1. (20 %)

A force **P** is gently and slowly applied on the left frame of the window (600 mm width, 1000 mm height) and the window is hoped to slide horizontally along the rail X-X to the right as shown in Fig. 1. A small clearance exists between the window and the top rail Y-Y. The mass of the window **m** is 2 kg and the center of gravity c.g. is at its center of symmetry. The friction coefficient between the window and the rail is 0.4. Please find the largest value **H** so that the force **P** will not cause the window being jammed.

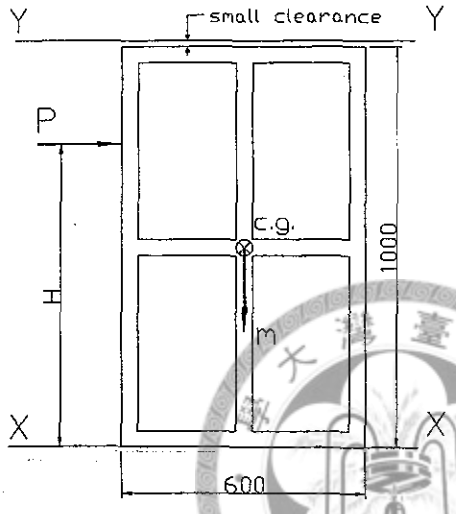

Fig. 1 Window frame

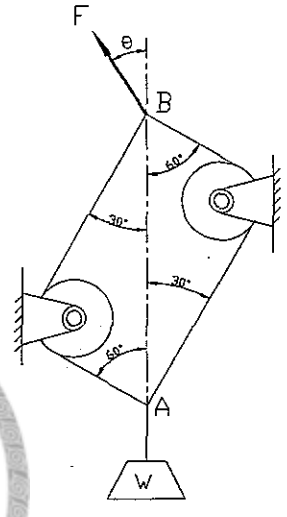

Fig. 2 Rope and pulley mechanism

2. (15 %)

A weight **W** is hanged by a rope at node A as shown in Fig. 2. A force **F** is applied on the rope at node B. No friction is assumed in this rope and pulley mechanism. Please find the force **F** and the angle θ at the equilibrium position shown in Fig. 2.

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3. (15 %)

A belt is wrapped around a circular pulley as shown in Fig. 3. The angle of wrap or called the angle of contact between the entering and leaving points P_1 and P_2 is β. The belt is assumed to be perfect flexible without bending stiffness. The friction coefficient between the belt and the pulley is μ.

a. Please derive the relationship between the tensions T_S and T_L in the two sides of the belt wrapped around a circular pulley when slipping is impending (about to start). (8%)

b. Please find T_L for μ=0.3, $\beta=\pi$, and T_S=100 N. (7%)

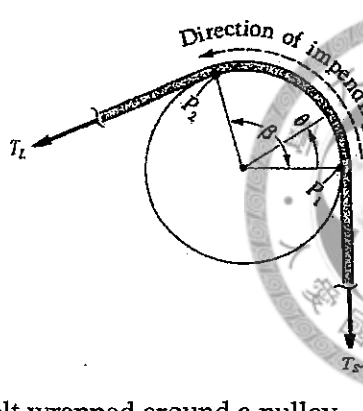

Fig. 3 Belt wrapped around a pulley

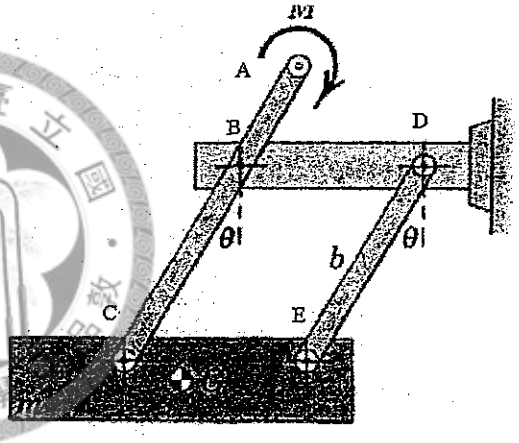

Fig. 4 Two parallel links with a block

4. (15 %)

