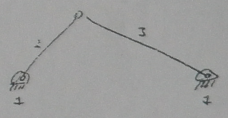
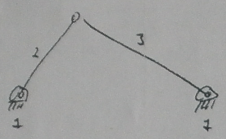
THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 1 Degree of Freedom

Calculate the degree of freedom of following figure.

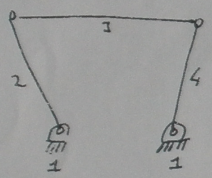
1.



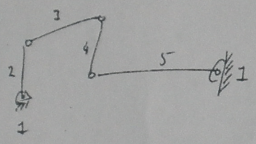
2.



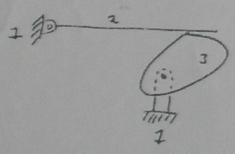
3.



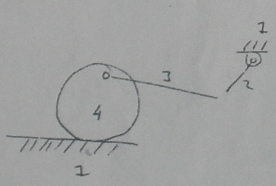
4.



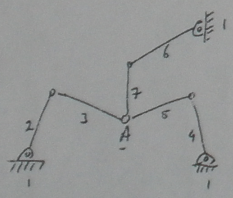
5.



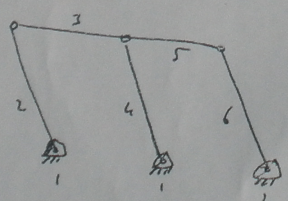
6.



7.



8.



THEORY OF MECHANISM AND MACHINE-I
TUTORIAL : 2
Simple and Compound gear Train

1. A gear box has an input speed of 1500rev/min clockwise and output s1peed of 300rev/min anticlockwise. The input power is 20kW and the efficiency is 70 % determine the following

   a. The gear ratio b. The input torque c. The output power
   d.The output torquee. The holding torque

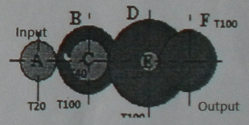
2. A gear box has an input speed of 2000 rev/min clockwise and an output speed of 500 rev/min anticlockwise. The input power is 50 kW and the efficiency is 60%.Determine the following.
   a. The input torque b. The output power c. The output torque d. The holding torque

3. A simple train has 3 gears. Gear A is the input and has 50 teeth. Gear C is the output and has 150 teeth. Gear A rotates at 1500 rev/min anticlockwise. Calculate a. the gear ratio and the output speed the input torques on A is 12 Nm and the efficiency is 75%. Calculate the outputpower and the holding torque.

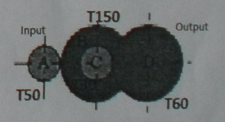
4. A simple gear train has 2 spur gears. The input gear has 20 teeth and the outputgear has 100 teeth. The input rotates at 2000 rev/min clockwise. Calculate the gear ratio and the output speed. (5 and 400 rev/min anticlockwise) The input torque is 15 Nm and the efficiency is 65%. Calculate the output power and the holding torque. (2 042 W and 33.75 Nm clockwise)

5. A simple gear train has 2 spur gears. The input gear has 20 teeth and the output gear has 100 teeth. The input rotates at 2000 rev/min clockwise. Calculate the gear ratio and the output speed. (5 and 400 rev/min anticlockwise) The input torque is 15 Nm and the efficiency is 65%. Calculate the output power and the holding torque. (2 042 W and 33.75 Nm clockwise)

6. Calculate the gear ratio for the compound chain shown below. If the input gearrotates clockwise, in which direction does the output rotate?



