Engineering & Physics Review
Part I

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Outline

- Forces
- Force & Gravity
- Energy
- Speed
- Hydraulics

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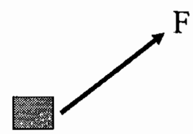
Force

- An influence that causes an object to accelerate.

- The size of the acceleration is proportional to the size of the force, and inversely proportional to the mass of the object.
  - Defines Newton's second law of motion.



- Force is a vector quantity
  - Has direction and magnitude

- Measured in Newtons.
  - One Newton will make a body of mass 1kg accelerate from rest to 1 metre per second, in a time of one second.

Force and Gravity

- Gravity, on earth accelerates at a rate of 9.8 meters per second Squared (m/sec^2) or 32 feet per second squared (32 ft/sec^2).

Force of an object = (mass of object) (acceleration)

$$F = ma$$

Force	Mass	Acceleration
Newtons	Kilograms	meters/second^2
Dynes	Grams	centimeter/second^2
Pounds	Pound	feet/second^2

" Beware of Inconsistent Units"

Determining Weight or Mass

Mass IS NOT the same as Weight

- Weight is influenced by Gravity, Mass is NOT.
- To determine an object's mass (or weight), use the following formula

Weight = (Mass)(Gravitational Acceleration)

- Same unit consistence as indicated in chart above.

Gravitational Acceleration
9.8 meters/second^2
32.2 feet/second^2
980 centimeters/second^2

- Because weight is dependent on gravitational acceleration, an object's weight can be slightly different in other parts of the world because the gravitational acceleration is different.

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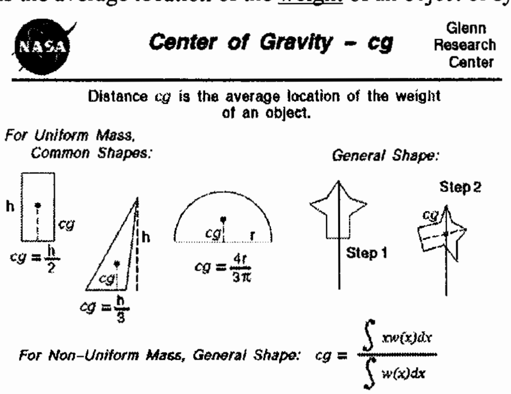
Force Related to Weight & Balance

W = mg equation is the same as F = ma

- Weight of an object is essentially the force of the object influenced by gravity.

Center of Gravity

- Defined as the average location of the weight of an object or system.



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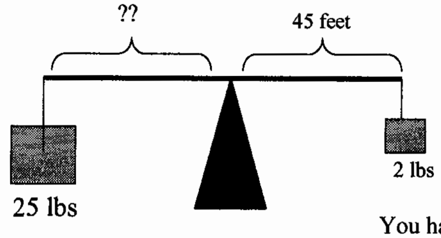
Force Related to Weight & Balance

Center of Gravity involving 2 objects connected together can be expressed by the following:

$(\text{Force}_{1\ \text{Object}})$ (Distance from Center of Gravity$_{1\ \text{Object}}$) = $(\text{Force}_{2\ \text{Object}})$ (Distance from Center of Gravity$_{2\ \text{Object}}$)



$F_1D_1 = F_2D_2$

You have an object weighing 2 lbs and 45 feet from the center of this rod. You, then, hang a 25 lb object on other end of the rod. What distance must the object be from the center of the rod to balance the system?

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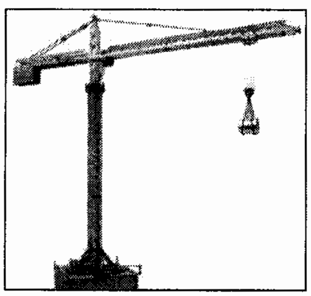
Force, Weight & Balance



$F_1D_1 = F_2D_2$

- Used to evaluate safe loads when a counterweight is used and fairly fixed from the mast of a tower crane as shown.

A tower crane has a counterweight of 350,000 lbs located about 45 feet from the crane's mast. If steel beams must be lifted from a distance 150 feet from the crane's mast, what is the maximum load in lbs that can be lifted safely?

(350,000 lbs) (45 feet) = (F) (150 feet)
Solve for F

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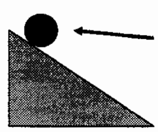
Energy

- Energy: the capacity to do work (or produce heat).