(a) A torque M is applied to point A of one of the two parallel links AC and DE which are hinged as shown in Fig. 4. The two links bring a block with mass m concentrated at the center of gravity, G, to an equilibrium position. The lengths of the links DE and BC are b. The angle θ is the angle between the link DE and the vertical line. It is assumed that the links have negligible mass and all friction is absent. Please derive the expression of the equilibrium angle θ for a given value of M by using the method of virtual work. (10%)

(b) If the mass m is equal to 10 kg and the lengths DE and BC are equal to 1 m, please calculate the minimum value of M when θ equals to 90°? (5%)

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5. (10 %)

The flat-belt pulley is shown in Fig. 5A. The material of the pulley is steel, and the mass density ρ of steel is $7800\,kg/m^3$. The dimensions are expressed in millimeter. Please find the second moment of mass or called mass moment of inertia of the pulley about the axis X-X.

Hint

The equation $I_{xx} = \dfrac{\rho l (b^4 - a^4)}{2}$ may be used for your calculation of the second moment of mass for the hollow shaft as shown in Fig. 5B.

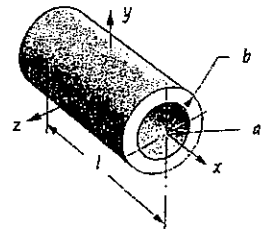

Fig. 5B Hollow shaft

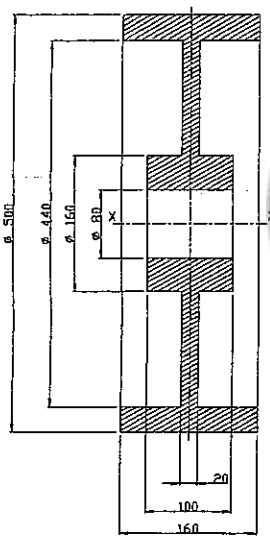

Fig. 5A Flat-belt pulley (unit: mm)

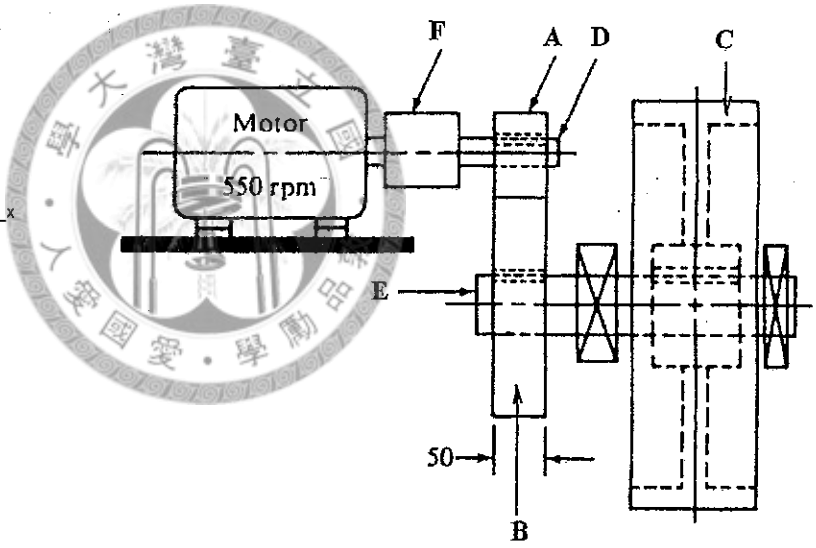

Fig. 6 Transmission system

6. (10 %)

A transmission system with every element made of steel is shown in Fig. 6. The gear A that is driven by an electric motor drives the gear B. The motor rotates at 550 rpm. The specifications of components are described as follows:

(1) The gear shaft D is 40 mm in diameter and 200 mm in length.
(2) The pitch diameter of the gear A is 100 mm, and the face width of the gear A is 50 mm.
(3) The pitch diameter of the gear B is 275 mm, and the face width of the gear B is 50 mm.
(4) The pulley C is the same as that shown in Fig. 5A.
(5) The shaft E is 80 mm in diameter and 400 mm in length.

