

p.10 – Add the following as a new paragraph before Example 1.5 :

We have now established one of the basic equations that are used in the analysis of linear motion:

$$a = \frac{\Delta V}{\Delta t}$$

There another basic equation that will be useful:

$$\Delta X = \bar{V} \Delta t$$

This may be understood as follows:

**EXAMPLE**

Imagine driving car at a constant speed of 44 ft/s (30 miles/hr). If you were to ask “How far did the car move during 5 minutes?”, the answer would be easy:

distance equals speed times time

$$\Delta X = V \Delta t$$

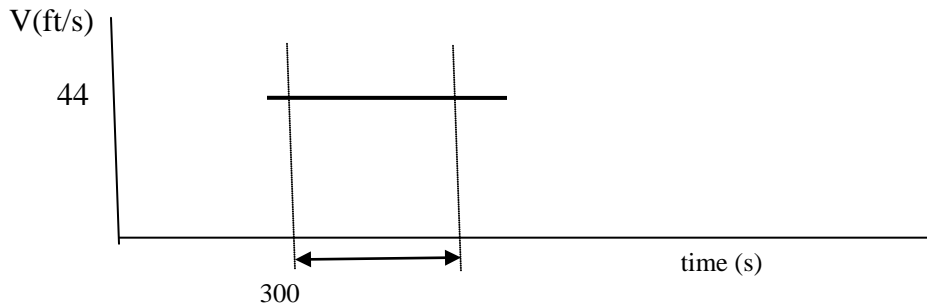
V must equal 44 ft/s and  $\Delta t$  must equal 300s [ (5 min)  $\left(\frac{60s}{1 \text{ min}}\right) = 300s$  ]

$$\Delta X = 13,200 \text{ ft.}$$

**EXAMPLE**

Now suppose that the speed of the car is not constant. Suppose that you start from rest, accelerated smoothly to 44 ft/s (30 miles/hr) in 20s, and then stay at that speed for the remainder of the 5 minutes. How far would the car move?

We can go back to the previous example and represent the information in the form of a graph.



We see that the displacement of the car is equal to the area of the rectangle that is bounded by the curve (dark line) that represents the velocity and the two dotted lines that represent the time interval.

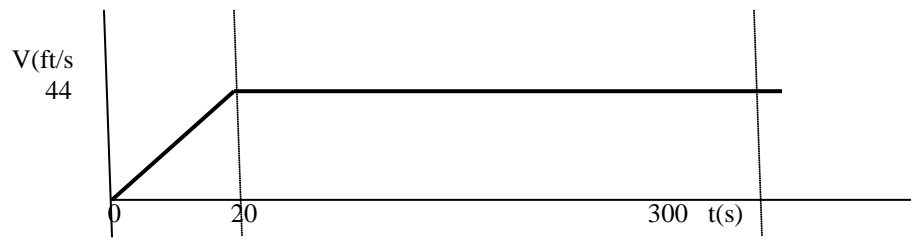
This may be generalized as follows:

On a graph of velocity versus time draw a curve that represents the motion of the object.

On the graph, draw vertical lines that represent the time interval that is specified in the problem.

The displacement of the object during this interval is equal to the area bounded by the curve and the two lines that represent the interval.

Now back to the second example.



We can now easily find the displacement of the car by adding together two areas (a triangle and a rectangle)

$$\begin{aligned}\Delta X &= (0.5)(44 \times 20) + (44 \times 280) \\ &= 12760 \text{ ft}\end{aligned}$$

Referring to the first example, we could ask "What was the car's average velocity?" Since the car was moving at a constant 44 ft/s, its average velocity must have also been 44 ft/s.

$$\bar{V} = 44 \text{ ft} / \text{s}$$

So, the displacement of the car,  $\Delta X$  could be written as:

$$\Delta x = \bar{V} \Delta t$$

This is also a general result. So for example, consider the first 20s of the second example. The graph will be a triangle. The displacement of the car during these 20s will be equal to the area of the triangle:

$$\Delta X = 440 \text{ ft}$$

However,  $\Delta X$  is also given by  $\bar{V} \Delta t$ , where  $\Delta t$  will be 20s.

