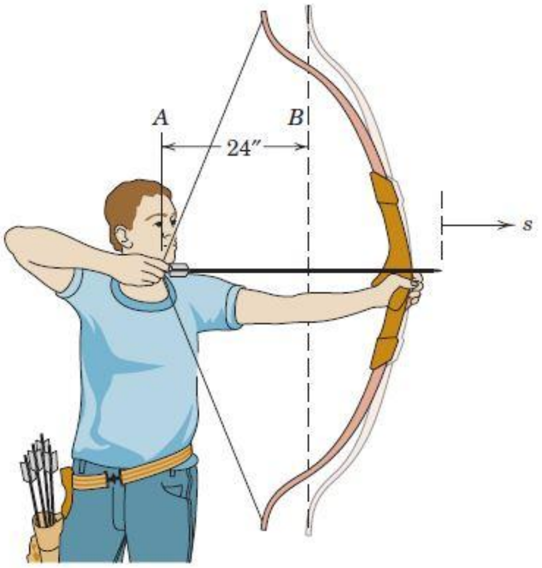
Dynamics, ESO209A

Date: 1/8/18.

Here are some homework problems from Meriam and Karaige, 7th edition (MK7). It is my intention to add to these problems, include notes, etc., from time to time, and to send you updated pdfs, so that you will not have to keep track of too many documents.

Tutors will discuss these problems next Tuesday if you need help, but you should not. I think you should be able to work these out at this time, or maybe after today's class.

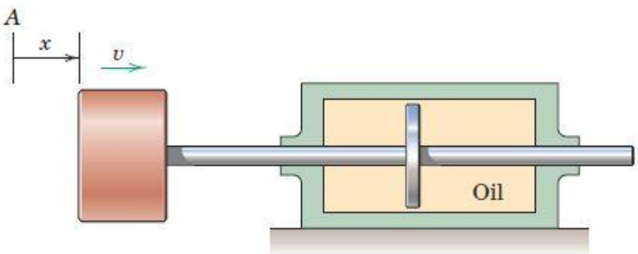
2/36 In an archery test, the acceleration of the arrow decreases linearly with distance s from its initial value of 16,000 ft/sec^2 at A upon release to zero at B after a travel of 24 in. Calculate the maximum velocity v of the arrow.



Problem 2/36

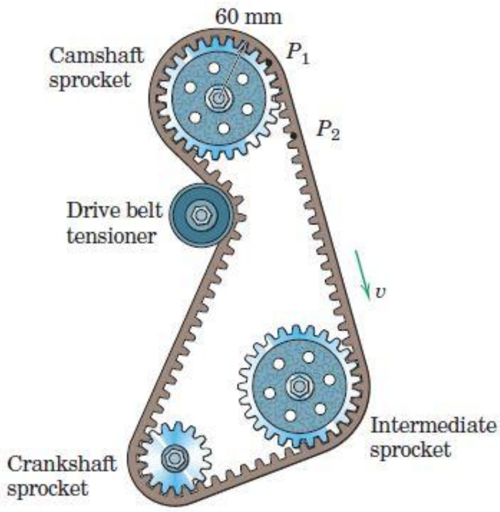
2/37 The 230,000-lb space-shuttle orbiter touches down at about 220 mi/hr. At 200 mi/hr its drag parachute deploys. At 35 mi/hr, the chute is jettisoned from the orbiter. If the deceleration in feet per second squared during the time that the chute is deployed is $-0.0003v^2$ (speed v in feet per second), determine the corresponding distance traveled by the orbiter. Assume no braking from its wheel brakes.

2/52 The horizontal motion of the plunger and shaft is arrested by the resistance of the attached disk which moves through the oil bath. If the velocity of the plunger is v_0 in the position A where $x = 0$ and $t = 0$, and if the deceleration is proportional to v so that $a = -kv$, derive expressions for the velocity v and position coordinate x in terms of the time t. Also express v in terms of x.



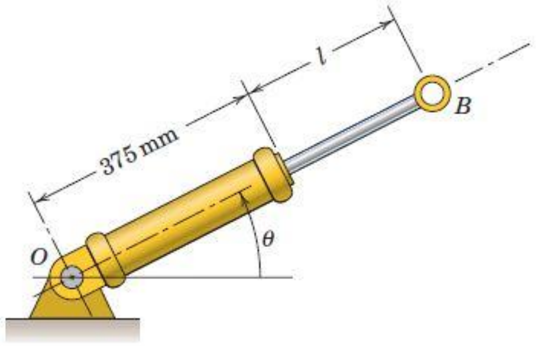
Problem 2/52

2/119 The design of a camshaft-drive system of a four-cylinder automobile engine is shown. As the engine is revved up, the belt speed v changes uniformly from 3 m/s to 6 m/s over a two-second interval. Calculate the magnitudes of the accelerations of points P_1 and P_2 halfway through this time interval.