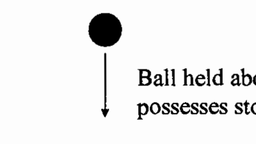
- Kinetic energy: the energy of motion.
  - Thermal energy: submicroscopic particles in motion.
  - Mechanical energy: macroscopic objects in motion.
  - Electrical energy: movement of electrons through a conductor.
  - Sound energy: compression/expansion of spaces between molecules.

- Potential energy: the energy of position; stored energy.
  - Chemical potential energy: position of electrons relative to atomic nuclei in bound atoms.
  - Gravitational energy: position of an object in a gravitational field.
  - Electrostatic energy: relative position of charged particles.

Potential Energy



Ball possesses stored energy.



Ball held above the ground possesses stored energy.

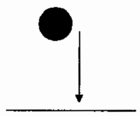
Gravitational Energy is expressed as:

PE = (mass)(gravitational acceleration)(height) = mgh

Energy	Mass	Acceleration	Height
Joules	Kilograms	mass/second^2	Meters
Foot-Pounds	Pounds	feet/second^2	Feet

Kinetic Energy

• Defined as the mechanical energy that a body has by virtue of its motion.



A falling object will give its kinetic energy to the ground

An object speeding towards another object will give its kinetic energy to the object that it collides with.

$$\text{Kinetic Energy} = \frac{(\text{mass})(\text{velocity})^2}{2}$$

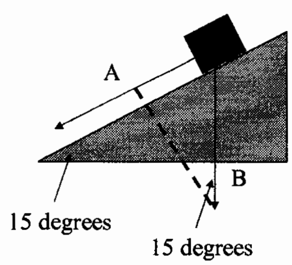
A car, whose mass is 93 lbs traveling at 35 miles per hour, hits a New Jersey barrier. How much KE was given out when the crash occurred? Then, using that KE value, at what equivalent height would that car need to be in order to produce the same amount of energy when it falls to the ground? (Famous All-State Insurance commercial)

$$\frac{(93\text{ lbs})(51.3\text{ feet per second})^2}{2} = 122{,}374\text{ ft-lbs} = PE = mgh = (93)(32.2\text{ ft/s}^2)(h)$$

$$h = 41\text{ feet}$$

Hitting the NJ Barrier at 35 mph with a car's mass of 93 lbs is equivalent to dropping it from 41 feet.

Force Problems



Force required to lift or prevent objects from moving down a ramp can be determined using the previous equations and use of trigonometry.

Example: How much force is required to prevent a 360 lb load from sliding down a ramp? Friction of the ramp is considered negligible.

1) Draw diagram representing different forces being exerted by the object on the ramp.
   A = Force of object down the ramp if no friction or other force placed against it = Solution to Problem
   B = Gravitational Force
2) Draw right triangle. Note that the degree of incline is equal to angle at B.
3) Using trigonometry, solve for A = Force of the object down the ramp, which one needs to minimally apply against it to prevent it from slipping.

$$\sin 15 = \frac{A}{B}$$

$$\sin 15 = \frac{A}{360\text{ lbs}}$$

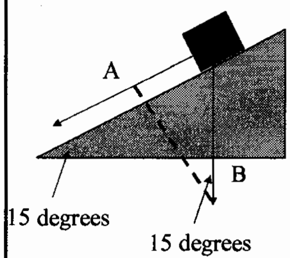
A = **93.2 lbs** required to keep object form sliding.

Frictional Forces

In reality, friction must be accounted for. Friction affects the amount of force used.

Frictional Force = uN

where u=coefficient of friction; N=amount of total force.



Object weighs 2500 lbs. If the ramp has a coefficient of friction of 0.10, how much frictional force is exerted on the object to keep it from sliding.

(1) Solve for C, force of object on ramp's surface.

$$\cos(15) = \frac{C}{2500 \text{ lbs}}$$

C = 2415 lbs = Represents total force; some of force represents frictional force.

(2) Use F = uN = (0.10) (2415) = <u>241.5 lbs</u> of frictional force is applied to the object to keep it from sliding.

