Paper P4, Structures and Mechanics

Examples Sheet 1P4F - Kinematics

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Bibliography

A - Recommended reading

Meriam, J.L and Kraige, L.G. ‘Engineering Mechanics’ Vol 2, Dynamics.

Fawcett, J.N. and Burdess, J.S. (1988) ‘Basic Mechanics with Engineering Applications’ Sections 1.6 and 1.7

B - Other reading

Drabble, G.E. (1990) ‘Dynamics’ Programmes 2 and 4
Norris, C.H., Wilber, J.B. and Utku, S. (1991) ‘Elementary structural analysis’ Section 8.6
Grosjean, J. (1991) ‘Kinematics and dynamics of mechanisms’ Chapters 1 and 2.

Kinematics of a Point

1. A golfer plans to pitch a ball from point A to land on a green at point B as shown in Figure 1. The initial velocity of the ball is V_0 and is inclined at angle a to the horizontal. Find the appropriate value of V_0 when tan $\alpha = 0.5$ and $d = 3h/4$.

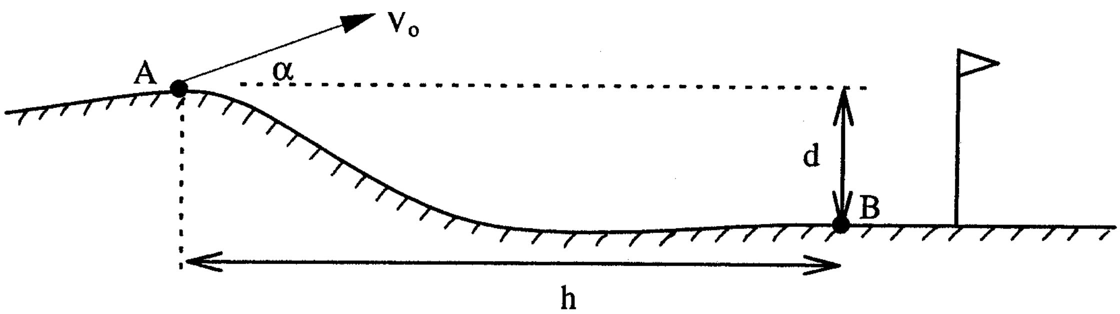

Figure 1

2. (a) The retarding acceleration a on a car is given by $a = \beta v^2 - \alpha$ where α and β are constants and v is the speed of the car. Show that the terminal speed v_t is:

$$v_t = \sqrt{\frac{\alpha}{\beta}}$$

(b) Show also that after rolling a distance x from rest the car will have reached a speed v where:

$$x = -\frac{1}{2\,b}\ln\left(1-\left(\frac{v}{v_t}\right)^2\right)$$

3. In the design of a timing mechanism, the motion of the pin A in the fixed circular slot is controlled by the guide B, which is being elevated by its lead screw with a constant upward velocity v_0=2 m/s (Figure 2). Calculate both the normal and tangential components of acceleration of pin A as it passes the position for which q=30º.

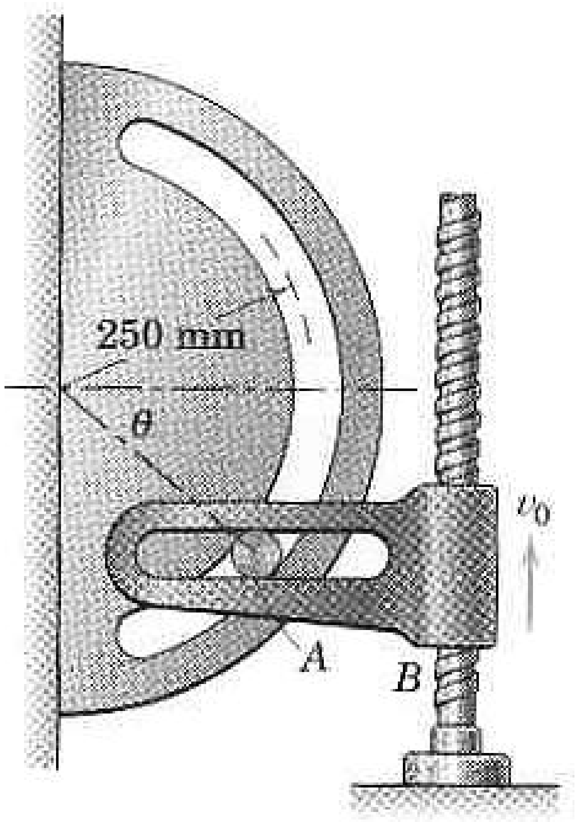

Figure 2 (after Meriam & Kraige 1998)

