, and danger zone.
(b) List general methods used to guard known tub grinder hazards.
(c) Write a paragraph explaining the procedure of lockout/tagout for the tractor and tub hay grinder.
(d) Develop a warning sign/label(s) that could be applied to the tub grinder shields (guards) on the tub grinder.
(e) Sketch a device that could be used to "immediately" stop a rotating hammer mill if the tractor engine is "turned off".

Schematic and Given Data:

U.S. Patent Apr. 22, 2008 Sheet 1 of 19 US 7,360,728 B2

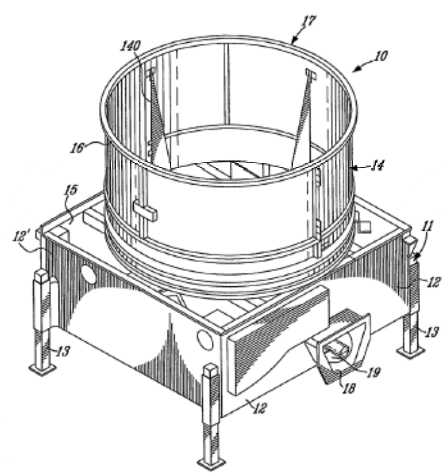
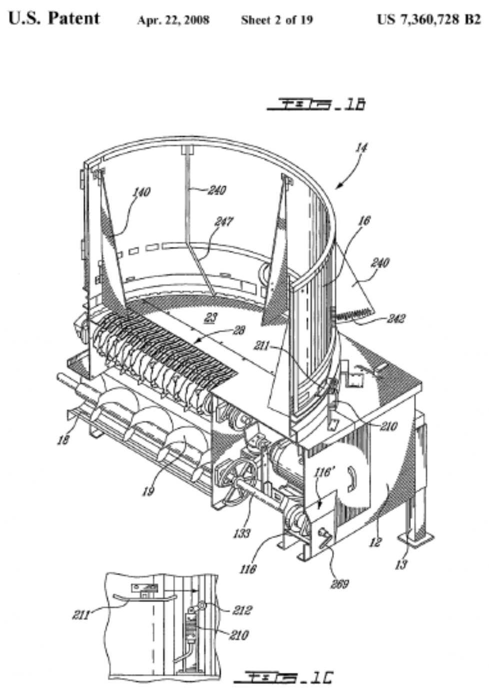


FIG. 1A



(Note: Figures 1A, 1B, and 1C show drawings of a tub grinder found in the patent literature. The figures are included herein solely to perk your interest.)

Analysis:
A. The exercise of sketching and labeling a hay grinder, listing methods for guarding, writing several paragraphs on lockout/tagout procedures, developing warning labels, and sketching a device that could be used to "immediately" stop a rotating hammer mill used in a tub grinder is left for the student.

B. Additional facts in this case are as follows:

1a. The purpose of a tub grinder is to grind and discharge various forage such as hay and alfalfa.

1b. The incident tub grinder allowed the user to shred circular hay bales by means of a rotating grinder hammer mill.

2a. The incident tub grinder mill had a spout shield (upper guard) and a mill-housing shield (lower guard) installed over the hammer mill grinding area. The hammer mill shields (guards) prevent the user from contacting the rotating hammer mill.

2b. The purpose of the shields (upper guard and lower guard) is to protect the operator from the rotating hammer mill as well as to allow access to the hammer mill and discharge area during maintenance (once the tractor is turned off, the key is removed from the ignition, and the hammer mill rotation has come to a complete stop).

3. The incident tub grinder upper shield and lower shield each contained a warning that stated: **"!WARNING KEEP SHIELD IN PLACE AND HANDS CLEAR OF MILL UNTIL TRACTOR IS SHUT OFF AND MILL ROTATION STOPS."**

4. The incident Case tractor cab has a warning label that states: **"!WARNING. <u>WHEN TRACTOR HAS STOPPED</u>: … • Disengage PTO, stop engine, and wait for all movement to stop before servicing or clearing equipment."**

5. The operator testified that *he had used grinding machines at his job with the owner almost the entire 20 years…* And he testified, *that he had been operating farm tractors his whole life*.

6a. The operator testified that he knew not to stick his hand in the machine when the machine was still rotating.

6b. The operator testified that he knew of the danger of reaching his arm into the rotating blades (hammers).

Comments: Conclusions that were reached by a mechanical engineer investigating this incident were as follows:

1. A manual was provided with the incident tub grinder mill. The manual was subsequently retained by the owner in his office.

2. The operator manual states: "**TO THE OWNER** … **It will pay you to read the entire manual carefully and familiarize yourself with all operations "before operating" the unit."**

3. The Operator and Parts Manual for the incident tub grinder states: "**DURING OPERATION:**

- **Do not attempt to remove any obstructions while operating the machine. First shut off tractor and put key in your pocket."**
- **Shut off tractor engine and be sure to wait until all moving parts have come to a complete stop before adjusting, cleaning, or lubricating."**

4. The operator did not read the operator manual.

5. The operator, without asking for a manual or consulting the incident manual attempted to operate/maintain//unclog the incident tub grinder. In so doing, he was assuming a risk.

6. The operator attempted to unclog the machine while leaving the tractor running, ignoring operator manual instructions, and disregarding a warning posted on the machine that stated: "!CAUTION. STOP ENGINE BEFORE LEAVING OPERATOR'S POSITION TO ADJUST, LUBRICATE, CLEAN OR UNCLOG THE MACHINE …"

7. The operator assumed a risk of injury by the manner in which he attempted to operate/maintain/unclog the incident tub grinder.

8. The operator's deposition testimony indicates that he knew of and recognized the rotating hammer mill and the danger of removing the shields (guards) while the hammer mill was rotating.

9. The danger of the rotating hammer mill was open and obvious. The danger of the rotating hammer mill and of removing the shields (guards) while the hammer mill was rotating was known to the operator.

10. The operator ignored an open and obvious hazard by placing his arm into a rotating hammer mill and not following the manufacture's warnings/instructions.

11. With the hammer mill rotating and the tractor engine running and with the key in the ignition, the operator placed his arm in the housing shield opening in an attempt to remove clogged material.

12. The operator ignored warning labels that instructed/warned to keep the shields in place and not open the upper and lower shields before the tractor is shut off and mill rotation stops. The labels stated:

> **WARNING. KEEP SHIELD IN PLACE AND HANDS CLEAR OF MILL UNTIL TRACTOR IS SHUT OFF AND MILL ROTATION STOPS.**
>
> **CAUTION:**
> **1. KEEP ALL SHIELDS IN PLACE.**
> **2. STOP ENGINE BEFORE LEAVING OPERATOR'S POSITION TO ADJUST, LUBRICATE, CLEAN OR UNCLOG MACHINES, UNLESS OTHERWISE SPECIFICALLY RECOMMENDED IN THE "OPERATOR'S MANUAL."**
> **3. WAIT FOR ALL MOVEMENT TO STOP BEFORE SERVICING THE MACHINE,**
> **4. KEEP HANDS, FEET, AND CLOTHING AWAY FROM POWER DRIVEN PARTS…**

13. The incident tub grinder had shields (guarding) to prevent tub grinder users from contacting the rotating hammer mill.

14. When the lower and upper shields are opened, the operator can both visually and audibly recognize the rotating hammer mill.

15. There is no evidence that the shields utilized by the incident tub grinder did not meet ASAE standards at the time of manufacture.

16a. There is no evidence of a design, manufacturing, and/or marketing defect at the time of manufacture of the tub grinder mill (≈ 2005).

16b. There has been no evidence presented that the incident tub grinder made the basis of this case, manufactured by XYZ, Inc. did not meet applicable standards at the time of manufacture.

17. The incident tub grinder is reasonably safe when used in a prudent manner.

18. The incident grinding mill is reasonably safe because a person can safely clean out the spout as designed if the tractor is properly turned off.

19. No alternative design has been proposed (by the Plaintiff).

20. The proximate cause of the accident (incident) was that the operator: (a) failed to properly disengage the PTO, shut off the tractor and/or remove the key from the ignition before servicing the incident tub grinder, (b) failed to wait for all movement to stop before servicing the tub grinder, (c) failed to keep the shields in place, and/or (d) failed to keep his hands clear of the hammer mill until the tractor was shut off and mill rotation stopped.

21. A producing cause of the accident was the operator placing his hand in and/or around a known open and obvious danger.

22. The operator knew or should have known of the dangers of the tub grinder with the hammer mill rotating and the grinder mill shield and spout shield guards out of place. A warning of the danger of keeping the shield(s) in place and hands clear of the hammer mill until the tractor is shut off and the mill stopped rotating was posted in two places on the tub grinder.

23. The operator knew or should have known that the hammer mill had not come to a complete stop when he reached into the shield opening.

24. The accident could have been avoided had the operator (a) followed proper operating procedures, (b) properly disengaged the PTO, shut off the tractor and removed the key from the ignition and placed it in his pocket, (c) complied with manufacturer’s warnings, (d) not opened the discharge spout shield (guard) and/or the hammer mill housing shield guard before the hammer mill (and the PTO shaft) had come to a complete stop, and/or (e) not placed his hand in the shielded opening.

25. In the end, the ultimate responsibility to be safe rested with the operator.

For additional information about this incident, please see the information provided with the previous problem and solution. ■

SOLUTION (1.9D)

Known: An incident occurred resulting in a worker's hand being amputated in a machine called a "pallet notcher" which cuts notches in 2 in. x 4 in. lumber (boards), used to build pallets. The boards move on a conveyor to the notcher where they drop into a covered area about four feet long. The covered area houses two sets of staggered rotating knives. The boards go through the first set of knives, notching one end, then through the second set which notches the opposite end. At the time of the accident, the worker was collecting the notched wood from the exit area of the machine. He was pulling the boards outward as they exited the machine. He felt something hit his fingertip, and when he pulled back, his hand had been removed near the wrist by one of the sets of knives that notches the 2 in. x 4 in. lumber (boards).

Additional facts in this accident include:

1. Prior to the day of the accident, the employee had not been stationed at the incident pallet notcher.
2. The incident pallet notcher machine was not the employee's usual station.
3. The employee was working near the exit area of the notcher at the time of the accident.
4. The area where the boards exit the machine is approximately 7 inches high and 19 to 20 inches from the point of operation. This distance is easily reachable by an employee working at the machine exit. (OSHA report)
5. A piece of "hung" carpet located toward the exit of the machine hindered the visibility of the blades and allowed an employee to reach under it and access the blades.
6. The pallet notcher was not guarded to protect the employees from the point of operation. (OSHA report)
7. The employer knew that guarding was required and was aware that the pallet notcher was not guarded. (OSHA report)
8. The employee reportedly was not informed of the location of the blades for the incident machine.
9. At the time of the accident there was not a warning label on the machine to alert the employee that a cutting blade was within his reach.
10. The employee was not instructed to use a pull stick to retrieve boards that do not exit the machine.
11. A 'willful' citation (issued when the employer knowingly commits a violation) was proposed for a violation of 1910.212(a)(3)(ii) (OSHA report)

Find: Search the OSHA regulations at http://www.osha.gov and specifically review the section 29 CFR 1910.212(a)(3)(ii). Write a paragraph relating the section to the above incident. Also, list ways in which this accident could have been prevented.

Analysis:

1. The Regulations (Standards - 29 CFR) - Table of Contents – shows:

• Part Number:	1910
• Part Title:	Occupational Safety and Health Standards
• Subpart:	O
• Subpart Title:	Machinery and Machine Guarding
• Standard Number:	1910.212
• Title:	General requirements for all machines.

2. Specifically for 29 CFR **1910.212(a):** Machine guarding.

1910.212(a)(1)
Types of guarding. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

1910.212(a)(2)
General requirements for machine guards. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

1910.212(a)(3)
Point of operation guarding.

1910.212(a)(3)(i)
Point of operation is the area on a machine where work is actually performed upon the material being processed.

1910.212(a)(3)(ii)
The point of operation of machines whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

1910.212(a)(3)(iii)
Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

3. This accident could have been prevented if (a) the machine had been properly guarded, (b) a warning label was visible by employees working at the machine exit, and/or (c) the employer had been properly trained and instructed as to the location of the blades.

Comments:

1. There was no guard on the machine's exit to prevent an employee from reaching the blades within the machine.
2. By leaving the machine unguarded, the employer allowed their employees to be at serious risk of injury on the unseen yet reachable blades.
3. The employer failed to provide a safe workplace. ■

SOLUTION (1.10D)

Known: A single pole hunting stand is supported on a vertical pole and stabilized using at least three guy wires. The guy wires can be attached to stakes that are placed in the ground or attached to surrounding objects such as rocks, trees, or roots. The single pole configuration allows erection on varied terrain with or without attaching to trees. The single pole hunting stand provides an unobstructed 360-degree field of view and complete rotational freedom of movement via a swivel seat that is attached to the top of the pole. The swivel seat with backrest may be elevated to the desired height by changing the length of the pole. The pole is equipped with steps that allows for access to the swivel chair without having to adjust or move the stand. The single pole device does not require attachment directly to a single tree or require climbing a tree for access or egress. The single pole may be collapsed or disassembled to create a shorter length; the swivel chair detached, and the guy wires coiled to allow compact packaging and shipment, assembly, easy movement and storage.

Find: Based on a study of the single pole hunting stand as described, review the design of the single pole hunting stand and address the question as to whether the single pole hunting stand is a "reasonable safe design" using the following categories:

(1) The usefulness and desirability of the product.

(2) The availability of other and safer products to meet the same or similar needs.

(3) The likelihood of injury and its probable seriousness.

(4) The obviousness of the danger.

(5) Common knowledge and normal public expectation of the danger (particularly for established products).

(6) The avoidability of injury by care in use of the product (including the effect of instructions and warnings).

(7) The ability to eliminate the danger without seriously impairing the usefulness of the product or making it unduly expensive.

Schematic and Given Data:

U.S. Patent Jun. 23, 1987 4,674,598

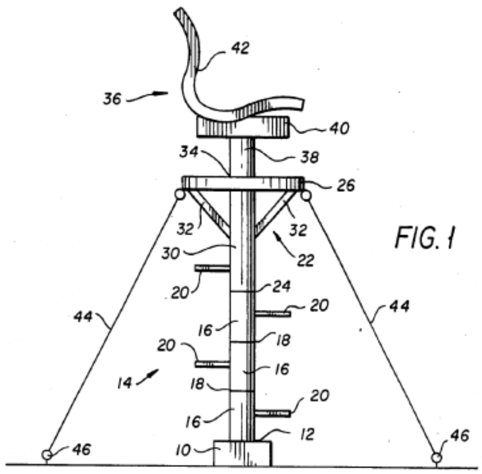


FIG. 1

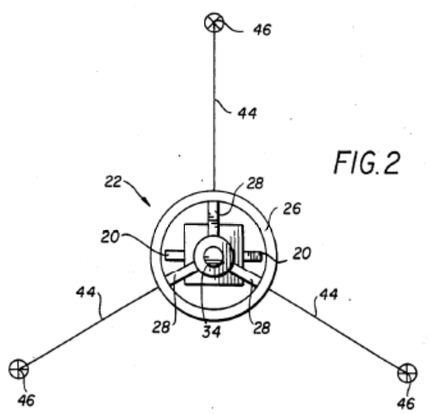


FIG. 2

For reference, see Sides, et al., 4,674,598.

Assumptions:
Three ground attachment points is somewhat like a three-legged stool and probably does not result in a reasonable safe product.

Analysis: An analysis would involve an objective review of items (1) to (7).

Comment: A cursory review of items (1) to (7) with respect to the hunting stand described in patent ‘598 lead one mechanical engineer to conclude that this stand does not represent a “reasonable safe design”.

A more exhaustive discussion on the question of whether the single pole hunting stand described is a reasonably safe design is left for the student and/or the instructor. ■

SOLUTION (1.11D)

Known: An incident occurred at the residence of a man wherein he was injured when he reportedly applied sandpaper to a rotating drive belt while attempting to repair an exercise treadmill. The incident treadmill was powered by a 2hp DC motor, and was being "operated" by the man while he was attempting to repair the machine by applying sandpaper to the motor drive V-belt at the time of the accident.

Indeed, he decided to remove the treadmill motor guard so he could better access the underside of the tread belt. He noticed and thought that the motor drive belt had a "sheen". He then took a roll of sandpaper, started the 2 hp electric motor, and attempted to apply-- in the area of an in-running nip point -- the sandpaper to the drive belt to remove the "sheen" while the treadmill motor and tread belt was powered and running. His middle finger on his right hand was reportedly drawn with the sandpaper into the motor belt and rotating drive pulley. He sustained injury to his finger as a result of the accident.

Find: From your viewpoint, address the issue of whether the incident treadmill was reasonably safe. Also, list possible causes of the accident.

Analysis: An analysis would involve an objective review of items (1) to (7) as listed in problem 1.10D and repeated below:

1 The usefulness and desirability of the product

Product helps promote fitness and general health for users. Allows users to exercise when weather conditions are bad and when time constraints do not allow travel to a gym. Also allows users have a custom tailored workout with precise speed and elevation changes. Product is desirable, as people want to maintain health and fitness and often desire convenience as an incentive.

2 The availability of other and safer products to meet the same needs

There are currently treadmills with more guarding on the treadbelt/roller areas but the motor guard design is essentially the same. No other treadmills have a safer motor guard design incorporating tamper resistant screws, guard interlocks, motor guard warnings and/or owners manual holders. Some other machines (elliptical trainer, stationary bike, stair stepper) provide similar cardio workouts but they are not as effective at maintaining fitness as treadmills.

3 The likelihood of injury and its probable seriousness

The likelihood of injury from placing your hands in and around a high speed rotating nip point is very high and should be protected against. The seriousness of the injury is very high with great probability of serious but not life threatening injury to hands and fingers.

4 The obviousness of the danger

The danger of a high speed rotating motor pulley and the drive belt associated is open and obvious. Everyone knows that spinning objects and cause harm (fans, car belts, grinder wheels).

5 Common knowledge and normal public expectation of the danger
(Particularly for established products)

People see treadmills as mostly safe. I believe the public knows that you can fall from a treadmill and then be injured from the moving treadbelt. The public may also be aware of pinch points and friction injury from the moving treadbelt. My thought is that the public would see treadmill as slightly more dangerous than running outside and falling during running is the major cause of injury. I do not believe the public is aware of the danger of the motor pulley and drive belt with the motor guard in place.

6 The avoid ability of injury by care in use of the product
(Including the effect of instructions or warnings)

The ability to avoid injury is very high when the users keeps the motor guard installed and in place. Warnings on the motor guard may prevent the accident by discouraging some users from disassembly of the motor guard but it is not an assurance. It is less likely that a warning placed inside the motor area would prevent the accident, as the location of the warning would have to be placed away from the hazard. Normal use of the product with the motor guard in place would avoid all potential of the user from being entangled in the motor nip points. If the owner's manual instructions were followed then the accident would have most probably not happened.