$$440 = \bar{V} (20)$$

$$\bar{V} = 22 \text{ ft} / \text{s}$$

Notice that this value of the average velocity is equal to

$$\bar{V} = \frac{1}{2}(0 + 44)$$

$$\bar{V} = \frac{1}{2}(V_{\text{start of interval}} + V_{\text{end of interval}})$$

$$\bar{V} = \frac{1}{2}(V_1 + V_2)$$

The last equation will also be one of the basic equations to be used when analyzing linear motion. NOTE, however, that it is only valid for interval in which the acceleration is constant. (Otherwise, the curve would not be a straight line and you would not be finding the area of a triangle.)

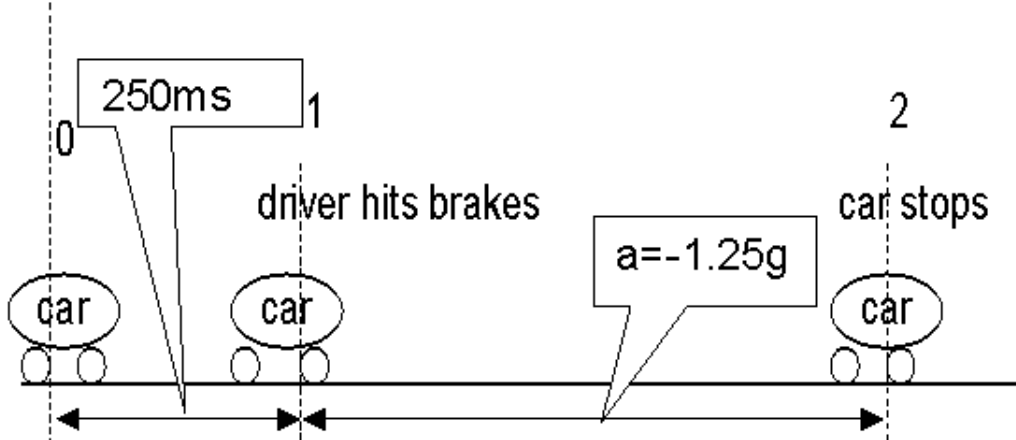
p.12 - There should not be arrows over the F and the  $a_g$  in the equation at the bottom of the page.

p. 18 - At the end of item #2 ".....is moving faster during the AB month than during the CD month."

p. 26 – Problems 2.7 and 2.8 should be inserted here as problems 1.16 and 1.17 respectively.

p. 26 – The following diagram should be added to problem 1.17

driver sees accident

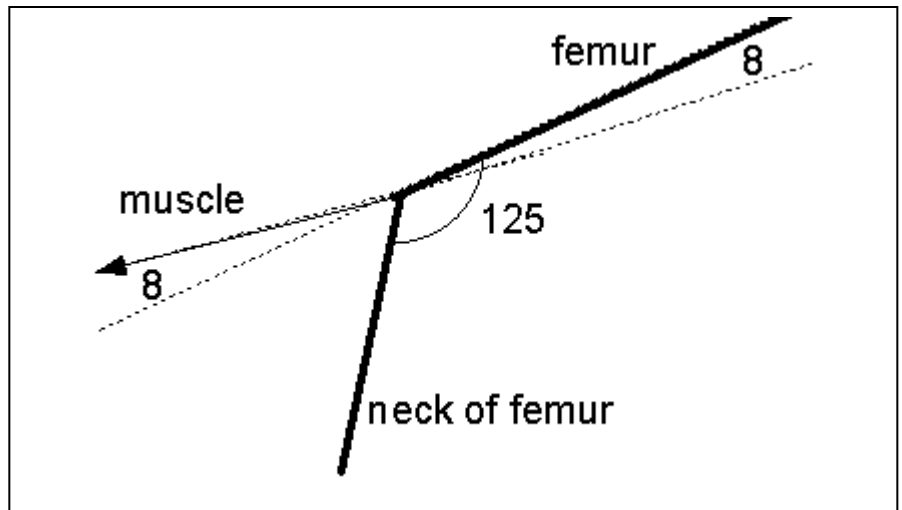


p. 34 - The second line should read: "8N and points at 30° counterclockwise..."

