PROBLEM 1-1

Statement: It is often said, "Build a better mousetrap and the world will beat a path to your door." Consider this problem and write a goal statement and a set of at least 12 task specifications that you would apply to its solution. Then suggest 3 possible concepts to achieve the goal. Make annotated, freehand sketches of the concepts.

Solution:

Goal Statement: *Create a mouse-free environment.*

Task Specifications:

1. Cost less than $1.00 per use or application.
2. Allow disposal without human contact with mouse.
3. Be safe for other animals such as house pets.
4. Provide no threat to children or adults in normal use.
5. Be a humane method for the mouse.
6. Be environmentally friendly.
7. Have a shelf-life of at least 3 months.
8. Leave no residue.
9. Create minimum audible noise in use.
10. Create no detectable odors within 1 day of use.
11. Be biodegradable.
12. Be simple to use with minimal written instructions necessary.

Concepts and sketches are left to the student. There are an infinity of possibilities.

PROBLEM 1-2

Statement: A bowling machine is desired to allow quadriplegic youths, who can only move a joystick, to engage in the sport of bowling at a conventional bowling alley. Consider the factors involved, write a goal statement, and develop a set of at least 12 task specifications that constrain this problem. Then suggest 3 possible concepts to achieve the goal. Make annotated, freehand sketches of the concepts.

Solution:

Goal Statement: *Create a means to allow a quadriplegic to bowl.*

Task Specifications:

1. Cost no more than $2 000.
2. Portable by no more than two able-bodied adults.
3. Fit through a standard doorway.
4. Provide no threat of injury to user in normal use.
5. Operate from a 110 V, 60 Hz, 20 amp circuit.
6. Be visually unthreatening.
7. Be easily positioned at bowling alley.
8. Have ball-aiming ability, controllable by user.
9. Automatically reload returned balls.
10. Require no more than 1 able-bodied adult for assistance in use.
11. Ball release requires no more than a mouth stick-switch closure.
12. Be simple to use with minimal written instructions necessary.

Concepts and sketches are left to the student. There are an infinity of possibilities.

PROBLEM 1-3

Statement: A quadriplegic needs an automated page turner to allow her to read books without assistance. Consider the factors involved, write a goal statement, and develop a set of at least 12 task specifications that constrain this problem. Then suggest 3 possible concepts to achieve the goal. Make annotated, freehand sketches of the concepts.

Solution:

Goal Statement: *Create a means to allow a quadriplegic to read standard books with minimum assistance.*

Task Specifications:

1. Cost no more than $1 000.
2. Useable in bed or from a seated position
3. Accept standard books from 8.5 x 11 in to 4 x 6 in in planform and up to 1.5 in thick.
4. Book may be placed, and device set up, by able-bodied person.
5. Operate from a 110 V, 60 Hz, 15 amp circuit or by battery power.
6. Be visually unthreatening and safe to use.
7. Require no more than 1 able-bodied adult for assistance in use.
8. Useable in absence of assistant once set up.
9. Not damage books.
10. Timing controlled by user.
11. Page turning requires no more than a mouth stick-switch closure.
12. Be simple to use with minimal written instructions necessary.

Concepts and sketches are left to the student. There are an infinity of possibilities.

PROBLEM 1-4

Statement: Convert a mass of 1 000 lbm to (a) lbf, (b) slugs, (c) blobs, (d) kg.

Units: $blob := \frac{lbf \cdot sec^2}{in}$

Given: Mass $M := 1000 \cdot lb$

Solution: See Mathcad file P0104.

1. To determine the weight of the given mass, multiply the mass value by the acceleration due to gravity, g.

$W := M \cdot g$ $W = 1000 \cdot lbf$

2. Convert mass units by assigning different units to the units place-holder when displaying the mass value.

Slugs $M = 31.081 \cdot slug$

Blobs $M = 2.59 \cdot blob$

Kilograms $M = 453.592 \cdot kg$

PROBLEM 1-5

Statement: A 250-lbm mass is accelerated at 40 in/sec2. Find the force in lb needed for this acceleration.

Given: Mass $M := 250 \cdot lb$ Acceleration $a := 40 \cdot \frac{in}{sec^2}$

Solution: See Mathcad file P0105.