7 The ability to eliminate the danger without seriously impairing
The usefulness of the product or making it unduly expensive

The danger is easy to eliminate by using a motor guard. The usefulness is not hampered in any way by the inclusion of a guard and does not add a significant cost. The guard also serves a useful cosmetic purpose. The guard could be interlocked and/or installed with tamper resistant bolts that would discourage unauthorized access to the motor area. But this would introduce additional parts that could fail and/or make the treadmill more difficult to maintain. Also, there is no apparent additional means to remove the danger of the motor pulley or drive belt once the user has removed and defeated the guard.

After a reconstruction of the accident and an objective review of the design of the exercise treadmill the following causes of the accident were identified:

The proximate cause of the accident (incident) was that the owner: (a) attempted to repair the incident treadmill apparently without being qualified, (b) removed the electrical motor cover guard and exposing the drive belt and pulleys, (c) provided electrical power (energized) the treadmill, (d) started the electrical motor and treadmill belt in motion, and/or (e) placed his fingers in an area of an in-running nip point.

A producing cause of the accident was the owner placing his hand in and/or around a known open and obvious danger.

The owner knew or should have known not to attempt to repair a treadmill with the electrical motor cover guard removed, the motor and electrical circuits exposed and energized, the tread belt moving, and the motor belt in operation, while his hand was in the area of an in-running nip point.

The incident treadmill was reasonably safe when it left the hands of the manufacturer.

Comments:

A. Additional facts in this case include:

1. The incident treadmill allows the user to walk, jog, or run by means of traversing a continuous moving surface – tread belt. The owner was not using the treadmill for its intended purpose at the time of his injury.
2. The incident treadmill had a motor guard installed over the drive motor and drive belt area. The motor guard prevents the user from being entangled in the in-running nip points of the motor and drive belt.
3. The motor guard was secured to the treadmill with two Phillips pan head machine screws (bolts) and four Allen bolts (socket cap screws).
4. The owner's deposition testimony indicates that he knew of and recognized the danger of removing the guard, and turning on the treadmill, and sanding the motor power belt while it was in operation.

B. Accident description:

1. The owner was in the process of repairing the incident treadmill prior to the incident made the basis of this case.
2. The owner removed the motor cover (motor guard) for the incident treadmill.
3. The owner examined the motor drive belt and noted a "sheen" on the drive belt.
4. The owner reportedly obtained a 6" length of sandpaper and decided to sand down or remove an apparent "sheen" from the motor drive belt.
5. The owner "plugged in" the treadmill electrical cord into a 120-volt source and also activated the electric motor, motor pulley and the treadmill's tread belt.
6. The owner then placed his right hand and sandpaper near the in-running nip point of the motor drive belt and drive pulley.
7. The sandpaper the owner was reportedly holding and/or the middle finger of his right hand was/were pulled into the in-running nip point of the drive belt and the incident pulley.
8. The owner injured his right middle finger.

C. A mechanical engineer that investigated the accident, reconstructed the accident event, and studied the design and operation of the treadmill concluded that:

<u>Accident event</u>

1. The owner did not have a background, training or experience in treadmill repair and was not a treadmill repair technician.

2. The danger of the exposed in-running nip point between the electric motor drive belt and pulley was open and obvious. The owner knew the danger of the in-running nip point.

Design

3. It is not the practice in the "industry" to use tamper resistant fasteners for securing the motor cover guard since the motor area needs to be accessible to a variety of technicians.

4. The use of tamper resistant fasteners for securing the motor cover guard in a treadmill is not specified/mentioned in a treadmill related and applicable standard.

5a. There was no evidence of a design, manufacturing, and/or marketing defect at the time of manufacture of the treadmill (≈ 1993).

5b. There is no evidence that the incident treadmill made the basis of this case did not meet applicable standards at the time of manufacture.

6. The incident treadmill had guarding to prevent treadmill users from being entangled in the motor and drive belt nip points.

Warnings

7. The incident treadmill control panel contained a warning that stated: **"CAUTION! READ OWNER'S MANUAL CAREFULLY BEFORE OPERATING THIS EQUIPMENT. Keep hands and clothing away from belt and rear roller when in motion. DO NOT ALLOW children or anyone unfamiliar with its operation on or near this treadmill".**

8. A manual was provided with the incident treadmill.

9. It is not the practice in the "industry" to mount a holder for an owners/operators (instruction) manual on treadmills (consumer or institutional).

10. The manual was subsequently "lost" by the owner.

11a. The owner knew or should have known of the dangers of operating the treadmill with the motor running and the motor cover guard removed. A warning of the danger of removing the motor guard while operating the treadmill with the guard removed and the motor running would most probably have not have prevented this accident.

11b. The owner assumed the risk of injury in the manner in which he attempted to repair the incident treadmill. ■

SOLUTION (1.12D)
Known: Lockout/tagout procedures are discussed in 29 CFR 1910.147, which can be located at the website **http://www.osha.gov**.

Find: Write a paragraph explaining the procedure of lockout/tagout for machines or equipment.

Analysis: When service or maintenance is being preformed on a machine or equipment it should be locked and tagged out. These service or maintenance activities include lubrication, cleaning, or unjamming of a machine or equipment and making adjustments or tool changes, where the employee may be exposed to the unexpected energization or startup of the equipment or release of hazardous energy. A lockout device, either a key lock or combination lock, must be placed on the energy isolating device locking it into the safe position so that the equipment being controlled cannot be operated until the lockout device is removed. The tagout device should be placed on the isolating device, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

SOLUTION (1.13D)
Known: Specifications for danger and caution signs are found in 29 CFR 1910.145, which can be located at the website **http://www.osha.gov**.

Find: Determine the difference between a danger sign and a caution sign. Determine when the word "warning" should be used.

Analysis:
1. Danger signs are to be used only where an immediate hazard exists. Caution signs are to be used only to warn against potential hazards or to caution against unsafe practices.

2. Warning tags may be used to represent a hazard level between "caution" and "danger," instead of the required "caution" tag, provided that they have a signal word of "warning," an appropriate major message, and otherwise meet the general tag criteria. ■

SOLUTION (1.14D)
Comment: This problem is left as an exercise for the student.

SOLUTION (1.15D)

Known: A driller was in the process of raising the traveling block and the attached kelly and swivel assembly when an oil drilling rig accident occurred. The drawworks drum was equipped with metal casing that enclosed the drum on the lower front, top, and sides. However, there was an opening of approximately 4 feet by 3 feet to allow the fast line to spool back and forth onto the drum -- see FIGURE P1.15D in the textbook and Figure 1 below. The drawworks drums had no barrier guard to protect workers in close proximity to the drawworks drum from the hazard of the ingoing nip point between the moving fast line and the drum.

Find: Search the OSHA regulations http://www.osha.gov and specifically review the section 29 CFR 1910.212(a)(1), *General requirement for all machines*. Write a paragraph explaining how this section would apply to the drum. Also, suggest a guard (design) that could have prevented this accident.

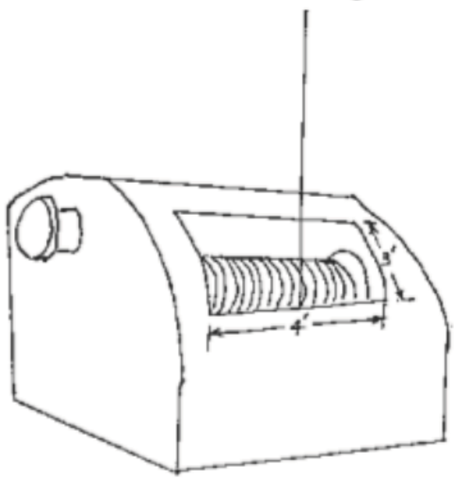
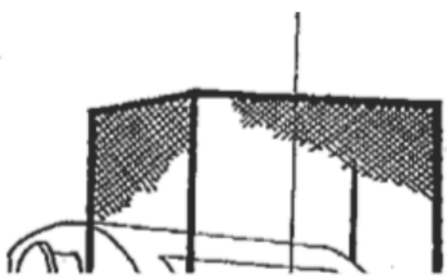


Figure 1



Extended Guard

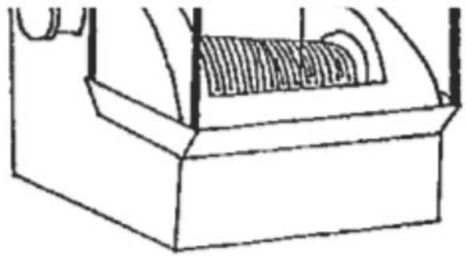


Figure 2

Figure 1. Drawworks drum and Figure 2. Drawworks drum with extended guard.

Analysis:

1. The OSHA regulations (standards – 29 CFR) state specifically for 29 CFR **1910.212(a):** Mach guarding.

1910.212(a)(1)
Types of guarding. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

1910.212(a)(2)
General requirements for machine guards. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

1910.212(a)(3)
Point of operation guarding.

1910.212(a)(3)(i)
Point of operation is the area on a machine where work is actually performed upon the material being processed.

1910.212(a)(3)(ii)
The point of operation of machines whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

1910.212(a)(3)(iii)
Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this section, but can only be used to supplement protection provided.

The entire OSHA regulation for 1910.212 can be reviewed at www.osha.gov.

2. Apparently, the drawworks drums, used on oil well drilling sites, were designed and constructed as shown above without any barrier guard to protect workers in close proximity to the drawworks drum from the hazard of the ingoing nip point between the moving fast line and the drum.

3. The oil drilling rig accident was caused by inadequate guarding of an approximate 4 foot by 3 foot opening that allowed the fast line adequate clearances to spool back and forth onto the drum that had no barrier guard.

4 This design also exposes the workers to the potential hazard of contacting the moving fast line cable in the zone immediately above the drum casing.

5 To protect workers, a barrier guard or screens must be installed in front of the drawworks drum or mounted on top of the existing drum casing to effectively isolate the ingoing nip point hazard. (See Figure 2)

6. The barrier or screen must be designed to eliminate any penetration by the worker's body parts such as hands and fingers, as well as materials such as chains or slings or any other object that could become entangled.

7. The shield should extend at least 7 feet above the working level and effectively isolate all exposed sides.

8. The guard should have features to allow for easy removal to provide access during servicing or inspection operations. The guard must be in place at all other times.

9. Figure 2 shows an OSHA approved solution that adds an extended guard to the inadequately guarded drawworks drum.

Comments:

1. The Bismarck Area Office of OSHA investigated this oil drilling rig accident caused by inadequate guarding of the drawworks drum.

2. Please see reference: http://www.osha.gov/dts/hib/hib_data/hib19950713.html. ■

SOLUTION (1.16D)

Known: Parking blocks prevent the forward movement of cars and other vehicle by acting like a “curb”. Unfortunately, for elderly persons or others with poor vision, they are sometimes difficult to “see” as they project only four to eight inches off the ground. An ASTM standard recommends that parking blocks not be used in parking lots and parking garages. On the other hand, the Americans for Disabilities Act (ADA) shows the use of parking blocks in the design of parking spaces for persons with disabilities.

Find: What are the advantages and disadvantages of parking blocks? What is your opinion as to whether the “utility outweighs the risk of harm” of using parking blocks? Are there certain places were parking blocks should not be used? Are there parking garages that do not use parking blocks?

Comments:

1. Grandmothers and grandfathers and others trip on parking blocks, fall and break bones, and end with black eyes. Grandmothers, grandfathers and others also drive their cars through storefronts and need a reminder at times of when and where to stop.
2. The world needs a better method and/or device for restraining vehicle forward motion in parking spaces; i.e., a better mousetrap is needed.
3. An exhaustive discussion on this topic and/or question is left for the student and/or the instructor. ■

SOLUTION (1.17D)

Known: Stairways have certain geometric requirements for their design; e.g., stairway steps shall be uniform with respect to rise and run.

Find: Review local and/or uniform building codes for stairways and steps and record the requirements for rise and run. Also, address and answer the question, why are building codes such as those for stairways required?

Comment:

1. Rise and run shall be uniform within a small tolerance for stairways and multiple steps.
2. Building codes are required because history, experience, analysis and/or research shows that following the codes leads to safer buildings in regard to their use and foreseeable misuse.
3. Codes also tend to standardize design, materials, manufacturing, methods and maintenance, which work to reduce cost.
4. A more exhaustive discussion on this topic and/or question is left for the student and/or the instructor. ■

SOLUTION (1.18D)

Known: An incident occurred in which a cantilevered section of a walkway (while under demolition) fell from a bagasse warehouse area at a sugar mill, resulting in the death of a worker on the walkway. The incident walkway was constructed of two 2.625 inch by 10 inch steel C-channel main beams with metal floor grating and welded on hand rails and was approximately 3 feet in width, 11 feet in length and located at a height of 40 feet from ground level. This section weighed more than 800 pounds. The worker was positioned on the cantilevered portion of the walkway cutting through the floor grating of the walkway when the cantilevered walkway section unexpectedly gave way and fell to the area below. The demolition of the walkway left one section of the walkway cantilevered and supported by the metal floor grating and by undersized weld. Demolition proceeded without a proper engineering study of the structural integrity of the bagasse walkway as well as an adequate plan for demolition. Demolition proceeded without a proper engineering study of the structural integrity of the bagasse walkway as well as an adequate plan for demolition. A proper engineering study of the structural integrity of the bagasse warehouse walkway as well as an adequate demolition plan in reasonable engineering probability would have prevented the accident.

Find: Search the OSHA regulation at http://www.osha.gov and review the sections 29 CFR 1926.501(a)(2) and 29 CFR 1926.850(a). Write a paragraph relating each section to the above incident, and describe how abiding by OSHA regulations could have reduced the risk to employees.

Schematic and Given Data: Please see textbook FIGURE P1.18D.

Analysis:

The OSHA document entitled "**Citation and Notification of Penalty**" for this incident lists the following citations:

Citation 1 Item 5 Type of Violation: Serious

29 CFR 1926.501(a)(2): The employer did not determine if the walking/working surfaces on which its employees are to work have the strength and structural integrity to support employees safely:

On or about August 7, 2007, employees were exposed to fall hazards when working from a cantilevered portion of a catwalk. The employer had not determined the strength of the catwalk to support workers and the workers had not tied off their harnesses to protect them from falls.

Citation 1 Item 7 Type of Violation: Serious

29 CFR 1926.850(a): An engineering survey was not performed by a competent person to determine the conditions of the framing floors and walls and the possibility of unplanned collapse of any portion of the structure prior to permitting employees to start demolition operations:

On or about August 6, 2007 and times prior thereto, evidence in writing was not available of an engineering survey was undertaken to determine safe methods for demolition of the B-C3 Conveyor in the Bagasse Warehouse.

Comments:

1. A proper engineering study of the structural integrity of the bagasse warehouse walkway as well as an adequate demolition plan in reasonable engineering probability would have prevented the accident.

2. Demolition proceeded without a proper engineering study of the structural integrity of the bagasse walkway as well as an adequate plan for demolition.

3. The specific exercise of writing a paragraph relating each section to the above incident, and describe how abiding by OSHA regulations could have reduced the risk to employees is left for the student. ■

SOLUTION (1.19D)

Comment: This problem is left as an exercise for the student.

SOLUTION (1.20D)

Comment: This problem is left as an exercise for the student.

SOLUTION (1.21D)

Comment: This problem is left as an exercise for the student.

SOLUTION (1.22D)

Known: The iPhone by Apple reportedly uses glass for the front display cover, steel for the trim, and plastic for the molded rear back.

Find: Write a report with three references on the efforts by Apple to design and manufacture an environmentally friendly iPhone.

Analysis: Important considerations for selection of materials for the iPhone with ecological factors in mind would include:
a. known availability in nature of the required raw materials (e.g., glass made from sand)
b. processing energy requirements
c. processing pollution problems (air, water, land, thermal, and noise)
d. recyclability
e. relative durability of alternative materials for use in a perishable part
f. compatibility of materials with respect to recycling

Comment: The report with three references is left for the student to write. ■

SOLUTION (1.23D)

Known: Catastrophes such as the Jonestown flood, Chernobyl, Tacoma Narrows Bridge, Kansas City hotel walkway, Challenger and Colombia continue to occur.

Find: How can engineers help avoid catastrophes? Are there any common root causes for these events? Can you plan for failure? Can you learn from failure?

Comments:

1. Learn from the mistakes of others, you can't live long enough to make them all yourself.
2. Think.
3. Consider Murphy's Law.
4. Be prepared.

An exhaustive discussion on this topic and/or question is left for the student and the instructor. ■

SOLUTION (1.24D)

Known: In an effort to counter the release of carbon dioxide by power plants in the United States, one thing that is being considered is that power plant owner's be allowed to invest in forests and trees that convert carbon dioxide to oxygen.

Find: Discuss the issues of the proponents and opponents to what is sometime referred to as a "carbon tax". What are your opinions regarding the advantages and disadvantages of the government providing incentives (tax breaks) for certain actions? Can these incentives be gamed; i.e., create interest and competitiveness and made an activity that companies participate in.

Schematic and Given Data:

Analysis: The "carbon tax" is an environmental tax that is applied to the carbon dioxide emissions emitted into the atmosphere while burning fossil fuels (i.e. coal, gas and oil). Carbon dioxide is emitted into the Earth's atmosphere when fossil fuels -- all of which contain carbon -- are burned. Excess CO_2 emissions are considered harmful to the environment.

The advantages of a carbon tax include an effort to protect the environment from reduced carbon dioxide emissions by means of reduced fossil fuel consumption. There is a general consensus within the scientific community that a continued increase in levels of CO_2 emissions from fossil fuels will destabilize global climate patterns and threaten ecosystems. Ultimately, the carbon tax theoretically creates incentives for corporations to develop and deploy carbon-reducing measures such as energy efficiency, low-carbon fuels, and renewable energy. Additionally, the revenue from the tax can be used for public goods and/or tax cuts. Also, a carbon tax is relatively easy to implement because the carbon content of all fossil fuels can be measured rather simply and subsequently taxed at a price per amount of carbon emitted.

The disadvantage of a carbon tax is that it can be politically unpopular. Some politicians hesitate to advocate for such a tax as it can be seen as politically risky. Would increased gas prices actually deter individuals from driving less? Would increased taxes to corporations emitting CO_2 drive jobs and work offshore to cheaper locales? Also, there is question regarding what is done with the tax revenue. Last, there is a possible negative impact on consumers and the economy. For instance, if a carbon tax increases the price of energy, it could affect the poor who currently struggle paying their current energy expenses.

The incentives created by the carbon tax can indeed create interest and competitiveness across corporations, as stated above. For instance, some companies offer carbon offsets as a luring incentive during the sales process so that customers can lessen the emissions related with their product or service purchase. Carbon offsetting has gained some appeal and popularity among consumers in western countries who are aware of the potentially negative environmental effects of CO_2 emissions. ■

SOLUTION (1.25D)
Known: You are given $10 million dollars to spend as an engineer in a business venture for the betterment and improvement of society.

Find: Describe how you would "spend" the money.

Comment: This problem when answered seriously can produce many interesting answers and may start engineers thinking and considering the steps they can follow to develop their own businesses that have a beneficial purpose for improving society.

