1. (15%) Figure 1(a) illustrates a person on an exercise machine. The "L" shaped beam shown in Figure 1(b) represents the left arm of the person. Points A and B correspond to the shoulder and elbow joints, respectively. The upper arm (AB) is extended towards the left (x direction) and the forearm (BC) is extended forward (z direction). At this instant the person is grasping a handle that is connected by a cable to a suspending weight. The weight applies an upward force (in the y direction) of F on the forearm at point C. The lengths of the upper arm and forearm are a=25 cm and b=30 cm, respectively, and the magnitude of the applied force is F=200 N.
(a) Explain how force F can be translated to the shoulder joint at A, and
(b) Determine the magnitudes and directions of moments developed at the forearm and upper arm by F.

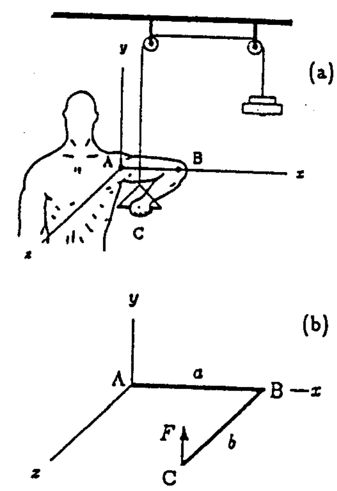

Figure 1

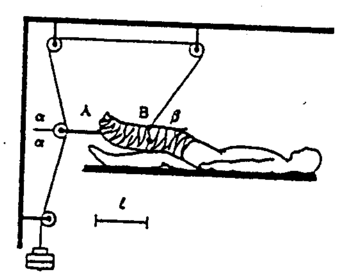

Figure 2

2. (15%) Consider the traction device shown in Figure 2. A weight pan is suspended on a long cable that passes over four pulleys. This cable is attached to the leg at B where the center of gravity of the leg is located. A second, relatively short cable is connected to the shaft of one of the pulleys and to the leg at point A, such that point A and the center of the pulley lie on a horizontal line. The distance between A and the center of gravity of the leg is l=50 cm. The total weight of the leg and the cast (石膏) is W_1=200 N, and angle α=75.5°. Determine the tensions in the cables, angle β, and weight W_2 of the block required to maintain the leg in the position shown.

3. (15%) Consider a person strengthening the shoulder muscles by means of dumbbell exercises. Figure 3 illustrates the position of the left arm when the arm is abducted to horizontal. The free-body diagram of the arm is shown in Figure 3 along with a mechanical model of the arm. O corresponds to the axis of the shoulder joint, A is where the deltoid muscle is attached to the humerus, B is the center of gravity of the entire forearm, and C is the center of gravity of the dumbbell, F_M is the magnitude of the tension in the deltoid muscle, and F_J is the joint reaction force at the shoulder. The resultant of the deltoid muscle force makes an angle θ with the horizontal. The distances between O and A, B, and C are measured as a, b, and c, respectively.
(a) Determine the magnitude F_M of the force exerted by the deltoid muscle to hold the arm at the position shown.
(b) Determine the magnitude and direction of the reaction force at the shoulder joint in terms of specified parameters.

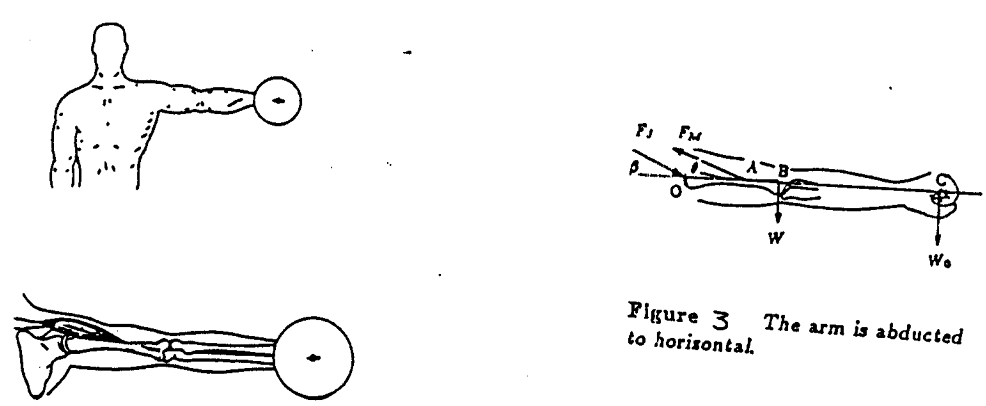

Figure 3 The arm is abducted to horizontal.