1. To determine the force required, multiply the mass value, in slugs, by the acceleration in feet per second squarec

Convert mass to slugs: $M = 7.770 \cdot slug$

Convert acceleration to feet per second squared: $a = 3.333\, s^{-2} \cdot ft$

$F := M \cdot a$ $F = 25.9 \cdot lbf$

PROBLEM 1-6

Statement: Express a 100-kg mass in units of slugs, blobs, and lbm. How much does this mass weigh?

Units: $blob := \frac{lbf \cdot sec^2}{in}$

Given: $M := 100 \cdot kg$

Assumptions: The mass is at sea-level and the gravitational acceleration is

$g = 32.174 \cdot \frac{ft}{sec^2}$ or $g = 386.089 \cdot \frac{in}{sec^2}$ or $g = 9.807 \cdot \frac{m}{sec^2}$

Solution: See Mathcad file P0106.

1. Convert mass units by assigning different units to the units place-holder when displaying the mass value.

   The mass, in *slugs*, is $M = 6.85 \cdot slug$

   The mass, in *blobs*, is $M = 0.571 \cdot blob$

   The mass, in *lbm*, is $M = 220.5 \cdot lb$

   Note: Mathcad uses lbf for pound-force, and lb for pound-mass.

2. To determine the weight of the given mass, multiply the mass value by the acceleration due to gravity, g.

   The weight, in *lbf*, is $W := M \cdot g$ $W = 220.5 \cdot lbf$

   The weight, in *N*, is $W := M \cdot g$ $W = 980.7 \cdot N$

PROBLEM 1-7

Statement: Prepare an interactive computer program (using, for example, Excell, Mathcad, or TKSolver) from which the cross-sectional properties for the shapes shown in the inside front cover can be calculated. Arrange the program to deal with both *ips* and *SI* unit systems and convert the results between those systems.

Solution: See the inside front cover and Mathcad file P0107.

1. Rectangle, let:

$b := 3 \cdot in$ $\qquad h := 4 \cdot in$

Area $\qquad A := b \cdot h \qquad A = 12.000 \cdot in^2$

$A = 7742 \cdot mm^2$

Moment about x-axis $\qquad I_x := \dfrac{b \cdot h^3}{12} \qquad I_x = 16.000 \cdot in^4$

$I_x = 6.660 \times 10^6 \cdot mm^4$

Moment about y-axis $\qquad I_y := \dfrac{h \cdot b^3}{12} \qquad I_y = 9.000 \cdot in^4$

$I_y = 3.746 \times 10^6 \cdot mm^4$

Radius of gyration about x-axis $\qquad k_x := \sqrt{\dfrac{I_x}{A}} \qquad k_x = 1.155 \cdot in$

$k_x = 29.329 \cdot mm$

Radius of gyration about y-axis $\qquad k_y := \sqrt{\dfrac{I_y}{A}} \qquad k_y = 0.866 \cdot in$

$k_y = 21.997 \cdot mm$

Polar moment of inertia $\qquad J_z := I_x + I_y \qquad J_z = 25.000 \cdot in^4$

$J_z = 1.041 \times 10^7 \cdot mm^4$

2. Solid circle, let:

$D := 3 \cdot in$

Area $\qquad A := \dfrac{\pi \cdot D^2}{4} \qquad A = 7.069 \cdot in^2$

$A = 4560 \cdot mm^2$

Moment about x-axis $\qquad I_x := \dfrac{\pi \cdot D^4}{64} \qquad I_x = 3.976 \cdot in^4$

$I_x = 1.655 \times 10^6 \cdot mm^4$

Moment about y-axis $\qquad I_y := \dfrac{\pi \cdot D^4}{64} \qquad I_y = 3.976 \cdot in^4$

$I_y = 1.655 \times 10^6 \cdot mm^4$

Radius of gyration about x-axis $\qquad k_x := \sqrt{\dfrac{I_x}{A}} \qquad k_x = 0.750 \cdot in$

$k_x = 19.05 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\dfrac{I_y}{A}}$ $\quad k_y = 0.750 \cdot in$

