1. It’s not a workout, it’s a revolutionary harnessing of “dynamic inertia”: this is Shake Weight, and it will be on your exam. The device below consists of a collar ($m = 1$ kg), a dumbbell ($M = 10$ kg) that slides through the collar without friction, and two massless springs ($k = 100$ N/m, datum length $l_o = 0.1$ m, installation length $L_{AB} = L_{CD} = 0.1$ m). Each spring is connected at one end to the collar, and at the other to the dumbbell; ignore the internal damping. Neglect the masses of the arm and hand.

To estimate its “dynamic inertia,” calculate the instantaneous acceleration of the collar in response to a horizontal force of magnitude $F = 10$ N:

(a) when $L_{AB} = 0.08$ m and $L_{CD} = 0.12$ m.

(b) when $L_{AB} = 0.1$ m and $L_{CD} = 0.1$ m.
2. But maybe “dynamic inertia” means instead that the direction of loading changes, as our TAs will illustrate throughout tonight’s exam.

(a) The TA jogs at a constant speed $v = 0.3$ m/s, holding Shake Weight horizontally, then stops suddenly, restraining the collar from moving. What will $L_{AB}$ be when the dumbbell reverses direction? Neglect wind resistance, and assume no vibratory motion of the dumbbell before the TA stops jogging.

(b) When the collar is again at rest, the TA applies a horizontal force to the collar for 1 second. The time-averaged magnitude of this force over the 1 second is 5 N. At the end of the 1 second, the collar has a velocity of 10 m/s in the direction of the applied force. Neglect the masses of the arm and hand. What is the velocity of the dumbbell at this instant (time $t = 1$ second)?

3. Shake Weight is also a revolutionary accelerometer! At the instant shown, Shake Weight is being held rigidly in a car that is driving in a circle of constant radius at a constant speed $v = 5$ m/s; the car has been driving along this circle for sufficiently long that vibratory motion may be neglected. The displacement of the dumbbell is such that $L_{AB} = 0.12$ m and $L_{CD} = 0.08$ m. What is distance $\rho$ from the center of the circle to the center of the dumbbell?

4. Shake Weight becomes so famous and successful that its components break up and start solo careers. Bar AB rotates at the constant rate of 40 rpm; the radial position of the collar’s center, C, is $R_c = 0.25$m. But the wire restraining Shake Weight’s collar breaks! What are the values of $dR/dt$ and $a_{collar}$ at the instant after the wire breaks?