Bengal Engineering and Science University, shibpur
B. E. (Aero.) Part-II 4th Semester Final Examination, 2012

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 four of the following:

1. a) The axial flow fan C pumps air through the duct of circular cross section and exhausts it with a velocity v at B. The air densities A and B are ρ_A and ρ_B, respectively, and the corresponding pressures are p_A and p_B. The fixed deflecting blades at D restore axial flow to the air after it passes through the propeller blades C. Write an expression for the resultant horizontal force R exerted on the fan unit by the flange and bolts at A. Fig. Q. 1 (a)

   b) At the instant of vertical launch the rocket expels exhaust at the rate of 220 kg/s with an exhaust velocity of 820 m/s. If the initial vertical acceleration is 6.8 m/s^2, calculate the total mass of the rocket and the fuel at launch. Fig. Q. 1 (b)

2. a) The jet aircraft has a mass of 4.6 Mg and a drag of 32 kN at a speed of 1000 km/h at a particular altitude. The aircraft consumes air at the rate of 106 kg/s through its intake scoop and uses fuel at the rate of 4 kg/s. If the exhaust has a rearward velocity of 680 m/s relative to the exhaust nozzle, determine the maximum angle of elevation α at which the jet can fly with a constant speed of 1000 km/h at the particular altitude in question. Fig. Q. 2 (a)

   b) An open-link chain of length L = 8 m with a mass of 48 kg is resting on a smooth horizontal surface when end A is doubled back on itself by a force P applied to end A. (a) Calculate the required value of P to give A a constant velocity of 1.5 m/s. (b) Calculate the acceleration a of end A if P = 20 N and if v = 1.5 m/s when x = 4 m. Fig. Q. 2 (b)

3. The spacecraft shown has a mass m with mass centre G. Its radius of gyration about its z-axis of rotational symmetry is k and that about either the x-axis or y-axis is k'. In space, the spacecraft spins within its x-y-z reference frame at the rate $p = \varphi$. Simultaneously, a point C on the z-axis moves in a circle about the z_0 axis with a frequency f (rotation per unit time). The z_0 axis has a constant direction in space. Determine the angular momentum $\mathbf{H}_G$ of the spacecraft relative to the axes designated. Note that the x-axis always lies in the z-z_0 plane and that the y-axis is therefore normal to z_0. Fig. Q. 3

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4. The elements of a reaction-wheel attitude-control system for a spacecraft are shown in the figure Q. 4. Point G is the centre of mass for the system of the spacecraft and wheels and x,y,z are principal axes for the system. Each wheel has a mass m and a moment of inertia I about its own axis and spins with a relative angular velocity p in the direction indicated. The center of each wheel, which may be treated as a disk, is a distance b from G. If the spacecraft has angular velocity components Ω_x, Ω_y and Ω_z, determine the angular momentum $\mathbf{H}_G$ of the three wheels as a unit.

5. The uniform square flaps, each of mass m, are freely hinged at A and B to the square plate and attached shaft, which rotate about the vertical z-axis with a constant angular velocity ω. Determine the angular velocity ω required to maintain a specified positive angle. (Fig. Q. 5)

6. a) An airplane has just cleared the runway with a takeoff speed v. Each of its freely spinning wheels has a mass m, with a radius of gyration k about its axel. As seen from the vront of the airplane, the wheel precesses at the angular rate Ω as the landing strut is folded into the wing about its pivot O. As a result of gyroscopic action, the supporting member A exerts a torsional moment M on B to prevent the tubular member from rotating in the sleeve at B. determine M and identify whether it is in the sense of M_1 or M_2. (Fig. Q. 6)

Group B

Answer any two of the following:

7. a) Vector form of inertial navigation is expressed by the following two equations

$$\mathbf{A}^I = \frac{d^2\mathbf{R}^I}{dt^2} = \mathbf{f}^I + \mathbf{g}^I \qquad \text{i)}$$

$$\frac{d^2\mathbf{R}^I}{dt^2} = \left[C_B^I\right]\mathbf{f}^B + \mathbf{g}^I \qquad \text{ii)}$$