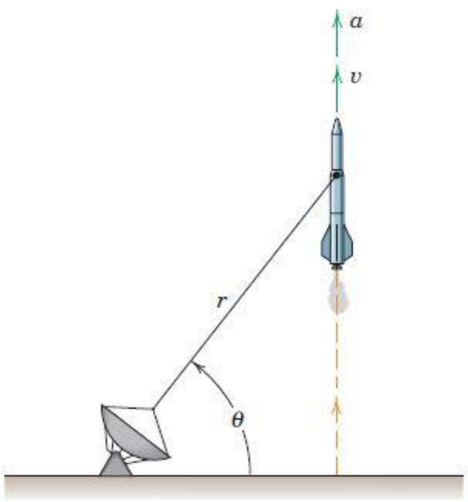
Problem 2/119

2/136 As the hydraulic cylinder rotates around O, the exposed length l of the piston rod P is controlled by the action of oil pressure in the cylinder. If the cylinder rotates at the constant rate $\dot{\theta} = 60$ deg/s and l is decreasing at the constant rate of 150 mm/s, calculate the magnitudes of the velocity **v** and acceleration **a** of end B when $l = 125$ mm.



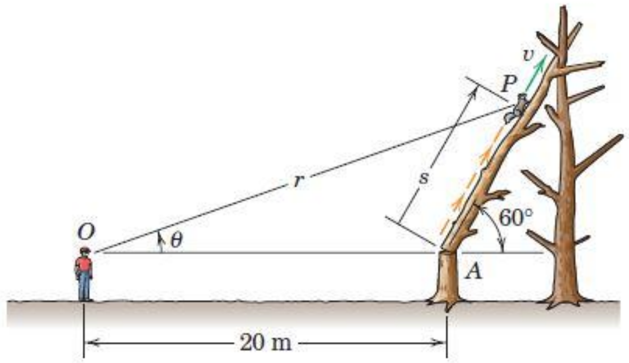
Problem 2/136

2/143 The rocket is fired vertically and tracked by the radar station shown. When θ reaches 60°, other corresponding measurements give the values $r =$ 30,000 ft, $\ddot{r} = 70$ ft/sec², and $\dot{\theta} = 0.02$ rad/sec. Calculate the magnitudes of the velocity and acceleration of the rocket at this position.



Problem 2/143

2/144 A hiker pauses to watch a squirrel P run up a partially downed tree trunk. If the squirrel's speed is $v = 2$ m/s when the position $s = 10$ m, determine the corresponding values of $\dot{r}$ and $\dot{\theta}$.



Problem 2/144

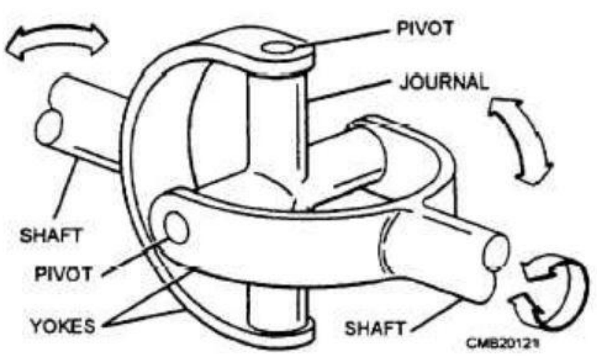
In addition to the above problems, also pay attention to the (different) problems being discussed in class, involving FBDs, moments about axes, wheels, and friction.

Date: 3/8/18

Discussions with individual students indicate to me that students are not used to the idea that forces and moments initially shown on free body diagrams (before further analysis) must correspond to motion restrictions at those locations.

I think universal joints can help to clarify these issues.

Here is a picture of a universal joint, taken from http://constructionmanuals.tpub.com/14273/css/Cross-and-Roller-Universal-Joint-179.htm



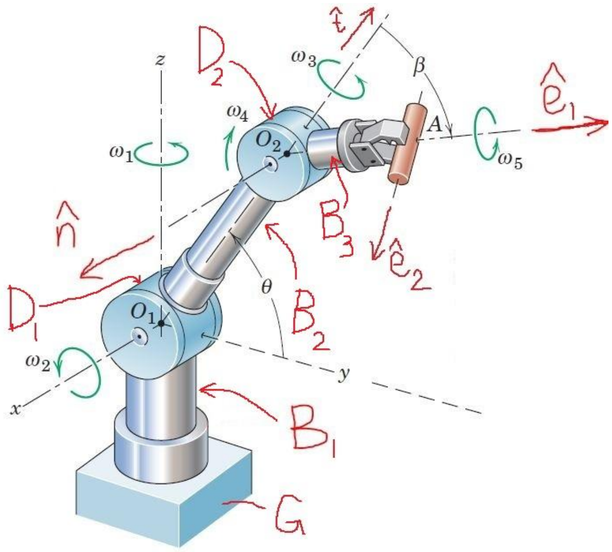
Note that the two shafts can be at an angle to each other, and the joint can still transmit torques. Here is another picture, from https://apexbits.com/ms20270-b12-apex-universal-joint-light-duty-bored-hub.aspx

The picture shows the possibility of the two shafts being at an angle.