$k_y = 19.05 \cdot mm$

Polar moment of inertia $\quad J_z := \dfrac{\pi \cdot D^4}{32}$ $\quad J_z = 7.952 \cdot in^4$

$J_z = 3.310 \times 10^6 \cdot mm^4$

3. Hollow circle, let:

$D := 3 \cdot in$ $\quad d := 1 \cdot in$

Area $\quad A := \dfrac{\pi}{4} \cdot \left(D^2 - d^2\right)$ $\quad A = 6.283 \cdot in^2$

$A = 4054 \cdot mm^2$

Moment about x-axis $\quad I_x := \dfrac{\pi}{64} \cdot \left(D^4 - d^4\right)$ $\quad I_x = 3.927 \cdot in^4$

$I_x = 1.635 \times 10^6 \cdot mm^4$

Moment about y-axis $\quad I_y := \dfrac{\pi}{64} \cdot \left(D^4 - d^4\right)$ $\quad I_y = 3.927 \cdot in^4$

$I_y = 1.635 \times 10^6 \cdot mm^4$

Radius of gyration about x-axis $\quad k_x := \sqrt{\dfrac{I_x}{A}}$ $\quad k_x = 0.791 \cdot in$

$k_x = 20.08 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\dfrac{I_y}{A}}$ $\quad k_y = 0.791 \cdot in$

$k_y = 20.08 \cdot mm$

Polar moment of inertia $\quad J_z := \dfrac{\pi}{32} \cdot \left(D^4 - d^4\right)$ $\quad J_z = 7.854 \cdot in^4$

$J_z = 3.269 \times 10^6 \cdot mm^4$

4. Solid semicircle, let:

$D := 3 \cdot in$ $\quad R := 0.5 \cdot D$ $\quad R = 1.5 \cdot in$

Area $\quad A := \dfrac{\pi \cdot D^2}{8}$ $\quad A = 3.534 \cdot in^2$

$A = 2280 \cdot mm^2$

Moment about x-axis $\quad I_x := 0.1098 \cdot R^4$ $\quad I_x = 0.556 \cdot in^4$

$I_x = 2.314 \times 10^5 \cdot mm^4$

Moment about y-axis $\quad I_y := \dfrac{\pi \cdot R^4}{8}$ $\quad I_y = 1.988 \cdot in^4$

$I_y = 8.275 \times 10^5 \cdot mm^4$

Radius of gyration about x-axis $k_x := \sqrt{\frac{I_x}{A}}$ $k_x = 0.397 \cdot in$

$k_x = 10.073 \cdot mm$

Radius of gyration about y-axis $k_y := \sqrt{\frac{I_y}{A}}$ $k_y = 0.750 \cdot in$

$k_y = 19.05 \cdot mm$

Polar moment of inertia $J_z := I_x + I_y$ $J_z = 2.544 \cdot in^4$

$J_z = 1.059 \times 10^6 \cdot mm^4$

Distances to centroid $a := 0.4244 \cdot R$ $a = 0.637 \cdot in$

$a = 16.17 \cdot mm$

$b := 0.5756 \cdot R$ $b = 0.863 \cdot in$

$b = 21.93 \cdot mm$

5. Right triangle, let:

$b := 2 \cdot in$ $h := 1 \cdot in$

Area $A := \frac{b \cdot h}{2}$ $A = 1.000 \cdot in^2$

$A = 645 \cdot mm^2$

Moment about x-axis $I_x := \frac{b \cdot h^3}{36}$ $I_x = 0.056 \cdot in^4$

$I_x = 2.312 \times 10^4 \cdot mm^4$

Moment about y-axis $I_y := \frac{h \cdot b^3}{36}$ $I_y = 0.222 \cdot in^4$

$I_y = 9.250 \times 10^4 \cdot mm^4$

Radius of gyration about x-axis $k_x := \sqrt{\frac{I_x}{A}}$ $k_x = 0.236 \cdot in$

$k_x = 5.987 \cdot mm$

Radius of gyration about y-axis $k_y := \sqrt{\frac{I_y}{A}}$ $k_y = 0.471 \cdot in$

$k_y = 11.974 \cdot mm$

Polar moment of inertia $J_z := I_x + I_y$ $J_z = 0.278 \cdot in^4$

$J_z = 1.156 \times 10^5 \cdot mm^4$

PROBLEM 1-8

Statement: Prepare an interactive computer program (using, for example, Excell, Mathcad, or TKSolver) from which the mass properties for the solids shown in the page opposite the inside front cover can be calculated. Arrange the program to deal with both *ips* and *SI* unit systems and convert the results between those systems.

