Department of Aerospace Engineering

AE21003 – Dynamics for Aerospace Engineers

Time: 2 hrs. Mid-Autumn Semester Examination, 2002-03 Marks: 30

Answer ALL questions

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1) A telescopic robotic arm (Fig.Q-1) grips a heavy object of mass M as shown. The arm is turning counter-clockwise at a rate ω and extending outward at a rate $\dot{r}$. The rate of turning is also increasing at a rate $\dot{\omega}$.

Determine the magnitudes of the axial force, shear force and bending moment induced at the base of the arm (near the hinge) due to the motion of the gripped mass alone.

(Q-1: 4 marks)

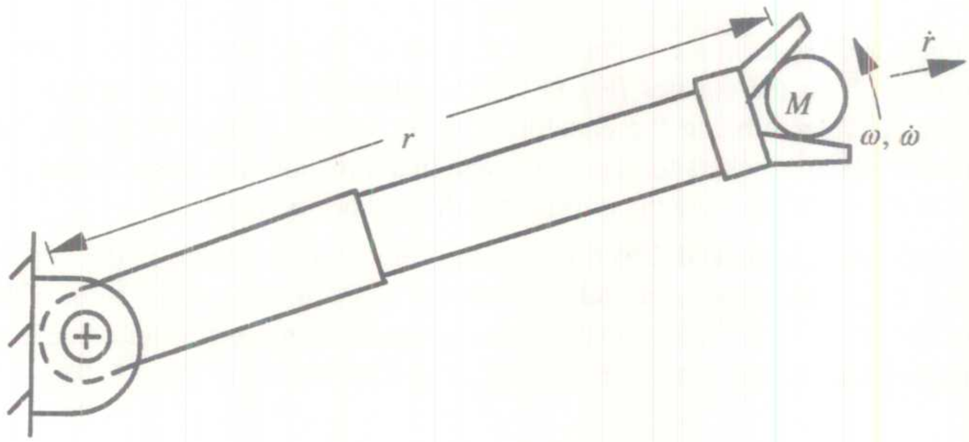

Fig.Q-1

2-a) A prototype of a road vehicle under development has a resistance law of the form $D = a + bv^2$, where D is the resistive force, v is the speed and a and b are constants. The mass of the vehicle is 640 kg.

During road tests it is found that the vehicle can just roll down a gradient of 1:40 without using its engine. Again, when the engine is developing its full power of 30 kW, the vehicle attains a speed of 108 km/h on level ground. Determine the constants a and b.

b) If the present engine is replaced with a more powerful one that can develop 40 kW, what top speed will the vehicle attain on level ground?

(Q-2: 2+3 marks)

3-a) A spy satellite is in orbit about the earth. At the closest point of its orbit, the satellite is 6.45×10^5 km above the earth's surface and moving at a speed of 8.28×10^3 m/s. Determine the orbital time period of the satellite.

b) At the closest point in its orbit, the satellite sends down a sub-satellite (containing a packet of exposed photographic film) by giving this packet a velocity component directly towards the earth's centre. What should the magnitude of this velocity be so that the packet comes to within 1.6×10^4 m of the earth's surface? What is the eccentricity of the resulting trajectory? What is its speed when it is closest to the earth? Ignore air resistance. (Take the radius of the earth as 6.37×10^6 m and the value of GM as 3.981×10^{14} m^3/s^2).

(Q-3: 4+4 marks)

4-a) Derive the expressions for the thrust and velocity increment of a rocket motor operating in a vacuum, far away from the influence of other bodies.

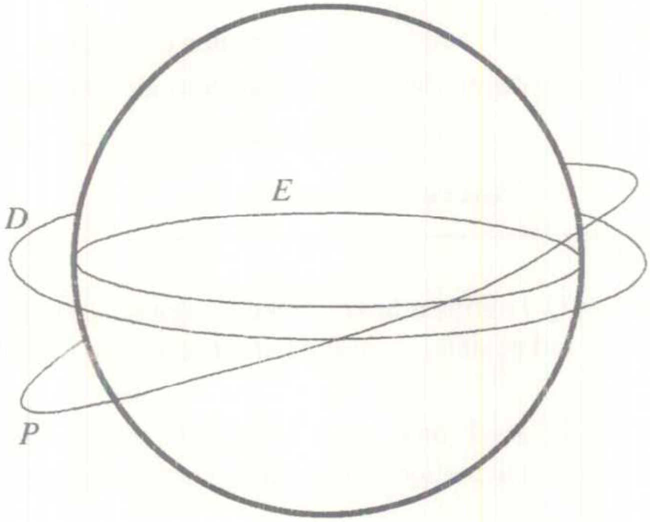

Fig.Q-4

b) A satellite of mass 1000 kg is in a circular orbit P, with a 24 h time period, the plane of the orbit being inclined at 17.7° to the equator (Fig.Q-4). It is desired to bring this satellite into *geostationery* orbit D (a circular orbit in the equatorial plane, with a 24 h time period). This is to be achieved by firing on-board rockets for a duration and in a direction that has to be determined. The firing has to occur at the point where the present and desired orbits intersect.

Determine, then, the magnitude and direction of i) the velocity change and ii) the impulse required for this purpose. If this impulse is provided by an on-board rocket motor from which mass is expelled at the rate of 2.3×10^3 m/s, what mass of propellant is used up in achieving this orbit change? (Take the radius of the earth as 6.37×10^6 m and the value of GM as 3.981×10^{14} m^3/s^2).

(Q-4: 3+4 marks)

5-a) Obtain the expression for the kinetic energy of a system of particles relative to a fixed point O by reference to the mass centre. What is the meaning of the two terms in this expression for the kinetic energy?

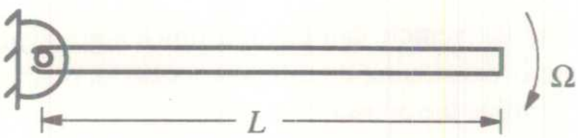

Fig.Q-5

b) A thin, rigid rod of length L and mass M rests on a horizontal floor with its entire length touching the floor. At one of its ends the rod is held to the floor by a pin, about which it may turn freely. The coefficient of sliding friction between rod and floor is μ. Now the rod is given a smart tap so that it starts rotating about the pinned end with angular speed Ω. Through what angle does the rod rotate before coming to a stop? (*Hint*: The friction force on any small section of the rod is proportional to the mass of that section.)

(Q-5: 2+4 marks)

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