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PROBLEM 1.3.1

Derive conversion fractors for changing the following U.S. Customary units to their SI equivalents:

GOAL : Derive conversion factors from U.S. Customary to SI for:

a. Pressure, lb/in^2

b. Force, kip

c. Volume, ft^3

d. Area, in^2

GIVEN : four units, (a)-(d)

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE**

(a):

$$\frac{1\,\text{lb}}{1\,\text{in}^2}\left(\frac{4.4482\,\text{N}}{1\,\text{lb}}\right)\left(\frac{12\,\text{in}}{0.3048\,\text{m}}\right)^2 = 6894.72\,\text{N/m}^2$$

(b):

$$1\,\text{kip}\left(\frac{1000\,\text{lb}}{1\,\text{kip}}\right)\left(\frac{4.4482\,\text{N}}{1\,\text{lb}}\right) = 4448.2\,\text{N}$$

(c):

$$1\,\text{ft}^3\left(\frac{0.3048\,\text{m}}{1\,\text{ft}}\right)^3 = 0.0283\,\text{m}^3$$

(d):

$$1\,\text{in}^2\left(\frac{0.3048\,\text{m}}{12\,\text{in}}\right)^2 = 0.0006452\,\text{m}^2$$

RESULTS :

(a)	$1\,\text{lb}/\text{in}^2$	=	$6894.72\,\text{N/m}^2$
(b)	1 kip	=	4448.2 N
(c)	$1\,\text{ft}^3$	=	$0.0283\,\text{m}^3$
(d)	$1\,\text{in}^2$	=	$0.0006452\,\text{m}^2$

CHECK : Check calculations, or perform reverse conversion to ensure accuracy.

PROBLEM 1.3.2

Derive conversion fractors for changing the following SI units to their U.S Customary equivalents:

GOAL : Derive conversion factors from SI to U.S. Customary for:

a. Pressure, N/m^2

b. Pressure, MPa

c. Volume, m^3

d. Area, mm^2

GIVEN : four units, (a)-(d)

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE**

(a):

$$\frac{1\ \text{N}}{1\ \text{m}^2}\left(\frac{0.2248\ \text{lb}}{1\ \text{N}}\right)\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^2 = 0.0209\ \text{lb/ft}^2$$

(b):

$$1\ \text{MPa}\left(\frac{1\text{x}10^6\text{Pa}}{1\text{MPa}}\right)\left(\frac{0.2248\ \text{lb}}{1\ \text{N}}\right)\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^2 = 20,885\ \text{lb/ft}^2$$

(c):

$$1\ \text{m}^3\left(\frac{3.2808\ \text{ft}}{1\ \text{m}}\right)^3 = 35.313\ \text{ft}^3$$

(d):

$$1\ \text{mm}^2\left(\frac{3.2808\ \text{ft}}{1000\ \text{mm}}\right)^2 = 0.0000108\ \text{ft}^2$$

RESULTS :

(a)	$1\ \text{N/m}^2$	=	$0.0209\ \text{lb/ft}^2$
(b)	MPa	=	$20,885\ \text{lb/ft}^2$
(c)	$1\ \text{m}^3$	=	$35.313\ \text{ft}^3$
(d)	$1\ \text{mm}^2$	=	$0.0000108\ \text{ft}^2$

CHECK : Check calculations, or perform reverse conversion to ensure accuracy.

PROBLEM 1.3.3

Jamaican sprinter Asafa Powell set the world record for the 100-meter dash on May 27,2010. His time was 9.07 seconds.

GOAL : Calculate Phis average speed in m/s, ft/s, and mph.

GIVEN : time of 9.07 seconds

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

For m/s:

$$\frac{100\,\text{m}}{9.07\,\text{s}} = 11.03\,\text{m/s}$$

For ft/s:

$$\frac{100\,\text{m}}{9.07\,\text{s}}\left(\frac{3.2808\,\text{ft}}{1\ \text{m}}\right) = 36.172\,\text{ft/s}$$

For mph:

$$\frac{100\,\text{m}}{9.07\,\text{s}}\left(\frac{3.2808\,\text{ft}}{1\,\text{m}}\right)\left(\frac{1\ \text{mile}}{5280\,\text{ft}}\right)\left(\frac{3600\,\text{s}}{1\ \text{hr}}\right) = 24.66\ \text{mph}$$

RESULTS : The average speed is:

$$\boxed{\begin{array}{l} 11.03\,\text{m/s} \\ 36.17\,\text{ft/s} \\ 24.66\ \text{mph} \end{array}}$$

CHECK : Check calculations.

PROBLEM 1.3.4

Calculate the percent difference between the mile and the metric mile

GOAL : Calculate the percent difference between the mile and the metric mile

GIVEN : a metric mile is 1500 meters

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

Convert 1 mile to meters:

$$1\text{ mile}\left(\frac{5280\,\text{ft}}{1\text{ mile}}\right)\left(\frac{0.3048\,\text{m}}{1\,\text{ft}}\right) = 1609.34\,\text{m}$$

Calculate the percent difference (difference divided by the average):

$$\frac{1609.34 - 1500}{\frac{1}{2}(1500 + 1609.34)} * 100 = 7.03\%$$

RESULTS : The percent difference is:

$$\boxed{7.03\%}$$

CHECK : Check calculations. Note that percent difference is different from percent error, which would be the difference divided by the "correct" number.