Units: $blob := \frac{lbf \cdot sec^2}{in}$

Solution: See the page opposite the inside front cover and Mathcad file P0108.

1. Rectangular prism, let: $a := 2 \cdot in$ $b := 3 \cdot in$ $c := 4 \cdot in$ $\gamma := 0.28 \cdot lbf \cdot in^{-3}$

Volume $V := a \cdot b \cdot c$ $V = 24.000 \cdot in^3$

$V = 393290 \cdot mm^3$

Mass $M := \frac{V \cdot \gamma}{g}$ $M = 0.017 \cdot blob$

$M = 3.048 \cdot kg$

Moment about *x*-axis $I_x := \frac{M \cdot \left(a^2 + b^2\right)}{12}$ $I_x = 0.019 \cdot blob \cdot in^2$

$I_x = 2130.4 \cdot kg \cdot mm^2$

Moment about *y*-axis $I_y := \frac{M \cdot \left(a^2 + c^2\right)}{12}$ $I_y = 0.029 \cdot blob \cdot in^2$

$I_y = 3277.6 \cdot kg \cdot mm^2$

Moment about *z*-axis $I_z := \frac{M \cdot \left(b^2 + c^2\right)}{12}$ $I_z = 0.036 \cdot blob \cdot in^2$

$I_z = 4097.0 \cdot kg \cdot mm^2$

Radius of gyration about *x*-axis $k_x := \sqrt{\frac{I_x}{M}}$ $k_x = 1.041 \cdot in$

$k_x = 26.437 \cdot mm$

Radius of gyration about *y*-axis $k_y := \sqrt{\frac{I_y}{M}}$ $k_y = 1.291 \cdot in$

$k_y = 32.791 \cdot mm$

Radius of gyration about *z*-axis $k_z := \sqrt{\frac{I_z}{M}}$ $k_z = 1.443 \cdot in$

$k_z = 36.662 \cdot mm$

2.Cylinder, let: $r := 2 \cdot in$ $L := 3 \cdot in$ $\gamma := 0.30 \cdot lbf \cdot in^{-3}$

Volume $V := \pi \cdot r^2 \cdot L$ $V = 37.699 \cdot in^3$

$V = 617778 \cdot mm^3$

Mass $M := \frac{V \cdot \gamma}{g}$ $M = 0.029 \cdot blob$

$M = 5.13 \cdot kg$

Moment about x-axis $\quad I_x := \dfrac{M \cdot r^2}{2} \quad I_x = 0.059 \cdot blob \cdot in^2$

$I_x = 6619.4 \cdot kg \cdot mm^2$

Moment about y-axis $\quad I_y := \dfrac{M \cdot \left(3 \cdot r^2 + L^2\right)}{12} \quad I_y = 0.051 \cdot blob \cdot in^2$

$I_y = 5791.9 \cdot kg \cdot mm^2$

Moment about z-axis $\quad I_z := \dfrac{M \cdot \left(3 \cdot r^2 + L^2\right)}{12} \quad I_z = 0.051 \cdot blob \cdot in^2$

$I_z = 5791.9 \cdot kg \cdot mm^2$

Radius of gyration about x-axis $\quad k_x := \sqrt{\dfrac{I_x}{M}} \quad k_x = 1.414 \cdot in$

$k_x = 35.921 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\dfrac{I_y}{M}} \quad k_y = 1.323 \cdot in$

$k_y = 33.601 \cdot mm$

Radius of gyration about z-axis $\quad k_z := \sqrt{\dfrac{I_z}{M}} \quad k_z = 1.323 \cdot in$

$k_z = 33.601 \cdot mm$

3. Hollow cylinder, let:

$a := 2 \cdot in \qquad b := 3 \cdot in \qquad L := 4 \cdot in \qquad \gamma := 0.28 \cdot lbf \cdot in^{-3}$

