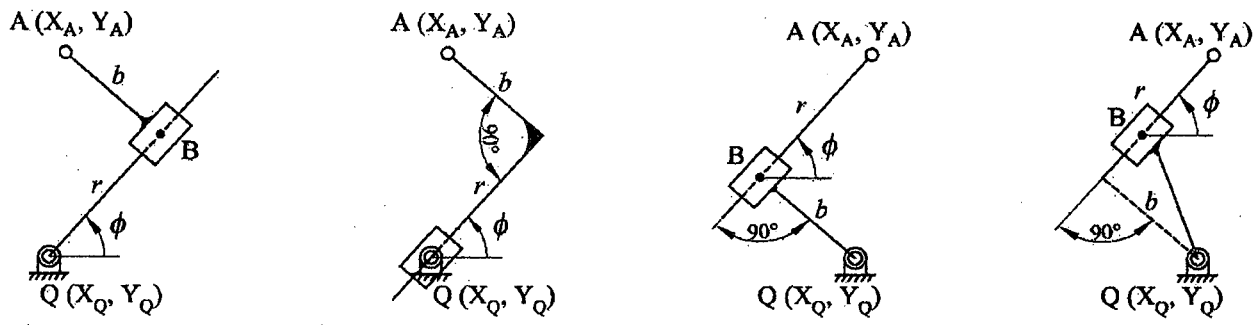
1. (40%) Figure 1 shows several open-loop robots which all have two moving arms. For each of them, one moving arm is connected to the ground by a revolute joint Q and two moving arms are constrained by a prismatic joint. The length b is a design parameter of such robots. ϕ and r are the input joint parameters that control the end effector position A (X_A, Y_A). Are they all kinematically equivalent? And are they all dynamically equivalent? Please explain your own opinions in detail. (8%)



(a) (b) (c) (d)

Fig. (1)

(a) In reference to Figure 1(a), if slider B has a linear stroke L and the rotary actuator has no rotation limit, what is the workspace of this robot? (8%)

(b) In reference to Figure 1(a), derive analytical expressions for position (X_A, Y_A), velocity ($\dot{X}_A$, $\dot{Y}_A$), and acceleration ($\ddot{X}_A$, $\ddot{Y}_A$) of the end effector A in terms of input joint parameters, where $\dot{r}$, and $\ddot{r}$ are the linear velocity and acceleration of the slider along the sliding path. $\dot{\phi}$, and $\ddot{\phi}$ are the common angular velocity and angular acceleration of both arms. Indicate acceleration components caused by the Coriolis effect. (8%)

(c) In reference to Figure 1(a) again, the end-effector of this robot, where b = 4 in and Q at (0, 0), is to be programmed to reach position (X_A, Y_A) = (4, 5) along a vertical line with a uniform speed of 10 in/sec upward. Find the required input parameters (ϕ, $\dot{\phi}$, $\ddot{\phi}$, r, $\dot{r}$, $\ddot{r}$) at reach of the designated position. Hint: this robot may have more than one configuration that can reach the designated position. (16%)

2. (35%) Fig. 2 shows a pulley (Link 1) of radius 'a' which is pivoted at A and has moment of inertia about A of J_1. A pin P is located at radius AP= r in the pulley and drives the vertically slotted rod (Link 2) of mass m_2, along the horizontal x direction. A string tied to and wrapped around the pulley hangs vertically and supports a weight W. An angle ϕ, measured from x axis to pin is used to represent the generalized coordinate of the system.

(a) (10%) Derive the linear velocity and acceleration of link 2 if the pulley rotates in angular velocity $\dot{\phi}$ and angular acceleration $\ddot{\phi}$.

(b) (15%) Take free body diagram of the system, the weight W, pulley (Link 1) and rod (Link 2), draw the force or moment on each body and write the necessary force or moment equilibrium equations for the motion of each free body.

(c) (10%) Find the equation of motion of the system in terms of the given parameters (J_1, W, a, r, m_2) and the generalized coordinate ϕ. (Note: The acceleration of weight, angular acceleration of pulley, and linear acceleration of rod are coupled.)

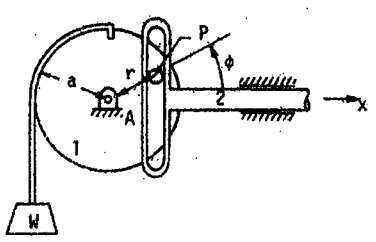


Fig. (2)

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3. (25%) Describe and explain the followings.

(a) Degree of freedom of a mechanical system (5%)

(b) State of equilibrium and state of stability (5%)

(c) Pressure angle of a cam system and of a gear pair (5%)

(d) Coriolis acceleration (5%)

(e) instant center of velocity and Kennedy-Aronhold theorem. (5%)

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