An exhaustive discussion on the topic and/or question is left for the student and the instructor. ■

SOLUTION (1.26D)
Known: A city along with owners' of semiconductor chip related manufacturing companies operating in the city, agree to fix a ceiling labor rate for their employees.

Find: List the advantages and disadvantages.

Assumption: The agreement is legal.

Comments:
1. The owner's would know before they invest and build a manufacturing plant in a certain city that their labor costs would be the same as the other competing manufacturing companies in that city.
2. Persons living in that city who love the city would probably work at a lower labor rate than employees doing the same job in another city.
3. A more exhaustive discussion on this topic and/or question is left for the student and the instructor. ■

SOLUTION (1.27D)
Known: Areas of the country have been allowed to legally establish casinos and facilities for gambling. Assume that you are an engineer involved in the development of gambling equipment.

Find: What would your state engineering board provide as guidelines, if any, for your conduct as an engineer? From a sociological perspective, what are the advantages and disadvantages of allowing gambling?

Comments:
1. We suggest inviting a member of your state engineering board to answer the first question.
2. The answer to the second question … well is this why engineers take courses in sociology?
3. An exhaustive discussion on this topic and/or question is left for the student and the instructor. ■

SOLUTION (1.28D)

Known: A state government in an effort to reduce the pollution in its larger cities has provided incentives to owner's of polluting companies to move to less populated areas with significantly lower pollution, especially companies such a foundries that produce noise and smelly smoky airborne pollution.

Find: What are the advantages and disadvantages of such a system of "distributing" the pollution? Does spreading the pollution solve the health problem and/or reduce citizen complaints?

Comments: If this would happen, for example, cities such as Milwaukee would be provided incentives to move to small rural northern Wisconsin towns where there is little pollution. In this instance, pollution would be reduced in Milwaukee, and the little rural town could have a smelly, smoky foundry. But the rural town would have foundry jobs that would probably pay better than other work in the small town.

An exhaustive discussion on this topic and/or question is left for the student and the instructor. ■

SOLUTION (1.29D)

Known: Risk has been defined mathematically as the severity of the outcome of a hazard-related event times the probability that the event could occur. Several publications include the concepts of residual risk and acceptable or tolerable risk.

Find: Review the literature including technical report ANSI B11.TR3-2000 and write a report (that includes three references) on the concept of tolerable risk. In this report, provide definitions for hazard, probability, residual risk, risk, safety, severity, and tolerable risk.

Analysis: Definitions that are typical of what is becoming universally accepted language with respect to hazards, risks and acceptable or tolerable risk are given below. The section numbers appearing after some definitions refer to ISO/IEC Guide 51.

1. Hazard: the potential source of harm (3.5). Hazards include the characteristics of things and the actions or inactions of people.
2. Probability: the likelihood of a hazard being realized and initiating an event or series of events that could result in harm or damage -- for a selected unit of time, events, population, items or activity.
3. Residual risk: the risk remaining after protective measures have been taken (3.9).
4. Risk: a combination of the probability of occurrence of harm and the severity of that harm (3.2).
5. Safety: freedom from unacceptable risk (3.1). To avoid the negative, safety can be defined as that state for which the risks are judged to be acceptable.
6. Severity: the worst credible consequence should a hazard-related incident occur.
7. Tolerable risk: risk that is accepted in a given context based on the current values of society (3.7). For those who prefer to deal in terms of acceptable risk, it is defined as that risk which is tolerated in a given context based on current values of society.

Comments:

1. The B11.TR3-2000 (Technical Report) provides a means to identify hazards associated with a particular machine or system when used as intended, and provides a procedure to estimate, evaluate, and reduce the risks of harm to individuals associated with these hazards under the various conditions of use of that machine or system.

   B11.TR3-2000
   Risk Assessment and Risk Reduction - A Guide to
   Estimate, Evaluate and Reduce Risks Associated with
   Machine Tools

2. For additional information, please see the reference:

   EHS Today**,** 1300 East 9th Street, Cleveland, OH 44114-1503
   The Magazine for Environment, Health and Safety Leaders
   http://www. ehstoday.com ■

SOLUTION (1.30D)

Known: Mario Andretti is quoted as saying: "At the beginning of a season, I would look around at a drivers' meeting and I would think, 'I wonder who's not going to be here at the end?' There were years when we lost as many as six guys." Although notable measures have been taken over the years to make racing less risky, nevertheless, the number of driver fatalities in relation to the number of drivers involved would be considered unacceptable in other employment settings.

Find: Review the literature including technical report ANSI B11.TR3-2000 and write a report (that includes three references) on the concept of tolerable risk. In this report, contrast tolerable risk for a racecar driver versus that for an employee and user of an office machine; e.g., a copier.

Analysis:

1. The technical report ANSI B11.TR3-2000, Risk Assessment and Risk Reduction - A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools is used in broad areas including machine tools to assess and reduce hazards, and acceptable or tolerable risks.

Risk is determined by assessing its two components: the severity of outcome of a hazard-related event and the probability that the event could occur. References provide below discuss the nature of risk and a risk assessment matrix:

> "A risk assessment matrix can help show how these two factors are combined to obtain a risk level. A risk matrix lists the occurrence probability (frequent, likely, occasional, remote, improbable) versus the severity of consequences (catastrophic, critical, medium, minimal). Risk levels are listed as high, serious, moderate and low. For example, if the occurrence probability is frequent, and the severity of consequences is high, then the risk level is high. If the occurrence probability is improbable and the severity of consequences is minimal, then the risk level is low.
>
> The purpose of a risk matrix is to provide a logical framework for hazard analysis and risk assessment. In the decision-making process, the implicit goal is to achieve acceptable risk levels. Several standards and guidelines now include the concepts of residual risk and acceptable or tolerable risk (e.g., ANSI B11.TR3-2000, ISO/IEC Guide 51, SEMI S10-1296, SEMI S10-0307; see references for full titles)."

2. It is suggested that the student's report utilize a risk assessment matrix to contrast tolerable risk for (a) the racecar driver versus (b) an employee and user of a machine.

Comments:

1. For additional information, please see the references:

EHS Today, 1300 East 9th Street, Cleveland, OH 44114-1503
The Magazine for Environment, Health and Safety Leaders
http://www. ehstoday.com

An article on auto racing that reportedly appeared in the Chicago Tribune on February 14, 2001.

2. The B11.TR3-2000, Risk Assessment and Risk Reduction - A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools (Technical Report) provides a means to identify hazards associated with a particular machine or system when used as intended, and provides a procedure to estimate, evaluate, and reduce the risks of harm to individuals associated with these hazards under the various conditions of use of that machine or system. ■

SOLUTION (1.31D)

Known: Investigate the web site www.analyticcycling.com that provides technical methods for evaluating and estimating cycling performance. Verify that the conversion calculator provided on the web site will convert units correctly for speed (mph to km/hr), temperature (F to C), and force (lb to N).

Find: Write a short paragraph on how you would verify that the conversion calculator was "correct". What would increase your confidence in the conversion calculator given on the web site?

Analysis:

1. Speed, temperature, and force calculations were verified using several range points that covered the span of conversions most likely to be used. This also includes the identity conversions for each unit transformation. For example, in temperature the Celsius points -273ºC, 0ºC, 100ºC can be quickly used to verify the accuracy of a conversion program to Fahrenheit degrees.
2. Confidence in a conversion calculation would generally be improved by (a) disclosure of the algorithm and/or method employed, (b) a self check of the algorithm/method, (c) a statement by the author of the conversion calculator of its accuracy and range of use, and (d) disclosure by the author of intended uses, misuses or other issues.

Comment: A more exhaustive discussion on this topic of "conversion and calculation verification" is left for the instructor. ■

SOLUTION (1.32)

Known: The parameters m, a, F, W, s, ω, T and $\dot{W}$ are identified.

Find: Check the dimensional homogeneity of the following equations: (a) F = ma, (b) W = Fs, (c) $\dot{W} = T\omega$.

Given Data:

m = mass
a = acceleration
F = force
W = work
s = distance
ω = angular velocity
T = torque
$\dot{W}$ = power

Analysis:

1. Let the dimensions of length, mass, and time be given by

length	[=] L
mass	[=] M
time	[=] t

Then,

m	[=] M
a	[=] L/t^2
F	[=] ML/t^2
W	[=] ML^2/t^2
s	[=] L
ω	[=] 1/t
T	[=] ML^2/t^2
$\dot{W}$	[=] ML^2/t^3

2. (a) F = ma

$ML/t^2 = M(L/t^2) = ML/t^2$ ■

(b) W = Fs

$ML^2/t^2 = (ML/t^2)(L) = ML^2/t^2$ ■

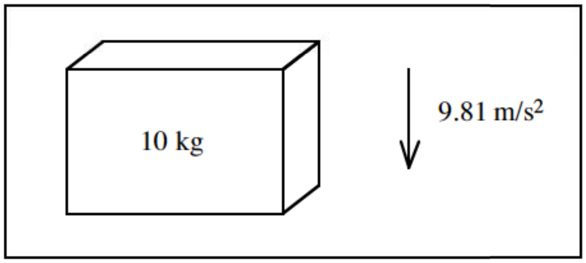
(c) $\dot{W} = T\omega$

$(ML^2/t^2)(1/t) = ML^2/t^3$ ■

SOLUTION (1.33)
Known: The mass and the acceleration of gravity are given.

Find: Determine the weight of the object in:
(a) English Engineering units
(b) British Gravitational units
(c) SI units

Schematic and Given Data:



Analysis:
(a) English Engineering units

$F = ma/g_c$ [Eq. (1.1a)]

where

$$m = \left(\frac{10\ \text{kg}}{1}\right)\left(\frac{1\ \text{slug}}{14.6\ \text{kg}}\right) = 0.685\ \text{slug}$$

or,

$$m = \left(\frac{0.685\ \text{slug}}{1}\right)\left(\frac{32.2\ \text{lbm}}{1\ \text{slug}}\right) = 22.1\ \text{lbm}$$

$$a = \left(\frac{9.81\ \text{m}}{\text{s}^2}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right) = 32.2\ \text{ft/s}^2$$

$$g_c = 32.2\ \text{ft·lbm/lb s}^2$$

Thus,

$$F = \frac{(22.057\ \text{lbm})(32.2\ \text{ft/s}^2)}{(32.2\ \text{ft·lbm/lb s}^2)} = 22.1\ \text{lb}$$ ■

(b) British Gravitational units

$F = ma$ [Eq. (1.1b)]

$F = (0.685\ \text{slug})(32.2\ \text{ft/s}^2) = 22.1\ \text{slug·ft/s}^2 = 22.1\ \text{lb}$ ■

(c) SI units

$F = ma$ [Eq. (1.1c)]

$F = (10\ \text{kg})(9.81\ \text{m/s}^2) = 98.1\ \text{kg·m/s}^2 = 98.1\ \text{N}$ ■

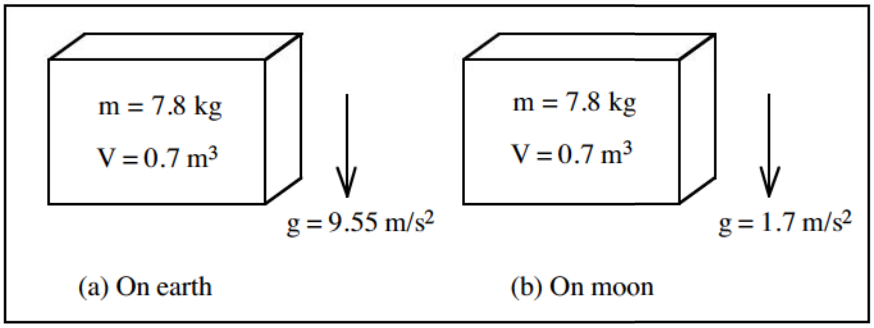
Comment: The answers in (a) and (b) are equivalent to the answer in (c), since

$$(98.1\ \text{N})\left(\frac{1\ \text{lb}}{4.448\ \text{N}}\right) = 22.1\ \text{lb}$$

SOLUTION (1.34)
Known: An object has known mass and volume.

Find:
(a) Determine the object weight and average density at a location where $g = 9.55\ m/s^2$.
(b) Determine the object weight and average density at a location where $g = 1.7\ m/s^2$.

Schematic and Given Data:



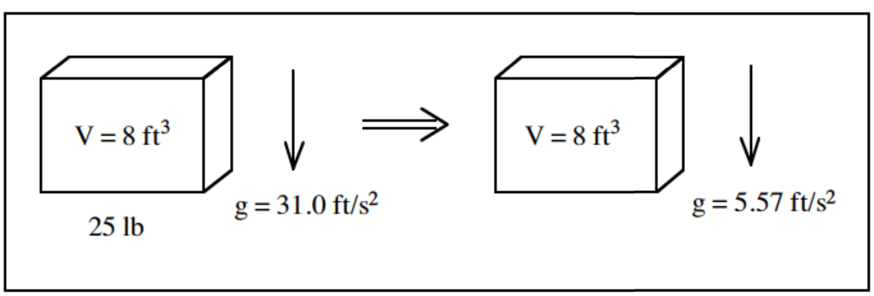
Analysis:
(a) On the earth where $g = 9.55\ m/s^2$, Weight = F = ma [Eq. (1.1c)]
$F = (7.8\ kg)(9.55\ m/s^2) = 74.5\ N$ ■
Average density, $\rho = m/V$
$\rho = (7.8\ kg/0.7\ m^3) = 11.1\ kg/m^3$ ■
(b) On the moon where $g = 1.7\ m/s^2$, Weight = F = ma.
$F = (7.8\ kg)(1.7\ m/s^2) = 13.3\ N$ ■
$\rho = (7.8\ kg)/(0.7\ m^3) = 11.1\ kg/m^3$ ■

Comment: The weight is dependent on gravity while the density is independent of gravity.

SOLUTION (1.35)
Known: A spacecraft component with known volume and weight is located where the acceleration of gravity is $31.0\ ft/s^2$.

Find: Determine its weight and its average density on the moon, where $g = 5.57\ ft/s^2$.

Schematic and Given Data:



Analysis:

1. Using British Gravitational units, and F = ma [Eq. (1.1b)]

$$m = \frac{F}{a} = \frac{(25\ \text{lb})}{(31.0\ \text{ft/s}^2)} = 0.806\ \text{slug}$$

2. On the moon,

$F = (0.806\ \text{slug})(5.57\ \text{ft/s}^2) = 4.49\ \text{lb}$ ■

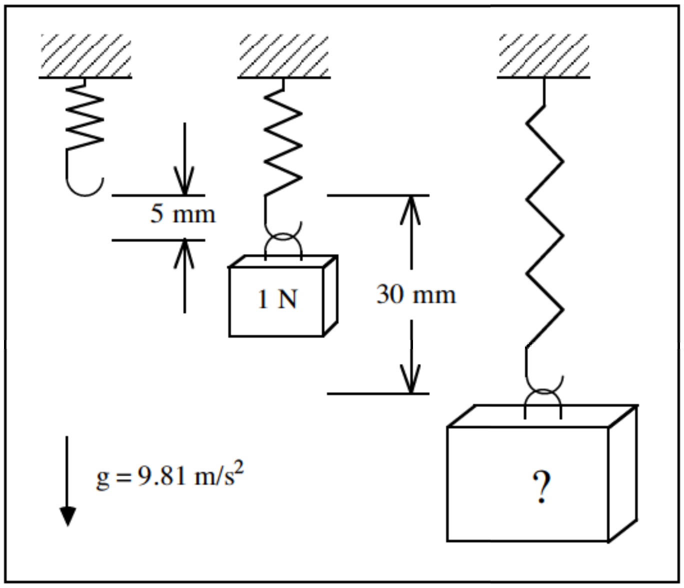
$\rho = (0.806)(32.2)\ \text{lbm}/8\ \text{ft}^3 = 3.24\ \text{lbm/ft}^3$ ■

SOLUTION (1.36)

Known: An object is suspended from a spring at a location where $g = 9.81\ \text{m/s}^2$. The deflection of the spring is known.

Find: Determine the mass of the object.

Schematic and Given Data:



Assumption: The spring has a linear force-deflection curve.

Analysis:

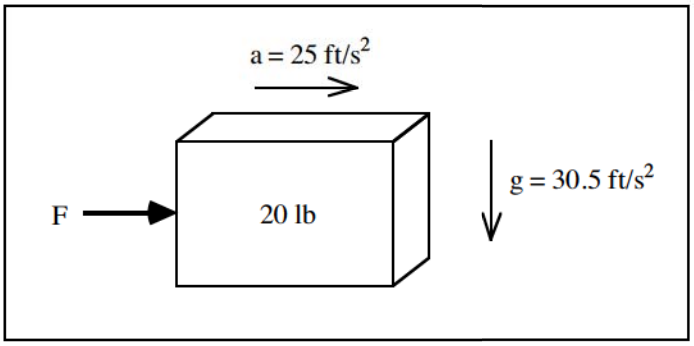
1. The weight of the object is $(30\ \text{mm})\left(\frac{1\ \text{N}}{5\ \text{mm}}\right) = 6\ \text{N}$
2. Using Eq. (1.1c), F = ma

$$m = \frac{F}{a} = \frac{6\ \text{N}}{9.81\ \text{m/s}^2} = 0.612\ \text{kg}$$ ■

SOLUTION (1.37)
Known: An object with known weight is located where the acceleration of gravity is $g = 30.5 \text{ ft/s}^2$.

Find: Determine the magnitude of the net force required to accelerate the object at 25 ft/s^2.

Schematic and Given Data:



Analysis:

1. Using British Gravitational units, F = ma [Eq. (1.1b)]

$$m = \frac{F}{a} = \frac{20 \text{ lb}}{30.5 \text{ ft/s}^2} = 0.656 \text{ slug}$$

2. $F = ma = (0.656 \text{ slug})(25 \text{ ft/s}^2) = 16.4 \text{ lb}$. ■

SOLUTION (1.38)
Known: The British Gravitational System uses the mass unit slug. By definition, a mass of 1 slug is accelerated at a rate of 1 ft/s^2 by a force of 1 lb.

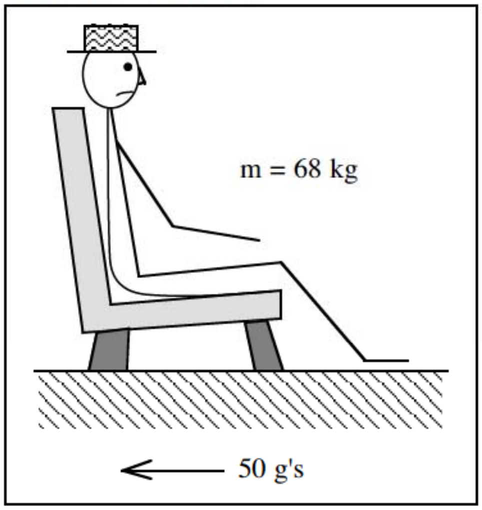
Find: Explain why the slug is a convenient mass unit.

Analysis: Unlike the English Engineering System, the British Gravitational System eliminates the need for g_c in F = ma since $g_c = 1$. ■

SOLUTION (1.39)
Known: An automobile passenger experiences a deceleration of 50 g's in a head-on crash.