PROBLEM 1.3.5

The world best performance in the women's marathon is 2:17:42, set by Paula Radcliffe of the United Kingdom on April 17,2005 in the London Marathon. On average, how long did it take her to run each mile? What was her average speed in m/s? A previous best performance was 2:18:47, turned in by Catherine Ndereba from Kenya. (The race was run in Chicago on October 7, 2001.) How much faster did Paula Radcliffe run each mile of the race?

GOAL : Calculate Radcliffe's average time per mile, and her average speed in m/s. Compared to Ndereba, calculate how much faster Radcliffe ran each mile of the race.

GIVEN : Marathon is 26.2 miles, Radcliffe's time was 2:17.42, Ndereba's time was 2:18.47.

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

Radcliffe's time per mile:

$$\frac{137.70 \text{ min}}{26.2 \text{ mile}} = 5.26 \text{ min/ mile}$$

Radcliffe's average speed:

$$\frac{26.2 \text{ mile}}{137.70 \text{ min}} \left(\frac{5280 \text{ ft}}{1 \text{ mile}}\right) \left(\frac{0.3048 \text{ m}}{1 \text{ ft}}\right) \left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 5.103 \text{ m/s}$$

Difference per mile

$$\frac{138.78 \text{ min} - 137.70 \text{ min}}{26.2 \text{ mile}} \left(\frac{60 \text{ s}}{\text{min}}\right) = 2.473 \text{ s/mile}$$

RESULTS :

Radcliffe's time per mile:	5.26 min
Radcliffe's average speed:	5.10 m/s
Radcliffe ran each mile faster by:	2.47 s

Note that the difference between the two runners could also be expressed in minutes (0.041 min), or as a difference in average speed (5.103 m/s for Radcliffe vs 5.064 m/s for Ndereba, or 0.04 m/s difference).

CHECK : Check calculations, and ensure that these values seem realistic.

PROBLEM 1.3.6

In the heavyweight division, Russian Aleksey Lovchev holds the world record for the clean and jerk. He lifted a mass of 264 kg. Calculate the mass in slugs. What is the corresponding weight in newtons and pounds? How many people would it take to clean and jerk a Porshe 911 if they were all as strong as Aleksey Lovchev?

GOAL : Convert the record mass to slugs and calculate the weight in newtons and pounds. Estimate how many people it would take to clean and jerk a Porsche 911 if each could match Lovchev's record.

GIVEN : Lovchev's record mass 264.0 kg. 2005 Porsche 911 standard curb weight of 3075 lb

ASSUME : Earth gravity

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

Lovchev's record in slugs:

$$264.0\,\text{kg}\left(\frac{0.06852\text{ slug}}{1\text{ kg}}\right) = 18.09\text{ slug}$$

Weight in newtons:

$$264.0\,\text{kg}\left(9.81\text{ m/s}^2\right) = 2589.8\,\text{N}$$

Weight in pounds:

$$2589.8\,\text{N}\left(\frac{0.2248\,\text{lb}}{1\,\text{N}}\right) = 582.2\,\text{lb}$$

Given the 911 curb weight, calculate the number of Lovchevs necessary:

$$3075\,\text{lb}\left(\frac{1\text{ Lovchev}}{582.2\,\text{lb}}\right) = 5.3\text{ Lovchev}$$

Thus it will take a minimum of 6 (very strong) people to clean and jerk a Porsche 911.

RESULTS :

Lovchev's record in slugs:	18.09 slugs
Weight in Newtons:	2589.8 N
Weight in Pounds:	582.2 lb
People it would take:	6

CHECK : Check calculations, and ensure that these values seem realistic.

PROBLEM 1.3.7

When a certain linear spring has a length of 180 mm, the tension in it is 170 N. for a length of 160 mm, the compressive force in the spring is 120 N.

GOAL : For the linear spring specified:

a. Calculate the spring stiffness in SI and U.S. Customary units.

b. Calculate the unstretched length in SI and U.S. Customary units.

GIVEN : At 180mm, the spring has a tensile force of 170N. At 160mm, the spring has a compressive force of 120N.

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

Stiffness is given as force over distance

$$\frac{170\,\mathrm{N} - (-120\,\mathrm{N})}{180\,\mathrm{mm} - 160\,\mathrm{mm}} = 14.5\,\mathrm{N/mm} = 14,500\,\mathrm{N/m}$$

Convert to U.S. Customary

$$1.45\mathrm{E{+}04}\,\mathrm{N/m}\left(\frac{0.2248\,\mathrm{lb}}{1\,\mathrm{N}}\right)\left(\frac{1\,\mathrm{m}}{3.2808\,\mathrm{ft}}\right) = 994\,\mathrm{lb/ft}$$

Unstretched length

$$180\,\mathrm{mm} - 170\,\mathrm{N}\left(\frac{1\,\mathrm{mm}}{14.5\,\mathrm{N}}\right) = 168.276\,\mathrm{mm}$$

Convert to U.S. Customary

$$0.168276\,\mathrm{m}\left(\frac{3.2808\,\mathrm{ft}}{1\,\mathrm{m}}\right) = 0.552\,\mathrm{ft}$$

RESULTS :

Stiffness:	1.45E+04 N/m	9.94E+02 lb/ft
Unstretched Length:	1.68E-01m	5.52E-01ft

CHECK : Check calculations, and ensure that these values seem realistic.