Please calculate the total second moment of mass of the transmission system including the gear A, gear B, pulley C, shaft D, and shaft E with respect to the center line of gear shaft D.

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7. (15 %)

The main frame of the backhoe bucket is shown in Fig. 7. The movement of the bucket is controlled by three hydraulic cylinders AB, CD and EF. The bucket carries a load W of 1000 N at G. It is assumed to be two-dimensional static loading situation. All dimensions are expressed in millimeter. Determine the pushing forces of the three hydraulic cylinders of the backhoe bucket.

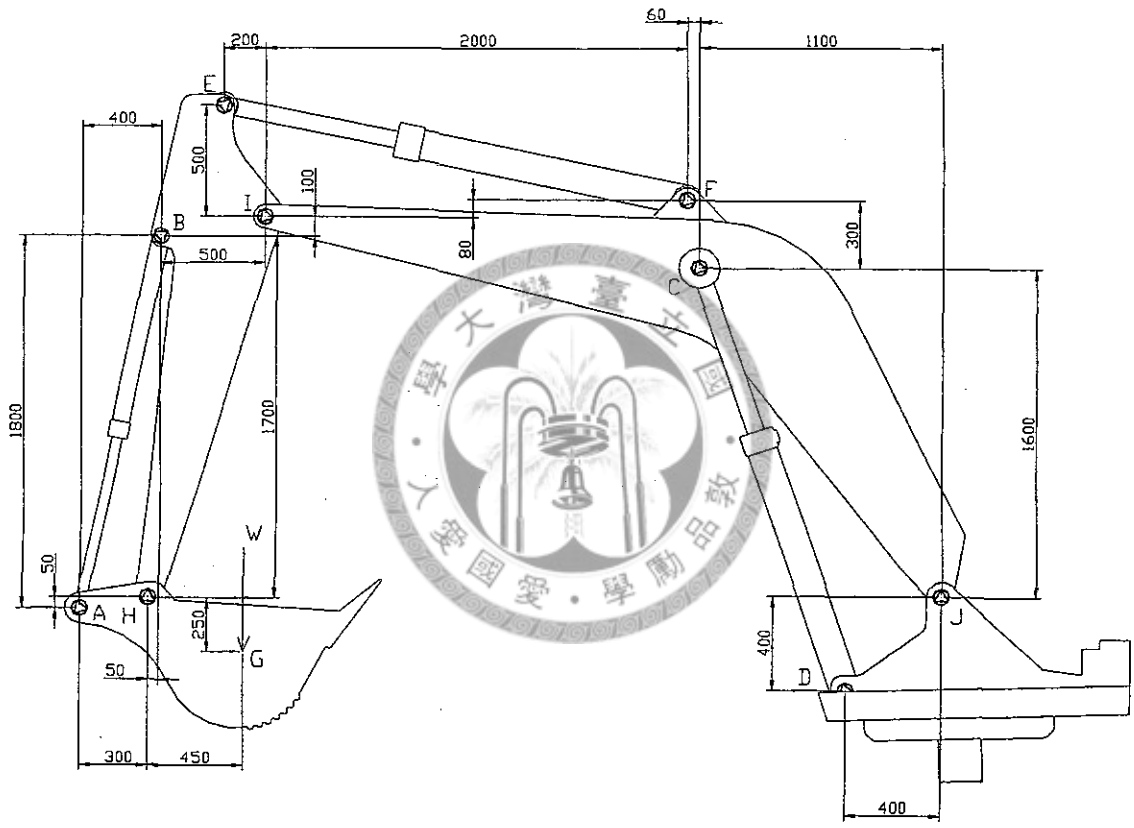

Fig.7 Backhoe bucket (unit: mm)

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