Volume $\quad V := \pi \cdot \left(b^2 - a^2\right) \cdot L \quad V = 62.832 \cdot in^3$

$V = 1029630 \cdot mm^3$

Mass $\quad M := \dfrac{V \cdot \gamma}{g} \quad M = 0.046 \cdot blob$

$M = 7.98 \cdot kg$

Moment about x-axis $\quad I_x := \dfrac{M}{2} \cdot \left(a^2 + b^2\right) \quad I_x = 0.296 \cdot blob \cdot in^2$

$I_x = 3.3 \times 10^4 \cdot kg \cdot mm^2$

Moment about y-axis $\quad I_y := \dfrac{M}{12} \cdot \left(3 \cdot a^2 + 3 \cdot b^2 + L^2\right) \quad I_y = 0.209 \cdot blob \cdot in^2$

$I_y = 2.4 \times 10^4 \cdot kg \cdot mm^2$

Moment about z-axis $\quad I_z := \dfrac{M}{12} \cdot \left(3 \cdot a^2 + 3 \cdot b^2 + L^2\right) \quad I_z = 0.209 \cdot blob \cdot in^2$

$I_z = 2.4 \times 10^4 \cdot kg \cdot mm^2$

Radius of gyration about x-axis $\quad k_x := \sqrt{\dfrac{I_x}{M}} \quad k_x = 2.550 \cdot in$

$k_x = 64.758 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\dfrac{I_y}{M}}$ $\quad k_y = 2.141 \cdot in$

$k_y = 54.378 \cdot mm$

Radius of gyration about z-axis $\quad k_z := \sqrt{\dfrac{I_z}{M}}$ $\quad k_z = 2.141 \cdot in$

$k_z = 54.378 \cdot mm$

4. Right circular cone, let:

$r := 2 \cdot in$ $\qquad h := 5 \cdot in$ $\qquad \gamma := 0.28 \cdot lbf \cdot in^{-3}$

Volume $\quad V := \dfrac{\pi \cdot r^2 \cdot h}{3}$ $\quad V = 20.944 \cdot in^3$

$V = 343210 \cdot mm^3$

Mass $\quad M := \dfrac{V \cdot \gamma}{g}$ $\quad M = 0.015 \cdot blob$

$M = 2.66 \cdot kg$

Moment about x-axis $\quad I_x := \dfrac{3}{10} \cdot M \cdot r^2$ $\quad I_x = 0.018 \cdot blob \cdot in^2$

$I_x = 2059.4 \cdot kg \cdot mm^2$

Moment about y-axis $\quad I_y := M \cdot \dfrac{\left(12 \cdot r^2 + 3 \cdot h^2\right)}{80}$ $\quad I_y = 0.023 \cdot blob \cdot in^2$

$I_y = 2638.5 \cdot kg \cdot mm^2$

Moment about z-axis $\quad I_z := M \cdot \dfrac{\left(12 \cdot r^2 + 3 \cdot h^2\right)}{80}$ $\quad I_z = 0.023 \cdot blob \cdot in^2$

$I_z = 2638.5 \cdot kg \cdot mm^2$

Radius of gyration about x-axis $\quad k_x := \sqrt{\dfrac{I_x}{M}}$ $\quad k_x = 1.095 \cdot in$

$k_x = 27.824 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\dfrac{I_y}{M}}$ $\quad k_y = 1.240 \cdot in$

$k_y = 31.495 \cdot mm$

Radius of gyration about z-axis $\quad k_z := \sqrt{\dfrac{I_z}{M}}$ $\quad k_z = 1.240 \cdot in$

$k_z = 31.495 \cdot mm$

5. Sphere, let:

$r := 3 \cdot in$

Volume $\quad V := \dfrac{4}{3} \cdot \pi \cdot r^3$ $\quad V = 113.097 \cdot in^3$

$V = 1853333 \cdot mm^3$

Mass $\quad M := \dfrac{V \cdot \gamma}{g}$ $\quad M = 0.082 \cdot blob$

$M = 14.364 \cdot kg$

Moment about x-axis $\quad I_x := \frac{2}{5} \cdot M \cdot r^2 \quad I_x = 0.295 \cdot blob \cdot in^2$

