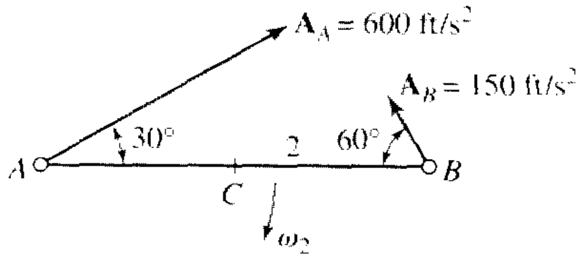
Chapter 4 HW Hints

Problem 4.6: Do this problem *analytically.* The problem is shown below:



Since you know the acceleration of two points on link 2, the "Two Points on a Body" equation applies; this should yield $\boldsymbol{\omega}_2$ and $\boldsymbol{\alpha}_2$. Then you can find the acceleration of point C.

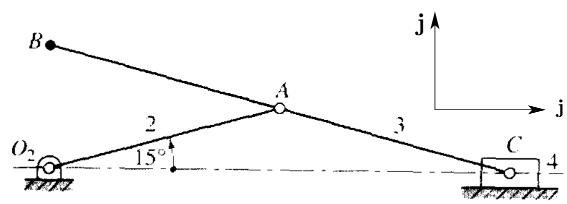
I found the angular velocity and angular acceleration of link 2 to be

$$\boldsymbol{\omega}_2 = 24.38\mathbf{k} \text{ rad/s}$$
$$\boldsymbol{\alpha}_2 = -145.8\mathbf{k} \text{ rad/s}^2$$

The acceleration of point B is for you to find.

Turns out that you can't create an ADAMS model—not enough information is given.

Problem 4.8: Do this problem both analytically and using ADAMS. Note that I changed the directions of both ω_2 and α_2 to be CCW (better for ADAMS solution). The mechanism is shown below:



(a) *Analytical Solution.* You can relate the motion of point A to both points O_2 and C. You know the direction of the velocity of C (it's in the **i** direction—this would be true regardless of the direction of ω_2). You will need ω_3 for the analysis—you can get this either by intuitive reasoning (note the symmetry of the mechanism) or a velocity analysis.

Some of my analytical results (some are intermediate results) are:

$$\mathbf{v}_A = -0.5176\mathbf{i} + 1.932\mathbf{j} \text{ m/s}$$
$$\boldsymbol{\omega}_3 = -\boldsymbol{\omega}_2 = -20\mathbf{k} \text{ rad/s}$$
$$\mathbf{v}_B = 3.864\mathbf{j} \text{ m/s}$$
$$\mathbf{a}_A = -42.26\mathbf{i} + 3.17\mathbf{j} \text{ m/s}^2$$

Angular acceleration $\boldsymbol{\alpha}_3$ and acceleration $\mathbf{a}_B$ are for you to find.

(b) *ADAMS Solution.* The text problem statement is for an *INSTANT*. Using ADAMS, we typically simulate the behavior of a mechanism over some time period. So the issue here is to deduce the initial conditions such that at $\theta_2 = 15°$ (as in the figure above) the angular velocity $\omega_2 = 20$ rad/s (CCW).

Assume the angular acceleration $\alpha_2(t)$ is *CONSTANT*, and assume the initial angular velocity $\omega_2(0) = 0$ (the system starts from rest). Now the problem is to find the initial value of θ_2 that results in $\omega_2 = 20$ rad/s (CCW) when $\theta_2 = 15°$.

Here's how to set this B.C. (boundary conditions) determination up. We are given that

$$\ddot{\theta}_2 = 140 \text{ rad/s}^2$$

so by integration we have

$$\dot{\theta}_2 = 140t + C_1$$
$$\theta_2 = 70t^2 + C_1 t + C_2$$

Integration constant C_1 can be found using the given initial condition (at time zero) on ω_2.

The *other* boundary condition is that you want $\omega_2 = 20$ rad/s when $\theta_2 = 15°$. If we define time t_1 as the time when $\theta_2 = 15°$, then this can be stated

$$\theta_2(t_1) = \frac{15\pi}{180} \text{ rad}$$

Note all calculations should be done using angles in radians. Anyway, at this point you should be able to solve for both t_1 and C_2, where $C_2 = \theta_2(0)$, the initial condition of θ_2.

This is not as difficult as it sounds. I got time t_1 to be about 0.14 sec, and initial angle θ_2 near $-70°$.

NOTE: Plot the velocity of Point B (y component only in units of m/s), the angular velocity of link 2 (rad/s), and the acceleration of link 3 (rad/s^2). Since in this case θ_2 is accelerating (rather than moving at a constant speed) you should plot all variables *vs* time. Please indicate the point (time) at which $\theta_2 = 15°$.

Rather than trying for one full revolution of link 2, I'd recommend just picking a time duration that is beyond the time at which $\theta_2 = 15°$; I used $t_{final} = 0.19$ sec. At that time link 2 is not quite vertical.

Problem 4.32: Do this problem both analytically and using ADAMS. Since the acceleration of link 4 is not given, assume it's zero.

(a) *Analytical Solution.* It cannot be done with just the "2 points on a body" equation; there is sliding motion between bodies 2 and 3. Thus there will be Coriolis acceleration. The critical thing is to visualize what relative path you know: I think you know the path of point A relative to link 2. So write the "One point moving on a body" equation accordingly, that is, using point A and body 2:

$$\mathbf{v}_A = \mathbf{v}_{A_2} + {}^2\mathbf{v}_A$$

where you know the velocity of A_2 using the "Two points..." equation from point O_2 (using $\boldsymbol{\omega}_2$), and you know the *direction* of the relative velocity ${}^2\mathbf{v}_A$; it's along link 2 (line O_2B).

Note that the xyz coordinate system is angled.

NOTE: Usually we use either English (lb-ft-slug-sec) or SI (N-m-kg-sec) units. However, in this problem the motions are *so slow* that I suggest you use units of "ft" and "min" for velocity & acceleration. You can still use units of "rad" for expressing angular displacement in your results.

You will need to do the velocity analysis first.

Some of my results are:

$$\boldsymbol{\omega}_2 = -1.25\mathbf{k} \text{ rad/min}$$
$$-1.7\mathbf{k} > \boldsymbol{\alpha}_2 > -2.0\mathbf{k} \text{ rad/min}^2$$

(b) *ADAMS Solution.* Similar to Problem 8, I created the ADAMS model with the angle of link 2 equal to 45°, then allowed enough time in the simulation for the angle to decrease beyond 30°. With the given velocity of link 4 of 10 ft/min to the left, and starting link 2 at 45°, I found the *time* when link 2 is at 30° to be $t = 0.253$ sec.

Evaluation of α_3 at this time agreed with my analytical result.