PROBLEM 1.3.8

Complete the following two tables

GOAL : Convert the records in the tables to the correct units.

GIVEN : Two tables for men's and women's world records, 1.3.8a and 1.3.8b

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** : using conversion factors from Table 1.3.

RESULTS for Table 1.3.8a:

Event	m	cm	in	ft	mi
High jump	2.45	245	96.5	8.04	1.52E-03
Pole vault	6.16	616	242.5	20.21	3.83E-03
Long jump	8.95	895	352.4	29.37	5.56E-03
Triple jump	18.29	1829	720.1	60.01	1.14E-02
Shot put	23.12	2312	910.2	75.85	1.44E-02
Discus throw	74.08	7408	2916.5	243.04	4.60E-02
Hammer throw	86.74	8674	3414.9	284.58	5.39E-02
Javelin throw	98.48	9848	3877.2	323.10	6.12E-02

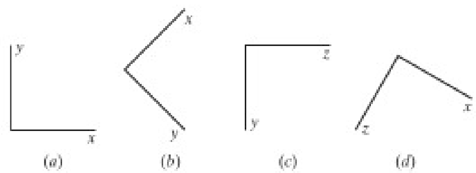
RESULTS for Table 1.3.8b:

Event	m	cm	in	ft	mi
High jump	2.09	209	82.3	6.86	1.30E-03
Pole vault	5.06	506	199.2	16.60	3.14E-03
Long jump	7.52	752	296.0	24.67	4.67E-03
Triple jump	15.50	1550	610.2	50.85	9.63E-03
Shot put	22.63	2263	890.9	74.25	1.41E-02
Discus throw	76.80	7680	3023.6	251.97	4.77E-02
Hammer throw	81.08	8108	3192.1	266.01	5.04E-02
Javelin throw	72.28	7228	2845.7	237.14	4.49E-02

CHECK : Use extra tables values to make sure conversions are correct.

PROBLEM 1.4.1

Determine whether the missing axis in each case is oriented into or out of the page for a right-handed coordinate system.



GOAL : Determine the direction of the missing axis (into or out of the page)

GIVEN : Four sets of axes

ASSUME : Right-hand rule

DRAW : No drawings necessary

FORMULATE EQUATIONS and **SOLVE** : No equations necessary

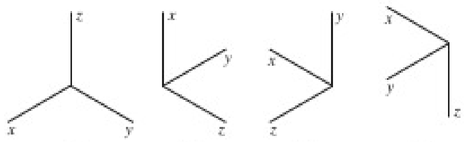
RESULTS : Using the right-hand rule:

(a)	z-axis points out
(b)	z-axis points in
(c)	x-axis points out
(d)	y-axis points out

CHECK : Each frame can be constructed using one's hands, following the convention of Figure 1.3.

PROBLEM 1.4.2

Which of the coordinate systems are right handed.



(a) (b) (c) (d)

GOAL : State which coordinate systems are right-handed, include assumptions.

GIVEN : four coordinate systems

ASSUME : (a) z-axis in the plane of the page, (b) x-axis in the plane of the page, (c) y-axis in the plane of the page, (d) z-axis in the plane of the page

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** : none necessary

RESULTS :

(a)	yes
(b)	no
(c)	no
(d)	no

CHECK : Use right-hand rule

PROBLEM 1.5.1

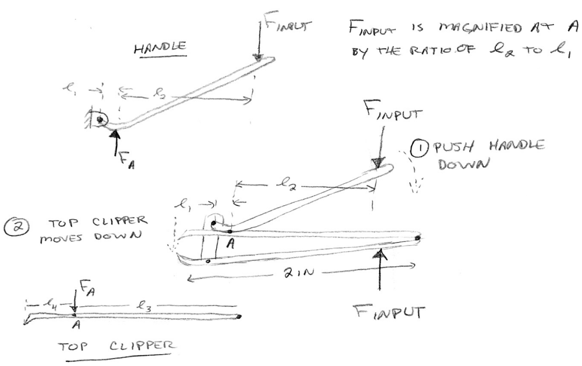
Identify three devices that involve a conversion of human input (i.e., forces and movements) into some other force or movement. Create sketches of each device that show how you think it works and what forces are involved.

GOAL : Sketch three devices that convert human input into some other force or movement and show how you think it works and what forces are involved.

GIVEN : No givens.