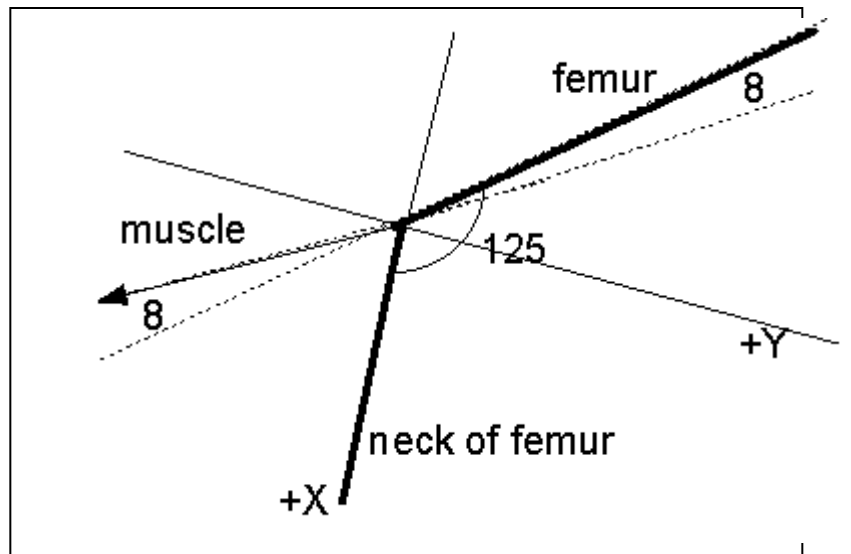
p. 37-39 - Re-write of the solution to example 1.18:

**SOLUTION**

The important idea to be used in this example is that if a force acts on a bone, the component that lies along the bone will cause compression or (rarely) dislocation of the joint, while the component that is perpendicular to the bone will cause rotation about the joint. Thus to answer question "a", we must determine the magnitude of the component of the 104 lb force that lies along the neck of the femur. In question "b" we must calculate the magnitude of the perpendicular component.



We want to determine the component that is along the neck of the femur (to calculate the compressive effect of the muscle). Recall that components are, by their basic definition, measured along the coordinate axes. Since we want to determine components that are either parallel to or perpendicular to the neck of the femur, these two directions must be used to draw the X and Y-axes. Let us label the neck of the femur to be the +X axis. Since the +Y axis must be 90° CCW from the +X axis, we label it as shown in the next figure.



We may now use the formulas established earlier. The angle between the +X axis and the extended muscle line is equal to  $125^\circ - 8^\circ = 117^\circ$ . This means that the angle between the +X axis and the actual muscle vector (angle  $\theta$  for the formulas) is  $180^\circ + 117^\circ = 297^\circ$ .

Substituting, we determine that the compressive effect of the 104-lb force (its component along the *neck of the femur*, the X component) is  $104 \cos 297^\circ = 47.2$  lb [answer to "a"] and the rotation effect (the component perpendicular to the *neck of the femur*, the Y component) is  $104 \sin 297^\circ = -92.7$  lb [answer to "b"] (the minus sign indicates the direction)

For a person suffering from *coxa valga*, the angle between the *femur* and the *neck of the femur* will be  $160^\circ$ . Proceeding as above, we determine that the angle between the *hip abductor muscle* and the *neck of the femur* would become  $332^\circ$ .

$F_{\text{rotation}} = F_{\text{muscle,y}} = F_{\text{muscle}} \sin \theta$ $92.7 = F_{\text{muscle}} \sin 332^\circ$ $F_{\text{muscle}} = 197.5 \text{ lb [answer to "c"]}$
--

**This means that a person who suffers from *coxa valga*, a larger than normal angle between the *neck of the femur* and the *axis of the femur* (see page???), must have a far greater tension in the *hip abductor muscles* to achieve the same amount of rotation of the legs about the hip. This, of course, will result in more compression of the *femur-acetabulum* joint.**

p.42 - The second equation should be:  $F_{LH} = F_L \sin A$

p.46 – The diagram in step 8 is not correct. The three arrows should point up, to the right, and diagonally up and to the right. There should not be an arrow pointing down.