Find: Determine the force experienced by the automobile passenger.

Schematic and Given Data:



Assumption: The acceleration of gravity, $g = 9.81\ m/s^2$.

Analysis:

1. With $g = 9.81\ m/s^2$, and F = ma [Eq. (1.1c)], we determine the force.
2. We have, $F = (68\ kg)(50)(9.81\ m/s^2) = 33{,}354\ N = 33.35\ kN$. ■

SOLUTION (1.40)

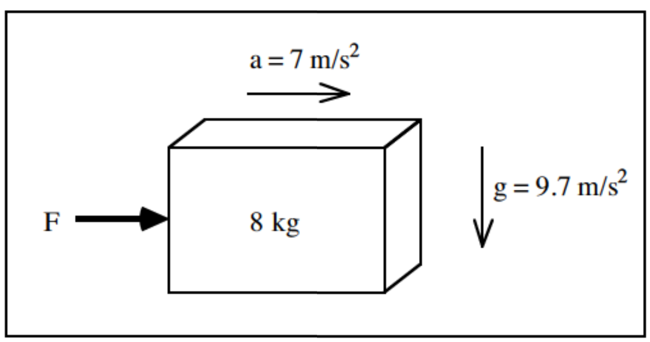
Known: The mass of an object is known.

Find: Determine:

(a) The object weight at a location where $g = 9.7\ m/s^2$.

(b) The magnitude of the net force required to accelerate the object at $7\ m/s^2$.

Schematic and Given Data:



Analysis:

(a) From Eq. (1.1c), $F = ma = (8\ kg)(9.7\ m/s^2) = 77.6\ N$

Thus, the object weighs 77.6 N ■

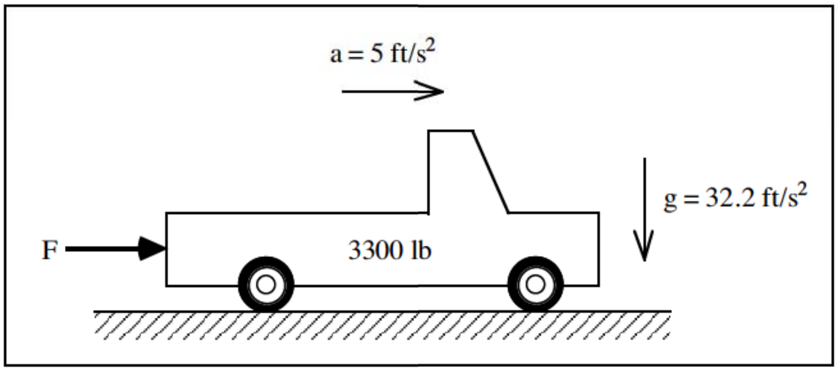
(b) $F = ma = (8\ kg)(7\ m/s^2) = 56.0\ N$

Thus, a force of 56.0 N is required to accelerate the object at $7\ m/s^2$. ■

SOLUTION (1.41)
Known: The weight of the truck is known and $g = 32.2$ ft/s^2.

Find: Determine the magnitude of the net force required to accelerate the truck at a constant rate of 5 ft/s^2.

Schematic and Given Data:



Assumption: The friction forces that resist the movement of the truck are negligible.

Analysis:

1. Using $F = ma$ [Eq. (1.1b)], $m = \frac{F}{a} = \frac{3300 \text{ lb}}{32.2 \text{ ft/s}^2} = 102.5$ slugs

2. $F = ma = (102.5 \text{ slugs})(5 \text{ ft/s}^2) = 512.4$ lb ■

SOLUTION (1.42D)

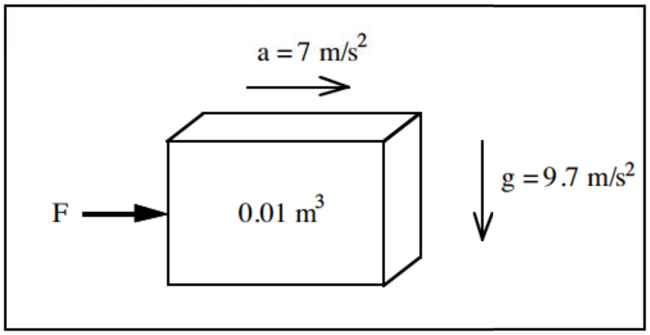
Known: The volume of an object is known.

Find: Determine:

(a) The object weight at a location where $g = 9.7\ m/s^2$.

(b) The magnitude of the net force required to accelerate the object at $7\ m/s^2$.

Schematic and Given Data:



Decision: Select steel with a density of $\rho = 7700\ kg/m^3$.

Analysis:

(a) From Eq. (1.1c), $F = ma = V\rho a = (.01\ m^3)(7700\ kg/m^3)(9.7\ m/s^2) = 746.9\ N$

Thus, the object weighs 746.9 N ■

(b) $F = ma = V\rho a = (.01\ m^3)(7700\ kg/m^3)(7\ m/s^2) = 539\ N$

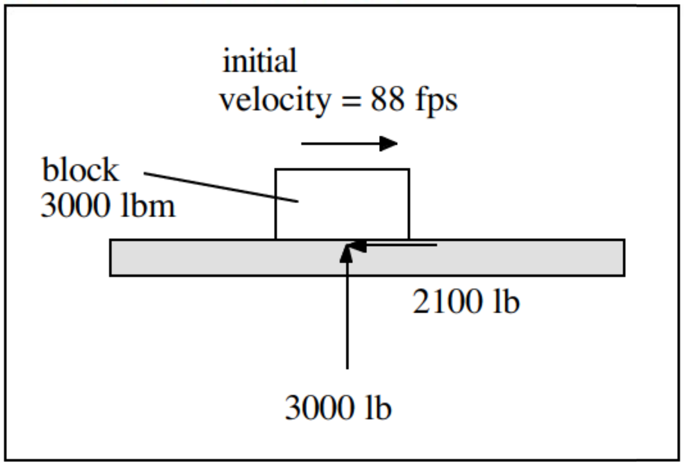
Thus, a force of 539 N is required to accelerate the object at $7\ m/s^2$. ■

SOLUTION (1.43)

Known: A block weighing 3000 lb slides on a flat surface at an initial velocity of 88 feet per second. The coefficient of friction between the block and the flat surface is 0.7.

Find: Determine the friction force causing the block to slow. How far does the block travel in slowing to a stop? How many seconds does this take? How much work was done to stop the block? What was the initial kinetic energy of the block?

Schematic and Given Data:



Analysis:

1. The friction force to slow the block is given by $F = \mu W = (0.7)(3000 \text{ lb}) = 2100 \text{ lb}$.

2. Newton's Second Law gives, $F = (1/g_c)\, ma$, where $F = 2100$ lb, $m = 3000\ lb_m$, $g_c = [(32.2\ lb_m \cdot ft) / (lb_f\ s^2)]$, and a = acceleration in ft/s^2.

3. Solving for a gives, $a = [(2100)(32.2)/(3000)] = 22.54\ ft/s^2 = 0.7g$ (where $g = 32.2\ ft/s^2$.

4. $t = V_{initial} / a = [88\ ft/s^2] / [\ 22.54\ ft/s^2] = 3.904$ s

5. $S = \frac{1}{2} \cdot at^2 = \frac{1}{2}\,(22.54)(3.904^2) = 171.78$ feet

6. Work is force times applied distance, $W = F\ S$. In this case, the force is the sliding friction force over the distance of 171.78 feet. Thus, $W = F \cdot S = (2100 \text{ lb})(171.78 \text{ feet}) = 360{,}738$ ft-lb.

7. The initial kinetic energy of the block is given by $KE = \frac{1}{2} \cdot (3000 \text{ lbm}/32.2) \cdot (88 \text{ ft/s})^2 = 360{,}738$ ft-lb. ■

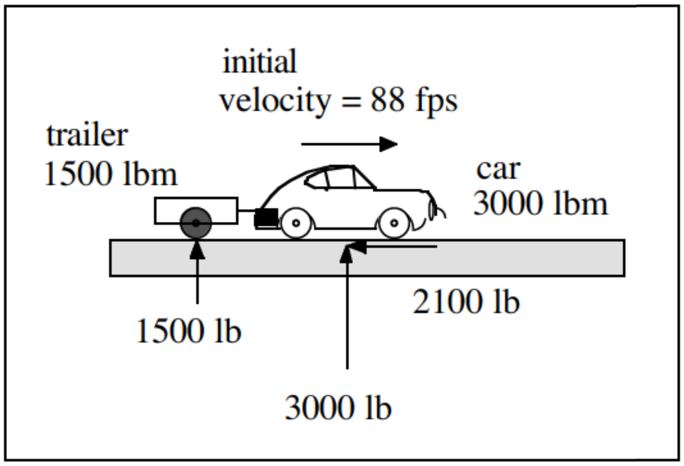
Comment: The deceleration of the block is equal to 0.7g; i.e., the coefficient of friction in g's. ■

SOLUTION (1.44)

Known: A car weighing 3000 lb tows a single axle two-wheel trailer weighing 1500 lb at 60 mph. There are no brakes on the trailer, and the car, which by itself can decelerate at 0.7g, produces the entire braking force.

Find: Determine the deceleration of the car and the attached trailer. Determine the force applied to slow the car and trailer. How far does the car and trailer travel in slowing to a stop? How many seconds does this take?

Schematic and Given Data:



Assumptions:

1. The car and trailer are stable during deceleration.

2. The deceleration of the car and trailer does not change the 3000 lb car tire force on the pavement.

Analysis:

1. The friction force to slow the car is given by $F = \mu W = (0.7)(3000\ lb) = 2100\ lb$.

2. Newton's Second Law gives, $F = (1/g_c)\ ma$, where $F = 2100$ lb, $m = (1500\ lb_m + 3000\ lb_m) = 4500\ lb_m$, $g_c = [(32.2\ lb_m \cdot ft) / (lb_f \cdot s^2)]$, and a = acceleration in ft/s^2.

3. Solving for a gives, $a = [(2100)(32.2)/(4500)] = 15.03\ ft/s^2 = 0.467g$ (where $g = 32.2\ ft/s^2$.

4. $t = V_{initial} /a = [88\ ft/s^2] / [15.03\ ft/s^2] = 5.855\ s$

5. $S = ½\ at^2 = ½\ (15.03)(5.855^2) = 257.62$ feet

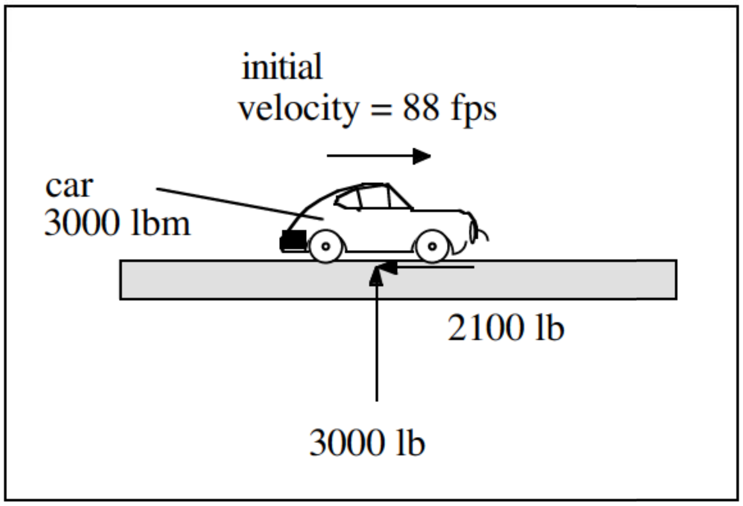
Comment: The deceleration of the car and attached trailer is 0.467g. The car by itself, decelerating at 0.7g, can stop in 171.78 feet rather that in 257.62 feet. ■

SOLUTION (1.45)

Known: A car weighing 3000 lb, traveling at 60 mph, decelerates at 0.70g after the brakes are applied.

Find: Determine the force applied to slow the car. How far does the car travel in slowing to a stop? How many seconds does this take?

Schematic and Given Data:



Analysis:

1. The friction force to slow the car is given by $F = \mu W = (0.7)(3000\ lb) = 2100\ lb$.

2. Newton's Second Law gives, $F = (1/g_c)\ ma$, where $F = 2100\ lb$, $m = 3000\ lb_m$, $g_c = [(32.2\ lb_m \cdot ft) / (lb_f \cdot s^2)]$, and a = acceleration in ft/s^2.

3. Solving for a gives, $a = [(2100)(32.2)/(3000)] = 22.54\ ft/s^2 = 0.7g$ (where $g = 32.2\ ft/s^2$.

5. $t = V_{initial} /a = [88\ ft/s^2] / [\ 22.54\ ft/s^2] = 3.904\ s$

6. $S = ½\ at^2 = ½\ (22.54)(3.904^2) = 171.78$ feet

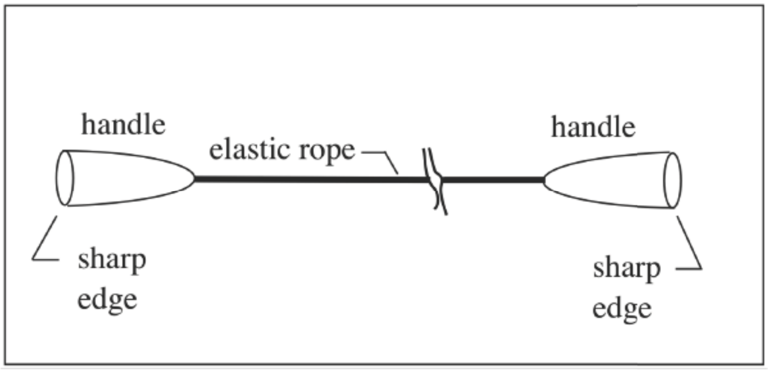
Comment: The deceleration of the car is equal to 0.7g; i.e., the coefficient of friction in g's. ■

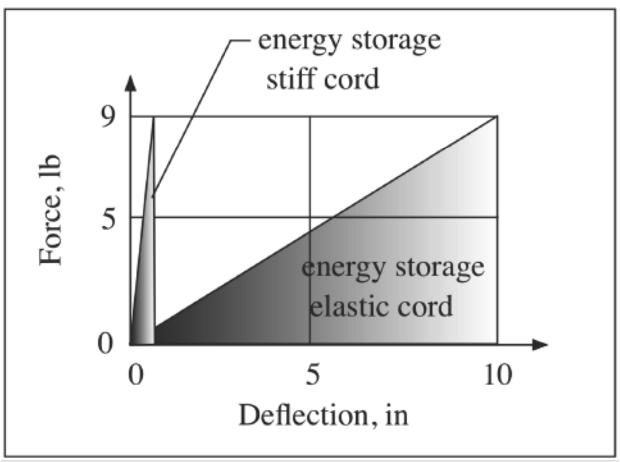
SOLUTION (1.46)

Known: A jump rope is made from an elastic cord. Two hollow hard plastic handles are attached to each end of the cord as shown in FIGURE P1.46 of the textbook. Two boys each pull on an end of the rope with a force of 9 lb, stretching the elastic rope 10 inches. Then one boy lets go of his handle. The rope and handles weigh 2 ounces.

Find: What was the approximate speed of the handle when it struck the boy's eye?

Schematic and Given Data:





Assumptions:
1. The potential energy stored in the rope is all converted to kinetic energy.
2. The rope/handle is a concentrated mass of two ounces.
3. The force of air drag can be neglected.

Analysis:
1. The potential energy stored by the stretched rope is calculated with PE = Work = ½ F · S where F = 9 lb, and S = 10 inches.

2. The kinetic energy of rope is given by KE = ½ $m_{rope}V^2_{rope}$ = ½ F · S where m_{rope}= 0.125 lb_m.

3. Solving one of the above equations gives $V^2_{rope} = (F \cdot S)/m_{rope}$ =

   (9 lb)(10 in)(32.2 $lb_m \cdot ft/lb \cdot s^2$)[12 in/ft]/(.125 lb_m) = 1932 ft^2/s^2.

4. Solving gives V_{rope} = 43.95 ft/s = 29.96 mph.

Comment: An experiment with an elastic cord could be conducted, and the speed of the cord and/or handle estimated from a videotape of the release jump rope. ■

SOLUTION (1.47D)

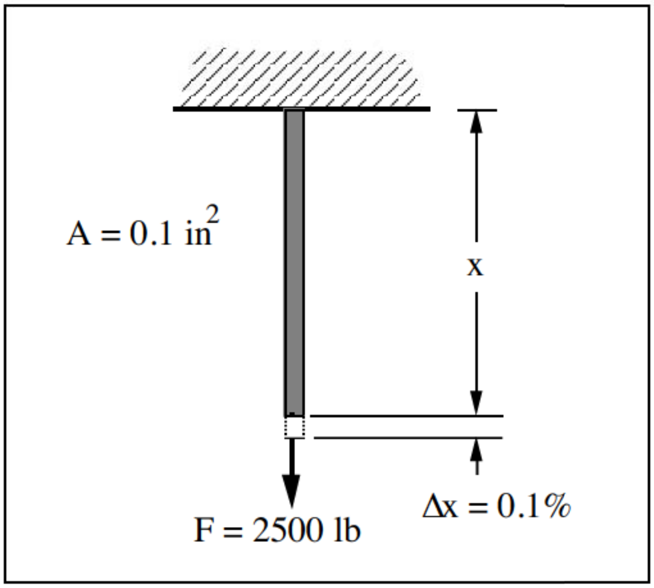
Known: A force is exerted on a wire with known cross-sectional area.

Find:

(a) Determine the normal stress in the wire.

(b) Determine the work done in stretching the wire.

Schematic and Given Data:



Decision: The wire is of length x = 10 ft.

Assumption:

1. The load is applied slowly so that the conditions can be regarded as static.
2. The mass of the wire is negligible.
3. The cross-sectional area of the wire remains constant.

