## Problems

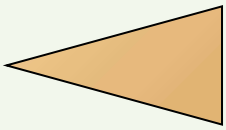
### 3.2 The Centre of Mass — The *G*ravity Spot!

20. a) Copy the following shapes (Figure 3.66) into your notebook and mark the centre of mass on each.

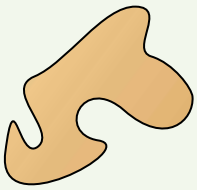
**Fig.3.66**

(a)

(b)



(c)



b) For each shape, explain your choice of position for the centre of mass.

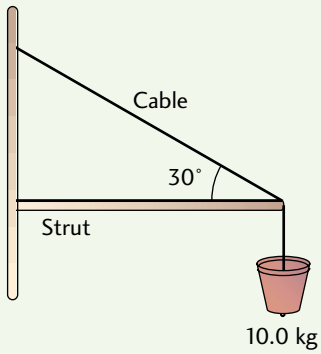
c) Trace these onto a piece of paper and use the technique described in Section 3.2 to verify the actual position of the centre of mass.

### 3.3 Balancing Forces … Again!

21. A 10.0-kg flowerpot is suspended from the end of a horizontal strut by a cable attached at 30° above the horizontal, as shown in Figure 3.67. If the strut has no mass, find the tension in the cable.

**Fig.3.67**

(a)

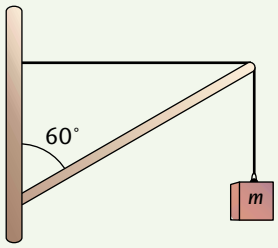



22. In problem 21, how much horizontal force must the strut provide?

23. A 100.0-kg mass is suspended from two ropes, each at an angle of 30° to the vertical. What is the tension in each rope?

24. What maximum mass, *m*, can be supported by the strut-and-cable arrangement in Figure 3.68 if the maximum force on the strut is 2500 N?

**Fig.3.68**




25. A 500-kg load of drywall is lifted up the side of a building by a crane. When the load is pulled to the side by a horizontal rope, the support cable of the crane makes an angle of 12° to the vertical. What is the tension in the support cable? What is the tension in the horizontal rope?

26. A 250-kg crate is being unloaded from a cargo ship by a crane with a cable 10 m long. The load must be pushed horizontally onto an awaiting wooden skid by a worker of mass 100 kg.

a) If the coefficient of friction between the worker's shoes and the floor is 0.63, what maximum horizontal force can he apply before his shoes begin to slip?

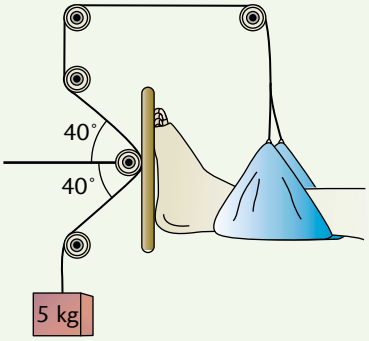
b) What is the crate's maximum horizontal displacement from rest?

27. A car is stuck in a snow bank, but the driver is very knowledgeable about physics. She ties a rope from her car to a tree 25.0 m away and then pulls sideways on the rope at the mid-point. If she applies a force of 425 N and draws the rope over a horizontal distance of 1.5 m, how much force is applied to the car?

28. A bird lands on a telephone wire midway between two poles 18 m apart. The wire (assumed weightless) sags by 52 cm. If the tension in the wire is 90 N, what is the mass of the bird?

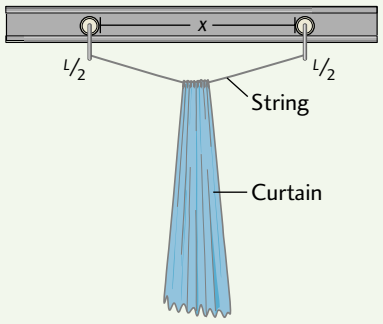
29. When a person's thighbone (femur) is broken, the muscles draw the broken parts so tightly together that the length of healed leg is slightly shorter than its original length. In the past, a traction device (see Figure 3.69) was used to oppose the natural muscle tension, allowing the bone to heal properly. What is the magnitude and direction of the tension force applied to the femur if the mass of the leg is 3.75 kg?