4. A jet plane flies at an altitude h=10 km at a constant speed v directly over a radar, which continues to track its further flight. When the radar is pointing at the angle q=60º above horizon, q is decreasing at the rate of 0.02 rad/s. At this instant, determine the magnitude of the velocity v of the plane, and the value of the acceleration term $\ddot{r}$.

Kinematics of Rigid Bodies and Mechanisms

5. In each of the mechanisms shown in Figure 3, rod AB rotates clockwise at angular velocity ω. Draw the velocity diagrams, and for each case find the velocity of C.

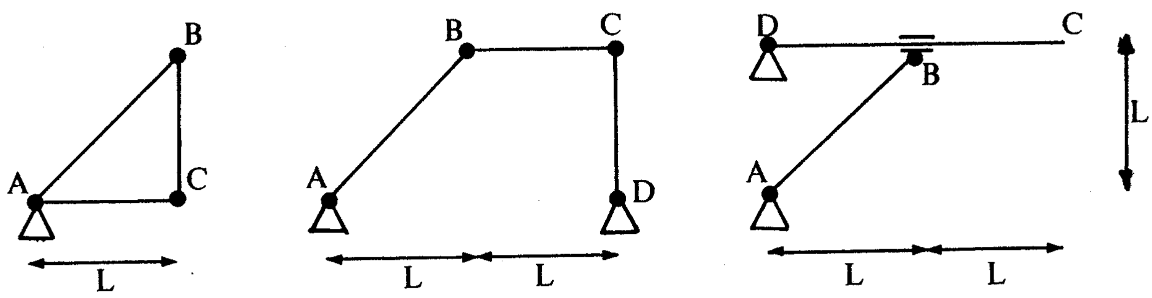

Figure 3

6. The Geneva wheel is a mechanism for producing intermittent rotation (Figure 4). Pin P in the integral unit of wheel A and locking plate B engages the radial slots in wheel C thus turning wheel C one-fourth of a revolution for each revolution of the pin. At the engagement position shown, q=45º. For a constant clockwise angular velocity ω_1=2 rad/s of wheel A, determine the corresponding CCW angular velocity of wheel C for q=20º.

(Note: the motion during engagement is governed by the geometry of triangle O_1O_2P with changing q).

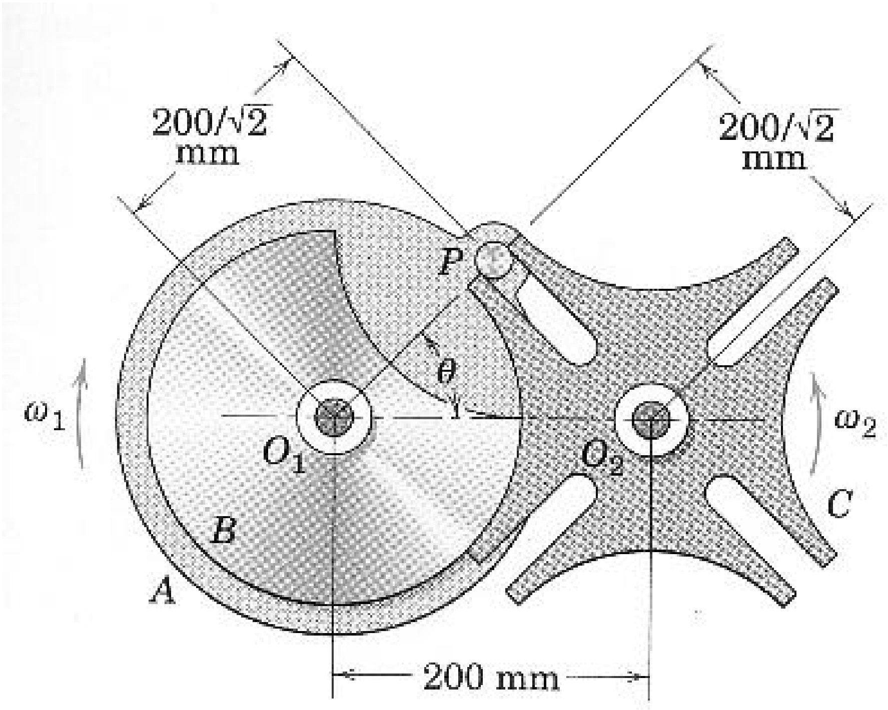

Figure 4 (after Meriam & Kraige 1998)

