THOMAS MACLAREN SCHOOL

PROJECT WEEK

Dear ___________________ & ____________________ ,

Your Project topic this year is Bridge Construction.

Your Project advisor is ☐ Dr. Holiday ☐ Mr. Mazzoni

Attached is all the information you need to have a successful Project Week.

1. Specific guidelines for your Project (concept guidelines, construction specifications and paper guidelines)
2. Book excerpt (example problems and math problem 55)
3. Recommendations for time management (all students must show they have worked at least 30 hours on their Project)
4. Guidelines about proper citations
5. Your timesheet that you must fill out each day and return with your project
6. Bridge building resource booklet
7. Large sheet of drafting graph paper

In addition to this packet, you will need your Physics book. You will be given all of the supplies required to complete this project. You may not buy additional supplies (except for blades or scissors and rulers) and you are responsible for storing/keeping your supplies.

You must come to school on ________________ from _________________________, in uniform, to test your first bridge construction. You must also come to school on_______________________________ from ______________________, in uniform, to break your second bridge and to submit your paper, problem, and other documentation. This is a mandatory requirement for this project. Your Project advisor will give you further direction about the second date.

Please remember that you must work at least 30 hours on the Project.
We hope you learn a great deal and enjoy yourself, too!

Senior Science Project

Your project focuses on bridges. It includes researching bridge design, construction two bridges made of balsa wood, solving a mathematical problem of a particular design, and writing a paper (three or more pages including diagrams) describing the physics of your design.

Each team will receive 30 pieces of balsa wood and one bottle of glue to build **two bridges**. These will be distributed before the end of the semester. Each team will have Monday, Tuesday and Wednesday morning of Project Week to research, plan and build your first bridge. Wednesday afternoon and evening, your first bridge will be tested for maximum load capacity and efficiency (the ratio of maximum load divided by the mass of the bridge).

To start the project, you should research several bridge structures online and/or in books. The chapter on static equilibrium in your physics book may be a good place to start. Additionally, another good place to look is the West Point Bridge software. It can be downloaded. Use it as a learning tool for modeling your bridge design. Note that the extensions and compressions indicated by the software may be somewhat different than those for your bridge as their calculations are based on building with steel and connecting with welds whereas you will be using balsa wood and glue. Nevertheless, many students in the past have found this software very helpful. Understanding the force principles of various bridge designs will aid you in constructing a strong bridge. Once you have the needed structural information and you have decided on a design, build the bridge according to the specifications below.

Once the first bridge has been tested, you will have Thursday, Friday and Saturday of Project Week to build your second bridge, to write your report and to solve the mathematical problem. Note that testing the bridge entails breaking it.

Bridge Construction Specifications

1. The two bridges must be constructed **ONLY** from the materials supplied by the instructor (balsa wood and glue).

2. The bridge must span a 30-cm gap.

3. The bridge must have a “roadbed”. This consists of two pieces of wood which run the length of the bridge. The centers of these pieces of wood should be 2.5 cm apart. The total roadbed must have a minimum width of 5.5 cm. There also should be a 5-cm “clearance” above the roadbed.

4. The wood cannot be treated in any way to change its strength or appearance. Only water/steam will be allowed in order to facilitate bending of the wood. Wood pieces may be bonded together with glue **ONLY** at joints and **may not be laminated** together in a parallel fashion. If two or more strips of wood are placed parallel to each other, they must be at least the thickness of this page apart from each other.

Written Report

1. The report must be more than three pages in length. Find a clear format for documenting your research, bridge design, building techniques and analysis.

2. One report should be submitted by each team. It should include:
   a. A description of the design.
   b. A force analysis of the structural members of the bridge and/or a theory of how the bridge supports the load. Include the appropriate language here – tension, compression, etc.
   c. Any predictions in regard to how the bridge will behave as it reaches maximum load.

3. An analysis of the first bridge's testing and a description of the types of improvements that were made in the second bridge.

4. Citation of all references.

Mathematical Problem

In addition to the construction of two bridges and writing the research paper, your team will be responsible for completing the assigned problem from the Physics textbook. **This is required for all groups.** Details of the problem will be discussed in your Physics class before Project week begins.

EXAMPLE 12–6 **Ladder.** A 5.0-m-long ladder leans against a smooth wall at a point 4.0 m above a cement floor as shown in Fig. 12–10. The ladder is uniform and has mass $m = 12.0\,\text{kg}$. Assuming the wall is frictionless (but the floor is not), determine the forces exerted on the ladder by the floor and by the wall.

APPROACH Figure 12–10 is the free-body diagram for the ladder, showing all the forces acting on the ladder. The wall, since it is frictionless, can exert a force only perpendicular to the wall, and we label that force $\vec{\mathbf{F}}_W$. The cement floor exerts a force $\vec{\mathbf{F}}_C$ which has both horizontal and vertical force components: F_{Cx} is frictional and F_{Cy} is the normal force. Finally, gravity exerts a force $mg = (12.0\,\text{kg})(9.80\,\text{m/s}^2) = 118\,\text{N}$ on the ladder at its midpoint, since the ladder is uniform.

SOLUTION Again we use the equilibrium conditions, $\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma\tau = 0$. We will need all three since there are three unknowns: F_W, F_{Cx}, and F_{Cy}. The y component of the force equation is

$$\Sigma F_y = F_{Cy} - mg = 0,$$

so immediately we have

$$F_{Cy} = mg = 118\,\text{N}.$$

The x component of the force equation is

$$\Sigma F_x = F_{Cx} - F_W = 0.$$

To determine both F_{Cx} and F_W, we need a torque equation. If we choose to calculate torques about an axis through the point where the ladder touches the cement floor, then $\vec{\mathbf{F}}_C$, which acts at this point, will have a lever arm of zero and so won't enter the equation. The ladder touches the floor a distance $x_0 = \sqrt{(5.0\,\text{m})^2 - (4.0\,\text{m})^2} = 3.0\,\text{m}$ from the wall (right triangle, $c^2 = a^2 + b^2$). The lever arm for mg is half this, or 1.5 m, and the lever arm for F_W is 4.0 m, Fig. 12–10. We get

$$\Sigma\tau = (4.0\,\text{m})F_W - (1.5\,\text{m})mg = 0.$$

Thus

$$F_W = \frac{(1.5\,\text{m})(12.0\,\text{kg})(9.8\,\text{m/s}^2)}{4.0\,\text{m}} = 44\,\text{N}.$$

Then, from the x component of the force equation,

$$F_{Cx} = F_W = 44\,\text{N}.$$

Since the components of $\vec{\mathbf{F}}_C$ are $F_{Cx} = 44\,\text{N}$ and $F_{Cy} = 118\,\text{N}$, then

$$F_C = \sqrt{(44\,\text{N})^2 + (118\,\text{N})^2} = 126\,\text{N} \approx 130\,\text{N}$$

(rounded off to two significant figures), and it acts at an angle to the floor of

$$\theta = \tan^{-1}(118\,\text{N}/44\,\text{N}) = 70°.$$

NOTE The force $\vec{\mathbf{F}}_C$ does *not* have to act along the ladder's direction because the ladder is rigid and not flexible like a cord or cable.

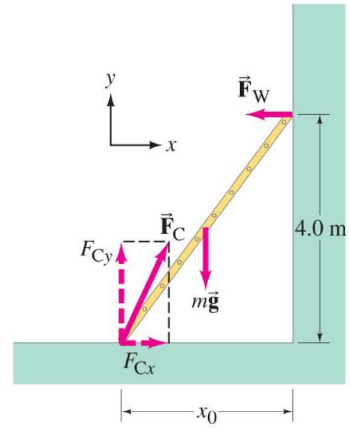


FIGURE 12–10 A ladder leaning against a wall. Example 12–6.

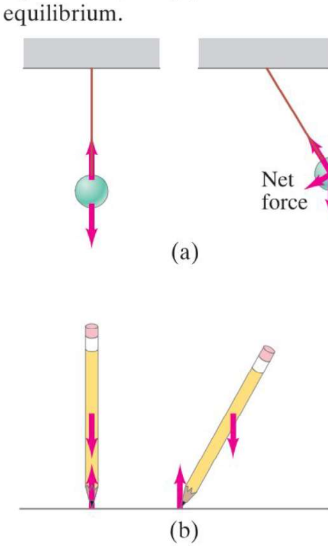
EXERCISE F Why is it reasonable to ignore friction along the wall, but not reasonable to ignore it along the floor?

12–3 Stability and Balance

An object in static equilibrium, if left undisturbed, will undergo no translational or rotational acceleration since the sum of all the forces and the sum of all the torques acting on it are zero. However, if the object is displaced slightly, three outcomes are possible: (1) the object returns to its original position, in which case it is said to be in **stable equilibrium**; (2) the object moves even farther from its original position, and it is said to be in **unstable equilibrium**; or (3) the object remains in its new position, and it is said to be in **neutral equilibrium**.