Analysis:

1. $\sigma = F/A = \dfrac{2500 \text{ lb}}{0.1 \text{ in}^2} = 25{,}000 \text{ lb/in}^2$ ■

2. $F = kx = \dfrac{\Delta F}{\Delta x} x = \dfrac{2500 \text{ lb}}{(10 \text{ ft})(.001)} x = F(x) = 250{,}000\, x$

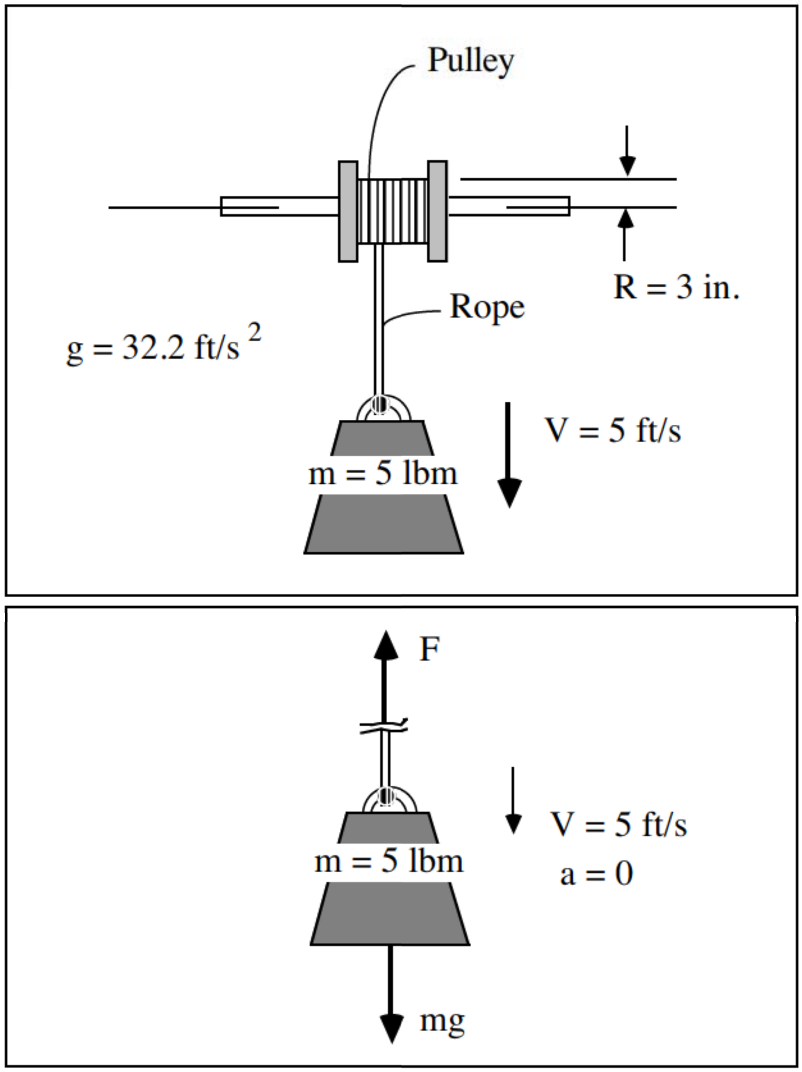
3. $\text{Work} = \displaystyle\int_0^{\Delta x} F(x)dx = 250{,}000 \frac{x^2}{2}\Bigg|_0^{.01}$

$= 125{,}000 \dfrac{\text{lb}}{\text{ft}} (.01 \text{ ft})^2 = 12.5 \text{ ft·lb}$ ■

SOLUTION (1.48)
Known: A known mass attached to a rope wound around a pulley is falling with a constant velocity.

Find: Determine the power transmitted to the pulley and the rotational speed of the pulley.

Schematic and Given Data:



Assumptions:
1. Wind resistance is negligible.
2. Bearing friction is negligible.
3. Mass of the rope is negligible.
4. The acceleration of gravity is a constant.

Analysis:
1. First, draw a free body diagram of the mass and solve for the tension on the rope.
   $F - mg = ma$
   $F - mg = 0$

$$F = mg = (5\ \text{lbm})(32.2\ \text{ft/s}^2)\left[\frac{1\ \text{lb}}{32.2\ \text{lbm ft/s}^2}\right] = 5\ \text{lb}$$

2. From Eq. (1.3), $\dot{W} = \dfrac{2\pi\ n\ T}{33{,}000}$

where $T = FR = 5\left(\dfrac{3}{12}\right) = 1.25\ \text{lb·ft}$

$$\omega = \frac{V}{R} = \frac{5}{\left(\frac{3}{12}\right)} = 20\ \text{rad/s}$$

$$n = \left|\frac{20\ \text{rad}}{\text{s}}\right|\frac{60\ \text{s}}{\text{min}}\left|\frac{1\ \text{rev}}{2\pi\ \text{rad}}\right| = 191.0\ \text{rpm}$$ ■

3. $\dot{W} = \dfrac{2\pi\,(191.0)(1.25)}{33{,}000} = 0.0455\ \text{hp}$

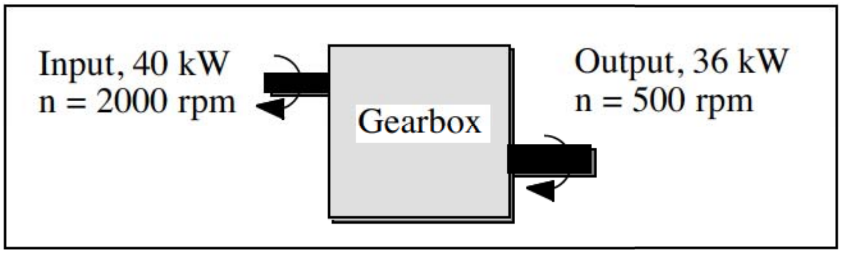
■

Comment: The power can also be calculated by using $\dot{W} = FV = (5\ \text{lb})(5\ \text{ft/s})/(550\ \text{ft lb/s hp}) = 0.0455\ \text{hp}$.

SOLUTION (1.49)
Known: The rotational speeds and the power of input and output shafts are given.

Find: Determine the torque on each shaft.

Schematic and Given Data:



Analysis:

1. From Eq. (1.2), $\dot{W} = \dfrac{2\pi\ n\ T}{60{,}000}$ or $T = \dfrac{60{,}000\ \dot{W}}{2\pi\ n}$

2. For the input shaft, $T = \dfrac{60{,}000(40)}{2\pi\ (2000)} = 191.0\ \text{N·m}$

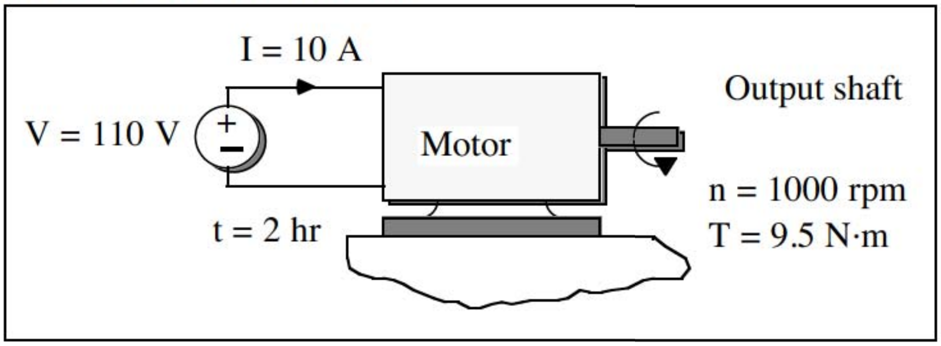
3. For the output shaft, $T = \dfrac{60{,}000(36)}{2\pi\ (500)} = 687.5\ \text{N·m}$ ■

Comment: The efficiency of the gearbox $\eta = \dfrac{36\ \text{kW}}{40\ \text{kW}} = 0.90 = 90\%$. If the gearbox is operating at steady state, the difference between the input power and the output power would be accounted for through heat energy transfer from the gearbox to its surroundings.

SOLUTION (1.50)
Known: An electric motor draws known values of current and voltage. The torque and the rotational speed of the output shaft are known.

Find:
(a) Determine the electric power requirement and the power developed by the output shaft.
(b) Determine the net power input to the motor.
(c) Determine the amount of energy transferred to the motor by electrical work and transferred out of the motor by the shaft during two hours of operation.

Schematic and Given Data:



Assumption: The conditions are steady state.

Analysis:

1. The electric power requirement can be calculated from $\dot{W}_{elec} = IV$.
   $\dot{W}_{elec} = (10\ A)(110\ V)(1\ kW/1000\ VA) = 1.10\ kW$ ■
2. The output shaft power can be calculated from Eq. (1.2).

   $$\dot{W}_{out} = \frac{2\pi\ n\ T}{60{,}000} = \frac{2\pi\ (1000)(9.5)}{60{,}000} = 0.995\ kW$$ ■
3. The net power input is $P_{net} = P_{in} - P_{out} = 1.10 - 0.995 = 0.105\ kW$ ■
4. The amount of energy transferred to the motor by electrical work is
   (1.10 kW)(2 hr) = 2.20 kW·h ■
   Applying unit conversion factors, 1 kW·h = 3.60 × 10⁶ J, and
   1 Btu = 1054 J, gives

   $$\left|\frac{2.20\ kW{\cdot}h}{1}\right|\frac{3.60 \times 10^6\ J}{1\ kW{\cdot}h}\left|\frac{1\ Btu}{1054\ J}\right| = 7514\ Btu$$ ■
5. The amount of energy transferred out of the motor by the shaft is
   (0.995 kW)(2 hr) = 1.99 kW·h ■

   $$\left|\frac{1.99\ kW{\cdot}h}{1}\right|\frac{3.60 \times 10^6\ J}{1\ kW{\cdot}h}\left|\frac{1\ Btu}{1054\ J}\right| = 6797\ Btu$$ ■

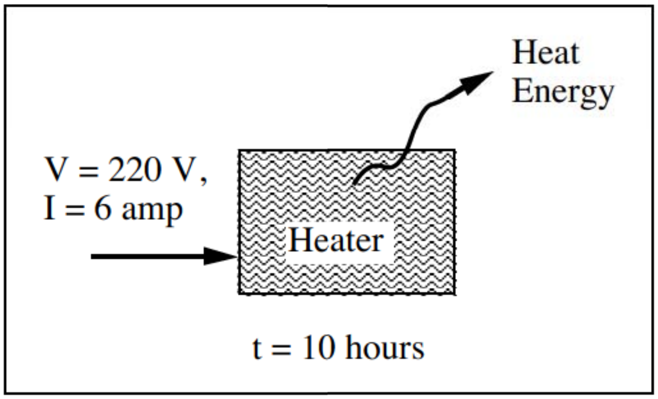
Comment: The efficiency of the motor can be written as $\eta = \frac{0.995\ kW}{1.10\ kW} = 0.905$ = 90.5%.

SOLUTION (1.51)

Known: An electric heater with known current and voltage values is turned on for a specified time.

Find: Determine the total amount of energy supplied to the heater by electrical work.

Schematic and Given Data:



Assumption: The current and voltage are constant with time.

Analysis:

1. $\dot{W} = IV = (6\ A)(220\ V) = 1320\ W = 1.32\ kW$

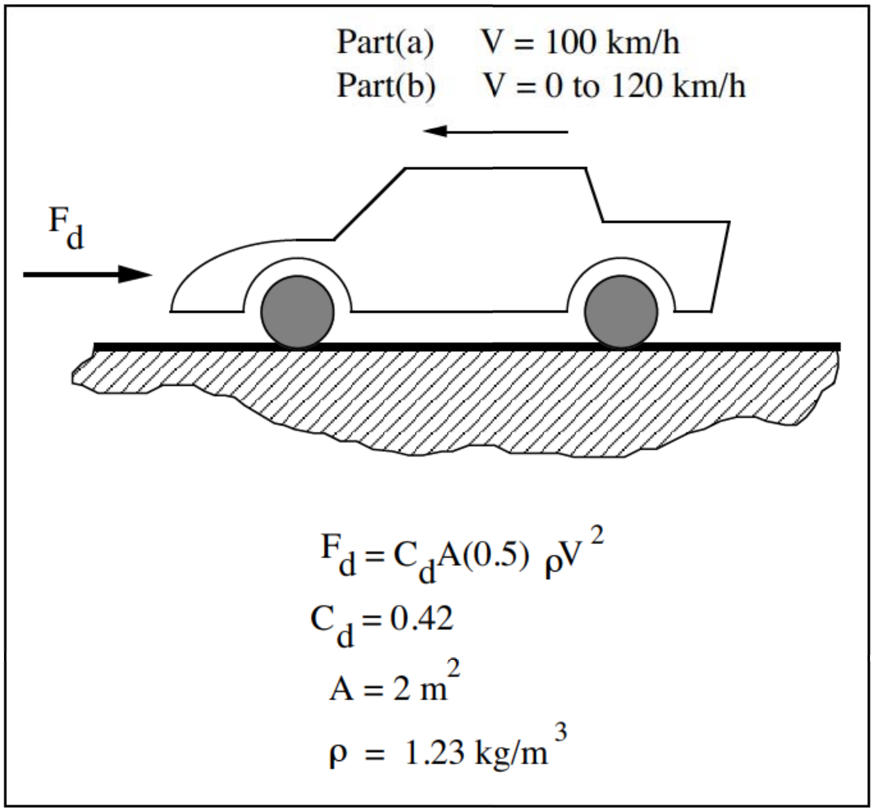
2. Total energy = electrical work = $\int \dot{W}dt = (1.32\ kW)(10\ hr) = 13.2\ kW{\cdot}h$ ■

SOLUTION (1.52D)

Known: An automobile moving with velocity V is subjected to a known drag force.

Find: Calculate the power required to overcome the drag force. Compute and plot the power to overcome drag as a function of velocity.

Schematic and Given Data:



Assumption: The automobile velocity is constant.

Analysis:

(a) For V = 100 km/h:

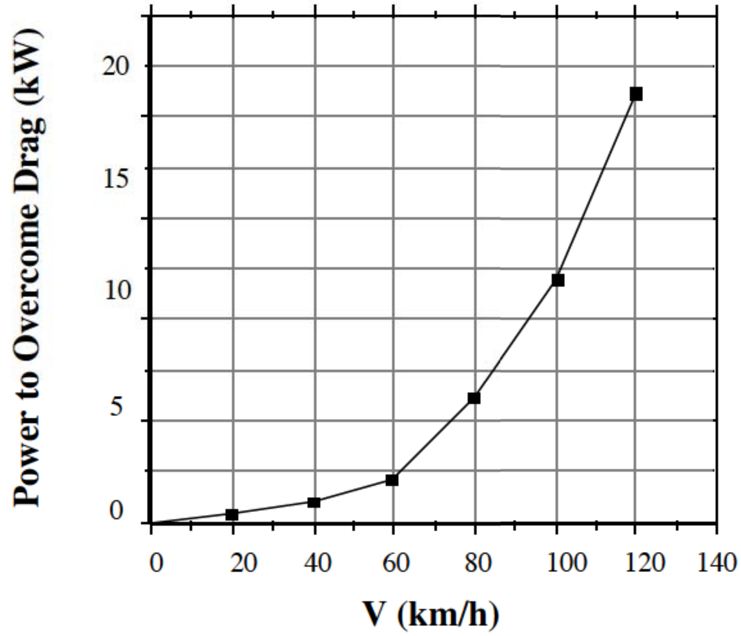
1. $V = \left| \frac{100\ km}{h} \right| \frac{1000\ m}{1\ km} \left| \frac{1\ h}{3600\ s} \right| = 27.78\ m/s$

2. Since $\dot{W} = F_d V$ and $F_d = C_d A \frac{1}{2} \rho V^2$,

$$\dot{W} = C_d A \frac{1}{2} \rho V^3$$

$$\dot{W} = (0.42)(2)\left(\frac{1}{2}\right)(1.23)(27.78)^3 = 11.07\ kW$$

(b) For V ranging from 0 to 120 km/h repeat steps 1 and 2. A plot is given in the following figure that shows **power to overcome drag** versus **vehicle velocity**.

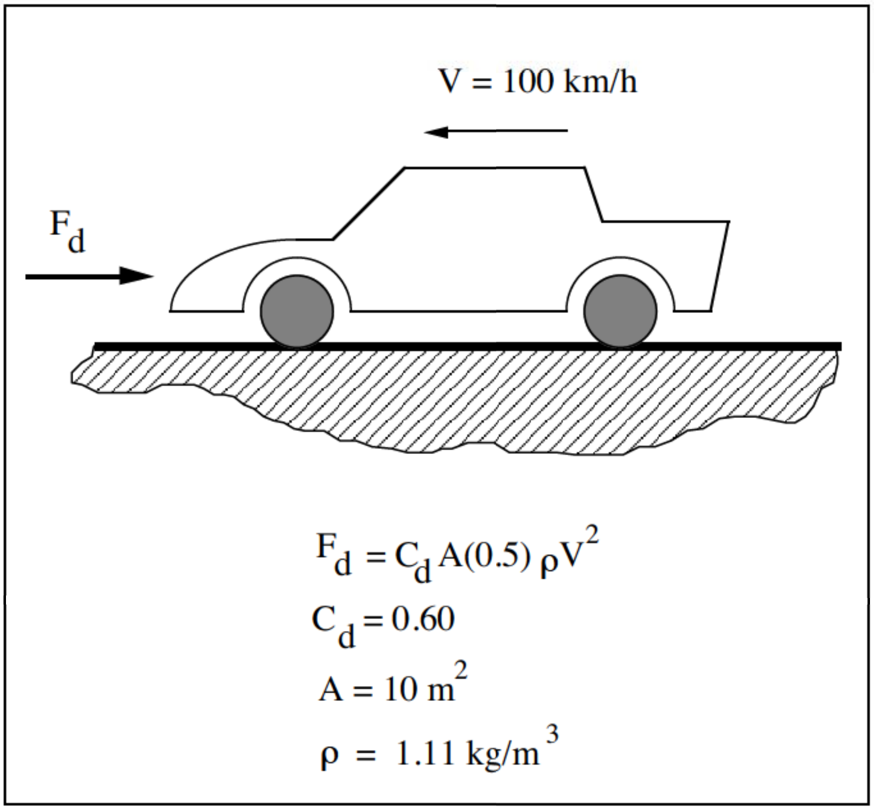


Comment: Note that $\dot{W} = F_d V = C_d A \frac{1}{2} \rho V^2 \bullet V$ or $\dot{W} \sim V^3$ ■

SOLUTION (1.53)
Known: An automobile moving with velocity V is subjected to a known drag force. For this vehicle, $C_d = 0.60$, $A = 10\ m^2$, $\rho = 1.1\ kg/m^2$, and V = 100 km/h.

Find: Calculate the power in kW required to overcome the drag force, F_d.

Schematic and Given Data:



Assumption: The automobile velocity is constant.

Analysis:

1. $V = \left| \frac{100\ km}{h} \right| \frac{1000\ m}{1\ km} \left| \frac{1\ h}{3600\ s} \right| = 27.78\ m/s$

2. Since $\dot{W} = F_d V$ and $F_d = C_d A \frac{1}{2}\rho V^2$,

$$\dot{W} = C_d A \frac{1}{2}\rho V^3 = (0.60)(10)\left(\frac{1}{2}\right)(1.10)(27.78)^3 = 70.75\ kW$$

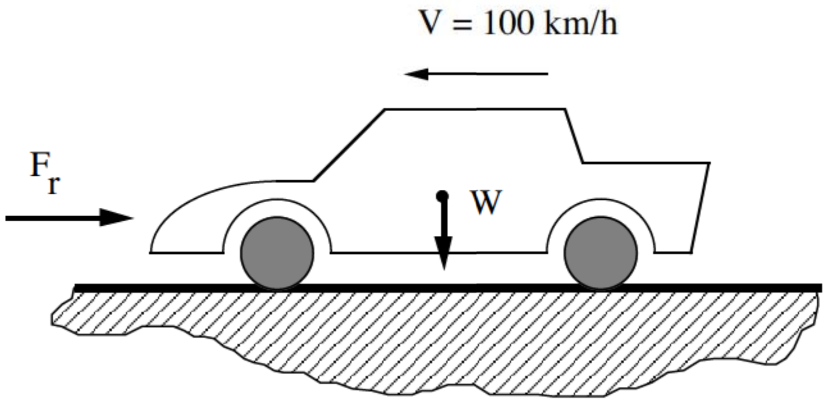
Comment: Note that $\dot{W} = F_d V = C_d A \frac{1}{2}\rho V^2 \bullet V$ or $\dot{W} \sim V^3$ ■

SOLUTION (1.54)

Known: An automobile moving with velocity V is subjected to a drag force due to rolling resistance.

