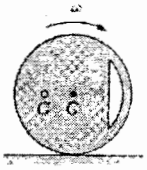
Indian Institute of Technology Kharagpur

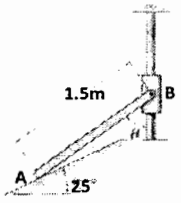
Date:__/__/__ (FN/AN) Time: 3 Hrs., Full Marks: 100, Department: Aerospace Engineering
No. of Student: 48, End Autumn Semester Examination (2012-13)
Sub. No. AE21003, Sub. Name : Dynamics for Aerospace engineers
2nd yr. B. Tech.(H)/M. Tech (Dual)

Note: Attempt all nine questions. Assume any missing data suitably.

Q.1a The mass centre G of a *5kg* wheel of radius *R=300mm* is located at a distance *r=100mm* from its geometric centre *C*. The centroidal radius of gyration is *k=150mm*. As the wheel rolls without sliding, its angular velocity varies and it is observed that *ω=8rad/s* in the position shown. Determine the corresponding angular acceleration of the wheel. 5

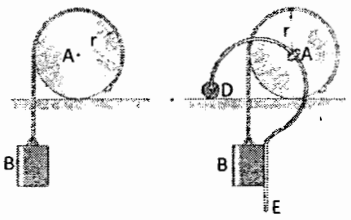


Q.1b 5

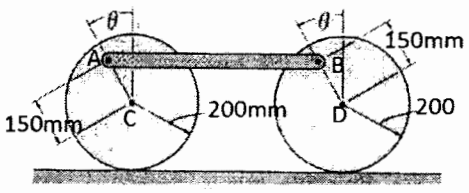


End *A* of the *6kg* uniform rod *AB* rests on the inclined surface, while end *B* is attached to a collar of negligible mass which may slide along the vertical rod shown. When the rod is at rest a vertical force ***P*** is applied at *B* causing end *B* of the rod to start moving upward with an acceleration of $4m/s^2$. Knowing that $\theta=35^\circ$, determine the force ***P***.

Q.2 A block *B* of mass *m* is attached to a cord wrapped around a cylinder of the same mass *m* and radius *r*. The cylinder rolls without sliding on a horizontal surface. Determine the components of the accelerations of the centre *A* of the cylinder and of the block *B* immediately after the system has been released from the rest if (a) the block hangs freely, (b) the motion of the block is guided by a rigid member *DAE*, frictionless and of negligible mass, which is hinged to the cylinder at *A*. 12

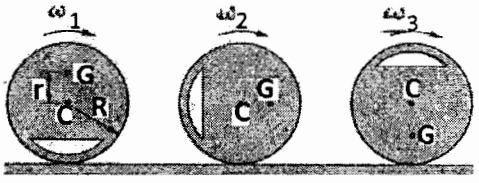


Q.3

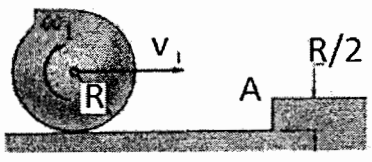


The *9kg* rod AB is attached by pins to two *6kg* uniform disks as shown. The assembly rolls without sliding on a horizontal surface. Knowing that the velocity of rod *AB* is *840mm/s* to the left when $\theta=0$, determine (a) the velocity of rod *AB* when $\theta=180^\circ$, (b) the force exerted by the surface on each disk at that instant. 12

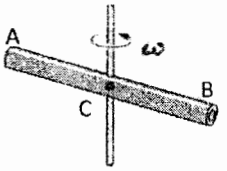
Q.4a The mass centre *G* of a wheel of radius *R* is located at a distance *r* from its geometric centre *C*. The centroidal radius of gyration of the wheel is denoted by *k*. As the wheel rolls freely and without sliding on a horizontal plane, its angular velocity is observed to vary. Denoting by ω_1, ω_2, and ω_3, respectively, the angular velocity of the wheel when *G* is directly above *C*, level with *C*, and directly below *C*, shown that ω_1, ω_2, and ω_3 satisfy the $\frac{\omega_2^2-\omega_1^2}{\omega_3^2-\omega_2^2}=\frac{g/R+\omega_1^2}{g/R+\omega_3^2}$ given relation 5



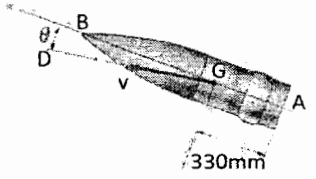
Q.4b A uniform sphere of radius *R* rolls to the right without slipping on a horizontal surface and strikes a step of height *R/2*. Assuming that the impact is perfectly plastic and that no slipping occurs between the sphere and the corner of the step, determine (a) the angular velocity of the sphere and the velocity of its centre immediately after the impact, (b) the smallest initial speed v_1 for which the sphere will reach the upper level of the step. 5



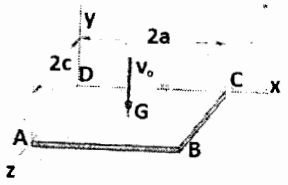
Q.4c A small *500g* ball may slide in a slender tube of length *1.2m* and of mass *1.5kg* which rotates freely about a vertical axis passing through its centre *C*. If the angular velocity of the tube is *8rad/s* as the ball passes through *C*, determine the angular velocity of the tube (a) just before the ball leaves the tube, (b) just after the ball has left the tube. 5



