NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

ZZ102 T ENGINEERING MECHANICS II--DYNAMICS

Test 1 (Module # 1) – 23 Jan 2006

Time: 2 Hours Marks: 20

Important Instructions: READ THESE BEFORE ANYTHING ELSE!

- Answer **all** questions. Read questions carefully before attempting to answer.
- *Do not* use any formula (except the Newton's laws) without deriving it!
- Use the concepts from Module 1 to solve the problems. **DO NOT** use the work-energy concepts or impulse-momentum concepts of later modules.
- Each question carries 4 marks.

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1 A hockey player, due to bad luck, hit the goal post during a strike as depicted in Fig. 1. The ball bounced off at a speed that is 80 percent of the pre-impact speed. If it moved in the same plane as the initial trajectory, compute the distance *d* from the post to the point where the ball hits the ground? Also calculate the total time needed for the entire travel.

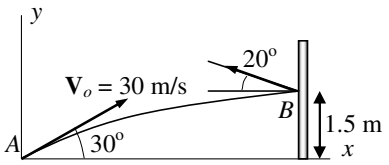

Figure 1

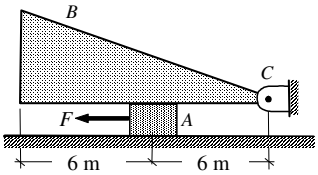

Figure 2

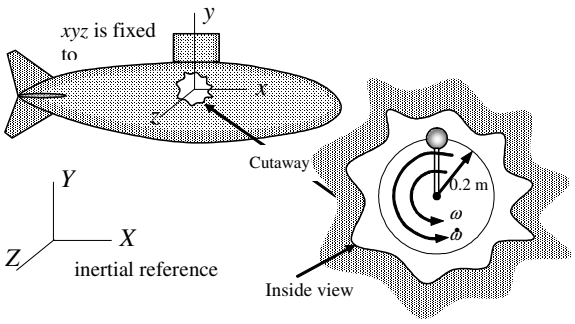

Figure 3

2 A force *F* of 5,000 N is suddenly applied to mass *A* as shown in Fig. 2. What is the speed after *A* has moved 0.1 m? Mass *B* is a triangular block of uniform thickness. M_A = 20 kg, M_B = 100 kg, and μ_d = 0.3.

3 **(a)** *Derive* expressions for the velocity and acceleration of a particle in terms of the path variables (i.e., in terms of $\boldsymbol{\varepsilon}_t$ and $\boldsymbol{\varepsilon}_n$, the unit vectors along the tangent and the normal directions). You may use the relation that $d\boldsymbol{\varepsilon}_t/ds = \boldsymbol{\varepsilon}_n/R$ where *R* is the radius of curvature of the path.

(b) A particle moves along a path given as $y = 3x^2$ m. The projection of the particle along the *x*-axis varies as $0.4t^2$ m (where *t* is in seconds) starting at the origin at *t* = 0. What are the acceleration components normal and tangential to the path at *t* = 2 s? What is the radius of curvature at this point?

4 **(a)** *Derive* expressions for the velocity and acceleration of a particle in terms of cylindrical coordinates (i.e., in terms of $\boldsymbol{\varepsilon}_r$ and $\boldsymbol{\varepsilon}_\theta$, the unit vectors along the radial and the tangential directions). You may use the following relations: $\dot{\boldsymbol{\varepsilon}}_r = \dot{\theta}\boldsymbol{\varepsilon}_\theta$ and $\dot{\boldsymbol{\varepsilon}}_\theta = -\dot{\theta}\boldsymbol{\varepsilon}_r$.

(b) An automobile is travelling uphill along a mountain road at a speed of 20 m/s which is increasing at a rate of 5 m/s^2. The slope of the highway is 10º to the horizontal and its radius of curvature with respect to a vertical axis is constant at 50 m. Using cylindrical coordinates, determine the acceleration of the automobile at this instant.

5 A submarine shown in Fig. 3 is moving in a translatory manner with the velocity $\mathbf{V} = (10\mathbf{i} + 13\mathbf{j} + 3.5\mathbf{k})$ km/hr and acceleration $\mathbf{a} = (0.35\mathbf{i} - 0.4\mathbf{j} + 0.95\mathbf{k})$ km/hr/s. A device inside the submarine consists of an arm and a mass at the end of the arm. At the instant of interest, the arm is rotating in a vertical plane with the angular speed of ω = 10 rad/s and angular acceleration of $\dot{\omega}$ = 3 rad/s^2. The arm is vertical at this instant of time. The mass at the end of the rod may be considered to be a particle having a mass of 5 kg. What are the velocity and acceleration vectors for the motion of the particle at this instant relative to the inertial reference? Use units of metres and seconds. What must be the force vector from the arm onto the particle at this instant?

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