Find: Calculate the power required to overcome the rolling resistance.

Schematic and Given Data:



$F_r = f\,W$

$W = 300$ kN

$f = 0.007$

Assumption: The automobile velocity is constant.

Analysis:

1. $V = \left| \frac{100\text{ km}}{\text{h}} \middle| \frac{1000\text{ m}}{1\text{ km}} \middle| \frac{1\text{ h}}{3600\text{ s}} \right| = 27.78\text{ m/s}$

2. Since $\dot{W} = F_r V$ and $F_r = fW$

$$\dot{W} = fWV = (0.007)(300000)(27.78) = 58.34\text{ kW}$$

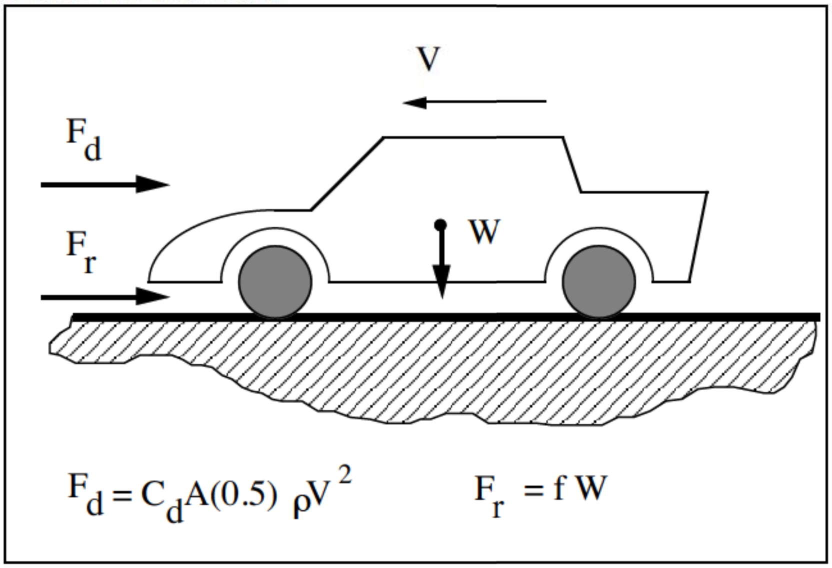
Comment: Note that $\dot{W} = F_r V = fWV$ or $\dot{W} \sim V$ ■

SOLUTION (1.55)

Known: An automobile moving with velocity V on a level road is subjected to known drag forces.

Find: Develop an equation for the power (hp) required to overcome (a) aerodynamic drag forces and (b) rolling resistance forces.

Schematic and Given Data:



Assumption: The automobile velocity is constant.

Analysis:

(a) For aerodynamic drag:

1. Since $\dot{W} = F_d V$ and $F_d = C_d A \frac{1}{2} \rho V^2$,

$$\dot{W} = C_d A \frac{1}{2} \rho V^3$$

2. Since $\dot{W} = F_r V$ and $F_r = fW$

$$\dot{W} = fWV$$ ■

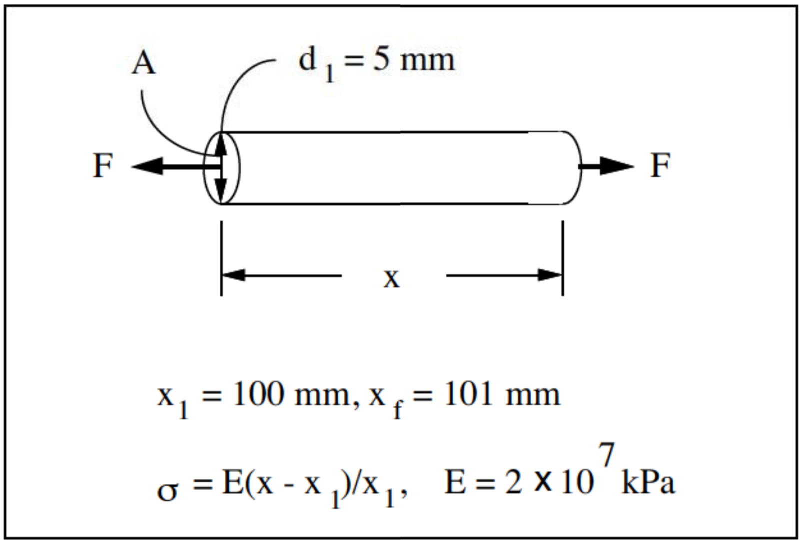
Comment: The total power required to propel the vehicle down the road would be the power to overcome the aerodynamic drag plus the power to overcome the rolling resistance forces. ■

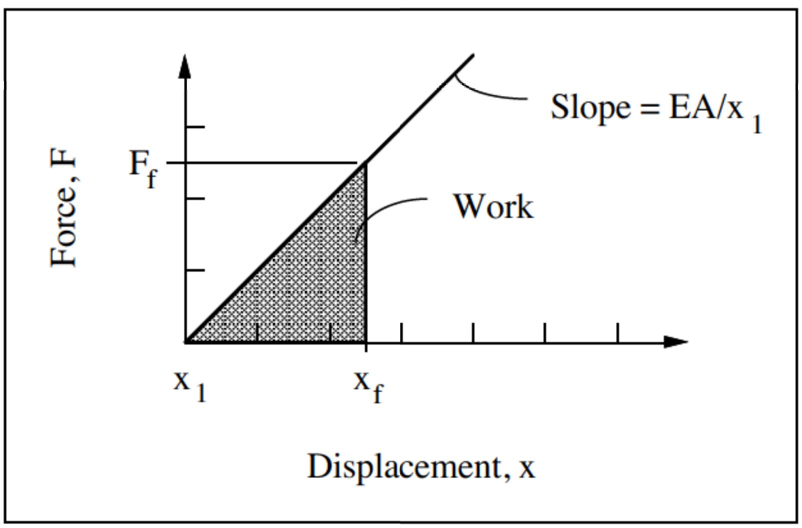
SOLUTION (1.56)

Known: A solid cylindrical bar of known diameter is slowly stretched from a known initial length to a known final length. The normal stress is given as a function of length.

Find: Determine the work done on the bar.

Schematic and Given Data:





Assumptions:
1. The load application can be considered as static loading.
2. The stress is uniform at both ends of the bar.
3. In the first solution method, cross-sectional area A is constant. In the second solution method, volume V is constant.

Analysis:
1. First we consider the case where A is a constant.
   Since $\sigma = F/A$

   $$F = \frac{\sigma}{A} = \frac{EA(x-x_1)}{x_1}$$

$$\text{Work} = \int_{x_1}^{x_f} F(x)dx$$

$$\text{Work} = \int_{0.100}^{0.101} \frac{EA}{x_1}(x - x_1)dx, \text{ and } A = \frac{\pi}{4}d_1^2$$

$$\text{Work} = \frac{E\pi d_1^2}{4x_1}\int_{0.100}^{0.101} (x - x_1)dx = \frac{E\pi d_1^2}{4x_1}\left[\frac{x^2}{2} - x_1 x\right]_{0.100}^{0.101}$$

$$= \frac{(2 \times 10^{10})\pi(0.005)^2}{4(0.100)}\left\{\left[\frac{0.101^2}{2} - (0.101)(0.1)\right] - \left[\frac{0.100^2}{2} - (0.100)^2\right]\right\} = 1.96 \text{ J} \blacksquare$$

2. Second we consider the case where V is a constant. Since A = V/x

$$F = \frac{EV}{x_1}\frac{(x - x_1)}{x} \text{ and } V = \frac{\pi}{4}d_1^2 x_1$$

$$F = \frac{E\pi d_1^2}{4}\left(1 - \frac{x_1}{x}\right)$$

$$\text{Work} = \int_{x_1}^{x_f} F(x)dx = \int_{0.100}^{0.101} \frac{E\pi d_1^2}{4}\left(1 - \frac{x_1}{x}\right)dx = \frac{E\pi d_1^2}{4}\left\{x - x_1 \ln x\right]_{0.100}^{0.101}\}$$

$$= \frac{(2 \times 10^{10})\pi(0.005)^2}{4}\left[(0.101 - 0.1 \ln 0.101) - (0.1 - 0.1 \ln 0.1)\right] = 1.95 \text{ J} \quad \blacksquare$$

Comment: Actually, mass is constant: m = ρ[Ax]. If ρ is also constant, then V = Ax is constant.

SOLUTION (1.57)

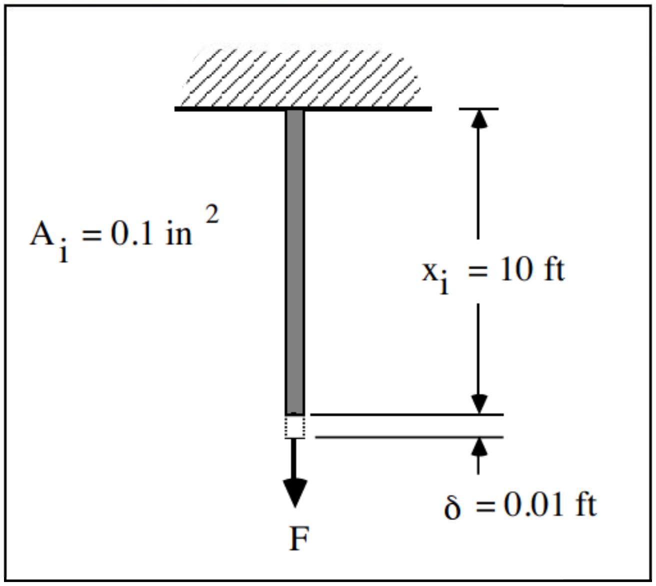
Known: A force that varies linearly with displacement is exerted on a steel wire with known cross-sectional area, initial length, and final length.

Find:

(a) Determine the normal stress as a function of the length of the wire.

(b) Determine the work done in stretching the wire.

Schematic and Given Data:



Assumption:

1. The load is applied slowly so that the conditions can be regarded as static.
2. The mass of the wire is negligible.
3. The wire volume remains constant.

Analysis:

1. Since V = constant, A = V/x or $A = \frac{A_i x_i}{x}$ where x is the distance from the wall to the end of the wire and A is the cross-sectional area of the wire when the length is x.

2. $F = k\delta = \frac{\Delta F}{\Delta \delta}\delta = \frac{2500}{0.01}\delta = 250{,}000\ \delta$

   where $\delta = x - x_i$

   $F = 250{,}000(x - x_i)$

3. $\sigma = F/A$

$$\sigma = \frac{250{,}000(x - x_i)}{\frac{A_i x_i}{x}}$$

$$\sigma = \frac{250{,}000}{A_i x_i}(x^2 - x_i x)$$ ■

where x and x_i are in ft, and A is in in.^{2}

4. $$\text{Work} = \int_{x_i}^{x_f} F(x)dx$$

$$= \int_{10}^{10.01} 250{,}000(x - x_i)dx$$

$$= 250{,}000\left[\frac{x^2}{2} - x_i x\right]_{10}^{10.01}$$

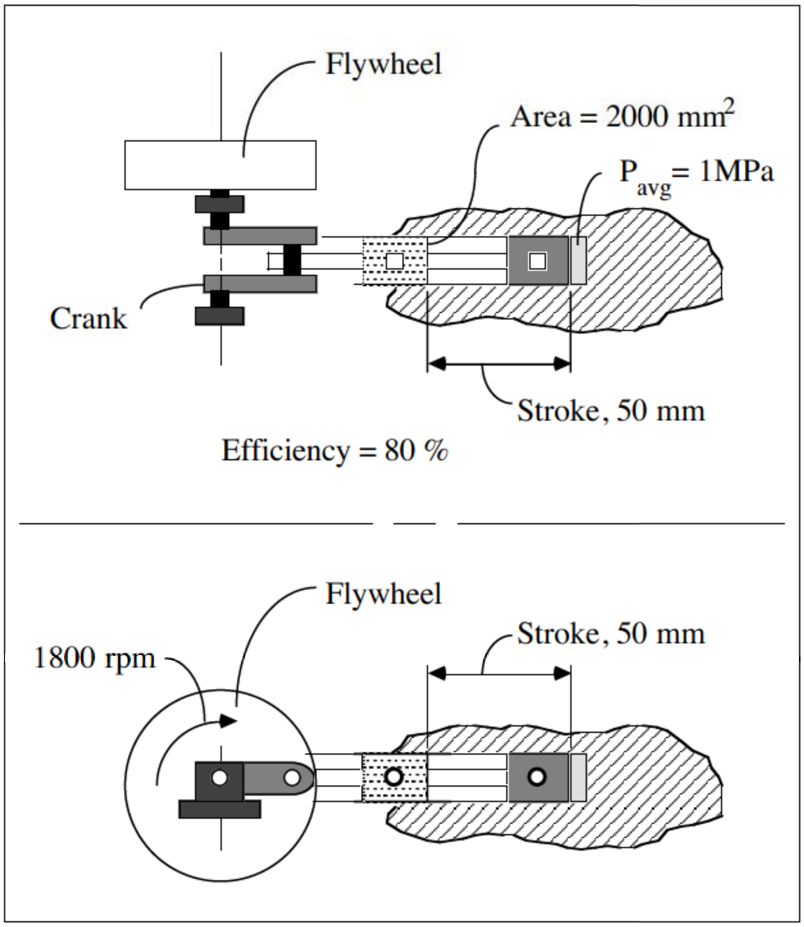
$$= 250{,}000\left\{\left[\frac{10.01^2}{2} - (10.01)(10)\right] - \left[\frac{10^2}{2} - (10)(10)\right]\right\}$$

$$= 12.5 \text{ ft}\cdot\text{lb}$$ ■

SOLUTION (1.58)
Known: A single cylinder piston of known area compresses air at an average pressure of 1 MPa through a stroke of 50 mm with overall 80% efficiency.

Find: (a) Determine the input power and (b) the input torque.

Schematic and Given Data:



Assumptions:
1. Work in = Work out + Losses
2. Losses are 20% of the work in.

Analysis:
1. The power to compress the gas and return the piston to the initial position is determined as

$$\text{Power} = \dot{W} = (1\ \text{MPa})(2000\ \text{mm}^2)(50\ \text{mm})\left(\frac{1800\ \text{rev}}{\text{min}}\ \frac{\text{min}}{60\ \text{sec}}\right) = 3\ \text{kW}$$

2. Power required = 3 kW/0.8 = 3.75 kW. ■

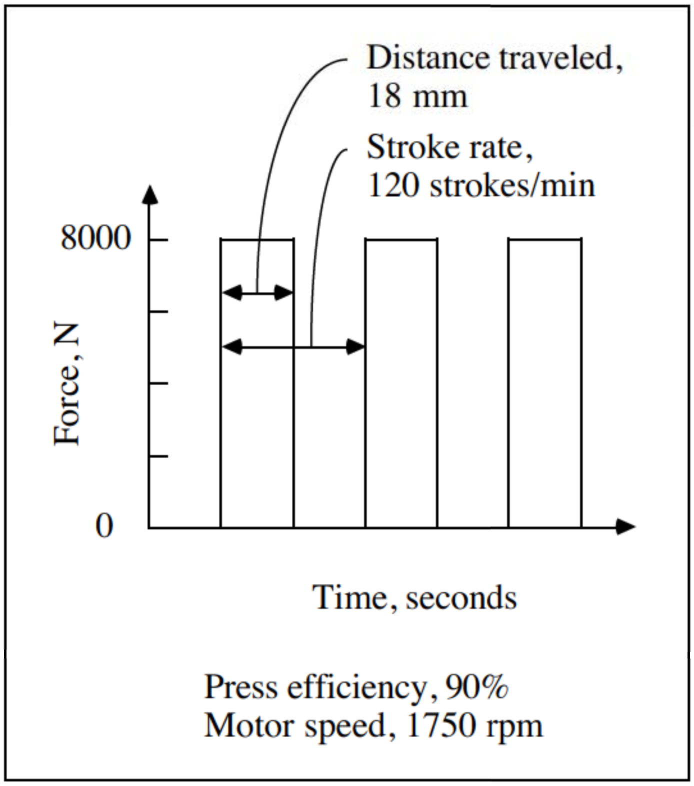
3. From Eq. (1.2), $T = \dfrac{9549(\dot{W})}{n} = \dfrac{9549(3.75)}{1800} = 19.89\ \text{N·m}$ ■

Comment: The work per stroke $W_S = pAS$, where p is the average pressure, A is the area of the piston and S equals the stroke length. The number of strokes per minute n, has the same numerical value as the rotational speed in rpm. The power, which is the time rate of doing work is thus $P = W_S \cdot n$.

SOLUTION (1.59)
Known: A press provides a force of 8000 N through a distance of 18 mm at a rate of 120 strokes per minute.

Find: Determine the rate of work output and the average motor torque.

Schematic and Given Data:



Assumptions:
1. Work in = Work out + Losses
2. Losses are 10% of the work in.

Analysis:
1. Work rate = $\dot{W}$ = (8000N)(18mm)(120 strokes/min) = 17,280 N·m/min = 288 N·m/s = 0.288 kW.

2. $$\text{Torque} = \frac{9549\,\dot{W}}{n(\text{eff})} = \frac{(9549)\,(0.288)}{(1750)\quad(0.9)} = 1.746\ \text{N·m}$$ ■

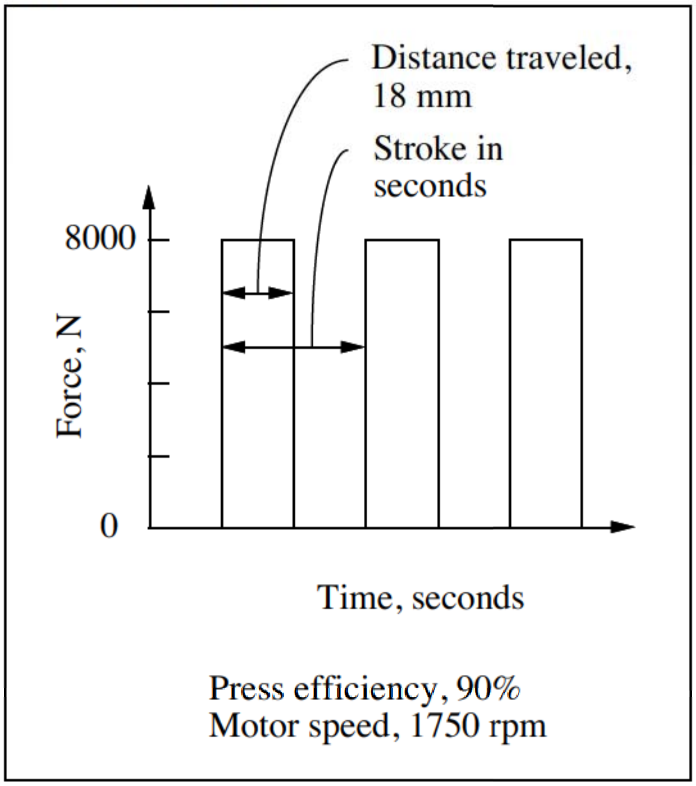
Comment: The torque can also be calculated using

$$\text{Torque} = \frac{\text{Work/min}}{2\pi n(\text{eff})} = \frac{17{,}280\ \text{N·m}}{\text{min}/2\pi(1750)\text{rev/min}(0.9)} = 1.746\ \text{N·m}$$

SOLUTION (1.60D)
Known: A press provides a force of 8000 N through a distance of 18 mm.