7. Gear A is the input and revolves at 1200 rev/minclockwise viewed from the leftend. The input torque is 30 Nm and the efficiency is 70%. Calculate



   a. The output speed and its direction.(200 rev/min clockwise)
   b. The output power.(2639 W)
   c. The fixing torque.(156 Nm anticlockwise)

THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 2
EPICYCLIC GEAR TRAIN

1. In an epicyclic gear train, as shown in Fig 1, the number of teeth on wheels *A*, *B* and *C* are 48, 24 and 50 respectively. If the arm rotates at 400 rpm., clockwise, find : 1. Speed of wheel *C* when *A* is fixed, and 2. Speed of wheel *A* when *C* is fixed. **[Ans. 16 rpm. (clockwise) ; 16.67 (anticlockwise)]**

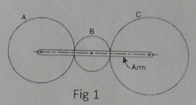


Fig 1

2. In an epicyclic gear train, as shown in Fig. 2, the wheel *C* is keyed to the shaft *B* and wheel *F* is keyed to shaft *A*. The wheels *D* and *E* rotate together on a pin fixed to the arm *G*. The number of teeth on wheels *C*, *D*, *E* and *F* are 35, 65, 32 and 68 respectively. If the shaft *A* rotates at 60 r.p.m. and the shaft *B* rotates at 28 r.p.m. in the opposite direction, find the speed and direction of rotation of arm *G*. **[Ans. 90 r.p.m., in the same direction as shaft *A*]**

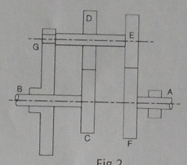


Fig 2

3. An epicyclic gear train, as shown in Fig. 3, is composed of a fixed annular wheel *A* having 150teeth. The wheel *A* is meshing with wheel *B* which drives wheel *D* through an idle wheel *C*, *D* beingconcentric with *A*. The wheels *B* and *C* are carried on an arm which revolves clockwise at 100 r.p.m.about the axis of *A* and *D*. If the wheels *B* and *D* have 25 teeth and 40 teeth respectively, find thenumber of teeth on *C* and the speed and sense of rotation of *C*. **[Ans. 30 ; 600 rpm. clockwise]**

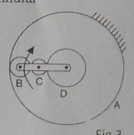


Fig 3

4. In a reverted epicyclic geartrain, the arm A carries two gears B and C and a compound gear D - E. The gear B meshes with gear E and the gear C meshes with gear D. The number of teeth on gears B, C and D are 75, 30 and 90 respectively. Find the speed and direction of gear C when gear B is fixed and the arm A makes 100 rpm. clockwise.**[Ans. 400 rpm. anticlockwise]**

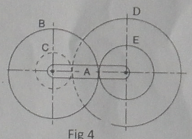
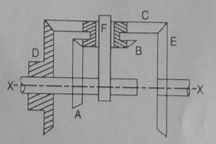


Fig 4

5. An epicyclic gear consists of bevel wheels as shown in Fig. 13.49. The driving pinion *A* has 20 teeth and meshes with the wheel *B* which has 25 teeth. The wheels *B* and *C* are fixed together and turn freely on the shaft *F*. The shaft *F* can rotate freely about the main axis *X X*. The wheel *C* has 50 teeth and meshes with wheels *D* and *E*, each of which has 60 teeth. Find the speed and direction of *E* when *A*rotates at 200 r.p.m., ifi)*D* is fixed, and **ii)***D* rotates at 100 r.p.m., in the same direction as *A*. In both the cases, find the ratio of the torques transmitted by the shafts of the wheels *A* and *E*, the friction being neglected. **[Ans. 800 r.p.m. in the opposite direction of *A* ; 300 r.p.m. in the oppositedirection of *A* ; 4 ; 1.5]**



THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 3 CAMS

Q1. A cam is to give the following motion to a knife-edged follower:

1. Outstroke during 60° of cam rotation;

2. Dwell for the next 30° of cam rotation;

3. Return stroke during next 60° of cam rotation, and

4. Dwell for the remaining 210° of cam rotation.

The stroke of the follower is 40 mm and the minimum radius of the cam is 50 mm. The follower moves with uniform velocity during both the outstroke and return strokes. Draw the profile of the cam when

(a) The axis of the follower passes through the axis of the cam shaft, and

(b) The axis of the follower is offset by 20 mm from the axis of the cam shaft. (p784)

Q2. A cam is to be designed for a knife edge follower with the following data:

1. Cam lift = 40 mm during 90° of cam rotation with simple harmonic motion.

2. Dwell for the next 30°.

3. During the next 60° of cam rotation, the follower returns to its original position with SHM.

4. Dwell during the remaining 180°.

Draw the profile of the cam when

(a) The line of stroke of the follower passes through the axis of the cam shaft, and

(b) The line of stroke is offset 20 mm from the axis of the cam shaft.