Consider the following examples. A ball suspended freely from a string is in stable equilibrium, for if it is displaced to one side, it will return to its original position (Fig. 12–11a) due to the net force and torque exerted on it. On the other hand, a pencil standing on its point is in unstable equilibrium. If its center of gravity is directly over its tip (Fig. 12–11b), the net force and net torque on it will be zero. But if it is displaced ever so slightly as shown—say, by a slight vibration or tiny air current—there will be a torque on it, and this torque acts to make the pencil continue to fall in the direction of the original displacement. Finally, an example of an object in neutral equilibrium is a sphere resting on a horizontal tabletop. If it is placed slightly to one side, it will remain in its new position—no net torque acts on it.

FIGURE 12–11 (a) Stable equilibrium, and (b) unstable equilibrium.



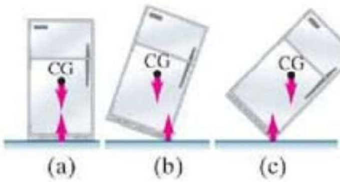
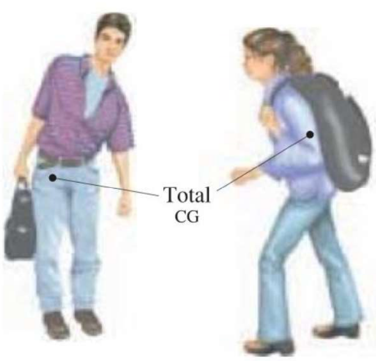


FIGURE 12–12 Equilibrium of a refrigerator resting on a flat floor.

In most situations, such as in the design of structures and in working with the human body, we are interested in maintaining stable equilibrium, or *balance*, as we sometimes say. In general, an object whose center of gravity (CG) is below its point of support, such as a ball on a string, will be in stable equilibrium. If the CG is above the base of support, we have a more complicated situation. Consider a standing refrigerator (Fig. 12–12a). If it is tipped slightly, it will return to its original position due to the torque on it as shown in Fig. 12–12b. But if it is tipped too far, Fig. 12–12c, it will fall over. The critical point is reached when the CG shifts from one side of the pivot point to the other. When the CG is on one side, the torque pulls the object back onto its original base of support, Fig. 12–12b. If the object is tipped further, the CG goes past the pivot point and the torque causes the object to topple, Fig. 12–12c. In general, *an object whose center of gravity is above its base of support will be stable if a vertical line projected downward from the CG falls within the base of support*. This is because the normal force upward on the object (which balances out gravity) can be exerted only within the area of contact, so if the force of gravity acts beyond this area, a net torque will act to topple the object.

FIGURE 12–13 Humans adjust their posture to achieve stability when carrying loads.



Stability, then, can be relative. A brick lying on its widest face is more stable than a brick standing on its end, for it will take more of an effort to tip it over. In the extreme case of the pencil in Fig. 12–11b, the base is practically a point and the slightest disturbance will topple it. In general, the larger the base and the lower the CG, the more stable the object.

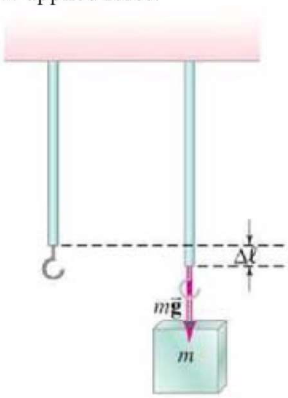
In this sense, humans are less stable than four-legged mammals, which have a larger base of support because of their four legs, and most also have a lower center of gravity. When walking and performing other kinds of movement, a person continually shifts the body so that its CG is over the feet, although in the normal adult this requires no conscious thought. Even as simple a movement as bending over requires moving the hips backward so that the CG remains over the feet, and you do this repositioning without thinking about it. To see this, position yourself with your heels and back to a wall and try to touch your toes. You won't be able to do it without falling. People carrying heavy loads automatically adjust their posture so that the CG of the total mass is over their feet, Fig. 12–13.

12–4 Elasticity; Stress and Strain

In the first part of this Chapter we studied how to calculate the forces on objects in equilibrium. In this Section we study the effects of these forces: any object changes shape under the action of applied forces. If the forces are great enough, the object will break, or *fracture*, as we will discuss in Section 12–5.

Elasticity and Hooke's Law

FIGURE 12–14 Hooke's law: $\Delta\ell \propto$ applied force.



If a force is exerted on an object, such as the vertically suspended metal rod shown in Fig. 12–14, the length of the object changes. If the amount of elongation, $\Delta\ell$, is small compared to the length of the object, experiment shows that $\Delta\ell$ is proportional to the force exerted on the object. This proportionality, as we saw in Section 7–3, can be written as an equation:

$$F = k\,\Delta\ell. \tag{12–3}$$

Here F represents the force pulling on the object, $\Delta\ell$ is the change in length, and k is a proportionality constant. Equation 12–3, which is sometimes called **Hooke's law**[†] after Robert Hooke (1635–1703), who first noted it, is found to be valid for almost any solid material from iron to bone—but it is valid only up to a point. For if the force is too great, the object stretches excessively and eventually breaks.

Figure 12–15 shows a typical graph of applied force versus elongation. Up to a point called the **proportional limit**, Eq. 12–3 is a good approximation for many

[†]The term "law" applied to this relation is not really appropriate, since first of all, it is only an approximation, and second, it refers only to a limited set of phenomena. Most physicists prefer to reserve the word "law" for those relations that are deeper and more encompassing and precise, such as Newton's laws of motion or the law of conservation of energy.

common materials, and the curve is a straight line. Beyond this point, the graph deviates from a straight line, and no simple relationship exists between F and $\Delta \ell$. Nonetheless, up to a point farther along the curve called the **elastic limit**, the object will return to its original length if the applied force is removed. The region from the origin to the elastic limit is called the *elastic region*. If the object is stretched beyond the elastic limit, it enters the *plastic region*: it does not return to the original length upon removal of the external force, but remains permanently deformed (such as a bent paper clip). The maximum elongation is reached at the *breaking point*. The maximum force that can be applied without breaking is called the **ultimate strength** of the material (actually, force per unit area, as we discuss in Section 12–5).

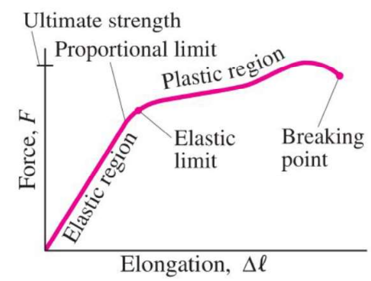


FIGURE 12–15 Applied force vs. elongation for a typical metal under tension.

Young's Modulus

The amount of elongation of an object, such as the rod shown in Fig. 12–14, depends not only on the force applied to it, but also on the material of which it is made and on its dimensions. That is, the constant k in Eq. 12–3 can be written in terms of these factors.

If we compare rods made of the same material but of different lengths and cross-sectional areas, it is found that for the same applied force, the amount of stretch (again assumed small compared to the total length) is proportional to the original length and inversely proportional to the cross-sectional area. That is, the longer the object, the more it elongates for a given force; and the thicker it is, the less it elongates. These findings can be combined with Eq. 12–3 to yield

$$\Delta \ell = \frac{1}{E}\frac{F}{A}\ell_0, \quad \textbf{(12–4)}$$

where ℓ_0 is the original length of the object, A is the cross-sectional area, and $\Delta \ell$ is the change in length due to the applied force F. E is a constant of proportionality[†] known as the **elastic modulus**, or **Young's modulus**; its value depends only on the material. The value of Young's modulus for various materials is given in Table 12–1 (the shear modulus and bulk modulus in this Table are discussed later in this Section). Because E is a property only of the material and is independent of the object's size or shape, Eq. 12–4 is far more useful for practical calculation than Eq. 12–3.

[†]The fact that E is in the denominator, so $1/E$ is the actual proportionality constant, is merely a convention. When we rewrite Eq. 12–4 to get Eq. 12–5, E is found in the numerator.

TABLE 12–1 Elastic Moduli

Material	Young's Modulus, E (N/m²)	Shear Modulus, G (N/m²)	Bulk Modulus, B (N/m²)
Solids			
Iron, cast	100×10^9	40×10^9	90×10^9
Steel	200×10^9	80×10^9	140×10^9
Brass	100×10^9	35×10^9	80×10^9
Aluminum	70×10^9	25×10^9	70×10^9
Concrete	20×10^9		
Brick	14×10^9		
Marble	50×10^9		70×10^9
Granite	45×10^9		45×10^9
Wood (pine) (parallel to grain)	10×10^9		
(perpendicular to grain)	1×10^9		
Nylon	5×10^9		
Bone (limb)	15×10^9	80×10^9	
Liquids			
Water			2.0×10^9
Alcohol (ethyl)			1.0×10^9
Mercury			2.5×10^9
Gases[†]			
Air, H_2, He, CO_2			1.01×10^5

[†]At normal atmospheric pressure; no variation in temperature during process.

EXAMPLE 12–7 **Tension in piano wire.** A 1.60-m-long steel piano wire has a diameter of 0.20 cm. How great is the tension in the wire if it stretches 0.25 cm when tightened?

APPROACH We assume Hooke's law holds, and use it in the form of Eq. 12–4, finding E for steel in Table 12–1.