Fig.3.69




30. A string of length $L$ is connected to two pulleys on an I-beam curtain rod, as shown in Figure 3.70. A curtain of mass $m$, is hung from the midpoint of the string and the pulleys are drawn as far apart as possible. The coefficient of static friction between the pulleys and the rod is $\mu$. Find the maximum distance, $x$, in terms of $L$ and $\mu$, between the pulleys before they begin to roll toward each other.

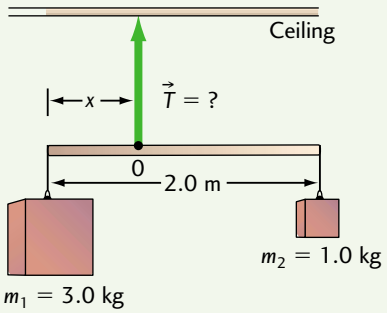
Fig.3.70




## 3.4 Balancing Torques

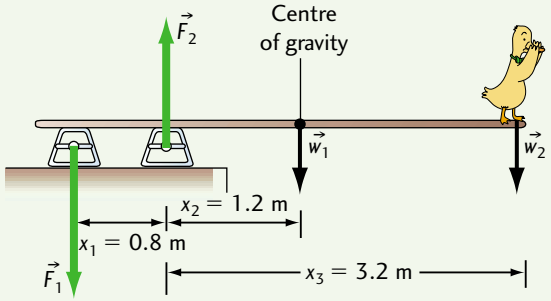
31. Figure 3.71 shows a 2.0-m-long rod with a 1.0-kg mass at one end and a 3.0-kg mass at the other end.
    a) If from the heavy end, the mass of the rod is negligible, where is the centre of gravity of the system?
    b) What is the tension in the single support cable?

Fig.3.71



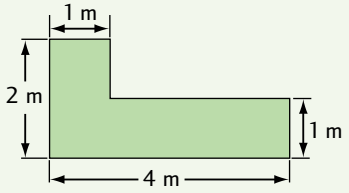

32. Find the forces exerted by the two supports of a 4.0-m, 50-kg uniform cantilever (diving board) when a 8.5-kg duck stands at the opposite end, as shown in Figure 3.72.

Fig.3.72




33. Find the centre of mass of the L-shaped steel plate shown in Figure 3.73. (Hint: Think of the $L$ as two separate figures, each with its own centre of mass. Use the total centre of mass in two dimensions as the coefficients of the two-dimensional centre of mass.)

Fig.3.73

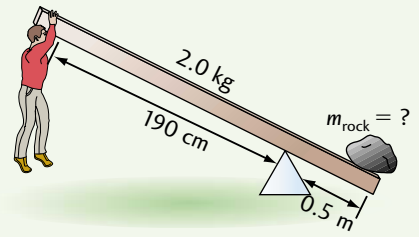


## 3.5 Static Equilibrium: Balancing Forces and Torque

34. Three people carry an extension ladder of length 5.0 m in the horizontal position. The lead person holds the ladder's front end, and the other two people are side by side on opposite sides of the ladder a distance $x$ from its back end. Calculate $x$ if the two people in the rear each support one-third of the ladder's weight.

35. An 86-kg man is trying to pry up a rock by hanging from the end of a class-one lever (a uniform piece of lumber of mass 2.0 kg), as illustrated in Figure 3.74. What is the maximum mass of the rock if it can be just lifted?

Fig.3.74




36. Two children of masses 17 kg and 27 kg sit at opposite ends of a 3.8-m teeter-totter that is pivoted at the centre. Where should a third child of mass 20 kg sit in order to balance the ride? Does the mass of the teeter-totter matter?

37. A 5.0-kg bag of cement is placed on a 2.5-m-long plank at 1.5 m from its end. The 2.0-kg plank is picked up by two men, one at each end. How much weight does each man support?

38. The centre of mass of a 30-kg dog standing on all fours is located 70 cm from her hind legs and 30 cm from her front legs. Find the force of the ground on each of her legs.

39. The hinges of a 20-kg door, 2.4 m high and 0.8 m wide, are placed at the top and bottom of the door's vertical edge. The door is supported by the upper hinge.
    a) What is the magnitude and direction of the force that the door exerts on the upper hinge?
    b) What is the magnitude and direction of the force that the lower hinge exerts on the door?

