Bengal Engineering and Science University, shibpur
B. E. (Aero.) Part-II 4th Semester Final Examination, 2013

Dynamics for Aerospace Engineers (AE 404)

Time: 3 Hrs. Full Marks: 70

All questions are of equal value

Separate Answer scripts are not required

Group A

Answer any three of the following:

1. In manipulating dumbbell, the jaws of the robotic device have an angular velocity ω_p = 2 rad/s about the axis OG with γ fixed at 60^0. The entire assembly rotates about the vertical z-axis at the constant rate Ω = 0.8 rad/s. Determine the angular velocity ω and angular acceleration α of the dumbbell. Express the results in terms of the given orientation of axes x-y-z, where the y-axis is parallel to the Y-axis. (Fig. Q.1)

2. The circular disc of 100-mm radius rotates about its vertical z-axis at the constant speed p = 240 rev/min, and arm OCB rotates about the y-axis at the constant speed N = 30 rev/min. Determine the velocity v and acceleration a of the point on the disk as it passes the position shown. Indicate the point of attachment of reference axes x-y-z in process of computation. (Fig. Q.2)

3. The uniform circular disk with the three components of angular velocity is shown in Fig. Q. 3. Determine the kinetic energy T and the angular momentum H_0 with respect to O of the disk for the instant shown when its x-y plane coincides with the XY plane. The mass of the disk is m.

4. The uniform slender rod of length ℓ is welded to the bracket at A on the underside of the disk B. The disk rotates about a vertical axis with a constant angular velocity ω. Determine the value of ω that will result in a zero moment supported by the weld at A for the position $\theta = 60^0$ with $b = \ell/4$. (Fig. Q.4)

5. a) The turbine rotor in a ship power plant has a mass of 1000 kg, with center of mass at G and radius of gyration of 200 mm. The rotor shaft is mounted in bearings A and B with its axis in the horizontal fore-and-aft direction and turns counterclockwise at a speed of 5000 rev/min when viewed from the stern. Determine the vertical components of the bearing reactions at A and B if the ship is making turn to port (left) of 400-m radius at a speed of 25 knots (1 knot = 0.514 m/s). (Fig. Q.5 (a))

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b) The special purpose fan is mounted as shown in Fig. Q. 5.(b). The motor armature, shaft and blades have a combined mass of 2.2 kg with radius of gyration of 60 mm. The axial position of the 0.8-kg block A can be adjusted. With the fan turned off, the unit is balanced about the x-axis when b = 180 mm. The motor and fan operate at 1725 rev/min in the direction shown. Determine the value of b that will produce a steady precession of 0.2 rad/s about the positive y-axis.

Group B

Answer any three of the following:

6. a) A block of mass m_1 smoothly slides along the inclined plane of a wedge of mass m_2 and angle θ as shown in Fig.Q.6 (a). The wedge slides freely on a horizontal plane. Choose suitable generalized coordinates and derive the equations of motion using Lagrange's equation.

   b) Derive Hamilton's equation of motion for a particle moving under a central inverse square force (say gravity).

7. A spring mass and pendulum system is shown in Fig. Q. 7. Assume that all motion takes place in a vertical plane. Identify the generalized coordinates of the given system. Derive the Lagrange's equations of motion.

8. a) Write down the Vector form of inertial navigation equations and define the terminologies when
   i) Specific force is sensed in inertial frame
   ii) Specific force is sensed in body frame

   b) Identify which one, out of the above two, represents strapdown navigation and why?
   c) Write down the schemes needed for body to inertial frame transformation in strapdown navigation and briefly describe any one of the schemes.

   d) Sketch of a strapdown system is shown below involving rotation about the y-axis only, where superscripts I & B denote inertial frame and body frame respectively and f is the specific force sensed in body frame

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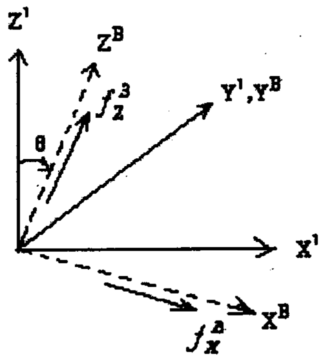

Fig. Q. 8

Obtain the equations for the specific force in inertial frame and from this write down the transformation matrix C_B^I

9. a) Explain the difference between gravitational acceleration g and local gravity g_p?
b) Sketch a spherical earth and assume it to be homogeneous. Write down the vector form of the equation for gravitational acceleration acting on a vehicle nearer to earth surface and define the terminologies. Show on the sketch the direction of g ? What is the significance of the term 'homogeneous'?
c) Sketch an ellipsoidal earth and assume it to be homogeneous. Show on it g and g_p? Which one of the two is perpendicular to earth surface?
d) If centripetal acceleration due to inertial earth rate is given by the triple vector cross product:
$\boldsymbol{\omega_e \times \omega_e \times R}$
Reduce mathematically the equation to its scalar form and then compute the acceleration magnitude at equator having radius of 6378137 m and inertial earth rate of 15.04 deg/h. What is the magnitude at the pole?