SOLUTION We solve for F in Eq. 12–4 and note that the area of the wire is $A = \pi r^2 = (3.14)(0.0010\,\mathrm{m})^2 = 3.14 \times 10^{-6}\,\mathrm{m}^2$. Then

$$F = E\frac{\Delta \ell}{\ell_0}A = \left(2.0 \times 10^{11}\,\mathrm{N/m^2}\right)\left(\frac{0.0025\,\mathrm{m}}{1.60\,\mathrm{m}}\right)\left(3.14 \times 10^{-6}\,\mathrm{m}^2\right) = 980\,\mathrm{N}.$$

NOTE The large tension in all the wires in a piano must be supported by a strong frame.

EXERCISE G Two steel wires have the same length and are under the same tension. But wire A has twice the diameter of wire B. Which of the following is true? (*a*) Wire B stretches twice as much as wire A. (*b*) Wire B stretches four times as much as wire A. (*c*) Wire A stretches twice as much as wire B. (*d*) Wire A stretches four times as much as wire B. (*e*) Both wires stretch the same amount.

Stress and Strain

From Eq. 12–4, we see that the change in length of an object is directly proportional to the product of the object's length ℓ_0 and the force per unit area F/A applied to it. It is general practice to define the force per unit area as the **stress**:

$$\text{stress} = \frac{\text{force}}{\text{area}} = \frac{F}{A},$$

which has SI units of $\mathrm{N/m^2}$. Also, the **strain** is defined to be the ratio of the change in length to the original length:

$$\text{strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta \ell}{\ell_0},$$

and is dimensionless (no units). Strain is thus the fractional change in length of the object, and is a measure of how much the rod has been deformed. Stress is applied to the material by external agents, whereas strain is the material's response to the stress. Equation 12–4 can be rewritten as

$$\frac{F}{A} = E\frac{\Delta \ell}{\ell_0} \qquad \textbf{(12–5)}$$

or

$$E = \frac{F/A}{\Delta \ell/\ell_0} = \frac{\text{stress}}{\text{strain}}.$$

Thus we see that the strain is directly proportional to the stress, in the linear (elastic) region of Fig. 12–15.

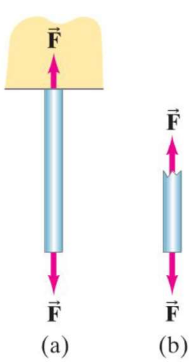


FIGURE 12–16 Stress exists *within* the material.

Tension, Compression, and Shear Stress

The rod shown in Fig. 12–16a is said to be under *tension* or **tensile stress**. Not only is there a force pulling down on the rod at its lower end, but since the rod is in equilibrium, we know that the support at the top is exerting an equal† upward force on the rod at its upper end, Fig. 12–16a. In fact, this tensile stress exists throughout the material. Consider, for example, the lower half of a suspended rod as shown in Fig. 12–16b. This lower half is in equilibrium, so there must be an upward force on it to balance the downward force at its lower end. What exerts this upward force? It must be the upper part of the rod. Thus we see that external forces applied to an object give rise to internal forces, or stress, within the material itself.

†Or a greater force if the weight of the rod cannot be ignored compared to F.

Strain or deformation due to tensile stress is but one type of stress to which materials can be subjected. There are two other common types of stress: compressive and shear. **Compressive stress** is the exact opposite of tensile stress. Instead of being stretched, the material is compressed: the forces act inwardly on the object. Columns that support a weight, such as the columns of a Greek temple (Fig. 12–17), are subjected to compressive stress. Equations 12–4 and 12–5 apply equally well to compression and tension, and the values for the modulus E are usually the same.

FIGURE 12–17 This Greek temple, in Agrigento, Sicily, built 2500 years ago, shows the post-and-beam construction. The columns are under compression.

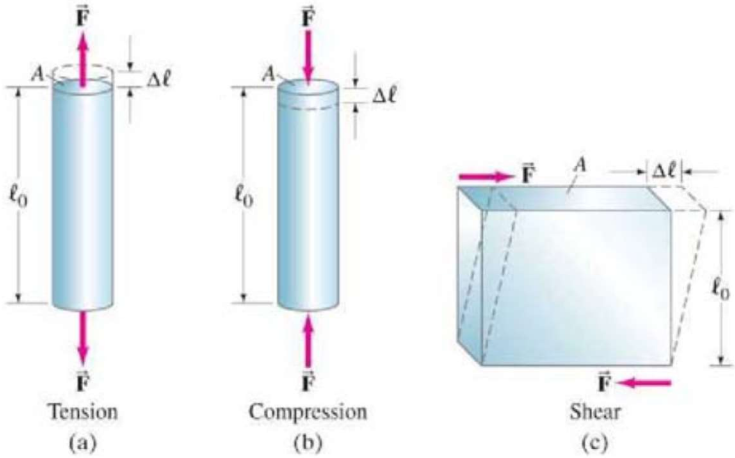


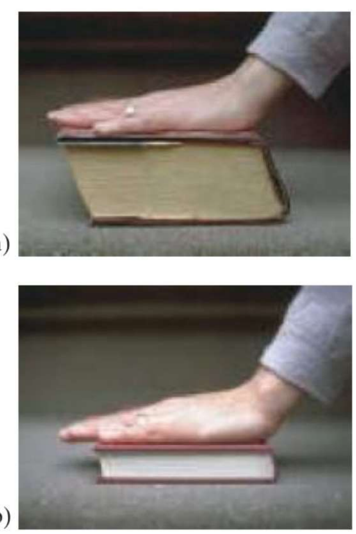
FIGURE 12–18 The three types of stress for rigid objects.

Figure 12–18 compares tensile and compressive stresses as well as the third type, shear stress. An object under **shear stress** has equal and opposite forces applied *across* its opposite faces. A simple example is a book or brick firmly attached to a tabletop, on which a force is exerted parallel to the top surface. The table exerts an equal and opposite force along the bottom surface. Although the dimensions of the object do not change significantly, the shape of the object does change, Fig. 12–18c. An equation similar to Eq. 12–4 can be applied to calculate shear strain:

$$\Delta \ell = \frac{1}{G}\frac{F}{A}\ell_0, \tag{12–6}$$

but $\Delta\ell$, ℓ_0, and A must be reinterpreted as indicated in Fig. 12–18c. Note that A is the area of the surface *parallel* to the applied force (and not perpendicular as for tension and compression), and $\Delta\ell$ is *perpendicular* to ℓ_0. The constant of proportionality G is called the **shear modulus** and is generally one-half to one-third the value of Young's modulus E (see Table 12–1). Figure 12–19 suggests why $\Delta\ell \propto \ell_0$: the fatter book shifts more for the same shearing force.

FIGURE 12–19 The fatter book (a) shifts more than the thinner book (b) with the same applied shear force.



(a)

(b)

Volume Change—Bulk Modulus

If an object is subjected to inward forces from all sides, its volume will decrease. A common situation is an object submerged in a fluid; in this case, the fluid exerts a pressure on the object in all directions, as we shall see in Chapter 13. *Pressure* is defined as force per unit area, and thus is the equivalent of stress. For this situation the change in volume, ΔV, is proportional to the original volume, V_0, and to the change in the pressure, ΔP. We thus obtain a relation of the same form as Eq. 12–4 but with a proportionality constant called the **bulk modulus** B:

$$\frac{\Delta V}{V_0} = -\frac{1}{B}\Delta P \tag{12–7}$$

or

$$B = -\frac{\Delta P}{\Delta V/V_0}.$$

The minus sign means the volume *decreases* with an increase in pressure.

Values for the bulk modulus are given in Table 12–1. Since liquids and gases do not have a fixed shape, only the bulk modulus (not the Young's or shear moduli) applies to them.

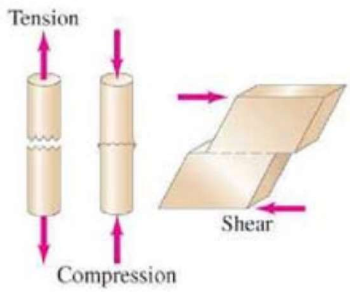


FIGURE 12–20 Fracture as a result of the three types of stress.

12–5 Fracture

If the stress on a solid object is too great, the object fractures, or breaks (Fig. 12–20). Table 12–2 lists the ultimate strengths for tension, compression, and shear for a variety of materials. These values give the maximum force per unit area, or stress, that an object can withstand under each of these three types of stress for various types of material. They are, however, representative values only, and the actual value for a given specimen can differ considerably. It is therefore necessary to maintain a *safety factor* of from 3 to perhaps 10 or more—that is, the actual stresses on a structure should not exceed one-tenth to one-third of the values given in the Table. You may encounter tables of "allowable stresses" in which appropriate safety factors have already been included.