ASSUME : No assumptions necessary

DRAW : Here is one device as an example:



FORMULATE EQUATIONS and **SOLVE** : none nec-

essary

RESULTS : Particular attention should be paid to guidelines given in Section 1.5, especially the last four items listed in Box 1.3. These include proportion, scale, symbols and planning. Objects should be in good proportion, there should be a sense of scale to the drawing (using something of known size, a textual note, grid, or a few dimensions), appropriate use of symbols (arrows, people, coordinates, etc.), and proper planning to show multiple views, etc.

CHECK : Review the items in Box 1.3 to ensure conformity.

PROBLEM 1.5.2

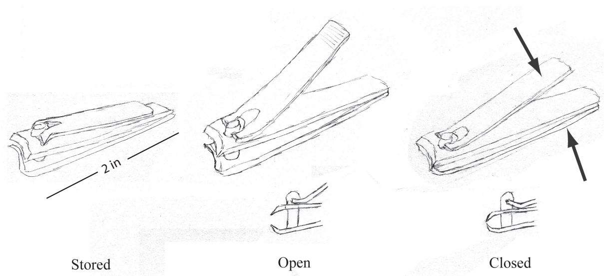
Find an interesting artifact in your kitchen, garage, or dorm room. Create a storyboard of how the artifact works or how it is operated.

GOAL : Create a storyboard of how an artifact works or is operated

GIVEN : none

ASSUME : none

DRAW : Here is an example of a simple storyboard:



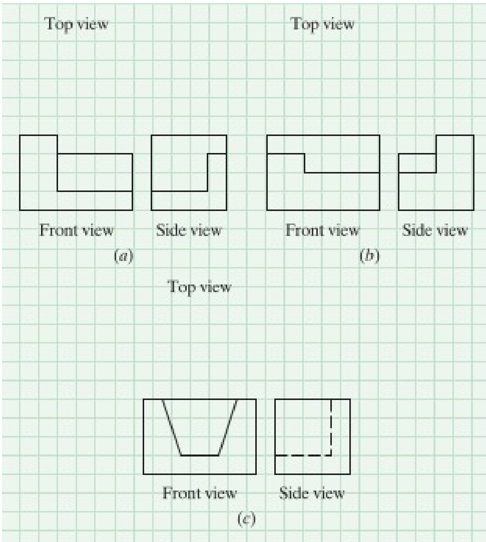
FORMULATE EQUATIONS and **SOLVE** : none

RESULTS : Particular attention should be paid to guidelines given in Section 1.5, especially the last four items listed in Box 1.3. These include proportion, scale, symbols and planning. Objects should be in good proportion, there should be a sense of scale to the drawing (using something of known size, a textual note, grid, or a few dimensions), appropriate use of symbols (arrows, people, coordinates, etc.), and proper planning to show multiple views, etc.

CHECK : Review the items in Box 1.3 to ensure conformity.

PROBLEM 1.5.3

Given the front and side views in the three multi-view drawings, sketch the missing top view in each case.

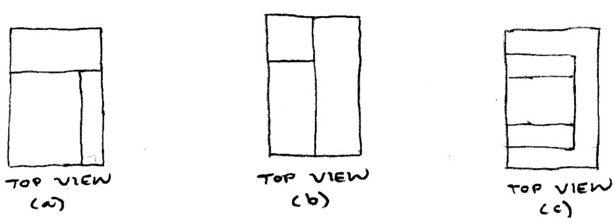


GOAL : Sketch the missing top views

GIVEN : Three multi-view drawings (a)-(c)

ASSUME : No assumptions necessary

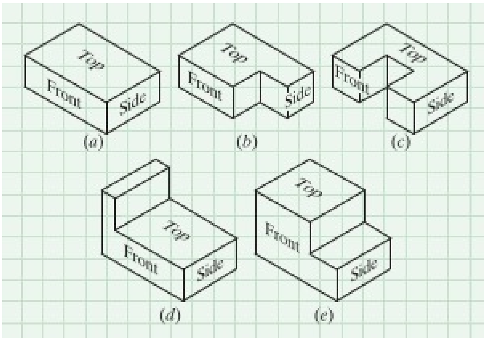
DRAW and **RESULTS** :



CHECK : Reconstruct either the side or front view from the other two to ensure correctness.

PROBLEM 1.5.4

For each of the five objects, create a multi-view drawing showing separate front, side, and top views.

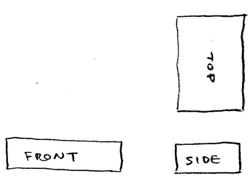


GOAL : Sketch the front, side and top views for the five objects in E1.5.4

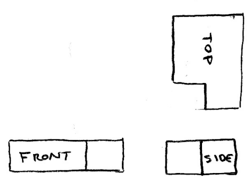
GIVEN : five objects, (a)-(e)

ASSUME : No assumptions necessary

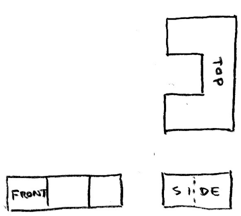
DRAW and **RESULTS** :



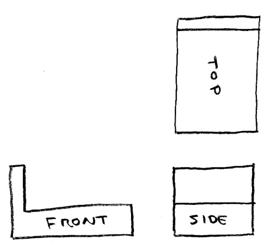
(a)



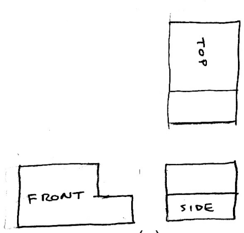
(b)



(c)



(d)



(e)

CHECK : reconstruct the three-dimensional images.