Find: Determine the work output per second and the average motor torque.

Schematic and Given Data:



Decision: The stroke rate is 120 strokes/min.

Assumptions:
1. Work in = Work out + Losses
2. Losses are 10% of the work in.

Analysis:
1. Work rate = $\dot{W}$ = (8000N)(18mm)(120 strokes/min) = 17,280 N·m/min = 288 N·m/s = 0.288 kW.

2. $$\text{Torque} = \frac{9549\,\dot{W}}{n(\text{eff})} = \frac{(9549)\,(0.288)}{(1750)\quad(0.9)} = 1.746\ \text{N·m}$$ ■

Comment: The torque can also be calculated using

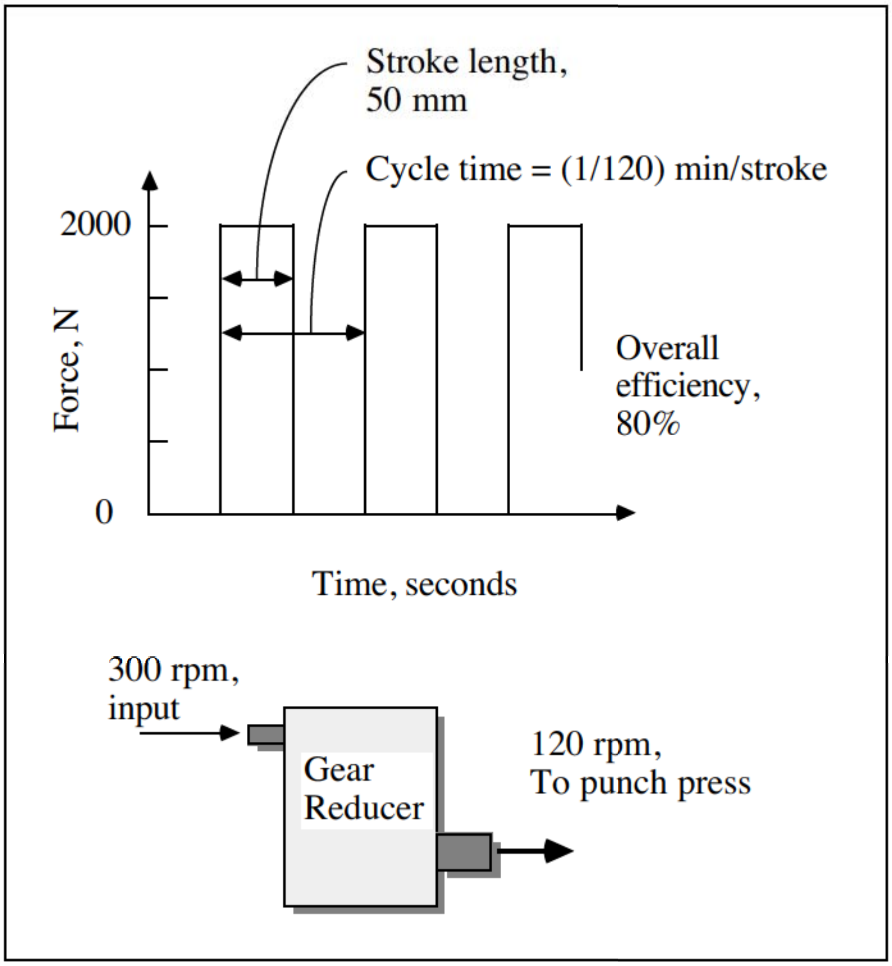
$$\text{Torque} = \frac{\text{Work/min}}{2\pi n(\text{eff})} = \frac{17{,}280\ \text{N·m}}{\text{min}/2\pi(1750)\text{rev/min}(0.9)} = 1.746\ \text{N·m}$$

SOLUTION (1.61)

Known: A punch press provides a force of 2000 N through a stroke of 50 mm at a rate of 120 strokes per minute.

Find: Determine the (a) input shaft power and (b) torque.

Schematic and Given Data:



Assumption: Power out = 0.80 (Power in)

Analysis:

1. Power in = (Power out)/(eff) = $(2000\text{ N})(0.05\text{ m/stroke})\left(\dfrac{120\text{ strokes}}{\text{min}}\ \dfrac{\text{min}}{60\text{ sec}}\right)$ $(1/0.8) = 250$ N·m/s ■

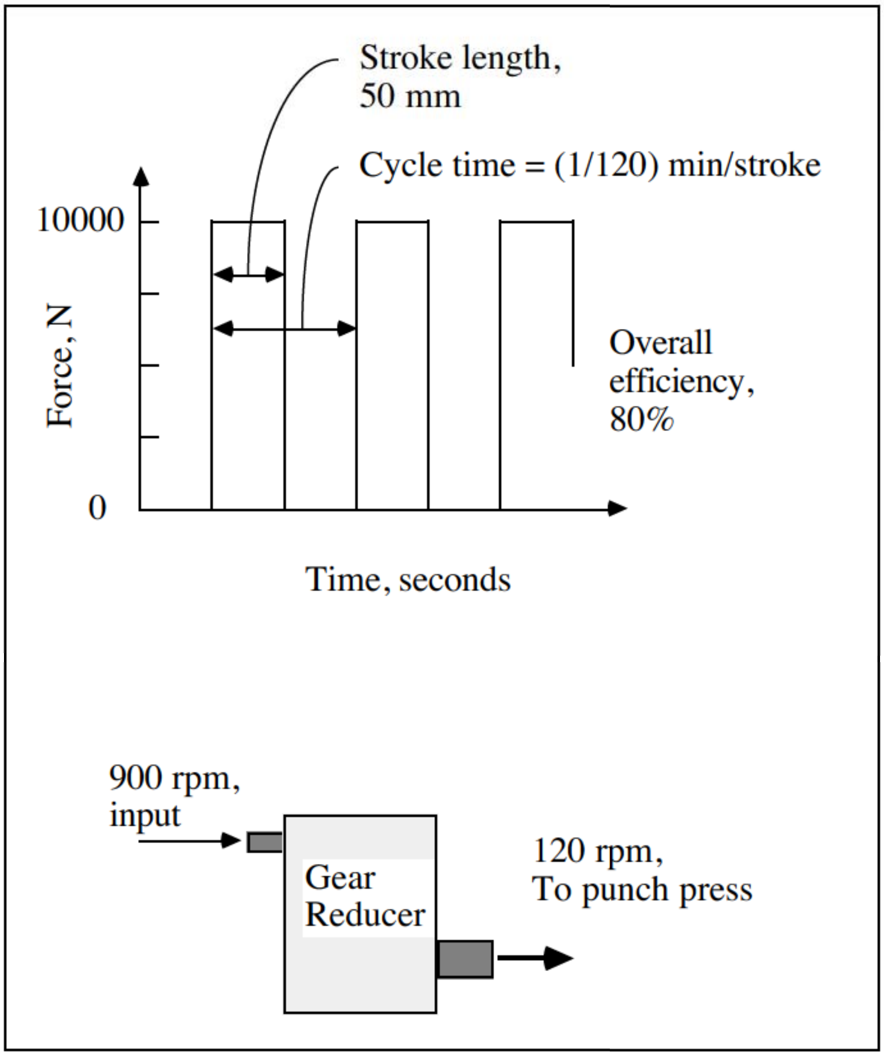
2. From Eq. (1.2), $T = \dfrac{9549\,(\dot{W})}{n} = \dfrac{9549\,(0.25)}{300} = 8.0$ N·m ■

SOLUTION (1.62)

Known: A punch press provides a force of 10,000 N through a stroke of 50 mm at a rate of 120 strokes per minute.

Find: Determine the input shaft (a) power and (b) torque.

Schematic and Given Data:



Assumption: The efficiency is 100%.

Analysis:

1. Power = $\dot{W}$ = (10,000 N)(0.05 m/stroke) $\left(\frac{120 \text{ strokes}}{\text{min}}\ \frac{\text{min}}{60 \text{ sec}}\right)$(1/.8)

   = 1250 W ■

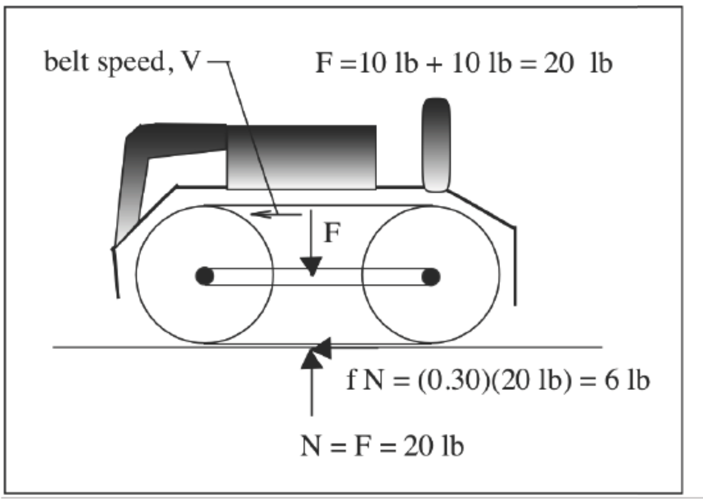
2. From Eq. (1.2), $T = \frac{9549\ (\dot{W})}{n} = \frac{9549\ (1.25)}{900} = 13.26$ N•m ■

SOLUTION (1.63)

Known: A belt sander weighs 10 lb and has a belt speed of 1000 ft/min. A downward force of 10 lb (in addition to the weight) is applied on the sander. The coefficient of friction between the belt and a flat tabletop being sanded is 0.30.

Find: Determine (a) the power transmitted by the belt in hp, and (b) the work done while sanding the tabletop for 15 minutes in ft-lb.

Schematic and Given Data:



Assumptions:

1. The work done (if any) in moving (pushing) the sander across the flat surface of the tabletop is negligible.

2. The coefficient of friction remains constant during the 15-minute period.

Analysis:

1. Power = dW/dt = F · V = (6 lb)(1000 fpm) = 6000 ft lb per minute. ■

2. Since, 1 hp = 33,000 ft·lb/min, we have dW/dt = power = 0.18 hp. ■

3. Distance, S = V · t.

3. Work = W = F · S = F · V · t = (6 lb)(1000 fpm)(15 min) = 90,000 ft-lb. ■

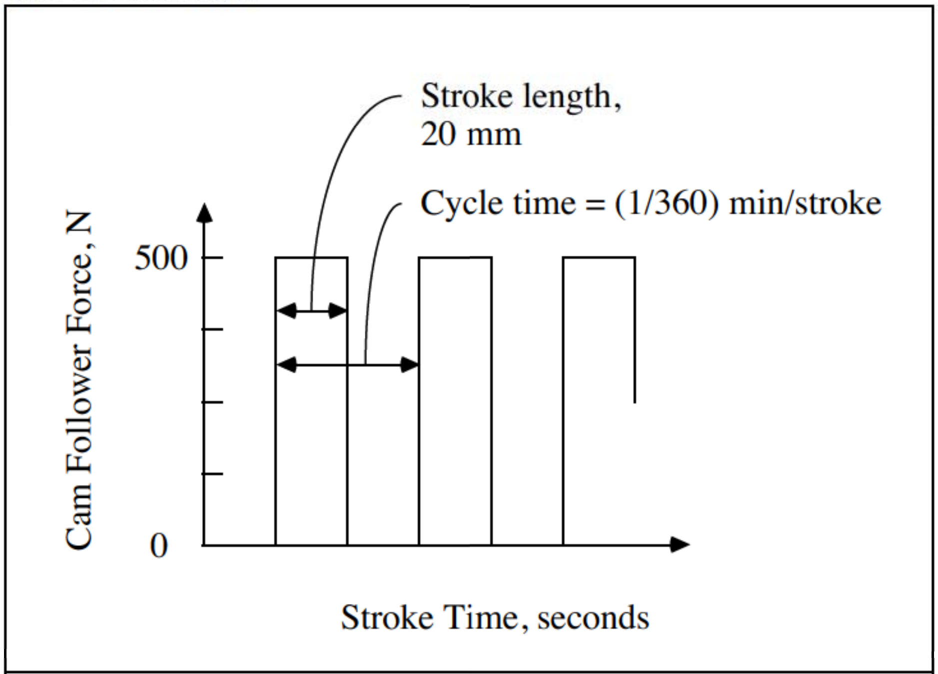
Comments: The work is done by the belt sander. The user applies a downward force but since the downward force is not applied in the direction of the force, the user does no work. The user also has to apply a 6 lb force to counteract the friction force in order to hold the sander in a stationary position.

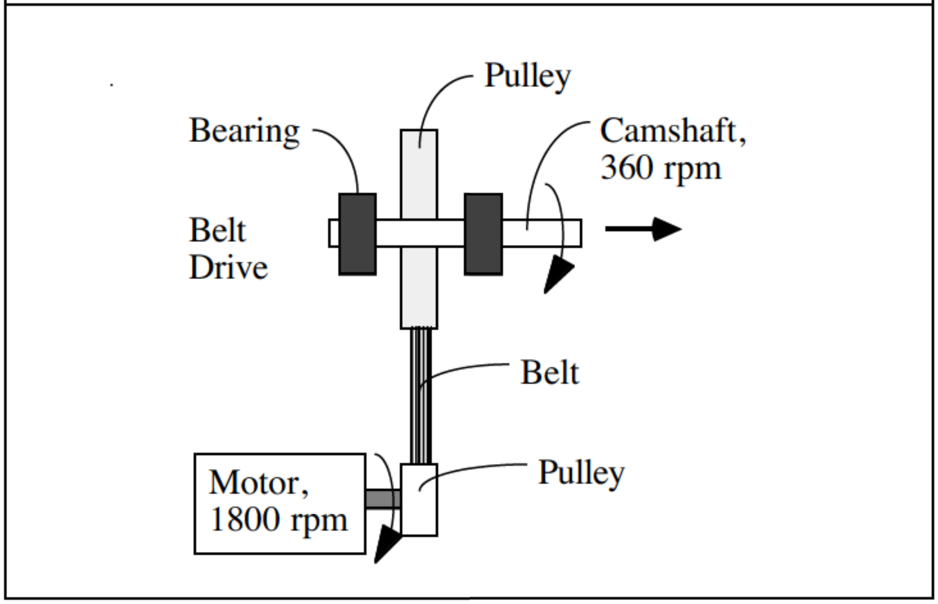
SOLUTION (1.64)

Known: A cam follower provides a force of 500 N through a distance of 20 mm at a rate of 360 strokes per minute.

Find: Estimate the power required.

Schematic and Given Data:





Assumption: The efficiency is 100%.

Analysis:

(a) The power at the follower is

$$\dot{W} = \text{power (W)} = (500\ \text{N})(0.02\ \text{m})\ \frac{360\ \text{strokes}}{\text{min}}\ \frac{\text{min}}{60\ \text{sec}} = 60\ \text{W}$$

(b) The power at the camshaft is determined by noting that the camshaft work/rev equals the pump work/stroke:

$$2\pi T = (20\ \text{mm})(500\ \text{N})\ \text{and}\ T = \frac{10}{2\pi}\ \text{N·m}$$

$$\text{From Eq. (1.2), } \dot{W} = \text{power (W)} = \frac{2\pi nT}{60} = \frac{2\pi(360)(10/2\pi)}{60} = 60\ \text{W}$$ ■

(c) The power at the motor is found by noting that the motor torque is 1/5 of the camshaft torque:

$$\text{Motor Torque} = \frac{1}{5}\ \text{Camshaft Torque} = \frac{1}{\pi}\ \text{N·m}$$

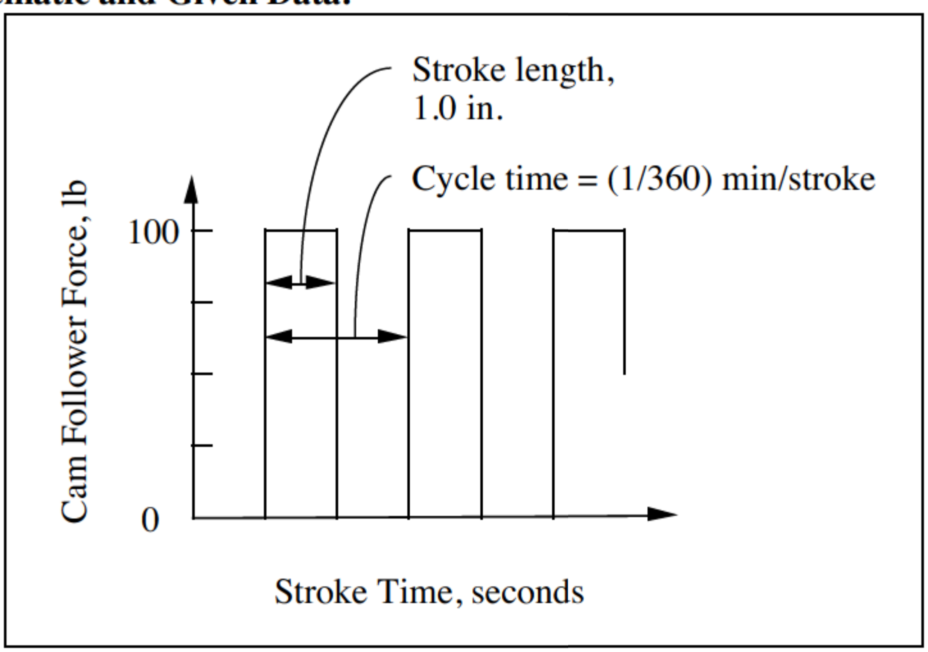
$$\text{From Eq. (1.2), } \dot{W} = \text{power (W)} = \frac{2\pi nT}{60} = \frac{2\pi(1800)(1/\pi)}{60} = 60\ \text{W}$$ ■

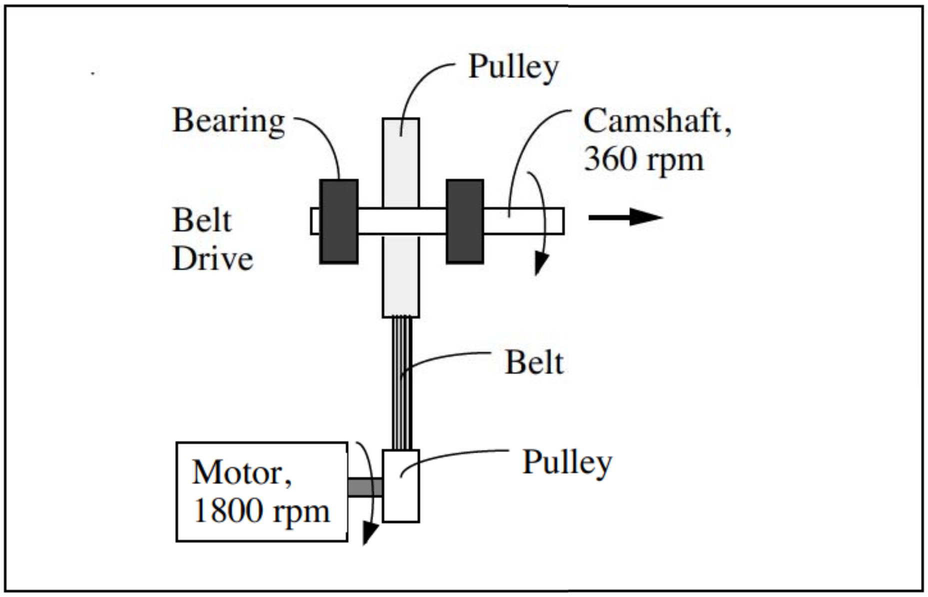
SOLUTION (1.65)

Known: A cam follower provides a force of 100 lb through a distance of 1 inch at a rate of 360 strokes per minute.