TABLE 12–2 Ultimate Strengths of Materials (force/area)

Material	Tensile Strength (N/m^2)	Compressive Strength (N/m^2)	Shear Strength (N/m^2)
Iron, cast	170×10^6	550×10^6	170×10^6
Steel	500×10^6	500×10^6	250×10^6
Brass	250×10^6	250×10^6	200×10^6
Aluminum	200×10^6	200×10^6	200×10^6
Concrete	2×10^6	20×10^6	2×10^6
Brick		35×10^6	
Marble		80×10^6	
Granite		170×10^6	
Wood (pine) (parallel to grain)	40×10^6	35×10^6	5×10^6
(perpendicular to grain)		10×10^6	
Nylon	500×10^6		
Bone (limb)	130×10^6	170×10^6	

EXAMPLE 12–8 ESTIMATE Breaking the piano wire. The steel piano wire we discussed in Example 12–7 was 1.60 m long with a diameter of 0.20 cm. Approximately what tension force would break it?

APPROACH We set the tensile stress F/A equal to the tensile strength of steel given in Table 12–2.

SOLUTION The area of the wire is $A = \pi r^2$, where $r = 0.10\text{ cm} = 1.0 \times 10^{-3}\text{ m}$. Table 12–2 tells us

$$\frac{F}{A} = 500 \times 10^6\ \text{N/m}^2,$$

so the wire would likely break if the force exceeded

$$F = \left(500 \times 10^6\ \text{N/m}^2\right)(\pi)\left(1.0 \times 10^{-3}\text{ m}\right)^2 = 1600\text{ N}.$$

As can be seen in Table 12–2, concrete (like stone and brick) is reasonably strong under compression but extremely weak under tension. Thus concrete can be used as vertical columns placed under compression, but is of little value as a beam because it cannot withstand the tensile forces that result from the inevitable sagging of the lower edge of a beam (see Fig. 12–21).

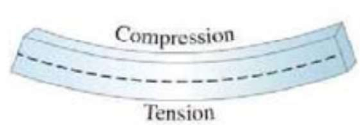


FIGURE 12–21 A beam sags, at least a little (but is exaggerated here), even under its own weight. The beam thus changes shape: the upper edge is compressed, and the lower edge is under tension (elongated). Shearing stress also occurs within the beam.

Reinforced concrete, in which iron rods are embedded in the concrete (Fig. 12–22), is much stronger. Stronger still is *prestressed concrete*, which also contains iron rods or a wire mesh, but during the pouring of the concrete, the rods or wire are held under tension. After the concrete dries, the tension on the iron is released, putting the concrete under compression. The amount of compressive stress is carefully predetermined so that when loads are applied to the beam, they reduce the compression on the lower edge, but never put the concrete into tension.

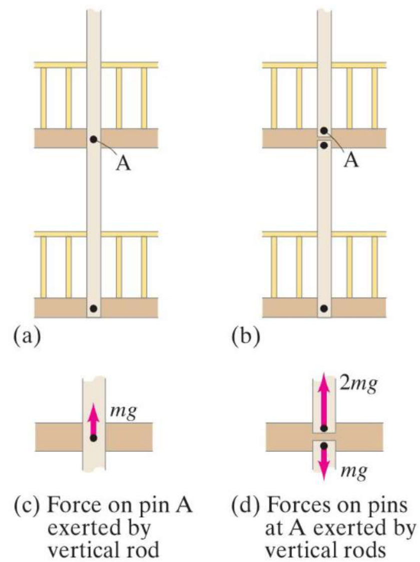
FIGURE 12–22 Steel rods around which concrete is poured for strength.

CONCEPTUAL EXAMPLE 12–9 **A tragic substitution.** Two walkways, one above the other, are suspended from vertical rods attached to the ceiling of a high hotel lobby, Fig. 12–23a. The original design called for single rods 14 m long, but when such long rods proved to be unwieldy to install, it was decided to replace each long rod with two shorter ones as shown schematically in Fig. 12–23b. Determine the net force exerted by the rods on the supporting pin A (assumed to be the same size) for each design. Assume each vertical rod supports a mass m of each bridge.

PHYSICS APPLIED
A tragic collapse

RESPONSE The single long vertical rod in Fig. 12–23a exerts an upward force equal to mg on pin A to support the mass m of the upper bridge. Why? Because the pin is in equilibrium, and the other force that balances this is the downward force mg exerted on it by the upper bridge (Fig. 12–23c). There is thus a shear stress on the pin because the rod pulls up on one side of the pin, and the bridge pulls down on the other side. The situation when two shorter rods support the bridges (Fig. 12–23b) is shown in Fig. 12–23d, in which only the connections at the upper bridge are shown. The lower rod exerts a force mg downward on the lower of the two pins because it supports the lower bridge. The upper rod exerts a force $2mg$ on the upper pin (labelled A) because the upper rod supports both bridges. Thus we see that when the builders substituted two shorter rods for each single long one, the stress in the supporting pin A was *doubled*. What perhaps seemed like a simple substitution did, in fact, lead to a tragic collapse in 1981 with a loss of life of over 100 people (see Fig. 12–1). Having a feel for physics, and being able to make simple calculations based on physics, can have a great effect, literally, on people's lives.

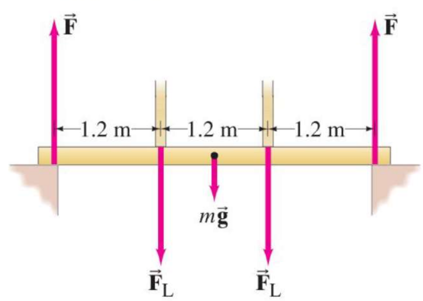
FIGURE 12–23 Example 12–9.



EXAMPLE 12–10 **Shear on a beam.** A uniform pine beam, 3.6 m long and 9.5 cm × 14 cm in cross section, rests on two supports near its ends, as shown in Fig. 12–24. The beam's mass is 25 kg and two vertical roof supports rest on it, each one-third of the way from the ends. What maximum load force F_L can each of the roof supports exert without shearing the pine beam at its supports? Use a safety factor of 5.0.

APPROACH The symmetry present simplifies our calculation. We first find the shear strength of pine in Table 12–2 and use the safety factor of 5.0 to get F from $F/A \leq \frac{1}{5}$(shear strength). Then we use $\Sigma\tau = 0$ to find F_L.

FIGURE 12–24 Example 12–10.



SOLUTION Each support exerts an upward force F (there is symmetry) that can be at most (see Table 12–2)

$$F = \frac{1}{5}A(5 \times 10^6\,\mathrm{N/m^2}) = \frac{1}{5}(0.095\,\mathrm{m})(0.14\,\mathrm{m})(5 \times 10^6\,\mathrm{N/m^2}) = 13{,}000\,\mathrm{N}.$$

To determine the maximum load force F_L, we calculate the torque about the left end of the beam (counterclockwise positive):

$$\Sigma\tau = -F_L(1.2\,\mathrm{m}) - (25\,\mathrm{kg})(9.8\,\mathrm{m/s^2})(1.8\,\mathrm{m}) - F_L(2.4\,\mathrm{m}) + F(3.6\,\mathrm{m}) = 0$$

so each of the two roof supports can exert

$$F_L = \frac{(13{,}000\,\mathrm{N})(3.6\,\mathrm{m}) - (250\,\mathrm{N})(1.8\,\mathrm{m})}{(1.2 + 2.4)} = 13{,}000\,\mathrm{N}.$$

The total mass of roof the beam can support is $(2)(13{,}000\,\mathrm{N})/(9.8\,\mathrm{m/s^2}) = 2600\,\mathrm{kg}$.

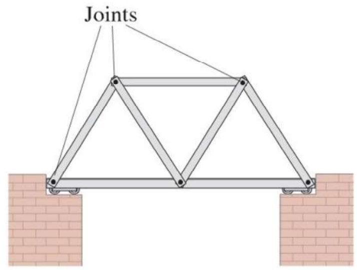


FIGURE 12–25 A truss bridge.

*12–6 Trusses and Bridges

A beam used to span a wide space, as for a bridge, is subject to strong stresses of all three types as we saw in Fig. 12–21: compression, tension and shear. A basic engineering device to support large spans is the *truss*, an example of which is shown in Fig. 12–25. Wooden truss bridges were first designed by the great architect Andrea Palladio (1518–1580), famous for his design of public buildings and villas. With the introduction of steel in the nineteenth century, much stronger steel trusses came into use, although wood trusses are still used to support the roofs of houses and mountain lodges (Fig. 12–26).

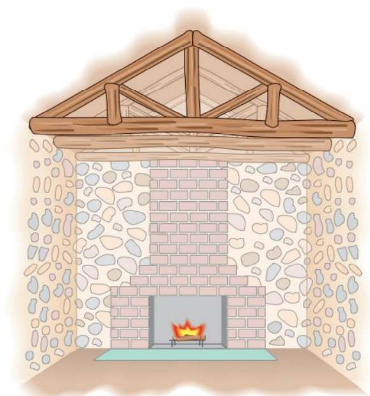


FIGURE 12–26 A roof truss.

Basically, a **truss** is a framework of rods or struts joined together at their ends by pins or rivets, always arranged as triangles. (Triangles are relatively stable, as compared to a rectangle, which easily becomes a parallelogram under sideways forces and then collapses.) The place where the struts are joined by a pin is called a **joint**.

