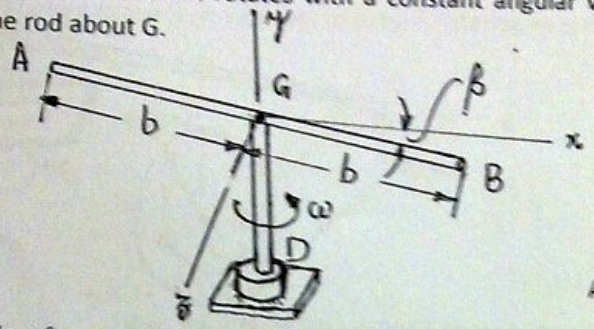
INDIAN INSTITUTE OF TECHNOLOGY, BHUBANESWAR

ASSIGNMENT NO. -04

Course: ME 20001 (DYNAMICS) (Third Semester, 2011)

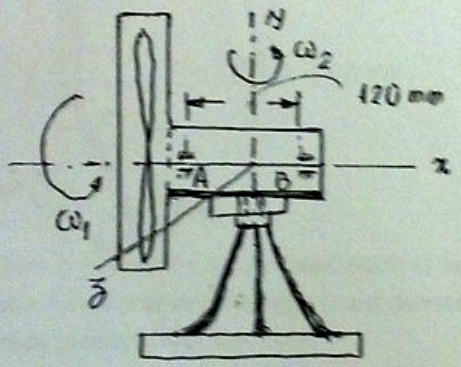
Sub: [Kinetics of Rigid Bodies in 3-Dimentiosns and Gyroscopic Effect]

Q.1. A thin homogeneous rod AB of mass m and length 2b is welded at its midpoint G to a vertical Shaft GD. Knowing that the shaft rotates with a constant angular velocity ω, determine the angular momentum of the rod about G.

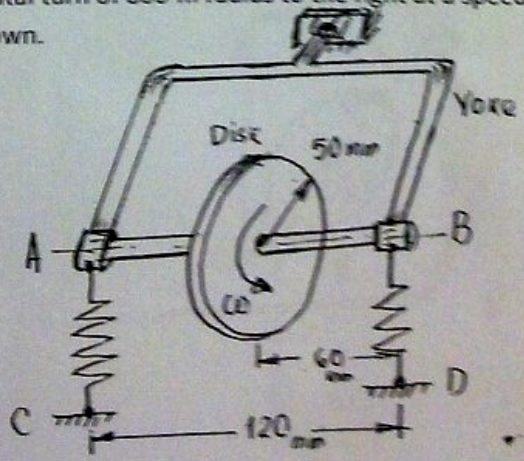


Ans. $\frac{1}{2}mb^2\,\omega\,(\sin 2\beta\,\mathbf{i} + 2\cos^2\beta\,\mathbf{j})$

Q.2. The blade of an oscillating fan and the rotor of its motor have a total mass of 200 g and combined radius of gyration of 75 mm. They are supported by bearing located at A and B, 120 mm apart, and have an angular velocity ω_1 of 2400 r/min at the high-speed setting. Determine the dynamic reactions at A and B when the motor casing has an angular velocity ω_2 of 0.5 rad/s as shown.



Q.3. The essential structure of a certain type of aircraft turn indicator is shown. Springs AC and BD are initially stretched and exert equal vertical forces at A and B when the airplane is traveling in a straight path. Each spring has a constant of 600 N/m and the uniform disk has a mass of 250 g and spins at the rate of 12000 r/min. Determine the angle through which the yoke will rotate when the pilot executes a horizontal turn of 800-m radius to the right at a speed of 720 km/h. Indicate whether point A will move up or down.

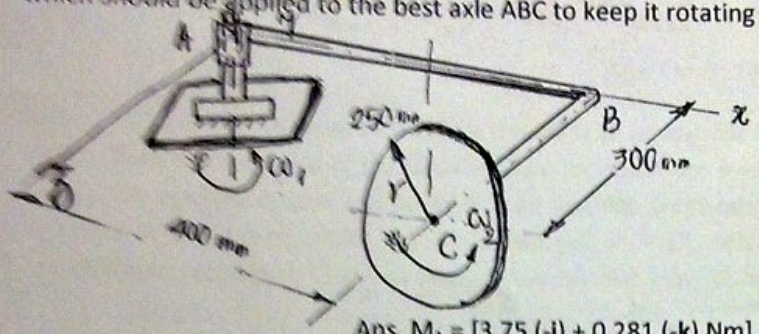


Ans. 1.30°; A will move up

Q.4. A three-bladed airplane propeller has a mass of 136 kg and has a radius of gyration of 0.9 m. knowing that the propeller rotates at 1500 r/min, determine the magnitude of the couple applied by the propeller to its shaft when the airplane travels in a circular path of 360-m radius at 560 km/h.

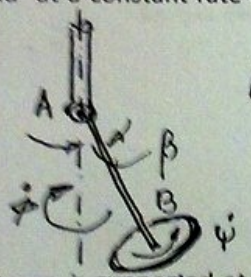
Ans. 7.47 kN

Q.5. A thin disk of mass m=5kg rotates with an angular velocity ω_2 with respect to the bent axle ABC, which itself rotates with an angular velocity ω_1 about the y axis. Knowing that ω_1 = 3 rad/s (constant rate) and ω_2 = 8 rad/s which decreases at the rate of 1.8 rad/sec^2 due to axle friction at C, determine the force-couple system representing the dynamic reaction at the support at A, as well as the couple M (j) which should be applied to the best axle ABC to keep it rotating as stated above.