40. A weightless ladder 7.0 m long rests against a frictionless wall at an angle of 65° above the horizontal. A 72-kg person is 1.2 m from the top of the ladder. What horizontal force at the bottom of the ladder is required to keep it from slipping?

41. A box of total mass 75 kg rests on a floor with a coefficient of static friction of 0.42. The box is 1.6 m high, 1.0 m deep, and has uniform weight distribution.
    a) What is the minimum horizontal force required to start the box sliding across the floor?
    b) What is the maximum height at which this force can be applied without tipping the crate?

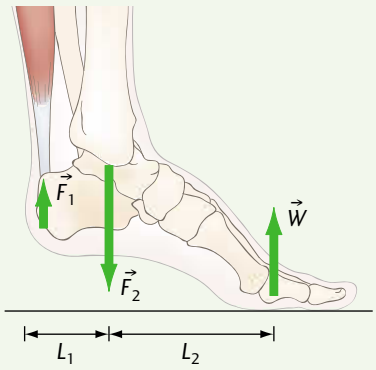
## 3.6 Static Equilibrium and the Human Body

42. Pierre holds a 10-kg bucket of water with his upper arm at his side and his forearm horizontal (90° at the elbow). The palm of his hand is 35 cm from the elbow, and his upper arm (shoulder to elbow) is 30 cm long. His biceps muscle is attached to the forearm 5.0 cm from the elbow. If the centre of mass of his 3.0-kg forearm is 16 cm from his elbow, what force does the biceps muscle exert to support both the arm and the bucket?

43. The hand, forearm, and upper arm of a gymnast have masses of 0.4 kg, 1.2 kg, and 1.9 kg, respectively, and their respective centres of mass are 0.60 m, 0.40 m, and 0.15 m from her shoulder joint. Find the centre of mass of her unbent arm as it is held horizontally from her shoulder.

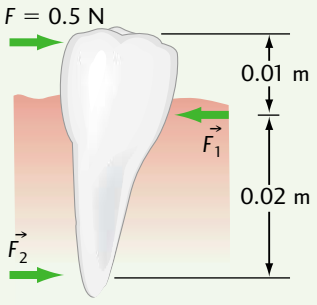
44. When you stand on the ball of your foot, the reaction force upward on the ball of your foot is equivalent to your weight. To raise your heel as shown in Figure 3.75, you must apply an upward force, $\vec{F}_1$, through your Achilles tendon so that the downward reaction force, $\vec{F}_2$, is greater than your weight. Calculate $\vec{F}_1$ and $\vec{F}_2$ for a 65-kg woman with foot dimensions $L_1 = 4.0$ cm and $L_2 = 12$ cm. If $L_1$ was greater than $L_2$, how would the force exerted by the Achilles tendon, $\vec{F}_1$, be affected?

Fig.3.75



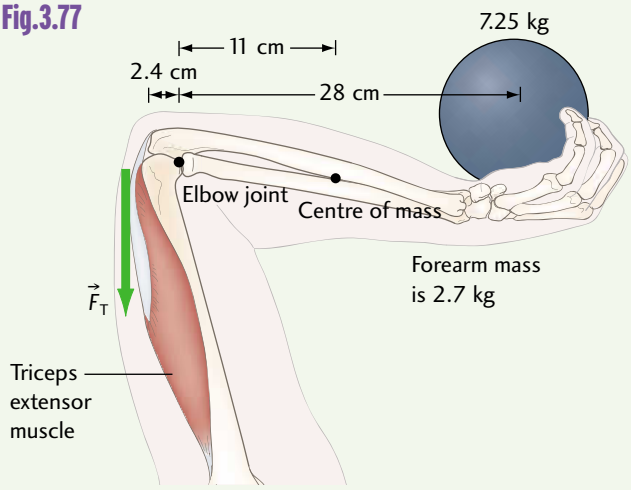

45. In Figure 3.76, what are the forces $\vec{F}_1$ and $\vec{F}_2$ if the tooth remains in static equilibrium?

Fig.3.76




46. An Olympic athlete is holding a 7.25-kg shot-put, as shown in Figure 3.77. Her forearm is 28.0 cm long and has a mass of 2.7 kg with centre of mass 11 cm for the elbow. The attachment of the triceps extensor muscle is 2.4 cm on the short end of the pivot and acts at 90° to the bone. What force must the triceps exert in order to hold the shot-put in static equilibrium?