$I_x = 33362 \cdot kg \cdot mm^2$

Moment about y-axis $\quad I_y := \frac{2}{5} \cdot M \cdot r^2 \quad I_y = 0.295 \cdot blob \cdot in^2$

$I_y = 33362 \cdot kg \cdot mm^2$

Moment about z-axis $\quad I_z := \frac{2}{5} \cdot M \cdot r^2 \quad I_z = 0.295 \cdot blob \cdot in^2$

$I_z = 33362 \cdot kg \cdot mm^2$

Radius of gyration about x-axis $\quad k_x := \sqrt{\frac{I_x}{M}} \quad k_x = 1.897 \cdot in$

$k_x = 48.193 \cdot mm$

Radius of gyration about y-axis $\quad k_y := \sqrt{\frac{I_y}{M}} \quad k_y = 1.897 \cdot in$

$k_y = 48.193 \cdot mm$

Radius of gyration about z-axis $\quad k_z := \sqrt{\frac{I_z}{M}} \quad k_z = 1.897 \cdot in$

$k_z = 48.193 \cdot mm$

PROBLEM 1-9

Statement: Convert the template in Problem 1-7 to have and use a set of functions or subroutines that can be called from within any program in that language to solve for the cross-sectional properties of the shapes shown on the inside front cover.

Solution: See inside front cover and Mathcad file P0109.

1. Rectangle:

Area $A(b,h) := b\cdot h$

Moment about x-axis $I_x(b,h) := \dfrac{b\cdot h^3}{12}$

Moment about y-axis $I_y(b,h) := \dfrac{h\cdot b^3}{12}$

2. Solid circle:

Area $A(D) := \dfrac{\pi\cdot D^2}{4}$

Moment about x-axis $I_x(D) := \dfrac{\pi\cdot D^4}{64}$

Moment about y-axis $I_y(D) := \dfrac{\pi\cdot D^4}{64}$

3. Hollow circle:

Area $A(D,d) := \dfrac{\pi}{4}\cdot\left(D^2 - d^2\right)$

Moment about x-axis $I_x(D,d) := \dfrac{\pi}{64}\cdot\left(D^4 - d^4\right)$

Moment about y-axis $I_y(D,d) := \dfrac{\pi}{64}\cdot\left(D^4 - d^4\right)$

4. Solid semicircle:

Area $A(D) := \dfrac{\pi\cdot D^2}{8}$

Moment about x-axis $I_x(R) := 0.1098\cdot R^4$

Moment about y-axis $I_y(R) := \dfrac{\pi\cdot R^4}{8}$

5. Right triangle:

Area $A(b,h) := \dfrac{b\cdot h}{2}$

Moment about x-axis $I_x(b,h) := \dfrac{b\cdot h^3}{36}$

Moment about y-axis $I_y(b,h) := \dfrac{h\cdot b^3}{36}$

PROBLEM 1-10

Statement: Convert the template in Problem 1-8 to have and use a set of functions or subroutines that can be called from within any program in that language to solve for the cross-sectional properties of the shapes shown on the page opposite the inside front cover.

Solution: See the page opposite the inside front cover and Mathcad file P0110.

1 Rectangular prism:

Volume $V(a,b,c) := a \cdot b \cdot c$

Mass $M(a,b,c,\gamma) := \dfrac{V(a,b,c) \cdot \gamma}{g}$

Moment about *x*-axis $I_x(a,b,c,\gamma) := \dfrac{M(a,b,c,\gamma) \cdot \left(a^2 + b^2\right)}{12}$

Moment about *y*-axis $I_y(a,b,c,\gamma) := \dfrac{M(a,b,c,\gamma) \cdot \left(a^2 + c^2\right)}{12}$

Moment about *z*-axis $I_z(a,b,c,\gamma) := \dfrac{M(a,b,c,\gamma) \cdot \left(b^2 + c^2\right)}{12}$

