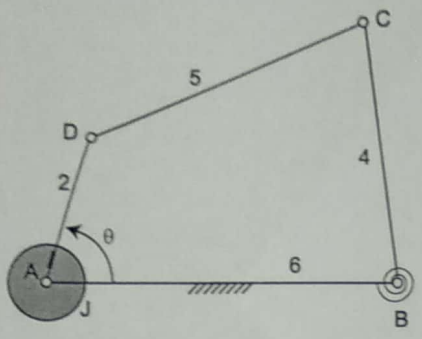
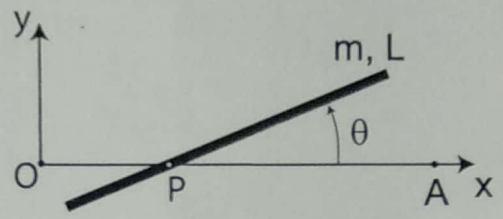
End-semester exam, ME352A

Nov 23, 2017 3 hours 60 marks

Note: No phones or other communication devices permitted. Calculators allowed (no sharing). One blue-ink, own-handwriting, one-sided, A4-sheet of notes is allowed, with student's name and roll number.
Instructions: Start each question/answer on a fresh page. Write the question number (BIG and CLEAR) on the top left.





1. (15 marks) See the figure (left). A four-bar linkage ABCD has no external load and no friction (no driving torque, no dissipation). Its links (rods) are rigid and massless. Rods AB, BC, CD, and DA have lengths 6, 4, 5 and 2 (meters) respectively, as shown. At hinge B, acting between links AB and BC, is a torsion spring with spring constant 40 Nm/rad. Centered at hinge A, rigidly attached to link DA, is a flywheel of moment of inertia $J = 10$ kg m^2. The torsion spring at B is unstressed when the angle $\theta = 1.2$ rad. At that instant, $\dot{\theta} = 30$ rad/s. Will link DA keep rotating indefinitely about A? If no, then how far will it rotate before it turns back? If yes, what is the minimum angular velocity link DA will achieve within each revolution?
2. (10 marks) See the figure (left). Now suppose an external agent drives link DA such that its angular velocity is constant at $\dot{\theta} = 30$ rad/s, over some nonzero interval of time. During such motion, when $\theta = 1.2$ rad, what is the velocity and acceleration of point C?
3. (15 marks) See the figure (right). A rigid slender uniform rod of mass m and length L lies in the x-y plane, making angle θ with the x-axis, with point P located at a distance from the origin O of $0.4L$ measured along the x-axis, and point P also located $0.3L$ from the left end of the rod (measured along the rod). This rod will rotate about the x-axis. Point A is located at a distance of $1.1L$ from the origin. Two-plane balancing is to be attempted. Two masses, m_O and m_A, are to be placed in the x-y plane, with their x-coordinates matching those of O and A, respectively. The corresponding y coordinates are to be chosen/determined, and we call them y_O and y_A respectively. The z-coordinates are zero in the present configuration.

   (i) If m_O and m_A are taken equal to $0.3m$ each, what are y_O and y_A?
   (ii) Conversely, if y_O and y_A are taken as $0.3L$ each, what are m_O and m_A? (Negative answers, if any, need to be interpreted.)
   (iii) Finally, if $m_O = 0.3m$ and $y_O = 0.3L$, can solutions for m_A and y_A be found?

   Hint: avoid moment of inertia matrices, consider integration along the rod.
4. (10 marks) A cam with a translating roller follower has a prime circle radius of 70 mm, eccentricity $e = 20$ mm, and a displacement curve given by $y(\theta) = 0.02\,\theta^4\,(2\pi - \theta)^4$ (mm, with θ in radians). It is found that the maximum pressure angle occurs at $\theta = 1.566$ rad. How much is the maximum pressure angle?
5. (10 marks) Recall the formula for the minimum number of pinion teeth needed to avoid interference:

$$N_1 = \frac{2f\lambda}{\left[1 + \lambda(\lambda+2)\sin^2\alpha\right]^{1/2} - 1}.$$

   Define all relevant quantities and present a brief derivation of the above formula.