p.52 - In the Analysis section at the bottom of the page: The equation numbers, i.e. (1), (5), and (3) refer to the equations on page 50.

p. 53 - Towards the bottom of the page, in step #4, equation #4 is not correct. The numerator of the right-hand side should be  $\Delta y$  not  $\Delta v$ .

p. 54 - Step 6.a. should read: Combine (6) and (5):  
Step 6.b. should read: Substitute into (4):

p.56 - In figure "b" (at the bottom of the page, the line that represents the vertical should be displaced slightly to the left so that it intersects the lines that represent the axis of the femur and the axis of the neck of the femur.

p. 57 - The answer to Problem 2.4, part b is incorrect. The correct answer is 459N.

p57. Problems 2.7 and 2.8 should be moved to page 26 as problem 1.16 and 1.17 respectively.

p. 57 - The following diagram should be added to Problem 2.8.

p. 61 - In the calculation of the mass of the Earth, the exponent in the denominator should be (-11) rather than (-1).

p.65 - The last equation on the page should be :

$$(10)(9.8) - F_r \sin 30^\circ - F_n = (10)(0)$$

p.66 – The values given at the top of the page should be:

$$F_r = 7.5\text{N}$$

$$F_n = 94.25\text{N}$$

$$\mu = 0.016$$

p.71 – In Example 1.34:

The latitude of Hartford, CT is  $41.47^\circ$ , not  $41.77^\circ$ .

In the solution:

a. “.... circle of radius 2894 miles.”

b. “... circle of radius 2894 miles”

“.....speed is 781 miles per hour (1146 ft/s)”

Last paragraph:

“....speed is very large (781 miles per hour)”

“ ....path is so large (2894 miles)”

p.74 – Problem 3.3 The question should be “ Find the magnitude of the push such that the box will accelerate to the right at  $1.5 \text{ ft/s}^2$ . “

p.76 – Problem 3.12

Part “a” is OK as it is

Replace part “b” by the following:

- b. Consider the instant when the gymnast is at the bottom of the swing.
  - i. Make a free body diagram.
  - ii. Derive an equation for the force that is exerted on her body by her arms.
  - iii. Is there a velocity such that her arms will not be exerting any force on her body?
  - iv. If there is such a velocity, determine its magnitude.
- c. Consider the instant when the gymnast is at the top of the swing.
  - i. Make a free body diagram.
  - ii. Derive an equation for the force that is exerted on her body by her arms.
  - iii. Is there a velocity such that her arms will not be exerting any force on her body?
  - iv. If there is such a velocity, determine its magnitude.

p. 98 - The statement of Example 2.9 should read as follows:

"Consider a 120-lb person who is holding a 115-gram baseball out to the side at arm's length. We want to determine the magnitude and direction of the force that is exerted by the shoulder (the scapula) on the upper arm (the humerus). There will be several forces acting on the arm: "

p. 99 - There should be plus signs with each of the "clockwise" symbols.

p. 100, 101 and 102 - In the first three free body diagrams, the arrow that represents  $F_v$  should be drawn pointing up, not down.

p. 102 - There should be plus signs with each of the "clockwise" symbols.

p. 103-106 – Example 2.11 has been re-written.

Consider a situation in which a 200-lb (889.6N) person is squatting down on both legs while supporting a 300-lb (1334.5N) weight. The person's heels will be off the ground, the lower legs will be bent forward, and the upper legs will be bent backward.



For this particular person, we are given the following information:

1. The lever arm for the quadriceps tendon with respect to the tibia-femur joint is 4.35 cm.
2. The axis of the lower leg makes an angle of  $30^\circ$  with the horizontal.
3. The foot is perpendicular to the axis of the lower leg.