It is commonly assumed that the struts of a truss are under pure compression or pure tension—that is, the forces act along the length of each strut, Fig. 12–27a. This is an ideal, valid only if a strut has no mass and supports no weight along its length, in which case a strut has only two forces on it, at the ends, as shown in Fig. 12–27a. If the strut is in equilibrium, these two forces must be equal and opposite in direction $(\Sigma\vec{\mathbf{F}} = 0)$. But couldn't they be at an angle, as in Fig. 12–27b? No, because then $\Sigma\vec{\boldsymbol{\tau}}$ would not be zero. The two forces *must* act along the strut if the strut is in equilibrium. But in a real case of a strut with mass, there are three forces on the strut, as shown in Fig. 12–27c, and $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ do not act along the strut; the vector diagram in Fig. 12–27d shows $\Sigma\vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + m\vec{\mathbf{g}} = 0$. Can you see why $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ both point *above* the strut? (Do $\Sigma\tau$ about each end.)

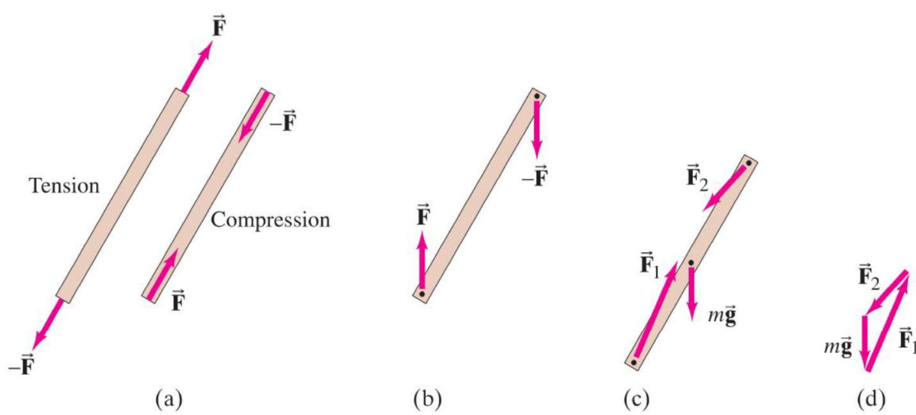


FIGURE 12–27 (a) Each massless strut (or rod) of a truss is assumed to be under tension or compression. (b) The two equal and opposite forces must be along the same line or a net torque would exist. (c) Real struts have mass, so the forces $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ at the joints do not act precisely along the strut. (d) Vector diagram of part (c).

Consider again the simple beam in Example 12–5, Fig. 12–9. The force $\vec{\mathbf{F}}_H$ at the pin is *not* along the beam, but acts at an upward angle. If that beam were massless, we see from Eq. (iii) in Example 12–5 with $m = 0$, that $F_{Hy} = 0$, and $\vec{\mathbf{F}}_H$ would be along the beam.

The assumption that the forces in each strut of a truss are purely along the strut is still very useful whenever the loads act only at the joints and are much greater than the weight of the struts themselves.

EXAMPLE 12–11 **A truss bridge.** Determine the tension or compression in each of the struts of the truss bridge shown in Fig. 12–28a. The bridge is 64 m long and supports a uniform level concrete roadway whose total mass is 1.40×10^6 kg. Use the **method of joints**, which involves (1) drawing a free-body diagram of the truss as a whole, and (2) drawing a free-body diagram for each of the pins (joints), one by one, and setting $\Sigma\vec{\mathbf{F}} = 0$ for each pin. Ignore the mass of the struts. Assume all triangles are equilateral.

PHYSICS APPLIED
A truss bridge

PROBLEM SOLVING
Method of joints

APPROACH Any bridge has two trusses, one on each side of the roadway. Consider only one truss, Fig. 12–28a, and it will support half the weight of the roadway. That is, our truss supports a total mass $M = 7.0 \times 10^5$ kg. First we draw a free-body diagram for the entire truss as a single unit, which we assume rests on supports at either end that exert upward forces $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$, Fig. 12–28b. We assume the mass of the roadway acts entirely at the center, on pin C, as shown. From symmetry we can see that each of the end supports carries half the weight [or do a torque equation about, say, point A: $(F_2)(\ell) - Mg(\ell/2) = 0$], so

$$F_1 = F_2 = \tfrac{1}{2}Mg.$$

SOLUTION We look at pin A and apply $\Sigma\vec{\mathbf{F}} = 0$ to it. We label the forces on pin A due to each strut with two subscripts: $\vec{\mathbf{F}}_{AB}$ means the force exerted by the strut AB and $\vec{\mathbf{F}}_{AC}$ is the force exerted by strut AC. $\vec{\mathbf{F}}_{AB}$ and $\vec{\mathbf{F}}_{AC}$ act along their respective struts; but not knowing whether each is compressive or tensile, we could draw four different free-body diagrams, as shown in Fig. 12–28c. Only the one on the left could provide $\Sigma\vec{\mathbf{F}} = 0$, so we immediately know the directions of $\vec{\mathbf{F}}_{AB}$ and $\vec{\mathbf{F}}_{AC}$.† These forces act on the pin. The force that pin A exerts on strut AB is opposite in direction to $\vec{\mathbf{F}}_{AB}$ (Newton's third law), so strut AB is under compression and strut AC is under tension. Now let's calculate the magnitudes of $\vec{\mathbf{F}}_{AB}$ and $\vec{\mathbf{F}}_{AC}$. At pin A:

$$\Sigma F_x = F_{AC} - F_{AB}\cos 60^\circ = 0$$
$$\Sigma F_y = F_1 - F_{AB}\sin 60^\circ = 0.$$

Thus

$$F_{AB} = \frac{F_1}{\sin 60^\circ} = \frac{\frac{1}{2}Mg}{\frac{1}{2}\sqrt{3}} = \frac{1}{\sqrt{3}}Mg,$$

which equals $(7.0 \times 10^5\,\text{kg})(9.8\,\text{m/s}^2)/\sqrt{3} = 4.0 \times 10^6\,\text{N}$; and

$$F_{AC} = F_{AB}\cos 60^\circ = \frac{1}{2\sqrt{3}}Mg.$$

Next we look at pin B, and Fig. 12–28d is the free-body diagram. [Convince yourself that if $\vec{\mathbf{F}}_{BD}$ or $\vec{\mathbf{F}}_{BC}$ were in the opposite direction, $\Sigma\vec{\mathbf{F}}$ could not be zero; note that $\vec{\mathbf{F}}_{BA} = -\vec{\mathbf{F}}_{AB}$ (and $F_{BA} = F_{AB}$) because now we are at the opposite end of strut AB.] We see that BC is under tension and BD compression. (Recall that the forces on the struts are opposite to the forces shown which are on the pin.) We set $\Sigma\vec{\mathbf{F}} = 0$:

$$\Sigma F_x = F_{BA}\cos 60^\circ + F_{BC}\cos 60^\circ - F_{BD} = 0$$
$$\Sigma F_y = F_{BA}\sin 60^\circ - F_{BC}\sin 60^\circ = 0.$$

Then, because $F_{BA} = F_{AB}$, we have

$$F_{BC} = F_{AB} = \frac{1}{\sqrt{3}}Mg,$$

and

$$F_{BD} = F_{AB}\cos 60^\circ + F_{BC}\cos 60^\circ = \frac{1}{\sqrt{3}}Mg\left(\tfrac{1}{2}\right) + \frac{1}{\sqrt{3}}Mg\left(\tfrac{1}{2}\right) = \frac{1}{\sqrt{3}}Mg.$$

The solution is complete. By symmetry, $F_{DE} = F_{AB}$, $F_{CE} = F_{AC}$, and $F_{CD} = F_{BC}$.

NOTE As a check, calculate ΣF_x and ΣF_y for pin C and see if they equal zero. Figure 12–28e shows the free-body diagram.

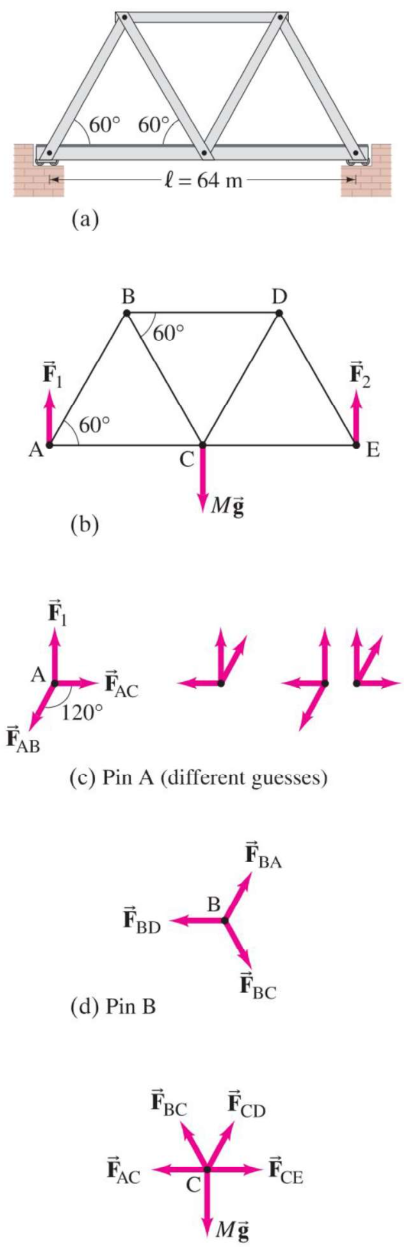


FIGURE 12–28 Example 12–11. (a) A truss bridge. Free-body diagrams: (b) for the entire truss, (c) for pin A (different guesses), (d) for pin B and (e) for pin C.