Fig.3.77



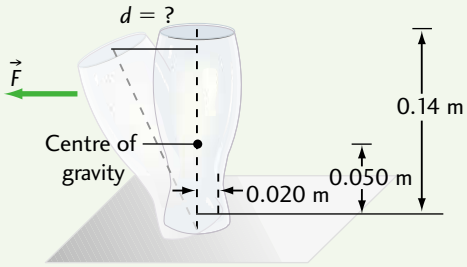

## 3.7 Stability and Equilibrium

47. A square table is 0.6 m long with a centre of mass 0.6 m above the ground. What is its tipping angle?

48. A square-based box of length 1.00 m and uniform weight distribution tips when tilted past 30°. How tall is the box?

49. The centre of mass of a 0.14-m-tall drinking glass is 0.050 m from the bottom, which is a circle with radius 0.020 m, as shown in Figure 3.78. How far can the top of the glass be tipped without toppling it?

Fig.3.78



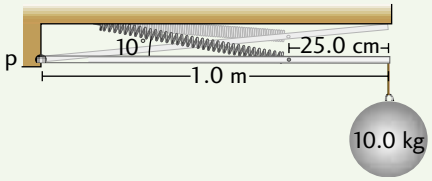
50. A transport truck 4.3 m tall and 2.5 m wide has a centre of mass 2.5 m high along the midline. How steep a side slope can the truck be parked on without tipping over sideways?

## 3.8 Elasticity: Hooke's Law

51. A spring scale is used to measure the weight of nails in a hardware store. Nails of mass 3.0 kg cause the spring to stretch 1.8 cm. What is the spring constant?

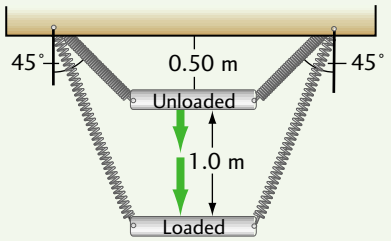
52. The spring in Figure 3.79 must support the lever in static equilibrium when a mass is placed on its end. What is the spring constant if the stretched spring is only 4.0 cm longer than its rest position?

Fig.3.79




53. A heavy steel bar is hung from the ceiling by two springs attached at each end, then released, as shown in Figure 3.80. What is the mass of the steel bar?

Fig.3.80




## 3.9 Stress and Strain — Cause and Effect

54. An aluminum wire is 20 m long and has a radius of 2.0 mm. The linear limit of force for aluminum is $6.0 \times 10^7$ N/m$^2$.
    a) What tension must be applied to reach this limit?
    b) How much will the wire stretch when this force is applied?

55. A 100-kg mass is suspended from the end of a vertical 2-m-long cast-iron post with a cross-sectional area of 0.1 m$^2$.
    a) What are the stress and strain on the post?
    b) How much does this post stretch?
    c) What is the maximum mass that can be suspended from this post?

56. What tension load will cause a femur to fracture if the minimum cross-sectional area of this leg bone is $6.40 \times 10^{-4}$ m$^2$?

57. What is the "spring constant" for a human femur under a compression force of 200 N if it has an average cross-sectional area of $10^{-3}$ m$^2$ with a length of 0.38 m?

58. A cylindrical steel rod 2.0 m long has a radius of 0.01 m. If a load causes it to bend elastically with a radius of curvature of 20 m, what is the torque on the rod?

59. A freight elevator and its contents have a mass of $1.00 \times 10^4$ kg and are at rest. The steel cable supporting them has a stress equal to 10% of its maximum tension.
    a) What is the radius of the cable's cross-section?
    b) What is the strain on the cable when the elevator is accelerating upward at 2.0 m/s$^2$?

## 3.10 Stress and Strain in Construction

60. A pine post with dimensions 10 cm by 15 cm by 3 m supports a load of 1000 N along its length.
    a) What are the stress and strain on the post?
    b) What is the change in length of the post while supporting this load?

61. In ancient Rome, marble columns were used to support heavy structures. In one application, a cylindrical column 1.00 m in diameter and 22.0 m long was used to support a mass of $2.5 \times 10^4$ kg. What length of unloaded column, 0.80 m in diameter, must be used to support the same mass at the same height when loaded?