PROBLEM 1.5.5

To get more experience inspecting and drawing systems, complete exercise SA D.1 (1,2, and 4) in Appendix D on how a bicycle works.

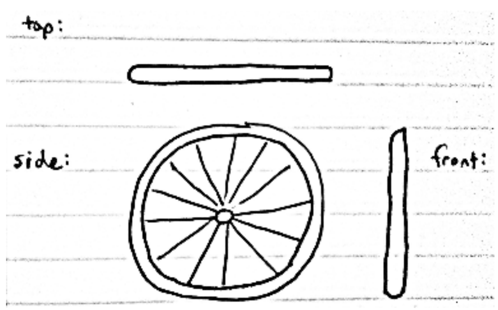
GOAL : Draw and inspect bicycle system and subsystems.

GIVEN : No givens

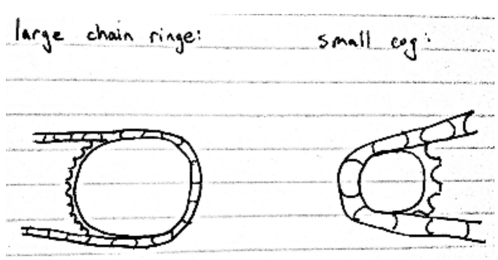
ASSUME : No assumptions necessary

DRAW and **RESULTS** :

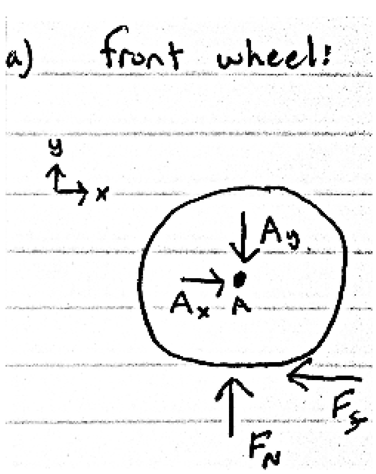
1:

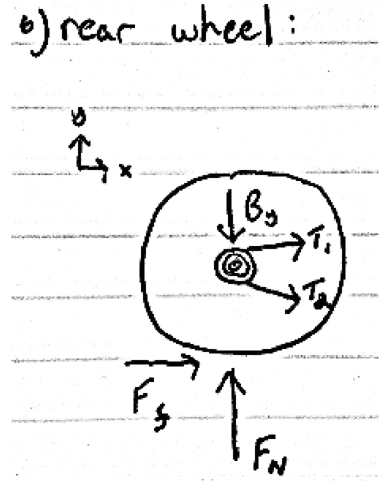


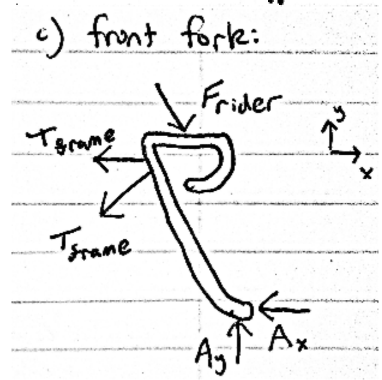
2 (answers will vary):



4:







PROBLEM 1.5.6

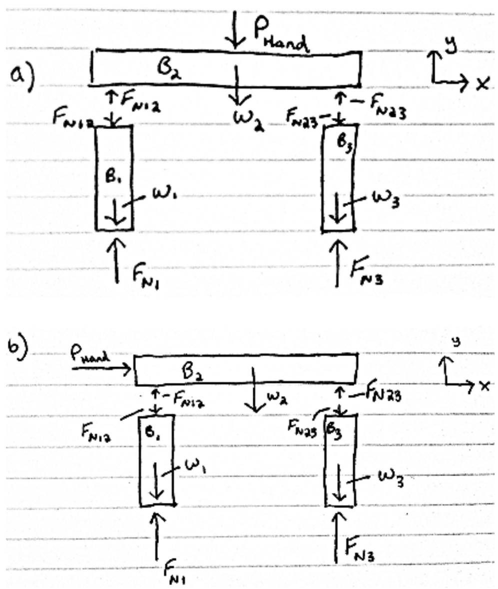
To get more experience inspecting and drawing systems, complete exercise SA E.2 in Appendix E on how a beam bridge works.

GOAL : Draw and inspect simple beam bridge design

GIVEN : Beam bridge build from 3 books.

ASSUME : No assumptions necessary

DRAW :



RESULTS : In part (b), the bridge falls over because there is no other force in the horizontal direction that balances the force of your hand. In part (c), the deck sags under the weight of your hand.