†If we were to choose the direction of a force on a diagram opposite to what it really is, we would get a minus sign.

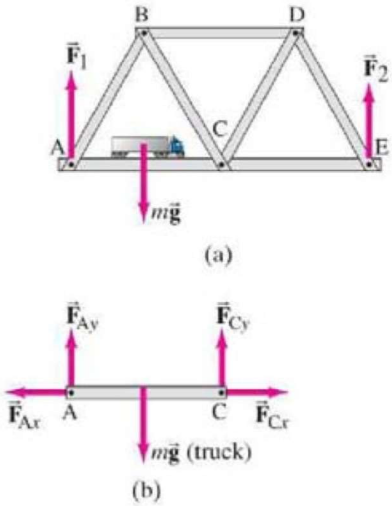


FIGURE 12–29 (a) Truss with truck of mass m at center of strut AC. (b) Forces on strut AC.

Example 12–11 put the roadway load at the center, C. Now consider a heavy load, such as a heavy truck, supported by strut AC at its middle, as shown in Fig. 12–29a. The strut AC sags under this load, telling us there is shear stress in strut AC. Figure 12–29b shows the forces exerted on strut AC: the weight of the truck $m\vec{\mathbf{g}}$, and the forces $\vec{\mathbf{F}}_A$ and $\vec{\mathbf{F}}_C$ that pins A and C exert on the strut. [Note that $\vec{\mathbf{F}}_1$ does not appear because it is a force (exerted by external supports) that acts on pin A, not on strut AC.] The forces that pins A and C exert on strut AC will act not only along the strut, but will have vertical components too, perpendicular to the strut to balance the weight of the truck, $m\vec{\mathbf{g}}$, creating shear stress. The other struts, not bearing weight, remain under pure tension or compression. Problems 53 and 54 deal with this situation, and an early step in their solution is to calculate the forces $\vec{\mathbf{F}}_A$ and $\vec{\mathbf{F}}_C$ by using torque equations for the strut.

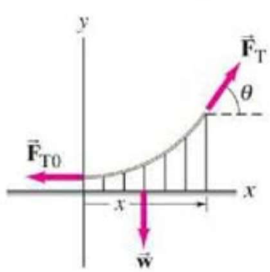
For very large bridges, truss structures are too heavy. One solution is to build suspension bridges, with the load being carried by relatively light suspension cables under tension, supporting the roadway by means of closely spaced vertical wires, as shown in Fig. 12–30, and in the photo on the first page of this Chapter.

PHYSICS APPLIED
Suspension bridge

FIGURE 12–30 Suspension bridges (Brooklyn and Manhattan bridges, NY).

EXAMPLE 12–12 **Suspension bridge.** Determine the shape of the cable between the two towers of a suspension bridge (as in Fig. 12–30), assuming the weight of the roadway is supported uniformly along its length. Ignore the weight of the cable.

FIGURE 12–31 Example 12–12.



APPROACH We take $x = 0$, $y = 0$ at the center of the span, as shown in Fig. 12–31. Let $\vec{\mathbf{F}}_{T0}$ be the tension in the cable at $x = 0$; it acts horizontally as shown. Let F_T be the tension in the cable at some other place where the horizontal coordinate is x, as shown. This section of cable supports a portion of the roadway whose weight w is proportional to the distance x, since the roadway is assumed uniform; that is,

$$w = \lambda x$$

where λ is the weight per unit length.

SOLUTION We set $\Sigma \vec{\mathbf{F}} = 0$:

$$\Sigma F_x = F_T \cos\theta - F_{T0} = 0$$

$$\Sigma F_y = F_T \sin\theta - w = 0.$$

We divide these two equations,

$$\tan\theta = \frac{w}{F_{T0}} = \frac{\lambda x}{F_{T0}}.$$

The slope of our curve (the cable) at any point is

$$\frac{dy}{dx} = \tan\theta$$

or

$$\frac{dy}{dx} = \frac{\lambda}{F_{T0}} x.$$

We integrate this:

$$\int dy = \frac{\lambda}{F_{T0}} \int x\, dx$$

$$y = Ax^2 + B$$

where we set $A = \lambda / F_{T0}$ and B is a constant of integration. This is just the equation of a parabola.

NOTE Real bridges have cables that do have mass, so the cables hang only approximately as a parabola, although often it is quite close.

31. (III) A refrigerator is approximately a uniform rectangular solid 1.9 m tall, 1.0 m wide, and 0.75 m deep. If it sits upright on a truck with its 1.0-m dimension in the direction of travel, and if the refrigerator cannot slide on the truck, how rapidly can the truck accelerate without tipping the refrigerator over? [*Hint*: The normal force would act at one corner.]

32. (III) A uniform ladder of mass m and length ℓ leans at an angle θ against a frictionless wall, Fig. 12–67. If the coefficient of static friction between the ladder and the ground is μ_s, determine a formula for the minimum angle at which the ladder will not slip.

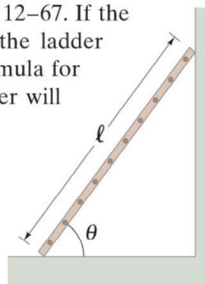


FIGURE 12–67 Problem 32.

12–3 Stability and Balance

33. (II) The Leaning Tower of Pisa is 55 m tall and about 7.0 m in diameter. The top is 4.5 m off center. Is the tower in stable equilibrium? If so, how much farther can it lean before it becomes unstable? Assume the tower is of uniform composition.

12–4 Elasticity; Stress and Strain

34. (I) A nylon string on a tennis racket is under a tension of 275 N. If its diameter is 1.00 mm, by how much is it lengthened from its untensioned length of 30.0 cm?

35. (I) A marble column of cross-sectional area 1.4 m^2 supports a mass of 25,000 kg. (*a*) What is the stress within the column? (*b*) What is the strain?

36. (I) By how much is the column in Problem 35 shortened if it is 8.6 m high?

37. (I) A sign (mass 1700 kg) hangs from the end of a vertical steel girder with a cross-sectional area of 0.012 m^2. (*a*) What is the stress within the girder? (*b*) What is the strain on the girder? (*c*) If the girder is 9.50 m long, how much is it lengthened? (Ignore the mass of the girder itself.)

38. (II) How much pressure is needed to compress the volume of an iron block by 0.10%? Express your answer in N/m^2, and compare it to atmospheric pressure $(1.0 \times 10^5\,N/m^2)$.

39. (II) A 15-cm-long tendon was found to stretch 3.7 mm by a force of 13.4 N. The tendon was approximately round with an average diameter of 8.5 mm. Calculate Young's modulus of this tendon.

40. (II) At depths of 2000 m in the sea, the pressure is about 200 times atmospheric pressure $(1\text{ atm} = 1.0 \times 10^5\,N/m^2)$. By what percentage does the interior space of an iron bathysphere's volume change at this depth?

41. (III) A pole projects horizontally from the front wall of a shop. A 6.1-kg sign hangs from the pole at a point 2.2 m from the wall (Fig. 12–68). (*a*) What is the torque due to this sign calculated about the point where the pole meets the wall? (*b*) If the pole is not to fall off, there must be another torque exerted to balance it. What exerts this torque? Use a diagram to show how this torque must act. (*c*) Discuss whether compression, tension, and/or shear play a role in part (*b*).

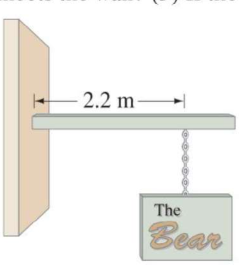


FIGURE 12–68 Problem 41.

12–5 Fracture

42. (I) The femur bone in the human leg has a minimum effective cross section of about $3.0\,cm^2$ $(= 3.0 \times 10^{-4}\,m^2)$. How much compressive force can it withstand before breaking?

43. (II) (*a*) What is the maximum tension possible in a 1.00-mm-diameter nylon tennis racket string? (*b*) If you want tighter strings, what do you do to prevent breakage: use thinner or thicker strings? Why? What causes strings to break when they are hit by the ball?

44. (II) If a compressive force of 3.3×10^4 N is exerted on the end of a 22-cm-long bone of cross-sectional area 3.6 cm^2, (*a*) will the bone break, and (*b*) if not, by how much does it shorten?

45. (II) (*a*) What is the minimum cross-sectional area required of a vertical steel cable from which is suspended a 270-kg chandelier? Assume a safety factor of 7.0. (*b*) If the cable is 7.5 m long, how much does it elongate?

46. (II) Assume the supports of the uniform cantilever shown in Fig. 12–69 $(m = 2900\,kg)$ are made of wood. Calculate the minimum cross-sectional area required of each, assuming a safety factor of 9.0.