Ans. M_A = [3.75 (-i) + 0.281 (-k) Nm] ; R_A = [-18.00 (i)- 13.50 (k)] N & M (j) = 0

Q.6. A 2-kg disk of 150-mm diameter is attached to the end of a rod AB of negligible mass which is supported by a ball-and-socket joint at A. If the disk is observed to precess about the vertical in the sense indicated and at a constant rate of 36 r/min, determine the rate of spin ψ of the disk about AB when $\beta = 30°$.

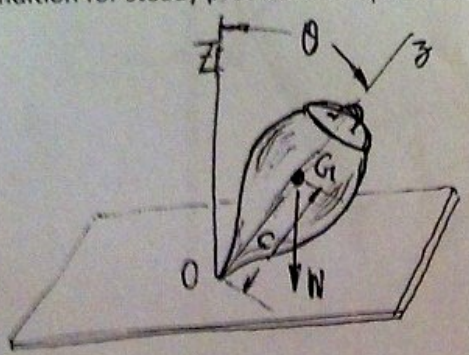


Ans. 1326 rpm

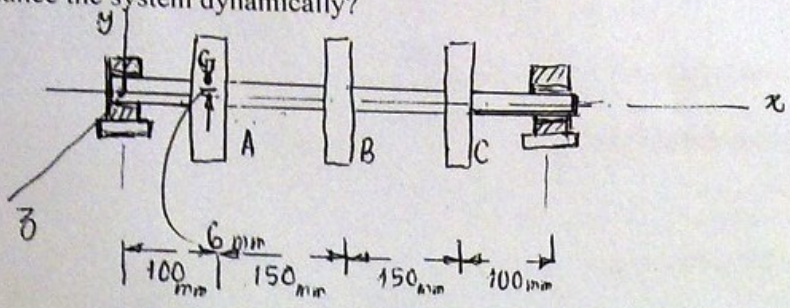
Q.7. The top shown is supported at the fixed point O and its moments of inertia about its axis of symmetry and about a transverse axis through O are denoted, respectively, by I and I'. (a) Show that the condition for steady precession of the top is

$$(I\omega_z - I'\dot{\Phi}\cos\theta)\dot{\Phi} = Wc$$

Where $\dot{\Phi}$ is the rate of precession and ω_z is the component of the angular velocity along the axis of symmetry of the top. (b) Show that if the rate of spin $\dot{\psi}$ of the top is very large compared with its rate of precession $\dot{\Phi}$, the condition for steady precession is $I\dot{\psi}\dot{\Phi} \approx Wc$, W & c are as shown in figure below.

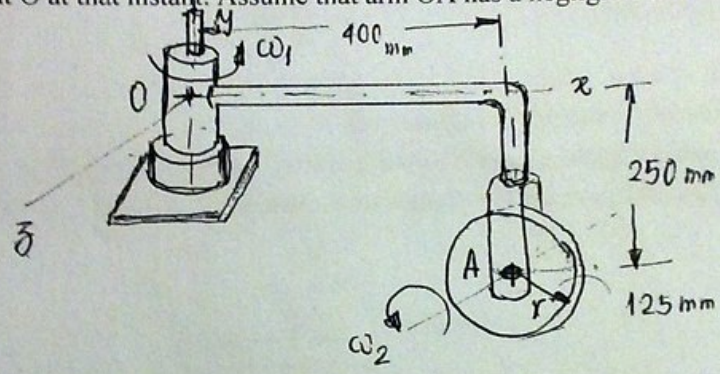


Q.8. Three 12-kg rotor disks are attached to a shaft which rotates at 720 r/min. Disk A is attached eccentrically so that its mass center is 6 mm from the axis of rotation, while disks *B* and *C* are attached so that their mass centers coincide with the axis of rotation. Where should 1-kg masses be bolted to disks B and C to balance the system dynamically?



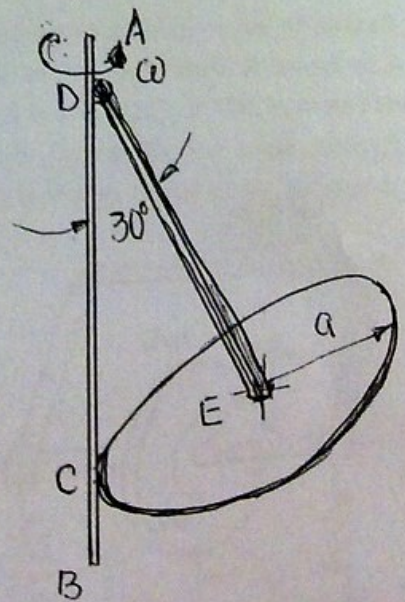
Ans. On B: 144 mm below shaft: On C: 72 mm above

Q.9. A thin disk of mass $m = 3.5$ kg rotates with an angular velocity $\omega_2 = 12$ rad/s with respect to arm OA, which itself rotates at the constant rate ω_1 about the y axis. Determine (a) the couple $M_1\mathbf{j}$ which should be applied to arm OA to give it an angular acceleration $\alpha_1 = (6 \text{ rad/s}^2)\,\mathbf{j}$ when $\omega_1 = 4$ rad/s, knowing that the disk rotates at the constant rate $\omega_2 = 12$ rad/s, (b) the force-couple system representing the dynamic reaction at O at that instant. Assume that arm OA has a negligible mass.



Ans. (a) (3.44 N.m)**j**, (b) F = -(22.7 N)I – (8.4 N)k; M_O = (3.41 N)**i** – (5.60 N.m)**k**

Q.10 A disk of mass m and radius a is rigidly attached to a rod DE of negligible mass. Rod DE is attached to a vertical shaft AB by a clevis at D and the disk leans again the shaft at C. Noting that when shaft AB is made to rotate, the same point of the disk will remain in contact with the shaft at C, determine the magnitude of the angular velocity ω for which the reaction at C will be zero.



Ans. $\sqrt{8g/11a}$