PROBLEM 1.5.7

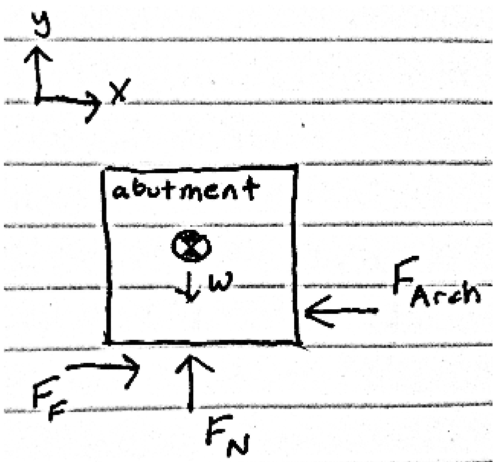
To get more experience inspecting and drawing systems, complete exercise SA E.3 in Appendix E on how an arch bridge works.

GOAL : Draw and inspect arch bridge design

GIVEN : Simple arch bridge with abutments.

ASSUME : No assumptions necessary

DRAW :



RESULTS :
(a) The arch is in compression and the ends of the arch want to slowly move outwards under increased load.

(b) The abutments restrict the ends of the arch from moving outward

(c) The arch is pushing on the abutments

(d) The frictional force of the abutments against the ground prevents them from sliding

(e) The abutments provide more resistance to the load pushing downward

(f) See drawing

(g) A heavier abutment will allow for higher load on the arch because it will not slide as easily

(h) There are no forces pulling on the abutment. In the suspension bridge, the anchorage is being pulled by the cables. This is the opposite from what is occurring with the abutment. The analysis requires modeling the amount of horizontal force that the arch bridge applies with a corresponding vertical load. The abutment will then need to balance that horizontal force without moving.

PROBLEM 1.6.1

Round off the numbers listed below to three significant figures.

GOAL : Round the numbers to three significant figures

GIVEN : six numbers, labeled (a) through (f)

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** : none necessary

RESULTS : for clarity, should be shown as the column on the far right:

(a)	0.0154	$1.54(10^{-2})$
(b)	0.837	$8.37(10^{-1})$
(c)	1.84	$1.84(10^{0})$
(d)	26.4	$2.64(10^{1})$
(e)	375	$3.75(10^{2})$
(f)	6470	$6.47(10^{3})$

CHECK : Make sure rounding was performed correctly.

PROBLEM 1.6.2

When an object moves through a fluid, the magnitude of the drag force F_{drag} acting on the object is given by $\frac{1}{2}C_D\rho V^2 A$, where ρ is the density of the fluid, V is the velocity of the objective relative to the fluid, and A is the cross-sectional area of the object.

GOAL : Find the dimensions of the drag coefficient, C_D

GIVEN : The drag force equation where F_{drag} is the drag force, ρ is the density of the fluid, V is the velocity of the object, and A is the cross-section area of the object

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

$$F_{\text{drag}} = \frac{1}{2}C_D\rho V^2 A$$

Solving for C_D:

$$C_D = \frac{2F_{\text{drag}}}{\rho V^2 A} = \frac{(force)}{\frac{(mass)}{(length)^3}\left(\frac{(length)}{(time)}\right)^2 (length)^2} = \frac{(force)}{\frac{(mass)(length)}{(time)^2}} = 1$$

RESULTS :

$$\boxed{C_D \text{ is dimensionless}}$$

CHECK :

$$F_{\text{drag}} = \frac{1}{2}(1)\frac{(mass)}{(length)^3}\left(\frac{(length)}{(time)}\right)^2 (length)^2 = \frac{(mass)(length)}{(time)^2} = (force)$$

PROBLEM 1.6.3

The pressure within objects subjected to forces is called stress and is given the symbol σ. The equation for stress in an eccentrically loaded short column is:

$$\sigma = -\frac{P}{A} - \frac{Pey}{I}$$

where P is force, A is area, and e and y are lengths. What are the dimensions of the stress σ and the second moment of area I?

GOAL : Find the dimensions for stress, σ, and the second moment of area, I

GIVEN : The equation for stress, where P is a force, A is an area, and e and y are lengths.

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

$$\sigma = -\frac{P}{A} = -\frac{Pey}{I}$$

Using the first relationship:

$$\sigma = -\frac{P}{A} = \frac{(force)}{(length)^2}$$

Using the second relationship:

$$I = -\frac{Pey}{\sigma} = \frac{(force)(length)(length)}{\frac{(force)}{(length)^2}} = (length)^4$$

RESULTS :

$\sigma = (force)/(length)^2$ or force over area
$I = (length)^4$ or length to the forth power

CHECK :

$$\sigma = \frac{(force)(length)(length)}{(length)^4} = \frac{(force)}{(length)^2}$$

PROBLEM 1.6.4

In the expressions that follows, c_1 and c_2 are constants, and θ is an angle.