Determine the following:

- i. the tension (Q) in the *quadriceps tendon*
- ii. the magnitude and direction of the force (R) that acts on the upper end of the *tibia*

**SOLUTION:**

1. The object of interest will be one of his lower legs (including the foot).
2. The forces acting on this object are as follows:

Weight<sub>lower leg</sub> :  $W_{\text{lower leg}} = 4.5\%$  of body weight =  $(0.045)(889.6\text{N}) = 40\text{N}$  (acting at the cg of the lower leg)

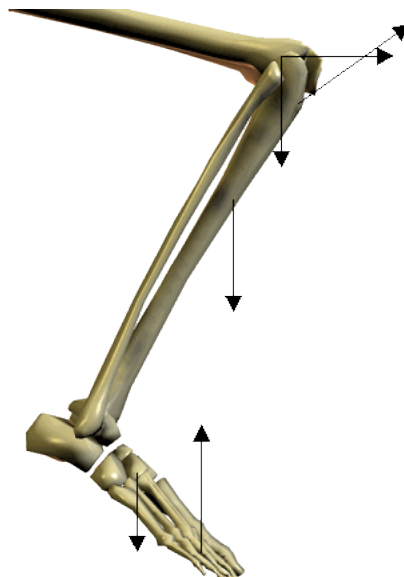
Weight<sub>foot</sub> :  $W_{\text{foot}} = 1.4\%$  of body weight =  $(0.014)(889.6\text{N}) = 12.5\text{N}$  (acting at the cg of the foot)

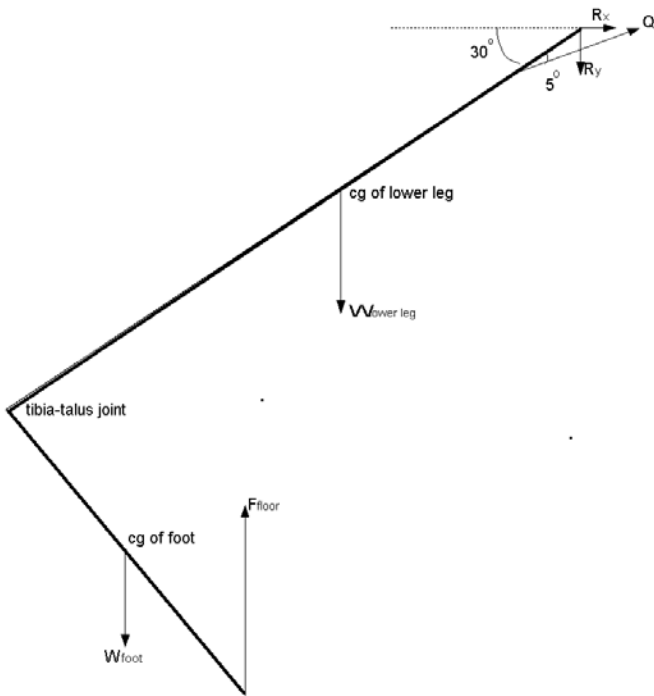
Force<sub>Floor</sub> :  $F_n = 0.5[\text{weight of person } (889.6\text{N}) + \text{weight of the load } (1334.5\text{N})] = 1112.1\text{N}$ . [NOTE: the factor 0.5 is due to the fact that the person is standing on two feet and we are considering only the forces that act on one of them.]

Tension in the *quadriceps tendon* : Q

Force at the *femur-tibia* contact point : R. Neither the magnitude nor the direction of this force is known. It will be represented on the FBD by two components. In example 2.10, we pointed out that it would usually be easier to assume that the components of an unknown vector point in the +x and +y directions. In this example, we will not follow that suggestion, and see what happens. The x component of the force exerted at the top of the tibia will be assumed to point to the right (the +x direction) but the y component will be assumed to point down (the - y direction).

3. The FBD :





According to the chart in Appendix 9, the cg of the lower leg is 43.3% of the length of the lower leg down from the knee. The length of the tibia is given as 36cm and so the cg of the lower leg is 43% of 36cm measured down from the knee. Thus the cg of the lower leg is 15.6 cm down from the knee. The cg of the foot is 42.8% of the length of the foot, measured from the heel. The length of the entire foot (heel to toes) is given as 24 cm. So the cg of the foot is 42.8% of 24cm, measured from the heel. The cg of the foot is located 10.27 cm from the heel. Since we are given that the tibia-talus joint is 4 cm from the heel, the distance from the joint to the cg of the foot is 6.27 cm.