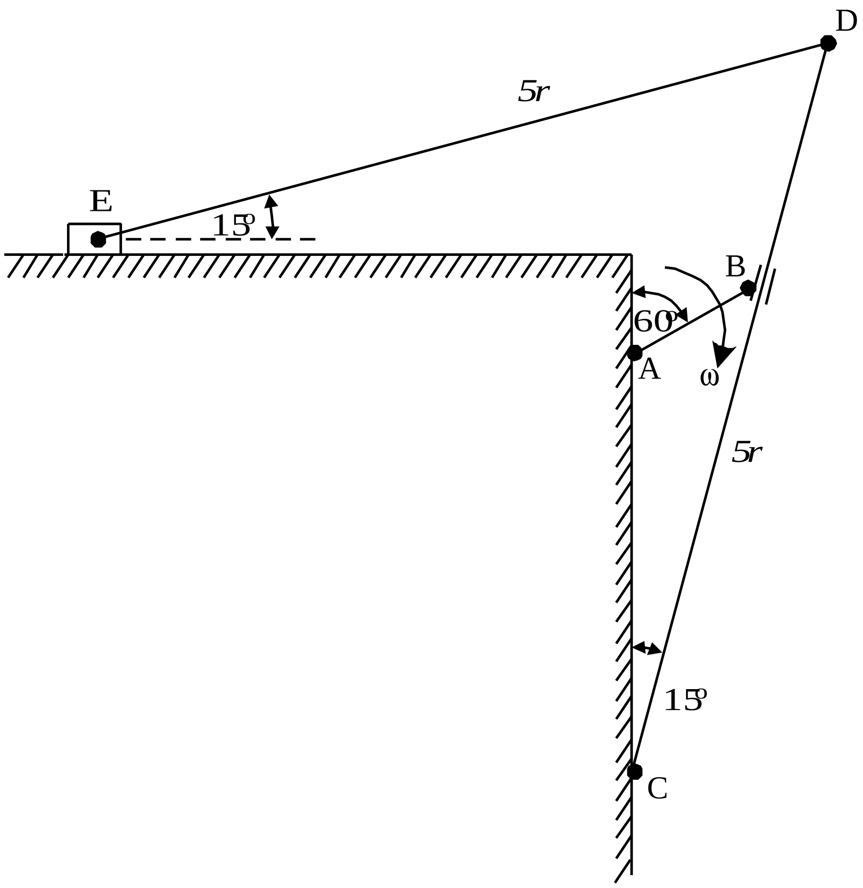

Figure 5

7. Figure 5 shows a quick-return mechanism. The arm AB is of length *r* and rotates at a constant angular velocity *w* . The end A is pinned on the same vertical surface as the end C of the rod CD, which is of length 5*r*. The end B slides along the rod CD. The rod DE is also of length 5*r* and the end E slides in an horizontal slot. At a given instant, the rods AB, CD and ED are at 60°, 15° and 75° respectively to the vertical. From a sketch of the velocity diagram of the mechanism, find the sliding velocity of E, the sliding velocity of B along CD, and the angular velocities of CD and DE.

8. Figure 6 shows an assembly of a light piston and connecting rod AB attached to a flywheel of moment of inertia 10 kgm^2 rotating about C with a clockwise angular velocity 60 rad/s. The dimensions AB and BC are 0.6m and 0.25m.

(a) Draw the velocity diagram for the instant when AC= 0.65 m.

(b) Find the velocity of A.

(c) If the area of the piston is 0.007 m^2 and the pressure *p* is 1.2 MN/m^2, calculate the acceleration of the flywheel at this instant if the bearings at A and B are frictionless.