4. (15%) (a) What is the mass moment of inertia?
   (b) Does the mass moment of inertia of a body depend on its material, geometric properties, as well as the location and orientation of the axis about which it is to be determined?
   (c) Physically interpret the mass moment of inertia.

5. (20%) A force platform, as illustrated in Figure 4, is a flat, rectangular, force-sensitive device which electrically records forces exerted against its upper surface. This device can be used to measure the impulsive forces involved during walking, running, jumping, and other activities. Consider the force versus time recording shown in Figure 4 for an athlete making vertical jumps on a force platform. The force scale is normalized with the weight of the athlete so that the force reading is zero when the athlete is stationary (standing still or crouching). In this case, a positive force means a force exerted on the platform due to factors other than the weight of the person. The force versus time graph has three distinct regions. An initial "takeoff push" during which the athlete exerts a positive force on the platform, an "airborne" region during which the athlete is not in contact with the platform and a "landing" period in which the athlete again exerts impulsive forces on the platform. These regions are approximated with rectangular areas A_1 and A_2, and a triangular area A_3. Boundaries of these regions are shown with dashed lines in Figure 4. The approximate force applied and the duration of takeoff push are about $F_1 = 600$ N and $\Delta t_1=0.3$ s. The force reading is about $F_2 = -800$ N while the athlete is airborne, and the athlete remains in the air for about $\Delta t_2=0.4$ s. This suggests that the weight of the athlete is about 800 N. Therefore, the athlete has a mass of about $m=(800\text{N})/(9.8\ \text{m/s}^2) = 82$ kg. The maximum impulsive force the athlete exerts on the platform during landing is about $F_3 = 1000$ N which reduces to zero in a time interval of about $\Delta t_3=0.4$ s.
   (a) Determine an approximate takeoff velocity of the center of gravity of the athlete,
   (b) Calculate the height of jump, and
   (c) Determine the impulse and momentum of the athlete during landing by using the approximated areas under the force versus time curve.

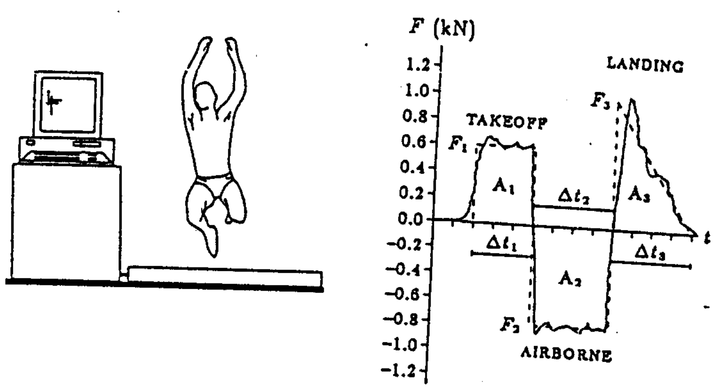

Figure 4 A force platform.

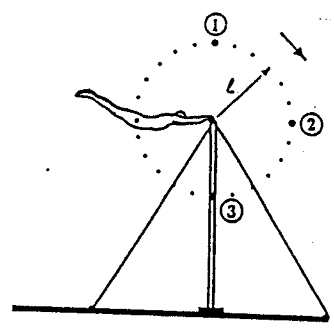

Figure 5 A gymnast doing giant circles.

6. (20%) As illustrated in Figure 5, consider a 70 kilogram gymnast doing giant circles. The motion of the gymnast may be analyzed by assuming that the total mass of the gymnast is concentrated at the center of gravity of the gymnast. Assuming that the center of gravity of the gymnast is located at a distance $l=1$ m from the high bar and the speed of the gymnast is negligibly small at position 1,
   (a) Determine the speeds of the gymnast's center of gravity at positions 2 and 3 shown in Figure 5.
   (b) Calculate the forces exerted on the arms of the gymnast at positions 1, 2, and 3.