10. a) Write down the vector form of gyroscopic precession motion of a spinning rotor and define the terms used in the equation.
b) A perfectly balanced spinning rotor of a gyro, supported at the base as shown, is rotating at a constant rate in the direction shown in the figure below.

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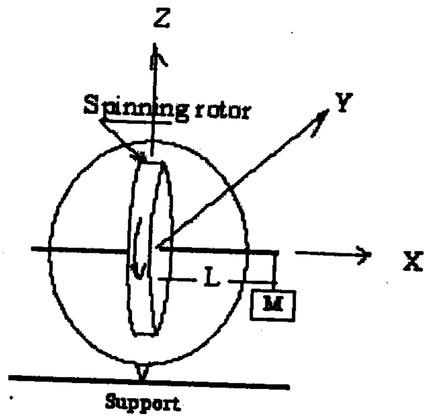

Fig. Q. 10 (b)

A mass M is placed at a distance L from the centre of the wheel on the spin axis. Explain what happens thereafter and compute if $M = 1x10^{-3}$ gm, L = 1 cm and rotor momentum = $1x10^{5}$ gm.cm^2/s and gravity of 980 cm/s^2

c) . Sketch of a spinning rotor gyro is shown below

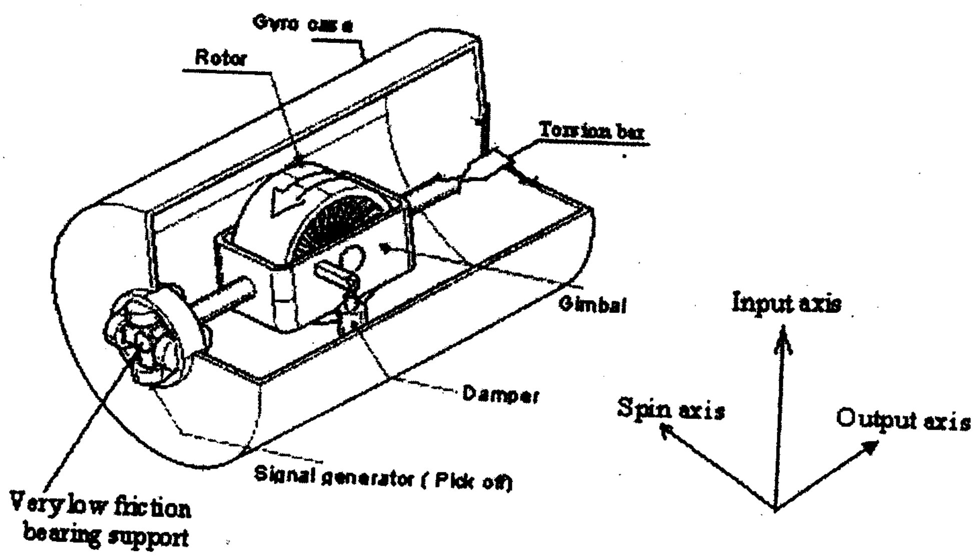

Fig. Q. 10. (c)

i) Assume normal gyro parameters, draw its block schematic and write down its input-output relation under steady state condition? What type of gyro it is called?
ii) Suppose the torsion bar is removed and the gimbal is mounted to the gyro case on a friction less bearing, what will be the gyro called?