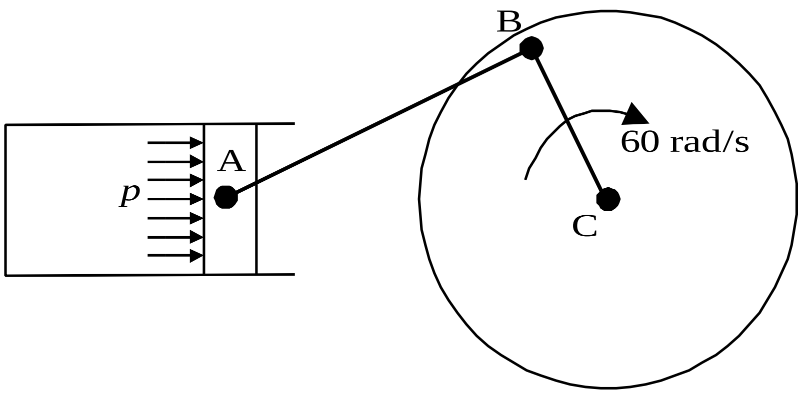

Figure 6

9. Figure 7 shows the offset nose wheel of an airliner. A, D and E are pivots fixed to the frame of the aircraft. C is a pivot fixed to the undercarriage leg and F is a pivot fixed to the nose wheel door. For the case where the aircraft frame is stationary, the link AB rotates at 0.25 rad/s in the direction shown and the nose wheel makes an angle of 30° to the vertical, estimate graphically the velocity of G, the angular velocity of leg DG, and the angular velocity of the door EF. The dimensions are AB=432mm; BC=229mm; CF=330mm; EF=229mm; DH=254mm; CH=63.5mm (perpendicular to DH); DG=990mm; A is 584mm to the left of D and 229 mm above D; E is 127 mm to the right of D and 63.5mm below D.

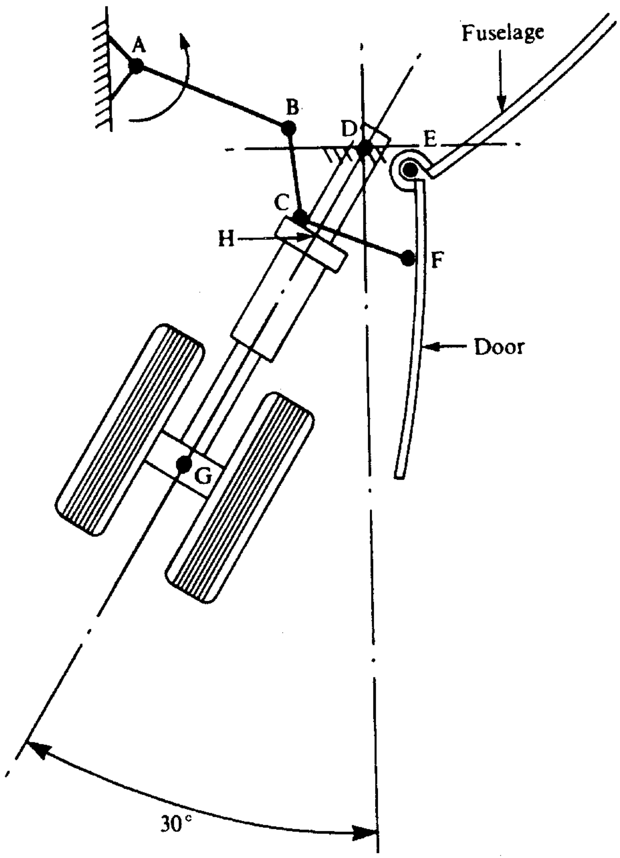

Figure 7 (after Grosjean 1991)

ANSWERS

1. $V_o = \sqrt{\dfrac{gh}{2}}$
3. a_n = 21.33 m/s^2, a_t = -12.32 m/s^2
4. V=960 km/h, $\ddot{r}$ =4.62 m/s^2
5. wL, wL, $2wL$
6. w_2 = 1.923 rad/s
7. $0.947wr$, $wr/\sqrt{2}$, $0.211w$, $0.0566w$.
8. (b) 16.25 m/s ; (c) 227.5 rad/s^2
9. 0.48 m/s, 0.49 rad/s, 0.53 rad/s