For simple analysis, treat the shaft on the right as being horizontal and held in a bearing that allows free rotation; and treat the shaft on the left as being at 45 degrees (CW from vertical), also held in a bearing that allows free rotation. If a torque T is applied to the shaft on the left, how much is the shaft on the right transmitting? The pins in the coupler ("journal" above) may be taken as (i) one at 45 degrees (CCW from vertical), and (ii) one coming out of the page.

Tutors will discuss this on Tuesday.

Date: 19/8/18



This is a somewhat complicated problem.

See the robot picture above. First find the following in the picture. Ground G, stationary. Cylindrical arms B1, B2 and B3. Drums D1 and D2. Axes *xyz*, with *z* vertical. Angles theta and beta. Note the angular rates omega1 through omega5. At the instant of interest, unit vector n_hat is perpendicular to the *yz* plane. Unit vectors t_hat and e1_hat are in the *yz* plane. Unit vector e2_hat is perpendicular to e1_hat, but not perpendicular to the *yz* plane.

Workpiece A is attached rigidly to cylinder B3, which rotates relative to drum D2 at a constant rate omega5. Drum D2 rotates relative to cylinder B2 at a constant rate omega4 (which tends to lower cylinder B3). Cylinder B2 rotates relative to drum D1 at a constant rate omega3 (which tends to move cylinder B3 out of the *yz* plane). Drum D1 rotates relative to cylinder B1 at a constant rate omega2 (which tends to raise cylinder B2). The *xyz* axes rotate such that *z* always remains vertical, and the axis of drum D1 always remains along *x*. Finally, cylinder B1 rotates about a vertical axis at a constant rate omega1; and the axis of drum D1 rotates at the same rate.

Take time to understand the motions being described.

Now, for arbitrarily chosen numerical values of all necessary quantities given (don't try to derive a formula unless you like symbolic algebra!), compute the first and second derivatives of the unit vector e2_hat, with respect to fixed frame G.

Note that e2hat is fixed in workpiece A, so

dot e2hat = omega_(A/G) X e2hat

and

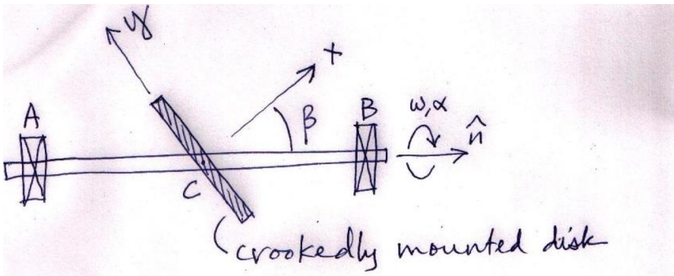
ddot e2hat = alpha_(A/G) X e2hat + omega_(A/G) X omega_(A/G) X e2hat

Discuss this problem extensively with your friends. That is your homework.

I think it might, probabilistically speaking, be a good idea not to miss Tuesday's tutorial!

Date: 30/8/2018

The crooked rotor discussion in class had the rotor axis as the y-axis. The following problem statement shows why it may be convenient to use crooked axes. The attached body is now a crookedly mounted disk.



$AC = L_1$, $CB = L_2$, disk mass $= m$, disk radius $= R$, x-axis makes angle β with rotor axis $\hat{n}$, rotor shaft is massless and rigid, bearings at A & B are frictionless, $\underline{M}_A = \underline{M}_B = \underline{0}$, disk center of mass is on rotor axis, rotor speed is ω, $\alpha = 0$ as discussed in class, and in xyz axes, the disk's

$$I_{cm} = \begin{bmatrix} \frac{mR^2}{2} & 0 & 0 \\ 0 & \frac{mR^2}{4} & 0 \\ 0 & 0 & \frac{mR^2}{4} \end{bmatrix}.$$

Find $\underline{F}_A$ & $\underline{F}_B$ using xyz coordinates.

The final answers will be in terms of **i**, **j**, **k** along *xyz* axes. Assume bearing force components along the rotor axis are zero. Calculate the force magnitudes.

Consider the special case where ω = 300 rad/s, m = 5 Kg, R = 0.2 m, β = 1 degree, and $L_1 = L_2 = 0.04$ m. Before you calculate anything, think for a minute and write down a guess for the force magnitude; and after you compute, see how good your guess was.

I think it may be a good idea to discuss this problem extensively with your friends *before* class on Monday!