GOAL : Determine the dimensions of c_1, c_2 and θ for the given equations to be dimensionally correct

GIVEN : four equations

ASSUME : none necessary

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** : (a)

$$a = c_1 \frac{v^2}{x}$$

Solving for c_1

$$c_1 = \frac{ax}{v^2} = \frac{\frac{(length)}{(time)^2}(length)}{\left(\frac{(length)}{(time)}\right)^2} = 1$$

RESULTS : (a)

c_1 is dimensionless

CHECK :

$$\frac{(length)}{(time)^2} = (1)\frac{\left(\frac{(length)}{(time)}\right)^2}{(length)}$$

FORMULATE EQUATIONS and **SOLVE** : (b)

$$\frac{1}{2}mv^2 = c_1 x^2$$

Solving for c_1

$$c_1 = \frac{mv^2}{2x^2} = \frac{(mass)\left(\frac{(length)}{(time)}\right)^2}{(length)^2} = \frac{(mass)}{(time)^2}$$

RESULTS : (b)

$c_1 = (mass)/(time)^2$ or mass over time squared

CHECK :

$$\frac{1}{2}(mass)\left(\frac{(length)}{(time)}\right)^2 = \frac{(mass)}{(time)^2}(length)^2$$

FORMULATE EQUATIONS and **SOLVE** : (c)

$$x = c_1 v + c_2 a^2$$

Using the first half of the equation and solving for c_1

$$c_1 = \frac{x}{v} = \frac{(length)}{\frac{(length)}{(time)}} = (time)$$

Using the second half of the equation and solving for c_2

$$c_2 = \frac{x}{a^2} = \frac{(length)}{\left(\frac{(length)}{(time)^2}\right)^2} = \frac{(time)^4}{(length)}$$

RESULTS : (c)

$c_1 = (time)$

$c_2 = (time)^4/(length)$ or time to the fourth power over length

CHECK :

$$(length) = (time)\frac{(length)}{(time)} + \frac{(time)^4}{(length)}\left(\frac{(length)}{(time)^2}\right)^2$$

FORMULATE EQUATIONS and **SOLVE** : (d)

$$\theta(\text{degrees}) = c_1 \theta(\text{radians})$$

Solving for c_1

$$c_1 = \frac{\theta(\text{degrees})}{\theta(\text{radians})} = \frac{(degrees)}{(radians)}$$

RESULTS : (d)

$c_1 = (degrees)/(radians)$ or degrees over radians

CHECK :

$$(degrees) = \frac{(degrees)}{(radians)}(radians)$$

PROBLEM 1.6.5

The ability to make good educated guesses (often called engineering estimation or intuition) is an important engineering skill that can be practiced. In this problem, you'll practice your skill in estimating how far an average individual would have to run or jog in order to burn off the calories found in a typical candy bar.

GOAL : Estimate how far an average person would have to run to burn off the calories of a candy bar. Then solve the problem using the given information. Calculate the weight of fat this would convert to in newtons and pounds.

GIVEN : a typical runner burns 100 kcal per mile. 9.4 kcal converts to 1 gram of fat

ASSUME : earth gravity

DRAW : none necessary

FORMULATE EQUATIONS and **SOLVE** :

$$d_{\text{miles}} = \frac{C}{100\text{kcal/mile}} = 0.01C \text{ mile/kcal}$$

$$d_{\text{meters}} = \frac{C}{100\text{kcal/mile}} \frac{5280\text{ ft}}{1\text{mile}} \frac{0.3048\text{ m}}{1\text{ ft}} = 16.09C \text{ m/kcal}$$

$$f_{\text{Newtons}} = \frac{C}{9.4\text{kcal/g}} \frac{0.00981\text{ N}}{1\text{g}} = 0.00104C \text{ N/kcal}$$

$$f_{\text{pounds}} = \frac{C}{9.4\text{kcal/g}} \frac{0.00981\text{ N}}{1\text{g}} \frac{0.2248\text{ lb}}{1\text{ N}} = 0.000235C \text{ lb/kcal}$$

RESULTS :

Candy	kcal	mi	m	N	lb
Crunch	230	2.3	3700	0.24	0.054
100 Grand	190	1.9	3100	0.20	0.045
Butterfinger	270	2.7	4300	0.28	0.063
Kit-Kat	220	2.2	3500	0.23	0.052
3 Musketeers	260	2.6	4200	0.27	0.061
Twix	280	2.8	4500	0.29	0.066
Snickers	280	2.8	4500	0.29	0.066
Milky Way	270	2.7	4300	0.28	0.063
M.W.-Lite	170	1.7	2700	0.18	0.040
M.W.-Midnight	220	2.2	3500	0.23	0.052

CHECK : A rule-of-thumb is that 3500 Calories yields one pound, so the conversion seems fairly accurate.

PROBLEM 1.6.6

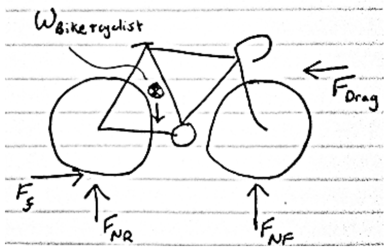
Read sections D.1 and D.2 in Appendix D on how a bicycle works.

GOAL : Draw an FBD of the bicycle and cyclist traveling at constant speed. Estimate the maximum velocity if the coefficient of drag is reduced by 15 percent. List two suggestions for how aerodynamic draw might be reduced.