#### 4. Basic equations:

$$\sum F_x = 0$$

$$R_x + Q \cos 25^\circ = 0$$

$$\sum F_y = 0$$

$$-12.5 - 40 + 1112 + Q \sin 25^\circ - R_y = 0$$

Notice that  $R_y$  was assigned a negative sign. This is because it was drawn pointing down and up was the assumed +y direction.

$$CW + \sum_{knee} \Gamma_{external} = 0$$

I have chosen to place the axis of rotation at the knee [upper end of the *tibia* (0)]. This choice will produce lever arms of zero length for both  $R_x$  and  $R_y$ .

Usually, the lever arm for the *quadriceps tendon* would have to be calculated. However, in this problem, that calculation would involve more trigonometry than is appropriate for the course. The lever arm is therefore given as 4.35 cm.

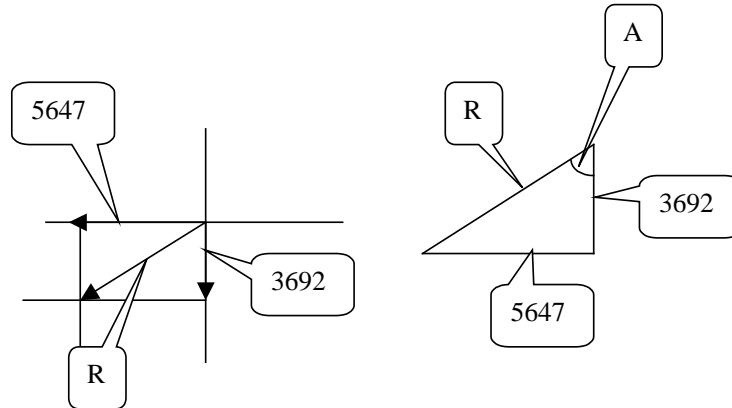
$$(1112)[(0.36\cos 30^\circ) - (0.12\cos 60^\circ)] - (40)(0.156 \cos 30^\circ) - (12.5)[(0.36\cos 30^\circ) - (0.0627\cos 60^\circ)] - (Q)(0.0435) = 0$$

$$Q = 6231 \text{ N } (= 1401\text{pd})$$

5. Calculate the components of the unknown force "R".

$R_x = -5647 \text{ N}$  (the negative sign means that we guessed wrong and that  $R_x$  really points to the left)

$R_y = 3692 \text{ N}$  (the positive sign means that we guessed correctly and that  $R_y$  really does point down)



6. Determine the magnitude and direction of R:

$$R = 6.76 \times 10^3 \text{ N } (1.52 \times 10^3 \text{ lb})$$

$$A = 56.6^\circ$$

Notice that the *femur* seems to be pushing to the left on the *tibia*. This doesn't seem possible. It is really the ligaments, the ACL in particular, that stabilize the knee (rather than the *femur* itself) and that are applying the force on the *tibia*. When a competitive weight lifter does a lift as described in this example, great stress is placed on these ligaments. This explains why weight lifters commonly wrap their knees in Ace bandages and why ligament failure (knee dislocation) is so common among weight lifters.

Also notice that the short lever arm associated with the tendon results in a large tension within the tendon that, in turn, results in a large force of compression on the joint. This lever arm would be much shorter if it were not for the *patella*. The *patella* rides on the end of the *femur* and the tendon passes over it. Thus the *patella* serves to move the tendon out, farther away from the joint. The *patella* serves, both by its placement and by its motion (review the discussion of the knee in the section entitled "Torque: Introduction"), to reduce the amount of force that must be exerted by the *quadriceps tendon*.

p. 105 - There should be plus signs with each of the "clockwise" symbols.

p. 111 - There should be plus signs with each of the "clockwise" symbols.

p. 113 – example 2.13, answers should be

$$F_m = 2609.63 \text{ N } = 587 \text{ lb}$$

$$F_{ax} = 892.55 \text{ N}$$

$$F_{ay} = 2977.89 \text{ N}$$

$$F_a = 3.1 \times 10^3 \text{ N } = 699 \text{ lb}$$

In the following paragraph, change "6 times" to "5 times", change 983 lb to 587 lb, change 873 lb to 699 lb.

p. 115 - There should be plus signs with each of the "clockwise" symbols.