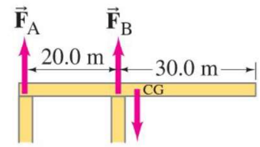


FIGURE 12–69 Problem 46.

47. (II) An iron bolt is used to connect two iron plates together. The bolt must withstand shear forces up to about 3300 N. Calculate the minimum diameter for the bolt, based on a safety factor of 7.0.

48. (III) A steel cable is to support an elevator whose total (loaded) mass is not to exceed 3100 kg. If the maximum acceleration of the elevator is 1.2 m/s^2, calculate the diameter of cable required. Assume a safety factor of 8.0.

* 12–6 Trusses and Bridges

***49.** (II) A heavy load $Mg = 66.0\,kN$ hangs at point E of the single cantilever truss shown in Fig. 12–70. (*a*) Use a torque equation for the truss as a whole to determine the tension F_T in the support cable, and then determine the force $\vec{F}_A$ on the truss at pin A. (*b*) Determine the force in each member of the truss. Neglect the weight of the trusses, which is small compared to the load.

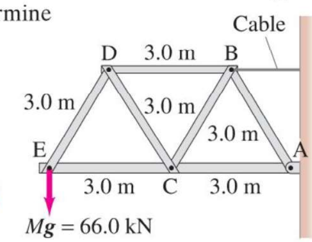


FIGURE 12–70 Problem 49.

***50.** (II) Figure 12–71 shows a simple truss that carries a load at the center (C) of 1.35×10^4 N. (*a*) Calculate the force on each strut at the pins, A, B, C, D, and (*b*) determine which struts (ignore their masses) are under tension and which under compression.

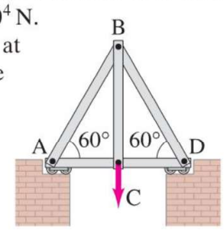


FIGURE 12–71 Problem 50.

***51.** (II) (*a*) What minimum cross-sectional area must the trusses have in Example 12–11 if they are of steel (and all the same size for looks), using a safety factor of 7.0? (*b*) If at any time the bridge may carry as many as 60 trucks with an average mass of 1.3×10^4 kg, estimate again the area needed for the truss members.

*52. (II) Consider again Example 12–11 but this time assume the roadway is supported uniformly so that $\frac{1}{2}$ its mass M $(= 7.0 \times 10^5\,\text{kg})$ acts at the center and $\frac{1}{4}M$ at each end support (think of the bridge as two spans, AC and CE, so the center pin supports two span ends). Calculate the magnitude of the force in each truss member and compare to Example 12–11.

*53. (III) The truss shown in Fig. 12–72 supports a railway bridge. Determine the compressive or tension force in each strut if a 53-ton $(1\text{ ton} = 10^3\,\text{kg})$ train locomotive is stopped at the midpoint between the center and one end. Ignore the masses of the rails and truss, and use only $\frac{1}{2}$ the mass of train because there are two trusses (one on each side of the train). Assume all triangles are equilateral. [*Hint*: See Fig. 12–29.]

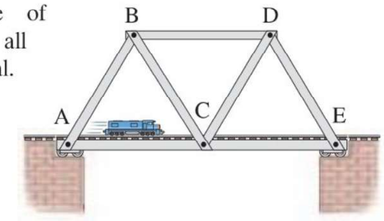


FIGURE 12–72 Problem 53.

*54. (III) Suppose in Example 12–11, a 23-ton truck $(m = 23 \times 10^3\,\text{kg})$ has its CM located 22 m from the left end of the bridge (point A). Determine the magnitude of the force and type of stress in each strut. [*Hint*: See Fig. 12–29.]

*55. (III) For the "Pratt truss" shown in Fig. 12–73, determine the force on each member and whether it is tensile or compressive. Assume the truss is loaded as shown, and give results in terms of F. The vertical height is a and each of the four lower horizontal spans has length a.

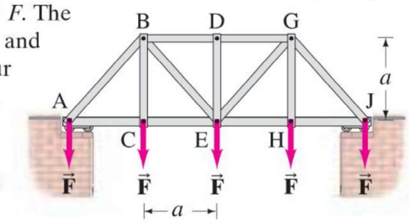


FIGURE 12–73 Problem 55.

*12–7 Arches and Domes

*56. (II) How high must a pointed arch be if it is to span a space 8.0 m wide and exert one-third the horizontal force at its base that a round arch would?

General Problems

57. The mobile in Fig. 12–74 is in equilibrium. Object B has mass of 0.748 kg. Determine the masses of objects A, C, and D. (Neglect the weights of the crossbars.)

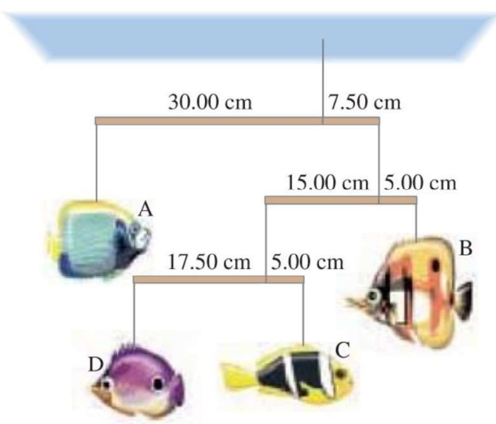


FIGURE 12–74 Problem 57.

58. A tightly stretched "high wire" is 36 m long. It sags 2.1 m when a 60.0-kg tightrope walker stands at its center. What is the tension in the wire? Is it possible to increase the tension in the wire so that there is no sag?

59. What minimum horizontal force F is needed to pull a wheel of radius R and mass M over a step of height h as shown in Fig. 12–75 $(R > h)$? (*a*) Assume the force is applied at the top edge as shown. (*b*) Assume the force is applied instead at the wheel's center.

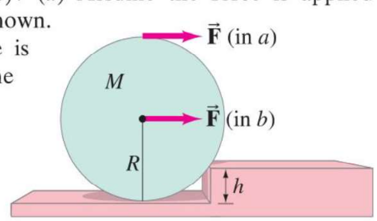


FIGURE 12–75 Problem 59.

60. A 28-kg round table is supported by three legs equal distances apart on the edge. What minimum mass, placed on the table's edge, will cause the table to overturn?

61. When a wood shelf of mass 6.6 kg is fastened inside a slot in a vertical support as shown in Fig. 12–76, the support exerts a torque on the shelf. (*a*) Draw a free-body diagram for the shelf, assuming three vertical forces (two exerted by the support slot—explain why). Then calculate (*b*) the magnitudes of the three forces and (*c*) the torque exerted by the support (about the left end of the shelf).

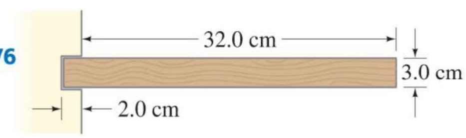


FIGURE 12–76 Problem 61.

62. A 50-story building is being planned. It is to be 180.0 m high with a base 46.0 m by 76.0 m. Its total mass will be about 1.8×10^7 kg, and its weight therefore about 1.8×10^8 N. Suppose a 200-km/h wind exerts a force of $950\,\text{N/m}^2$ over the 76.0-m-wide face (Fig. 12–77). Calculate the torque about the potential pivot point, the rear edge of the building (where $\vec{\mathbf{F}}_E$ acts in Fig. 12–77), and determine whether the building will topple. Assume the total force of the wind acts at the midpoint of the building's face, and that the building is not anchored in bedrock. [*Hint*: $\vec{\mathbf{F}}_E$ in Fig. 12–77 represents the force that the Earth would exert on the building in the case where the building would just begin to tip.]

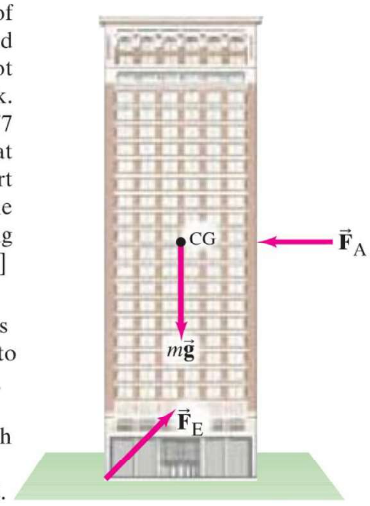


FIGURE 12–77 Forces on a building subjected to wind $(\vec{\mathbf{F}}_A)$, gravity $(m\vec{\mathbf{g}})$, and the force $\vec{\mathbf{F}}_E$ on the building due to the Earth if the building were just about to tip. Problem 62.

THOMAS MACLAREN SCHOOL

HOW TO WRITE A RESEARCH PAPER

1. Make a schedule. Figure out how much time to spend on particular tasks. In general, plan to spend about 20 hours researching (reading, taking notes, etc.), and about 10 hours in the writing process (including revisions and citations). Give yourself a deadline for the research to be completed, the first draft, etc.

2. Do some initial reading. You should read some general articles on the subject – secondary sources are OK – to grasp the basic issues and topics involved. These should be descriptive, in the way an encyclopedia article is descriptive, rather than argumentative. From what you learn, you should be able to sketch an outline of the subject that will structure your paper.

