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1 A two-arm robot is used for welding works. Between the first arm and the frame is a spherical (S) joint, and that between two arms is a revolute (R) joint. The coordinates of the S joint is (0, 0, 0), the lengths of the first and second arms are L_1 and L_2, respectively. The tip-end of the second arm is required to move between two points (P_1 & P_2), whose coordinates are (X_1, Y_1, Z_1) and (X_2, Y_2, Z_1), respectively (their Z coordinates are the same). During the movement, the rotational axis of the R joint is kept parallel to Z axis. Please (a) give a skeleton drawing (with the reference coordinate system and the given symbols) of the robot (4 %), (b) determine the angular displacements about the reference coordinate system of both arms when the tip-end moves from P_1 to P_2 (8 %).

2. For the disk cam with an oscillating flat-faced follower mechanism as shown in Fig. 2, AC = 840 mm, AG_2 = 160 mm, BG_2 = 300 mm, CG_3 = 460 mm, AB = 400 mm, CB = 580 mm and the width of the follower is 80 mm. The weights, W_1 = 98 N and W_2 = 196 N, and the load T_{13} = 50 Nm. There is friction between the cam and follower only, and the frictional coefficient is 0.15 If ω_2 = 300 rad/sec (constant) and the inertial forces should be considered, please (a) determine the angular velocity of the follower (4 %) (b) determine the angular acceleration of the follower (6 %), (c) give the free-body diagrams of the cam and follower, respectively (4 %), (d) give X & Y force components and moment equivalent equations of the cam and follower, respectively (6 %), (e) determine the input torque T_{12}, and the forces at A (denoted as $\mathbf{F}_{12}$), B (denoted as $\mathbf{F}_{23}$ or $\mathbf{F}_{32}$), and C (denoted as $\mathbf{F}_{13}$) (18 %).

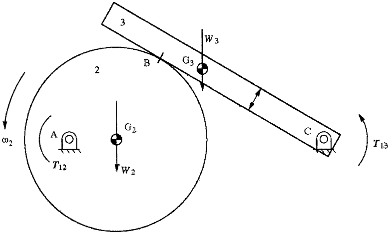

Fig. 2

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考試科目 動力學及專業英文

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3 A small ball rolls around a horizontal circle at height y inside a hemispherical bowl of radius R as shown in Figure 3-1 Assume perfect rolling, find the expression for the ball's angular velocity to stay at the height y using the suggested coordinate system in Figure 3-2. The downward direction in Figure 3-2 comes from the gravity. (25%)

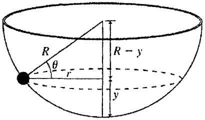

Figure 3-1 Pictorial Representation for Problem 3

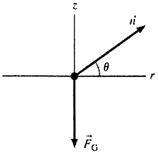

Figure 3-2 Suggested Coordinate System

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4. Figure 4-1 shows the forces acting on a two-axle vehicle We assume the traction-force of a front (rear) drive vehicle can be calculated via the equilibrium of the moment about the rear (front) wheel and the vehicle is climbing uphill. Please compare the traction forces of front-wheel drive and rear-wheel drive vehicles using the following notations. List at least three observations from your comparisons between front and rear-wheel drive vehicles. (25%)

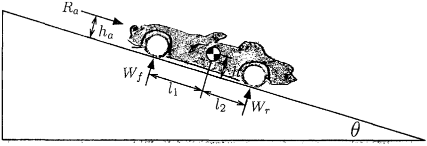

Figure 4-1 Vehicle Dynamics

- W the weight of the vehicle
- m vehicle mass
- R_a resistance due to aerodynamics
- R_{rf} (R_{rr}) rolling resistance of the front (rear) tires
- R_g resistance due to the grade of the slope
- F_f (F_r) the tractive effort of the front (rear) tires. For rear(front)-wheel drive vehicle, F_f=0 (F_r=0)
- l_1 (l_2) the distance between the front (rear) axle and the center of gravity of the vehicle
- h_a the height of the point of application of the aerodynamic resistance
- h the height of the center of gravity
- θ slope angle
- μ the coefficient of road adhesion