The answers in step #10 should be:

$$F_{ay} = 1.21 \times 10^3 \text{ N}$$

$$F_m = 838 \text{ N } (=188 \text{ lb})$$

$$F_{ax} = 287 \text{ N}$$

$$F_a = 1.24 \times 10^3 \text{ N } (=279 \text{ lb})$$

In the paragraph at the bottom of the page, the numbers 873 and 273 should be changed to 699 and 279 respectively.

p.118 – Answers to Problem 6.8 are incorrect. The correct answers are:

a. 68.3 lb

b. 160 lb

c. Up and to the right at  $65^\circ$  above the horizontal.

p. 118 – In Problem 6.9, "...the angle between the boom and the horizontal is  $40^\circ$ ."

a. 348kN

b. 393kN

c.  $41^\circ$  up and to the right above the horizontal.

p. 120 - Problem 6.12 The information stated in the book is not consistent with that given in the appendix.

To remove this inconsistency,

Distance from the humerus/radius/ulna/joint to the hand : 8.66 inches

Biceps brachii muscle : inserts onto the radius at a point that is 1.57 inches in front of the radius/humerus joint.

a.  $T_{\text{biceps}} = 197 \text{ pd}$ ,  $F_{\text{joint}} = 184 \text{ pd}$ . directed down and to the right at  $68^\circ$  below the horizontal.

b. 282 pd, straight down

p. 121 – in the line drawing that appears in Problem 6.13, the 20 lb should be 10 lb.

p.122 – The picture at the top of the page (the foot, flat on the floor) is part of problem 6.14. The lower picture (the foot inclined at  $50^\circ$  with respect to the floor) is part of problem 6.15.

p. 123 – The skeletal picture in Problem 6.16 should be modified. The hip should be removed.

p. 143 –  $E_{\text{energy bar}}$  should equal 1544 k lb ft

p. 144 – The equation at the top of the page should contain "1544" rather than "1604".

$$\Delta U_{\text{body}} = -2606 \text{ k lb ft}$$

In the summary .....

$$\Delta U_{\text{body}} = -2606 \text{ k lb ft} = -843.9 \text{ kcal}$$

$$E_{\text{energy bar}} = 1544 \text{ k lb ft} = 500 \text{ kcal}$$

p. 146 – In line 2, the number  $-3.5$  should be  $-73.5$

p.152 – Example 3.9

The body weight (in kilograms) of the person should be 47.6 kg. Thus the power consumed will be 10 kcal/min, the energy consumed will be 600 kcal, and the amount of glucose consumed will be 0.38 pounds.

p. 165 – The answer to Problem 8.7 should be 732 Watts

p. 166 – The answers to Problem 8.18 should be:

- a. 8 boxes at 1 box per trip, or 14 boxes at 2 boxes per trip
- b. If we define the rate at which she is working as the rate of increase of mechanical energy (PE of her body plus work done on the boxes), then the answer is 0.007 hp
- c. 2.9 C° at 1 box per trip or 3.24 C° at 2 boxes per trip.

p. 180 – The answer to Problem 9.8, part a should be 12.6 MJ  
 The answer to part c should be 15.8 MJ

p. 181 – The answer to Problem 9.14 part c should be 104 grams

p. 182 – In step 3 of the solution, the result should read:

$$\frac{\Delta T}{\Delta t} = 3.53 \frac{C^\circ}{h}$$

p.194 - Problem 102.  
 The answer should be 17.4kW

- p. 194 – Problem 10.3  
 .....at a slow rate (2 miles per hour).  
 answers
- a. 293 kcal/hr
  - b. 112 kcal/hr
  - c. 355 kcal/hr
  - d. 227 kcal/hr
  - e. 987 kcal/hr
  - f. 0.23 C°/min
  - g. 1.4 kg/hr = 1.4 L/hr

p.200 - Add to the table of reasonable lengths of major bones:  
 foot: 24cm