Q.5a The *25kg* projectile shown has a radius of gyration of *72mm* about its axis of symmetry *Gx* and of *300mm* about its transverse axis *Gy*. Its angular velocity ω may be resolved into two components: one component, directed along the axis of symmetry *Gx*, measure the *rate of spin* of the projectile, while the other, directed along GD, measure its *rate of precession*. Knowing that $\theta=8^\circ$ and that the angular momentum of the projectile about its mass centre *G* is $\boldsymbol{H_G}=(600g.m^2/s)\boldsymbol{i}+(16g.m^2/s)\boldsymbol{j}$, determine (a) the rate of spin, (b) the rate of precession. 5

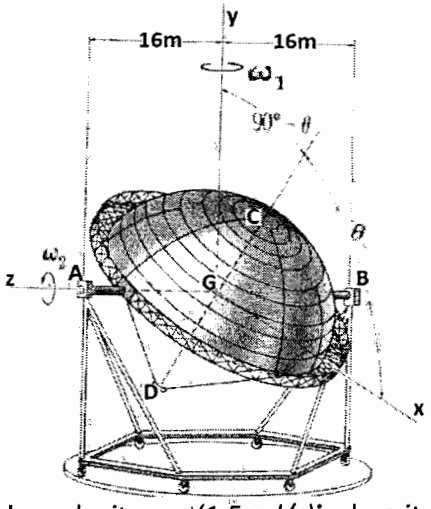


Q.5b 5

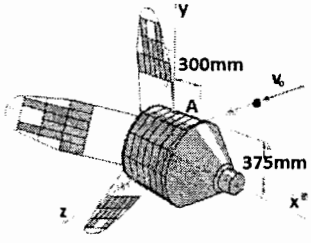


A rectangular plate of mass *m* is falling with a velocity v_o and no angular velocity when its corner *A* strikes an obstruction. Assuming the impact at *A* to be perfectly plastic, determine immediately after the impact (a) the angular velocity of the plate, (b) the velocity of its mass centre *G*.

Q.6 An experimental Fresnel-lens solar-energy concentrator may rotate about the horizontal axis *AB* which passes through its mass centre *G*. It is supported at *A* and *B* by a steel framework which may rotate about the vertical *y* axis. The concentrator has a mass of *30Mg*, a radius of gyration of *12m* about its axis of symmetry *CD*, and a radius of gyration of *10m* about any transverse axis through *G*. Knowing that the angular velocities ω_1 and ω_2 have constant magnitudes equal to *0.25rad/s* and *0.20rad/s*, respectively, determine for the position $\theta=60^\circ$ (a) the forces exerted on the concentrator at *A* and *B*, (b) the couple $\boldsymbol{M_2k}$ applied to the concentrator at that instant. 10

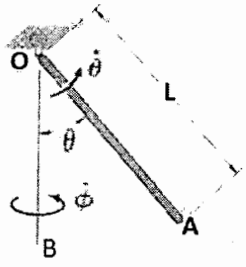


Q.7 10

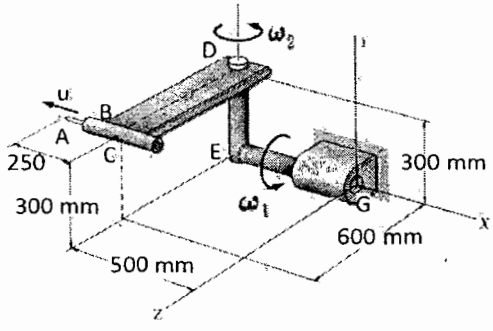


A *240kg* satellite is spinning with an angular velocity $\boldsymbol{\omega_0}=(1.5rad/s)\boldsymbol{i}$ when it is struck at *A* by a *30g* meteorite traveling with a velocity $\boldsymbol{v_o}=-(576m/s)\boldsymbol{i}-(432m/s)\boldsymbol{j}+(960m/s)\boldsymbol{k}$ relative to the satellite. Knowing that the radii of gyration of the satellite are $k_x=300mm$ and $k_y = k_z=400mm$, determine the angular velocity of the satellite immediately after the meteorite has become embedded.

Q.8 A slender homogeneous rod *OA* of mass *m* and length *L* is supported by a ball-and-socket joint at *O* and may swing freely under its own weight. If the rod is held in a horizontal position ($\theta=90^\circ$) and given an initial angular velocity $\dot{\varphi}_o=\sqrt{8g/L}$ about the vertical *OB*, determine (a) the smallest value of θ in the ensuing motion, (b) the corresponding value of the angular velocity $\dot{\varphi}$ of the rod about *OB*. 10



Q.9 11



The position of the stylus tip *A* is controlled by the robot shown. In the position shown the stylus moves at a constant speed $u = 180mm/s$ relative to the solenoid *BC*. At the same time, arm *CD* rotates at the constant rate $\omega_2 = 1.6\ rad/s$ with respect to component *DEG*. Knowing that the entire robot rotates about the X axis at the constant rate $\omega_1 = 1.2rad/s$, determine (a) the velocity of *A*, (b) the acceleration of *A*.