Find: Estimate the power required.

Schematic and Given Data:





Assumption: The efficiency is 100%.

Analysis:

(a) The power at the follower is

$$\text{Power} = (100\text{ lb})(1.0\text{ in.})\left(\frac{360\text{ strokes}}{\text{min}}\ \frac{\text{min}}{60\text{ sec}}\right)\left(\frac{\text{ft}}{12\text{ in.}}\ \frac{\text{sec hp}}{550\text{ ft-lb}}\right)$$

$= 0.091$ hp ■

(b) The power at the camshaft is determined by noting that the camshaft work/rev equals the pump work/stroke:
$2\pi T = (100\text{ lb})(1\text{ in.})$ and $T = 100/2\pi$ in-lb

$$\text{From Eq. (1.3), } \dot{W} = \frac{2\pi nT}{33{,}000} = \frac{2\pi(360)(100/2\pi)}{33{,}000} = 0.091\text{ hp}$$

(c) The power at the motor is found by noting that the motor torque is 1/5 of the camshaft torque:

$$\text{Motor torque} = (1/5)\text{ Cam shaft torque} = \frac{10}{\pi}\text{ in-lb} = \frac{10}{12\,\pi}\text{ ft-lb}$$

$$\text{From Eq. (1.3), } \dot{W} = \frac{2\pi nT}{33{,}000} = \frac{2\pi(1800)(10/12\pi)}{33{,}000} = 0.091\text{ hp}$$

SOLUTION (1.66D)
Known: The web sites **http://www.bodine-electric.com** and **http://www.electricmotors.machine.design.com** provide information on fractional and sub-fractional motors.

Find: Print or copy speed torque curves and list applications for electric motors.

Analysis: This exercise is left for the student.

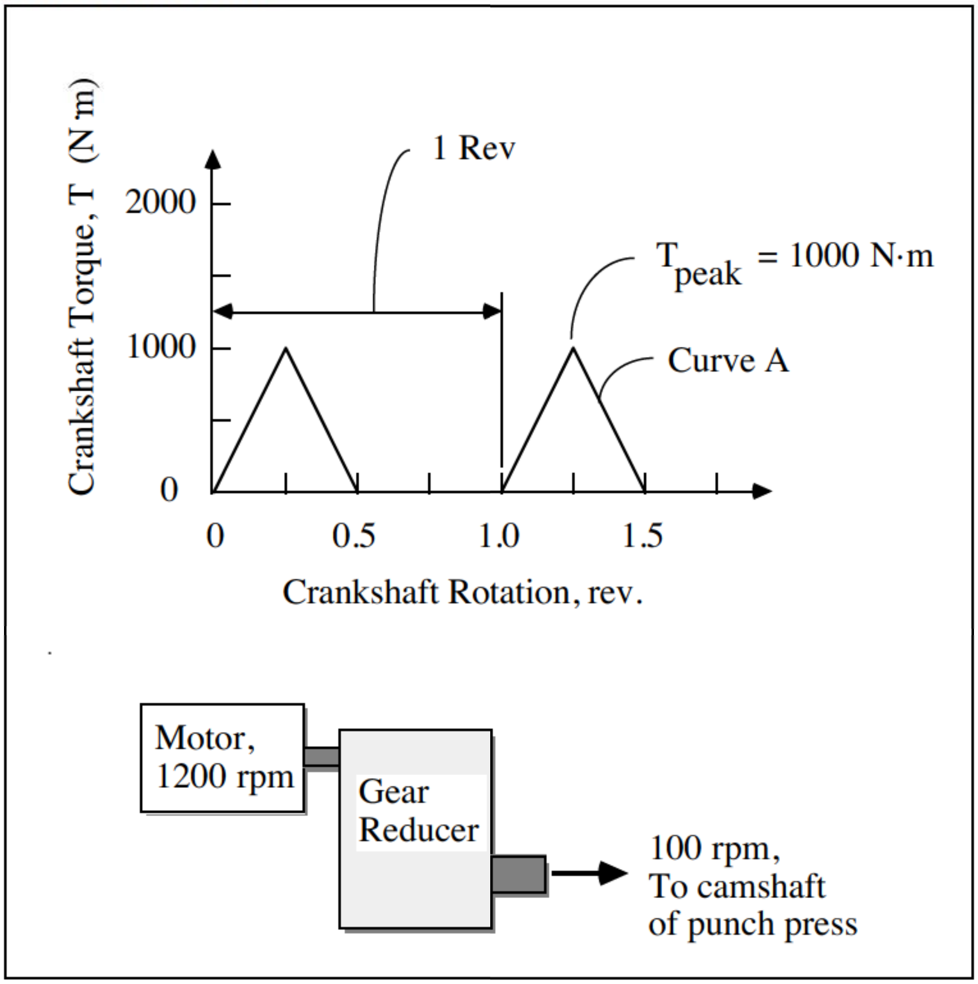
Comment: Beside the web sites listed above also see Greenwood, Product Engineering Design Manual, McGraw-Hill, p. 236-237. ■

SOLUTION (1.67)

Known: A 1200 rpm motor through a gear reducer drives a crankshaft which rotates at 100 rpm and has torque fluctuations between 0 and 1000 N·m.

Find: Determine the motor power required (a) with a flywheel, and (b) without a flywheel.

Schematic and Given Data:



Assumption: The problem states that friction losses are negligible. This means that the input power from the motor equals the output power of the punch press.

Analysis:

1. With a flywheel adequate to minimize speed fluctuations, we need only to provide sufficient power to equal that required by the crankshaft, which is proportional to the area under the crankshaft torque vs rotation curve.
2. The average torque per revolution is computed by noting that $P_{avg} = \int T d\omega$

   or (1 rev) $T_{avg} = \frac{1}{2}(\frac{1}{2}$ rev)(1000 N·m) and T_{avg} = 250 N.m.

3. The power is then calculated as

$$\text{Power} = 2\pi T_{avg} n = 2\pi(250 \text{ N·m})\left(\frac{100 \text{ rev}}{\text{min}} \frac{\text{min}}{60 \text{ sec}}\right)$$

$= 2618$ N·m/s $= 2618$ W ■

4. Without the flywheel the motor must be capable of supplying the peak torque continuously at any point in the cycle. Therefore the power is

$$\text{Power} = 2\pi T_{peak} n = 2\pi(1000 \text{ N·m})\left(\frac{100 \text{ rev}}{\text{min}} \frac{\text{min}}{60 \text{ sec}}\right) = 10{,}472 \text{ W}$$ ■

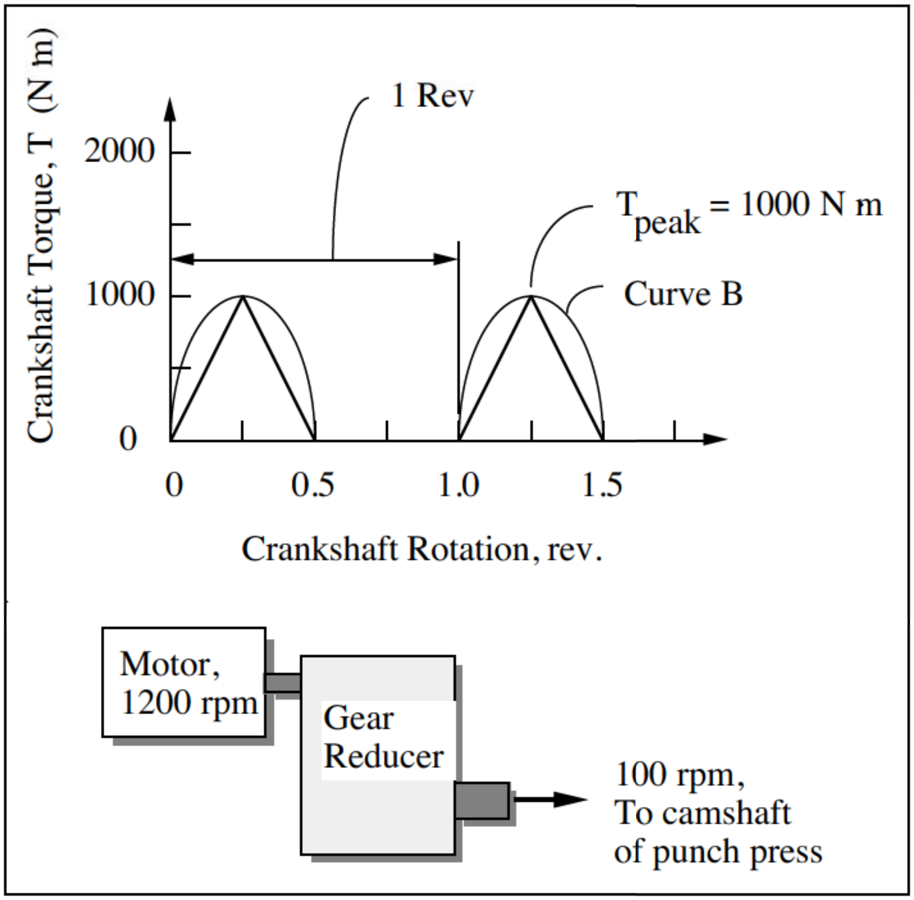
Comment: By using a flywheel which minimizes speed fluctuation, the punch press requires a motor of only 1/4 the size of that of a punch press without a flywheel.

SOLUTION (1.68)

Known: A 1200 rpm motor through a gear reducer drives a crankshaft which rotates at 100 rpm and has torque fluctuations between 0 and 1000 N•m.

Find: Determine the motor power required (a) with a flywheel, and (b) without a flywheel.

Schematic and Given Data:



Assumptions:
1. The input power from the motor equals the output power of the punch press.
2. The crankshaft torque versus angle curve is approximately sinusoidal in form.

Analysis:
1. The average torque per revolution is computed by noting that $P_{avg} = \int T d\omega$ or that

$$\left(\frac{2\pi rad}{rev}\right)(1\ rev)(T_{avg}) = \int_0^{\pi} 1000 \sin\theta d\theta = 2000\ N{\cdot}m$$

or

$$T_{avg} = \frac{2000}{2\pi} = 318.3\ N{\cdot}m$$

2. The power is then calculated as

$$Power = 2\pi T_{avg} n = 2\pi(318.3)\left(\frac{100\ rev}{min}\ \frac{min}{60\ sec}\right) = 3333W$$ ■

3. Without the flywheel the motor must supply the peak torque continuously. Therefore the power is

$$\text{Power} = 2\pi T_{peak} n = 2\pi(1000\ \text{N·m})\left(\frac{100\ \text{rev}}{\text{min}}\ \frac{\text{min}}{60\ \text{sec}}\right) = 10{,}472\ \text{W} \qquad \blacksquare$$

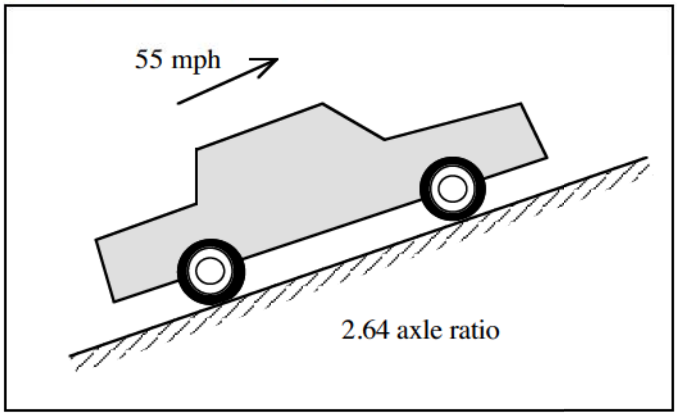
Comment: By using a flywheel the punch press requires a motor size 31.8% of that for a press without a flywheel.

SOLUTION (1.69)

Known: The automobile in Sample Problem 1.6 (with a 2.64 axle ratio) climbs a grade while maintaining a constant 55 mph.

Find: Determine the steepest grade that the automobile can climb:
(a) with the transmission in direct drive.
(b) with the transmission reduction ratio of 1.6.

Schematic and Given Data:



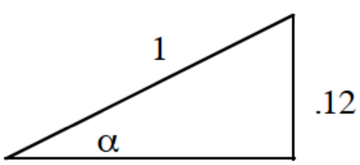
Assumption: Friction losses are negligible.

Analysis:
(a) From Sample Problem 1.6, the engine rpm = 1880.

At 55 mph, the power required = 23 hp: available = 93 hp: difference = 70 hp

$$\left(\frac{33{,}000 \text{ ft·lb/min}}{\text{hp}}\right)(70 \text{ hp})\left(\frac{1}{4000 \text{ lb}}\right) = 577.5 \text{ ft/min}$$

$$55 \text{ mph} = \frac{\left(55 \frac{\text{mi}}{\text{hr}}\right)\left(5280 \frac{\text{ft}}{\text{mi}}\right)}{\left(60 \frac{\text{min}}{\text{hr}}\right)} = 4840 \text{ ft/min}$$



$$\frac{577.5 \text{ ft/min}}{4840 \text{ ft/min}} = .12 \text{ and } \sin\alpha = .12$$

$$\tan\alpha = \tan(\sin^{-1}.12) = .12$$

Thus, a 12% grade is the steepest grade the automobile can climb with the transmission in direct drive. ■

(b) Engine speed = (1.6)(1880) = 3008 rpm

The power required = .23 hp: available = 140 hp: difference = 117 hp

$$\left(\frac{33{,}000 \text{ ft lb}}{\text{min}\cdot\text{hp}}\right)(117 \text{ hp})\left(\frac{1}{4000 \text{ lb}}\right) = 965.25 \text{ ft/min}$$

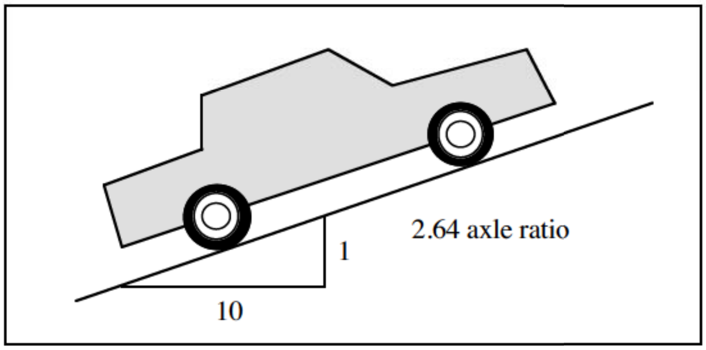
$$\left(\frac{965.25}{4840}\right) = .20$$

Thus, a 20% grade is the steepest grade the automobile can climb with the transmission reduction ratio of 1.6. ■

SOLUTION (1.70)
Known: The car in Sample Problem 1.6 (with 2.64 axle ratio) climbs a continuous 10% grade.

Find: Determine the maximum speed that the car can maintain.

Schematic and Given Data:



Assumption: Friction losses are negligible.

Analysis:

1. The car in Sample Problem 1.6 has a 2.64 axle ratio and direct drive.

2. By trial and error, for 65 mph and rpm = 2222, 110 hp available: 33 hp required: difference = Δ = 77 hp

$$\frac{33{,}000\ \frac{\text{ft}\cdot\text{lb}}{\text{min hp}} \cdot 77\ \text{hp}}{4000\ \text{lb}} = 635.25\ \text{ft/min}$$

65 mph = 5720 fpm

$$\text{Grade} \cong \frac{635.25}{5720} = 11.1\%$$

For 70 mph and rpm = 2393, 118 hp available: 40 hp required: Δ = 78 hp

$$\frac{(33{,}000)(78)}{4000} = 643.5\ \text{ft/min}$$

70 mph = 6160 fpm

$$\text{Grade} \cong \frac{643.55}{6160} = 10.4\%$$

For 73 mph and rpm = 2496, 123 hp available: 45 hp required: Δ = 78 hp

$$\frac{(33{,}000)(78)}{4000} = 643.5\ \text{ft/min}$$

73 mph = 6424 ft/min

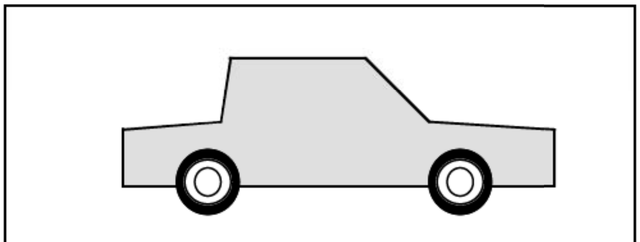
$$\frac{643.5}{6424} = 10\% \text{ grade}$$

Therefore, the car could maintain a maximum speed of 73 mph. ■

SOLUTION (1.71)
Known: A car with an "ideal" transmission gets 30 miles per gallon at 70 mph.

Find: Determine the necessary reduction in the Fig. 1.10 "road-load" horsepower requirement.

Schematic and Given Data:



Assumption: The engine would have a minimum brake specific fuel consumption of 0.45 lb/hp-hr, as shown in Fig. 1.12.

Analysis:
For 30 mpg at 70 mph the fuel consumption rate is

$$\left(70\ \frac{\text{miles}}{\text{hr}}\right)\left(5.8\ \frac{\text{lb}}{\text{gal}}\right)\left(\frac{\text{gal}}{30\ \text{miles}}\right) = 13.53\ \text{lb/hr}$$

For BSFC = .45 lb/bhp•hr, the horsepower output is:

$$\left(13.53\ \frac{\text{lb}}{\text{hr}}\right)\left(\frac{\text{bhp}\cdot\text{hr}}{.45\ \text{lb}}\right) = 30.07\ \text{bhp}$$

Fig. 1.10 shows about 40 hp needed with the "standard" car; hence, a 25% reduction is required to reduce to 30 bhp. ■