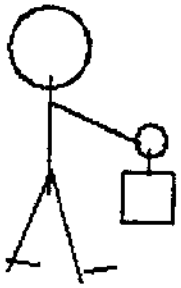
1. (20%) A child has picked up a bucket of muddy water and is carrying it with an outstretched arm so that he doesn't splash his clothes. Given the following information, calculate the resultant joint forces and moments at the elbow and shoulder. What general effect would motion, such as swinging the arm further upwards, have on these values? Why?



Mass of bucket: 10 kg
Mass of forearm: 1 kg
Mass of arm: 2 kg
Angle between arm and torso: 60 degrees
Angle between forearm and arm: 180 deg.
Length of arm: 0.33 m
Length of forearm: 0.25 m

2. (20%) When the position of a particle P moving in a plane is defined by its polar coordinates r and θ, it is convenient to use radial and transverse components directed, respectively, along the position vector $\mathbf{r}$ of the particle and in the direction obtained by rotating $\mathbf{r}$ through 90° counterclockwise. Assume P has unit vectors $\mathbf{e}_r$ and $\mathbf{e}_\theta$ in the radial and transverse directions, respectively. Derive the velocity and acceleration of the particle in terms of radial and transverse components.

3. (20%) When a two-dimensional rigid body is moving freely in a plane, it can have both translation and rotation. At any instance of time, an approximate center of rotation can be determined which is defined as the *instantaneous center of rotation (ICR)*. What is the velocity at the ICR? Describe a method of determination of ICR.

4. (20%) Explain i) Principle of impulse and momentum; ii) Principle of work and energy.

5. (20%) (a) Describe the definitions of *moments of inertia* and *products of inertia* in three-dimensional Cartesian system. (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) What are their physical meanings?