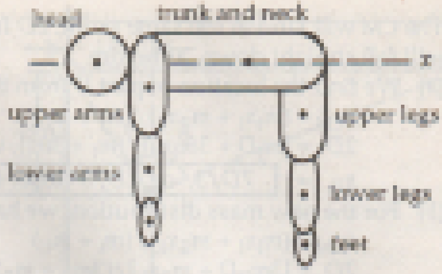
55. We use the line of the torso as the origin. The vertical locations of the centers of mass for each of the segments, as a percentage of the height, are




torso and head: 0;
upper arms: $y_{ua} = -(81.2 - 71.7) = -9.5$;
lower arms: $y_{la} = -(81.2 - 55.3) = -25.9$;
hands: $y_h = -(81.2 - 43.1) = -38.1$;
upper legs: $y_{ul} = -(52.1 - 42.5) = -9.6$;
lower legs: $y_{ll} = -(52.1 - 18.1) = -33.9$;
feet: $y_f = -(52.1 - 1.8) = -50.3$.

Because all masses are percentages of the body mass, we can use the percentages rather than the actual mass. Thus we have

$y_{CM} = (m_{ua}y_{ua} + m_{la}y_{la} + m_h y_h + m_{ul}y_{ul} + m_{ll}y_{ll} + m_f y_f)/m_{body}$
$= [(6.6)(-9.5) + (4.2)(-25.9) + (1.7)(-38.1) + (21.5)(-9.6) + (9.6)(-33.9) + (3.4)(-50.3)]/100$
$= -9.4.$

The CM will be **9.4% of the body height** below the line of the torso. For a height of 1.8 m, this is about 17 cm, so **yes,** this will most likely be outside the body.

56. (*a*) If we choose the origin at the center of the Earth, we have

$x_{CM} = (m_{Earth}x_{Earth} + m_{Moon}x_{Moon})/(m_{Earth} + m_{Moon})$
$= [0 + (7.35 \times 10^{22}\text{ kg})(3.84 \times 10^8\text{ m})]/(5.98 \times 10^{24}\text{ kg} + 7.35 \times 10^{22}\text{ kg})$
$=$ **$4.66 \times 10^6$ m.**

Note that this is less than the radius of the Earth and thus is inside the Earth.

(*b*) The CM found in part (*a*) will move around the Sun on an elliptical path. The Earth and Moon will revolve about the CM. Because this is near the center of the Earth, the Earth will essentially be on the elliptical path around the Sun. The motion of the Moon about the Sun is more complicated.

57. We choose the origin of our coordinate system at the woman.

(*a*) For their CM we have

$x_{CM} = (m_{woman}x_{woman} + m_{man}x_{man})/(m_{woman} + m_{man})$
$= [0 + (90\text{ kg})(10.0\text{ m})]/(55\text{ kg} + 90\text{ kg})$
$=$ **6.2 m.**

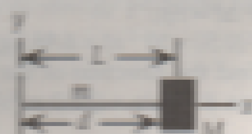
(*b*) Because the CM will not move, we find the location of the woman from

$x_{CM} = (m_{woman}x_{woman}' + m_{man}x_{man}')/(m_{woman} + m_{man})$
$6.2\text{ m} = [(55\text{ kg})x_{woman}' + (90\text{ kg})(10.0\text{ m} - 2.5\text{ m})]/(55\text{ kg} + 90\text{ kg})$, which gives
$x_{woman}' = 4.1\text{ m}.$

The separation of the two will be 7.5 m – 4.1 m = **3.4 m.**

(*c*) The two will meet at the CM , so he will have moved 10.0 m – 6.2 m = **3.8 m.**

58. Because the two segments of the mallet are uniform, we know that the center of mass of each segment is at its midpoint.
We choose the origin at the bottom of the handle. The mallet will spin about the CM, which is the point that will follow a parabolic trajectory.




$x_{CM} = (md + ML)/(m + M)$
$= [(0.500\text{ kg})(12.0\text{ cm}) + (2.00\text{ kg})(24.0\text{ cm} + 4.00\text{ cm})]/(0.500\text{ kg} + 2.00\text{ kg})$
$=$ **24.8 cm.**