Briefly explain the difference in the navigation operation represented by the two equations and answer which one represents a strapdown system. What is the significance of the term inside the bracket in eqn (ii).
Write down the three schemes used to transform rotation measurement in body frame to inertial frame along with their relative advantages and disadvantages.

b) Given the following two informations:

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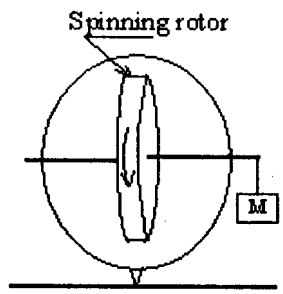
Velocity measured in i-frame as $V_x = V_y = V_z = 50$ m/s and an orthogonal transformation matrix given as:

$$C_G^i = \begin{bmatrix} -\sin L\cos\Phi & -\sin\Phi & -\cos L\cos\Phi \\ -\sin L\sin\Phi & \cos\Phi & -\cos L\sin\Phi \\ \cos L & 0 & -\sin L \end{bmatrix}$$

Compute the velocities in G-frame when L = $\Phi = 30^O$

8.

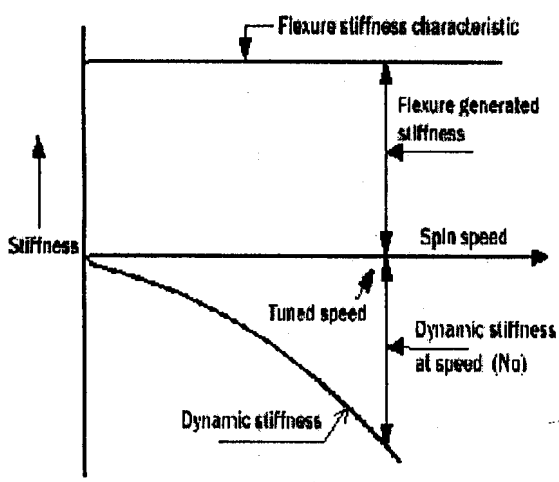
a) A perfectly balanced spinning rotor of a gyro is rotating at constant rate in the direction shown in the figure below.



What happens when a mass M is added at the end as shown? Clearly explain your choice.

i) The gyro topples ; ii) The gyro precesses about the vertical axis ; iii) The gyro precesses about the horizontal axis ; iv) Not enough information to answer.

b) The sketch of a gyro characteristic is shown below:



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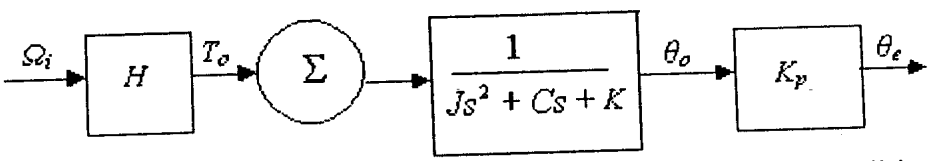
Answer the following:

i) What is the gyro called and why?
ii) What is the tuned speed equation for this gyro and define the parameters in the equation?
iii) How many degrees of freedom the rotor has and the number of sensitive axes of the gyro?
iv) Will the gyro have nutation frequency when operated at the tuned speed?
v) A DTG with angular momentum of $1x10^5$ gm cm^2/s experiences a rate of 100 °/s at an angle of 30° to x-sensitive axis in the x-y plane. Find the precessional torque generated about x-axis and about y-axis respectively?

9.
a) A spinning wheel gyro is represented by the following block diagram:



i) Write down its input-output relation under steady state condition What is the gyro called?

ii) If the term K is made theoretically zero, what type of gyro it becomes and write down its steady state input-output relation.

Assume for a gyro of the above type the output axis bearing friction torque value is only : $1x10^{-3}$ gm.cm and consider its angular momentum H = $1x10^5$ gm.cm^2/s. Compute the gyro drift and express it in deg/hr. Can you provide a physical appreciation of this drift error?

10. a) A particle of mass M lying on the table surface, travels outward with uniform velocity V from the centre of a table that starts rotating at angular rate Ω. Will the particle experience any force due to this velocity? If it experiences a force what is the force called? Write down the vector form of the equation for the acceleration felt by the mass and represent the equation on a rectangular coordinate *frame.*

b) A vehicle travels from equator to north pole at uniform velocity V relative to earth along the north direction. Write down the Coriolis acceleration as a function of latitude L. If V = 40 m/s, determine the Coriolis acceleration at the equator and at the pole. Assume earth rate ω_e as 15.04 deg/hr.