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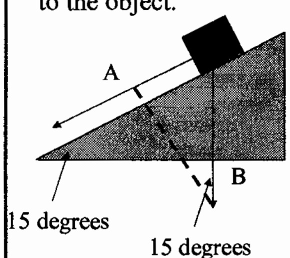
Frictional Forces

The amount of force needed to keep an object from moving down a ramp is affected by the frictional force already applied by the ramp to the object.



$$\sin(15 \text{ deg}) = \frac{A}{2500 \text{ lbs}}$$

A = 647 lbs

Object weighs 2500 lbs. If the ramp has a coefficient of friction of 0.10, how much force is needed to keep the object from sliding?

1) Here, you solve for A (as in previous slides). A represents the force the object will slide down the ramp; therefore, an equal, but opposite amount of force is needed to keep it from sliding.

2) Determine frictional force (as in previous slide). F = 241.5 lbs

3) If you already have 241.5 lbs of frictional force exerted on the object to keep it from moving down the ramp, how much more force do you need to keep the object from sliding

647 lbs (from A) – 241.5 lbs = <u>405.5 lbs Needed</u>

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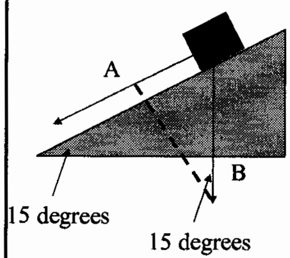
Force – Moving Up the Ramp

Often, the more important question is HOW MUCH FORCE is needed to move an object up the ramp.



Using the previous problem, how much force is needed to move the 2500 lb object UP the ramp?

1) Solve for both force needed to hold the object in place (A) and the frictional force placed on the object by the ramp (C).

Force Down the Ramp = 647 lbs (see previous slide)
Frictional Force = 241.1 lbs (see previous slide)

2) Force needed to OVERCOME the downward force and the frictional force.

647 lbs + 241.1 lbs = <u>888.1 lbs</u>

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Speed

Three expressions:

<u>Final velocity (v)</u>

$v = v_0 + (a)(t)$

<u>Distance traveled</u>

$s = v_0 t + [(a)(t)^2] / 2$

<u>Final velocity (v) if distance known</u>

$v^2 = v_0^2 + 2as$

<u>Velocity affected by Friction and Distance Traveled</u>

$V_{mph} = \sqrt{(30 \times S \times u)}$ where u = coefficient of friciton; S is distance in feet.

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Speed

A vehicle traveling on a straight section of a road makes an emergency stop. You measure the skid marks as 132 feet. What speed was the vehicle traveling? Dry asphalt has a friction of 0.66.

$$Vmph = \sqrt{(30 \times S \times u)}$$
$$= \sqrt{(30 \times 132 \times 0.66)} = 51 \text{ mph}$$

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Speed – Different Road Surfaces

A vehicle created 110 feet of skids on concrete with coefficient of friction of 0.65, and 36 feet of skid on asphalt with coefficient of friction of 0.7. What was the vehicle's estimated speed?

$$Vmph = \sqrt{(30 \times S \times u)}$$

Solve for each speed for each of the different road surfaces.
Then, add them algebraically.

Concrete: $\sqrt{(30 \times 110 \text{ ft} \times 0.65)} = 46.3$ mph
Asphalt: $\sqrt{(30 \times 36 \text{ ft} \times 0.7)} = 27.5$ mph

$$\sqrt{(V_1^2 + V_2^2)} = \sqrt{(46.3)^2 + (27.5)^2} = \underline{53.9 \text{ mph}}$$

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Speed – Incline/Declination

Rule: 1 percent incline/decline = 1 add/subtract 1 percent of the coefficient of friction

If a car leaves the road, and falls down on a embankment at 12 % grade down, and there are 23 feet skid marks on the grass with an estimated coefficient of friction of 0.35, what estimated speed was the car traveling?

Vmph = √(30 x S x u) = √(30 x 23 x (0.35-0.12) = 12.6 mph

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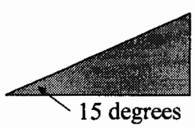
Speed – Incline/Declination

Rule: 1 percent incline/decline = 1 add/subtract 1 percent of the coefficient of friction

If a car leaves the road, and travels up on a embankment at 15 degree incline, and there are 52 feet skid marks on the gravel with an estimated coefficient of friction of 0.55, what estimated speed was the car traveling?