2. Cylinder:

Volume $V(r,L) := \pi \cdot r^2 \cdot L$

Mass $M(r,L,\gamma) := \dfrac{V(r,L) \cdot \gamma}{g}$

Moment about *x*-axis $I_x(r,L,\gamma) := \dfrac{M(r,L,\gamma) \cdot r^2}{2}$

Moment about *y*-axis $I_y(r,L,\gamma) := \dfrac{M(r,L,\gamma) \cdot \left(3 \cdot r^2 + L^2\right)}{12}$

Moment about *z*-axis $I_z(r,L,\gamma) := \dfrac{M(r,L,\gamma) \cdot \left(3 \cdot r^2 + L^2\right)}{12}$

3. Hollow cylinder:

Volume $V(a,b,L) := \pi \cdot \left(b^2 - a^2\right) \cdot L$

Mass $M(a,b,L,\gamma) := \dfrac{V(a,b,L) \cdot \gamma}{g}$

Moment about *x*-axis $I_x(a,b,L,\gamma) := \dfrac{M(a,b,L,\gamma)}{2} \cdot \left(a^2 + b^2\right)$

Moment about *y*-axis $I_y(a,b,L,\gamma) := \dfrac{M(a,b,L,\gamma)}{12} \cdot \left(3 \cdot a^2 + 3 \cdot b^2 + L^2\right)$

Moment about *z*-axis $I_z(a,b,L,\gamma) := \dfrac{M(a,b,L,\gamma)}{12} \cdot \left(3 \cdot a^2 + 3 \cdot b^2 + L^2\right)$

4. Right circular cone:

Volume $V(r,h) := \dfrac{\pi \cdot r^2 \cdot h}{3}$

Mass $M(r,h,\gamma) := \dfrac{V(r,h) \cdot \gamma}{g}$

Moment about *x*-axis $I_x(r,h,\gamma) := \dfrac{3}{10} \cdot M(r,h,\gamma) \cdot r^2$

Moment about *y*-axis $I_y(r,h,\gamma) := M(r,h,\gamma) \cdot \dfrac{\left(12 \cdot r^2 + 3 \cdot h^2\right)}{80}$

Moment about *z*-axis $I_z(r,h,\gamma) := M(r,h,\gamma) \cdot \dfrac{\left(12 \cdot r^2 + 3 \cdot h^2\right)}{80}$

5. Sphere:

Volume $V(r) := \dfrac{4}{3} \cdot \pi \cdot r^3$

Mass $M(r,\gamma) := \dfrac{V(r) \cdot \gamma}{g}$

Moment about *x*-axis $I_x(r,\gamma) := \dfrac{2}{5} \cdot M(r,\gamma) \cdot r^2$

Moment about *y*-axis $I_y(r,\gamma) := \dfrac{2}{5} \cdot M(r,\gamma) \cdot r^2$

Moment about *z*-axis $I_z(r,\gamma) := \dfrac{2}{5} \cdot M(r,\gamma) \cdot r^2$

PROBLEM 1-11

Statement: A fledgling, non-profit, recycling organization collects paper, cardboard, plastics, and metals from consumers in a rural county. After sorting plastics by grades 1 and 2, they are transported to a plastics recycler in a major city 150 miles away. In order to maximize the weight of the plastics that can be put into their trailer the organization desires to compact the plastic containers for transport. Consider this problem and write a goal statement and a set of at least 10 task specifications that you would apply to its solution. Then suggest 3 possible concepts to achieve the goal. Make annotated, freehand sketches of the concepts.

Solution:

Goal Statement: *Create a means to compact indivual plastic containers of various sizes and shapes.*

Task Specifications:

1. Cost no more than $200 for parts.
2. No special tools required for assembly.
3. Deposit crushed containers into plastic trash bags.
4. Provide no threat of injury to user in normal use.
5. Operate from a 110 V, 60 Hz, 20 amp circuit.
6. Require no more than 1 person to use.
7. Be rugged and reliable with minimal maintenance required.
8. Operate at ambient temperatures ranging from 40F to 100F.
9. Crush and bag a minimum of 1200 containers per hour.
10. Be simple to use with minimal written instructions necessary.

Concepts and sketches are left to the student. There are an infinity of possibilities.