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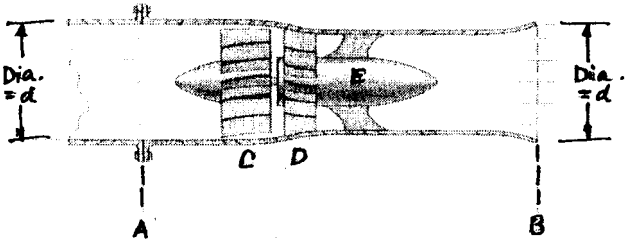

Fig. Q. 1 (a)

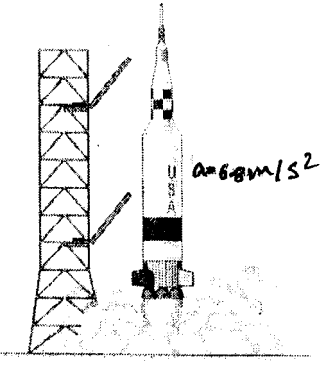

Fig. Q. 1 (b)

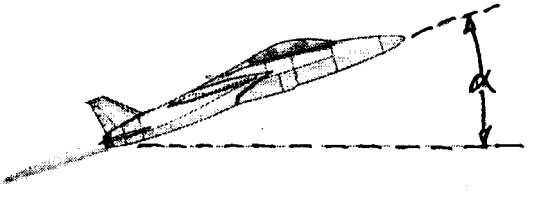

Fig. Q. 2 (a)

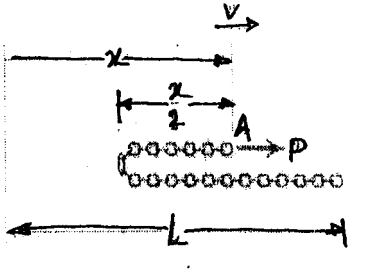

Fig. Q. 2 (b)

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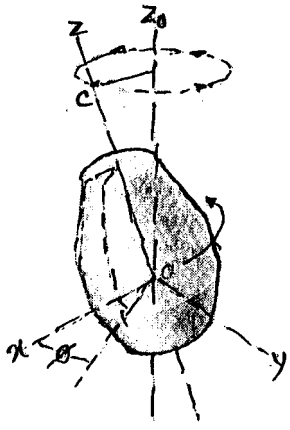

Fig. Q. 3

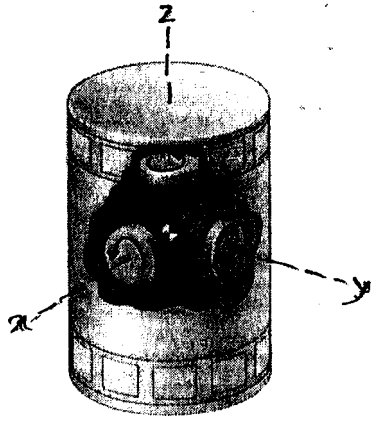

Fig. Q. 4

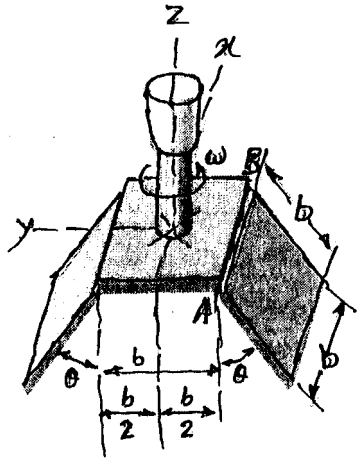

Fig. Q. 5

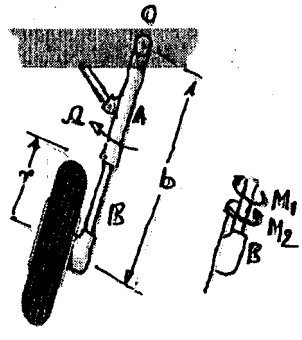

Fig. Q. 6