To determine the percent incline, simply take the Tangent of the incline (or decline) angle:
Tan (15 degrees) = 0.27

Vmph = √(30 x S x u) = √(30 x 52 ft x (0.55+0.27) = 35.7 mph

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Hydraulics

- Used to determine whether fire supply water systems are adequately designed to get the required flow.

$$Q_2 = Q_1 \frac{(S - R_2)^{0.54}}{(S - R_1)^{0.54}}$$

where
Q = Water Flow (Gallons per Minute (gpm))
S = Static Pressure in the line
(pounds per square inch (psi))
R = Residual Pressure (psi)

Higher the psi, the lower the water flow.
Lower the psi, the higher the water flow. (*A 15 psi differential is often preferred in fire supply water systems.

During a flow test on-board a vessel, the fire supply water system flowing at 6200 gpm dropped its pressure from 80 psi to 32 psi. Maximum flow was found to be achieved at a pressure of 25 psi. How much water flow, therefore, was available in this system?

$$Q_2 = 6200 \frac{(80 - 25)^{0.54}}{(80 - 32)^{0.54}} \quad = \underline{6673 \text{ gpm available}}$$

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Hydraulics

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where
Q = Water Flow (Gallons per Minute (gpm))
S = Static Pressure in the line
(pounds per square inch (psi))
R = Residual Pressure (psi)

During a flow test, 1500 gpm was flowing at a static pressure of 60 psi and dropped to a residual pressure of 50 psi. 2500 gpm was the maximum water flow achieved. If the insurance carrier requires a minimum residual pressure of 20 psi at the maximum flow rate, does this system pass the insurance carrier's test criteria?

$$2500 = 1500 \frac{(60 - R_2)^{0.54}}{(60 - 50)^{0.54}}$$

Solve for R_2 = Residual Pressure at Max Water Flow.

R_2 = **34.2 psi**

The fire supply water system meets the insurance carrier's criteria.

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Group Exercises

1. A ramp with a 30 degree incline angle must be used to transport a 3200 lb aircraft component. If the ramp has a coefficient of friction of 0.15, how much additional force must be added to keep the component from slipping?

2. Assuming a frictionless surface, a 2,000 lb forklift is keeping an object from slipping down a ramp, inclined at 4 degrees. How much must this object weigh?

Group Exercises

3. A vehicle is traveling 45 meters per second. If the vehicle weighs about 2500 lbs, how much kinetic energy must it have?

4. A tower crane operator is asked to lift a load at about 230 feet out from its mast. If it is counterweighed at 350,000 lbs at 25 feet from its mast, what is the maximum load a that reach can the crane safely lift?

Practical Test

5 Questions
10 Minutes to Complete

Battle Drills
Engineering and Physics Part I

1. A tower crane must lift a load weighing 1500 lbs. Its counterweight is located 60 feet from the mast. If the load is lifted about 100 feet from the mast, how much counterweight in pounds is required?

a. 450 lbs
b. 2500 lbs
c. 2200 lbs
d. 1200 lbs

2. During an accident investigation, an engineer, reviewing the damaged structure, estimated that approximately 150,000 ft-lbs/sec^2 of force had impacted into a store's structure. If the car had a mass of 2200 lbs, how fast in miles per hour must the car have traveled when it crashed?

a. 5.5 mph
b. 2.3 mph
c. 8.0 mph
d. 5.0 mph

3. There is a 5000 lb object that must be kept on the ramp for the evening. There is a 5 degree ramp. Assuming a negligible friction, what is the required force needed against the object to keep it from slipping off this ramp?

a. 435.8 lbs
b. 1,000 lbs
c. 235 lbs
d. 456.2 lbs

4. A tower crane has a standard counterweight of 345,000 lbs with a distance of 20 feet from the tower's mast. Is it sufficient to lift a 55,000 lb load at a reach of 140 feet from the mast as requested by the job foreman?

a. Yes
b. No

5. During an accident investigation, a vehicle created 220 feet of braking skids on asphalt having a coefficient of friction of 0.45, and 66 feet of skid on grass having a coefficient of friction of 0.67 before hitting a tree. What was the vehicle's estimated speed?

a. 45.5 mph
b. 65.6 mph
c. 76.5 mph
d. 89.3 mph