3. Prepare a preliminary (working) outline. This is important for labeling and organizing your note cards later. You should already have ideas of how to break your topic down into parts. Take the time to write this out on a piece of paper. You may run across other possible parts that you will add, but you need to have some way of classifying your note cards before you begin.

4. Prepare a working bibliography for each source. An easy way to do this is to write down the bibliographic information for each source on its own 3 x 5 card. It would include the full information for each source in the format that you will use for the final paper (see: Project Week Formatting and Citation Guidelines). If you do this in the beginning, you should not have to return to the book for this information. This method also enables you to re-alphabetize your cards quickly as you add or take away sources.

5. Read and take notes on cards. You should use 4 x 6 cards for this so they will hold a reasonable amount of information.

a. Label the card with the source (e.g., author's last name, pointing you to the correct bibliographic card) and the topic name or number that corresponds to your working outline.

b. Write a new card for each topic and each source. If one page of the source deals with three different topics in your outline, write three separate note cards. You are going to shuffle these cards around, arranging them by topic to fit your outline when you are finished. This will not work if you have put more than one topic on a single card.

c. Mark the precise page number. This will help you cite precisely and accurately later without having to return to the book to find out where you got that idea or fact. If the idea carries over from one page to another in the source, mark each part of the card with the correct page number.

d. In general, write the notes in your own words. This has two advantages: 1. You will be more likely to understand the notes when you come back to write the paper from them. 2. You are automatically one step removed from the original source's wording so that you are not likely to fall into plagiarism. If the author's words are important enough to quote in your paper, go ahead and copy them onto the note card, making sure to indicate a direct quote.

6. Review and arrange the cards within each topic. This step depends partly on the detail of your outline. You likely will find yourself subdividing some outline topics, even in the process of writing the cards. If so, mark the changes on the affected cards. The arrangement may reveal that your notes are thin on a particular topic. If so, go back and take some more notes.

7. Write the first draft from the cards. Depending on the quality of your work so far, you should be able to get a decent first draft just by typing in sentences from your note cards. You certainly should have enough information to make the writing go easily. Put the citations in the paper while you are writing, since the information is on the card in front of you.

8. Revise your paper. Reread the draft and make corrections on it. Write a second draft based on those revisions and continue to improve your paper. Work hard at making your writing clear and concise. Make sure all paraphrases and quotations are worked smoothly into the paper. Read the work aloud. Your ear will catch mistakes and awkward phrasing that your eye may not catch.

9. Produce the final copy.

10. Assemble your Bibliography pages.

THOMAS MACLAREN SCHOOL

Project Week Formatting and Citation Guidelines

Guidelines for Research Paper Bibliography

A large part of your Project Week work will be the researching and writing of a paper. A research paper requires you to gather, read, and evaluate multiple sources on your topic, and with these write a clear and informative paper.

Source requirements (*at minimum)*: **1 print; 3 electronic; you may download and use the bridge building software mentioned in your packet**

For the written component of your project, all material must be properly formatted and cited. The MacLaren manuscript form applies, specifically, *12 pt. Times New Roman font, double spacing, and 1-inch margins.*

Plagiarizing, Quoting, and Paraphrasing: Please be careful when quoting and paraphrasing that you DO NOT plagiarize an author's work. Here is a quick outline of the differences between quotation, paraphrasing, and plagiarism:

Plagiarism: Plagiarism is using someone else's ideas in your work without properly citing that information. Plagiarism can be using the exact words of an author without quoting and citing, or paraphrasing too closely to the original text. Simply moving words around or making slight changes DOES NOT mean you have created an original thought!

Quotation: If you are using the author's *exact* words, you must quote WORD FOR WORD, and include quotation marks around all quoted material.

Paraphrasing: If you paraphrase, that means you are taking material from the source and putting it into your own words. When you paraphrase you demonstrate your understanding of an author's argument or assertion, but you are still using his or her ideas, so this material MUST STILL BE CITED (as explained below). Be careful when you paraphrase that you really understand what the author is trying to say.

Paraphrasing Exercise (from http://owl.english.purdue.edu/owl/resource/563/02/):
We will continue to use MLA guidelines when paraphrasing material. Remember that you must still include a citation for a paraphrase.

The following passage is taken from an original source:
The twenties were the years when drinking was against the law, and the law was a bad joke because everyone knew of a local bar where liquor could be had. They were the years when organized crime ruled the cities, and the police seemed powerless to do anything against it. Classical music was forgotten while jazz spread throughout the land, and men like Bix Beiderbecke, Louis Armstrong, and Count Basie became the heroes of the young. The flapper was born in the twenties, and with her bobbed hair and short skirts, she symbolized, perhaps more than anyone or anything else, America's break with the past.
—from Kathleen Yancey, *English 102 Supplemental Guide* (1989): 25.

This is a legitimate paraphrase of the same passage (including the proper in-text citation):
During the twenties lawlessness and social nonconformity prevailed. In cities organized crime flourished without police interference, and in spite of nationwide prohibition of liquor sales, anyone who wished to buy a drink knew where to get one. Musicians like Louis Armstrong become favorites, particularly among young people, as many turned away from highly respectable classical music to jazz. One of the best examples of the anti-traditional trend was the proliferation of young "flappers," women who rebelled against custom by cutting off their hair and shortening their skirts (Yancey 25).

In-text Citations:

To cite material within the text, we will be using MLA guidelines. When you **paraphrase** or **quote** an author's work in your paper, you must include a citation. We do this by including the last name of the author and the page number on which the material was found. The citation goes inside of the end punctuation mark. For example,

> *Edmund is described by C.S. Lewis as "becoming a nastier person every minute" (48).*
>
> or
>
> *Edmund is described as "becoming a nastier person every minute" (Lewis 48).*

For electronic sources, you do not need a page number, but try to include the author of the webpage and article title.

Bibliography

For every source you cite, you will have a corresponding entry in your Works Cited page, or bibliography. Your Works Cited page must be on a separate sheet of paper (see sample page).

For books, your citation should follow this format:

> Last name, First name. *Title of book*. Place of Publication: Publisher, Year of Publication. Medium of Publication (i.e. Print).

For books with more than one author, the format should be:

> Last name, First name and First name, Last name.

For chapters or essays in an anthology, the format is:

> Last name, First name. "Title of Essay." *Title of Collection*. Ed. Editor's Name(s). Place of Publication: Publisher, Year. Page range of entry. Medium of Publication.

For an electronic source, try to find the following information:

- Author and/or editor names (if available)
- Article name in quotation marks (if applicable)
- Title of the Website, project, or book in italics. (Remember that some Print publications have Web publications with slightly different names. They may, for example, include the additional information or otherwise modified information, like domain names [e.g. .com or .net].)
- Any version numbers available, including revisions, posting dates, volumes, or issue numbers.
- Publisher information, including the publisher name and publishing date.
- Take note of any page numbers (if available).
- Date you accessed the material.
- URL (if required, or for your own personal reference).

For example:

> Stolley, Karl. "MLA Formatting and Style Guide." The OWL at Purdue. 10 May 2006. Purdue University Writing Lab. 12 May 2006 <http://owl.english.purdue.edu/owl/resource/557/01/>.

For additional information on MLA Guidelines and the writing process, please see the very useful OWL at Purdue website: http://owl.english.purdue.edu/owl/

Works Cited

The Purdue OWL. Purdue U Writing Lab, 2008. Web. 27 Dec. 2008.

Lewis, C.S. *The Lion, the Witch, and the Wardrobe.* New York: Harper Collins Children's Books, 1950. Print.

THOMAS MACLAREN SCHOOL

MANUSCRIPT FORM

Standards for Written Work

1. Use white, college-rule, loose-leaf paper, standard letter size.

2. Write only on one side of the sheet.

3. Write in blue or black ink or typewrite. Double space the lines. Word processors may be used. No erasable ink or felt tip pens may be used.

4. Leave a margin of about two inches at the top of the page and margins of about one inch at the sides and bottom. The left-hand margin must be straight; the right-hand margin should be as straight as you can make it.

5. Font: 12-point font/Times New Roman or Calibri.

6. Indent the first line of each paragraph about one-half inch from the left.

7. Identify your work with the following heading:

    Full name
    Course/Teacher's Name
    Assignment
    Date Due

    Put this heading in the upper right hand corner above the lines.

8. If your paper has a title, write it in the center of the first line. Do not enclose the title in quotation marks or underline it. Skip a line between the title and the first line of your composition.

9. If your paper is more than one page in length, number the pages after the first, placing the number in the bottom right corner, about a half inch up from the bottom.

10. Write legibly and neatly.

11. Do not fold paper. Keep them flat in your folders.

12. Staple or paper clip pages together. Do not fold or tear the corners.

13. Cross out errors with one line, or use white-out sparingly.

THOMAS MACLAREN SCHOOL

PROJECT WEEK TIME SHEET

Log the hours you spend on your project below. You must spend a minimum of 30 hours on your Project.

DATE	TIME	TASK	PARENT SIGNATURE
		TOTAL TIME SPENT ON PROJECT	