GIVEN : Geometry of bicycle and rider system.

ASSUME : earth gravity

DRAW :



FORMULATE EQUATIONS and **SOLVE** : From equation 4 in Appendix D, we know that the drag force on the bicycle and cyclist is given by:

$$||F_{drag}|| = (\frac{C_d \rho A}{2})V^2$$

At the cyclist's maximum velocity, there is no acceleration and we can assume that the cyclist and bicycle are in a state of equilibrium where the friction force that is being applied at the rear tire is equal to the drag force:

$$F_{Fmax} = ||F_{drag}|| \quad \Rightarrow \quad F_{Fmax} = (\frac{C_d \rho A}{2})V_{max}^2$$

If we solve for V_{max}:

$$V_{max} = \sqrt{\frac{2F_{Fmax}}{C_d \rho A}}$$

We can describe the relationship between maximum velocity and drag coefficient as:

$$V_{max} \propto \frac{1}{\sqrt{C_d}}$$

If we see a 15 percent reduction in the drag coeffecient then:

$$V_{max} \propto \frac{1}{\sqrt{0.85 C_d}} = \frac{1.08}{\sqrt{C_d}}$$

So we would expect to see an 8 percent increase in the maximum velocity of the cyclist. Using the range given in Appendix D of 43 mph $\leq$ V $\leq$ 54 mph with an 8 percent increase in maximum velocity:

$$\boxed{46 \text{ mph} \leq V_{max} \leq 59 \text{ mph}}$$

The force of drag is dependent on four things: the drag coefficient (C_d), the density of air (ρ), the frontal area of the cyclist-bicycle (A), and the velocity of the air around the bicycle (V). Since we wish to increase (V), our only ways to reduce drag are by changing C_d,A, and ρ. Air density is usually not a property that is controllable, so we can reduce air drag by minimizing A. This could be done by having the cyclist crouch into a more aerodynamic position. We could also effect the coefficient of drag by having the cyclist wear tight clothing that is more streamlined.

CHECK : This analysis intuitively seems correct and when comparing to professional cyclists, we see how they maintain a narrow profile crouching down to reduce the amount of drag on them and wearing streamlined cycling clothing to further reduce drag.

PROBLEM 1.6.7

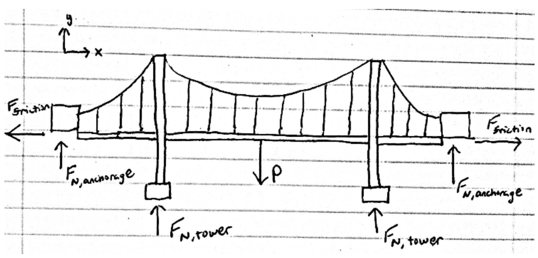
Read Sections E.1 and E.2 in Appendix E on how the Golden Gate Bridge works.

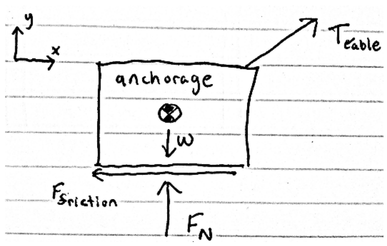
GOAL : Draw FBD of the Golden Gate Bridge. Estimate the anchorage weight if the coefficient of friction is increased by 15 percent. List two suggestions on how to increase the coefficient of friction.

GIVEN : Geometry of the Golden Gate Bridge.

ASSUME : earth gravity

DRAW :





FORMULATE EQUATIONS and **SOLVE** :

We can use equation (E.5) to describe the friction force required to prevent sliding and the Tension in the cable:

$$||F_{HOhorizontal}|| = T_{cable}\cos 19.7^\circ = ||F_{friction,anchorage}||$$

From equation (E.7):

$$||F_{friction,anchorage}|| = (251.2 \text{ MN})(\cos 19.7^\circ) = 236 \text{ MN}$$

From equation (E.8):

$$F_{frictionmax} = \mu_{static} F_{normal,anchorage}$$

With a 15 percent increase for the coefficient of static friction:

$$||F_{friction,anchorage}|| = F_{frictionmax} \quad \Rightarrow$$

$$= \mu_{static} F_{normal,anchorage} = 236.5 \text{ MN}$$

$$F_{normal,anchorage} = \frac{236.5 \text{ MN}}{1.15 \cdot 0.6} = 342.8 \text{ MN}$$

The weight of the anchorage to produce this normal force is found from (E.4):

$$||W_{anchorage}|| = ||F_{normal,anchorage}|| + ||F_{HOvertical}|| \quad \Rightarrow$$

$$= 342.8 \text{ MN} + 84.7 \text{ MN} = 427 \text{ MN}$$

To increase the coefficient of friction, we could add finer material to the ground under the anchorage weight to increase the contact. We could also tamp the material to make it more solid so that there is less loose material that the anchorage would sit on.

RESULTS :

$$\boxed{||W_{anchorage}|| = 427 \text{ MN}}$$

CHECK : Intuitively, an increase in frictional force should decrease the necessary anchorage weight which is the result we obtained.