PROBLEM 1-12

Statement: One square foot of ventilation is required for every 150 sq. ft. of floor space on a house with crawl-space under the floor. Prepare an interactive computer program (using, for example *Excel, Mathcad, MATLAB, or TK Solver*) from which the number of 40 cm by 20 cm vents can be determined that meet the ventilation requirement if only 75% of the nominal vent area is effective. Test the program using a house that is 13.5 m long by 8.25 m wide.

Given: Ratio of required floor area to effective vent area: $K := \frac{150 \cdot ft^2}{1 \cdot ft^2}$ $K = 150$

Nominal area of a single vent: $A_{nom} := 40 \cdot cm \cdot 20 \cdot cm$

$A_{nom} = 800 \cdot cm^2$

Solution:

1. Enter the length and width of the house in meters:

Length $L := 13.5 \cdot m$ Width $W := 8.25 \cdot m$

2. Calculate the floor area of the house:

$A_{floor} := L \cdot W$ $A_{floor} = 111.375\, m^2$

3. Calculate the total required ventilation area:

$A_{total} := \frac{A_{floor}}{K}$ $A_{total} = 7425 \cdot cm^2$

4. Calculate the number of 40 cm x 20 cm vents required (rounded to the next higher integer):

$N := ceil\left(\frac{A_{total}}{0.75 \cdot A_{nom}}\right)$ $N = 13$

PROBLEM 1-13

Statement: A start-up company (husband and wife) manufactures over 50 different health and beauty aids that they sell at craft shows and also over the internet. They make their products in small batches and package them in small jars that they buy unlabeled in case lots. They design and print their own labels on peelable, adhesive sheets. It is very difficult to place the labels on to the containers so that they are in the proper position and properly aligned. Consider this problem and write a goal statement and at least ten task specifications that you would apply to its solution.

Solution:

Goal Statement: *Create a means to apply a label to the required container for a particular product.*

Task Specifications:

1. Cost no more than $20 for parts.
2. No special tools required for assembly.
3. Leaves the operator's hands free to apply the label.
4. Provide no threat of injury to user in normal use.
5. Requires no source of electricity.
6. Requires no more than 1 person to use.
7. Be rugged and reliable with minimal maintenance required.
8. Operate at ambient temperatures ranging from 40F to 100F.
9. Supports the container while also guiding the the label to its correct position.
10. Be simple to use with minimal written instructions necessary.

PROBLEM 1-14

Statement: A 360-gram mass is accelerated at 250 cm/sec^2. Find the force in N needed for this acceleration.

Given: Mass $M := 360 \cdot gm$ Acceleration $a := 250 \cdot \frac{cm}{sec^2}$

Solution: See Mathcad file P0114.

1. To determine the force required, multiply the mass value, in kilograms, by the acceleration in meters per second squared.

   Convert mass to kg $M = 0.360 \cdot kg$

   Convert acceleration to meters per second squared: $a = 2.5\, m \cdot s^{-2}$

   $F := M \cdot a$ $F = 0.900 \cdot N$

PROBLEM 1-15

Statement: Express a 18-blob mass in units of slugs, kilograms, and lbm. How much does this mass weigh?

Units: $blob := \dfrac{lbf \cdot sec^2}{in}$

Given: $M := 18 \cdot blob$

Assumptions: The mass is at sea-level and the gravitational acceleration is

$$g = 32.174 \cdot \frac{ft}{sec^2} \quad \text{or} \quad g = 386.089 \cdot \frac{in}{sec^2} \quad \text{or} \quad g = 9.807 \cdot \frac{m}{sec^2}$$

Solution: See Mathcad file P0115.

1. Convert mass units by assigning different units to the units place-holder when displaying the mass value.

   The mass, in *slugs*, is $M = 216 \cdot slug$

   The mass, in *kilograms*, is $M = 3152.3 \cdot kg$

   The mass, in *lbm*, is $M = 6949.6 \cdot lb$

   Note: Mathcad uses *lbf* for pound-force, and *lb* for pound-mass.

2. To determine the weight of the given mass, multiply the mass value by the acceleration due to gravity, g.

   The weight, in *lbf*, is $W := M \cdot g \qquad W = 6949.6 \cdot lbf$

   The weight, in *kN*, is $W := M \cdot g \qquad W = 30.91 \cdot kN$