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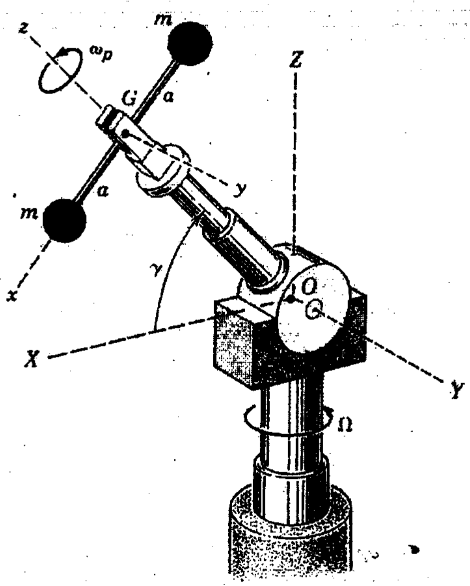

Fig Q. 1

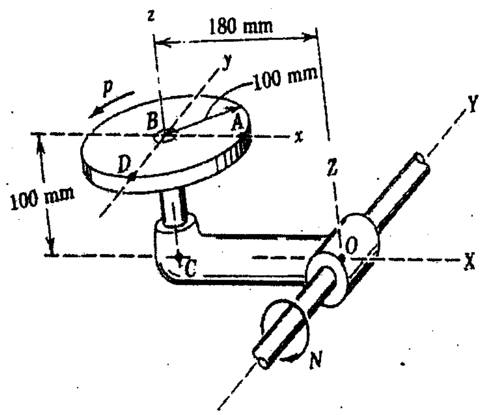

Fig. Q. 2

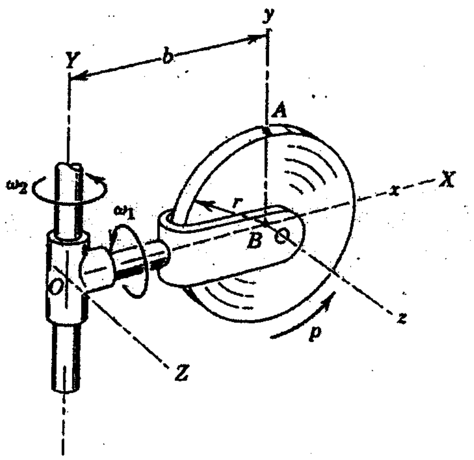

Fig. Q. 3

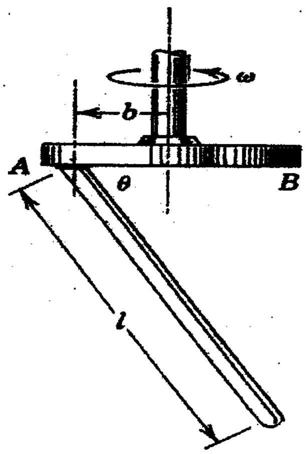

Fig. Q. 4

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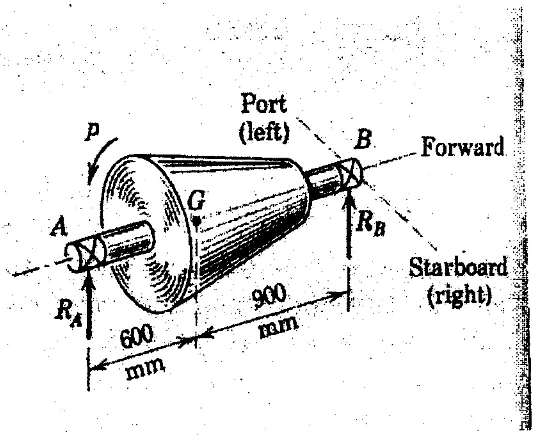

Fig. Q. 5 (a)

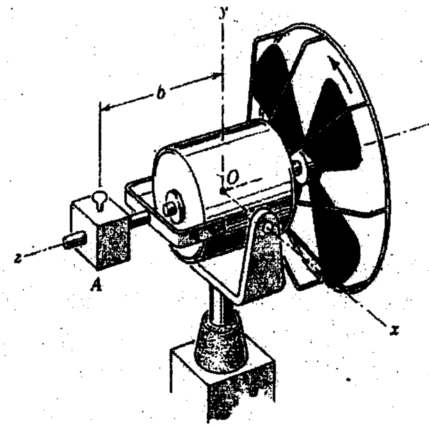

Fig. Q. 5 (b)

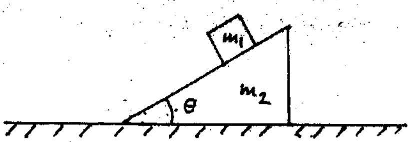

Fig . Q. 6 (a)

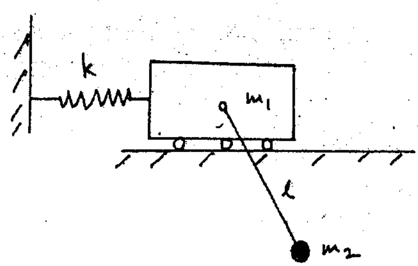

Fig. Q. 7