The radius of the base circle of the cam is 40 mm. Determine the maximum velocity and acceleration of the follower during its ascent and descent, if the cam rotates at 240 r.p.m. (p787)

Q3. A cam, with a minimum radius of 25 mm, rotating clockwise at a uniform speed is to be designed to give a roller follower, at the end of a valve rod, motion described below :

1. To raise the valve through 50 mm during 120° rotation of the cam;

2. To keep the valve fully raised through next 30°;

3. To lower the valve during next 60°; and

4. To keep the valve closed during rest of the revolution i.e. 150°;

The diameter of the roller is 20 mm and the diameter of the cam shaft is 25 mm. Draw the profile of the cam when

(a) The line of stroke of the valve rod passes through the axis of the cam shaft, and

(b) The line of the stroke is offset 15 mm from the axis of the cam shaft.The displacement of the valve, while being raised and lowered, is to take place with simple harmonic motion. Determine the maximum acceleration of the valve rod when the cam shaft rotates at 100 r.p.m. Draw the displacement, the velocity and the acceleration diagrams for one complete revolution of the cam. (p789)

Q4. A cam drives a flat reciprocating follower in the following manner:
1. During first 120° rotation of the cam, follower moves outwards through a distance of 20 mm with SHM. 2. Dwells during next 30° of cam rotation.
3. Next120° of cam rotation, the follower moves inwards with SHM.
4. Dwells for the next 90° of cam rotation.
The minimum radius of the cam is 25 mm. Draw the profile of the cam. (p792)

Q5. A cam, with a minimum radius of 50 mm, rotating clockwise at a uniform speed, is required to give a knife edge follower the motion as described below:
1. To move outwards through 40 mm during 100° rotation of the cam;
2. To dwell for next 80°;
3. To return to its starting position during next 90°, and
4. To dwell for the rest period of a revolution i.e. 90°.
Draw the profile of the cam
(i) When the line of stroke of the follower passes through the center of the cam shaft, and
(ii) When the line of stroke of the follower is off-set by 15 mm.
The displacement of the follower is to take place with uniform acceleration and uniformretardation. Determine the maximum velocity and acceleration of the follower when the cam shaft rotates at 900 r.p.m. draw the displacement, velocity and acceleration diagrams for one complete revolution of the cam.

Q6. Design a cam for operating the exhaust valve of an oil engine. It is required to give equal uniform acceleration and retardation during opening and closing of the valve each of which corresponds to 60° of cam rotation. The valve must remain in the fully open position for 20° of

cam rotation. The lift of the valve is 37.5 mm and the least radius of the cam is 40 mm. The follower is provided with a roller of radius 20 mm and its line of stroke passes through the axis of the cam.(p799)

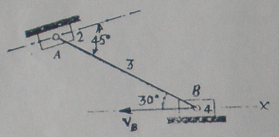
Q7. A cam rotating clockwise at a uniform speed of 1000 r.p.m. is required to give a roller follower the motion defined below:
1. Follower to move outwards through 50 mm during 120° of cam rotation,
2. Follower to dwell for next 60° of cam rotation,
3. Follower to return to its starting position during next 90° of cam rotation,
4. Follower to dwell for the rest of the cam rotation.
The minimum radius of the cam is 50 mm and the diameter of roller is 10 mm. The line of stroke of the follower is off-set by 20 mm from the axis of the cam shaft. If the displacement of thefollower takes place with uniform and equal acceleration and retardation on both the outward and return strokes, draw profile of the cam and find the maximum velocity and acceleration during out stroke and return stroke. (p802)

8. **Draw the cam profile for following conditions:**
Follower type = roller follower, in-line; lift = 25mm; base circle radius = 20mm; roller radius = 5mm; out stroke with UAM, for 120° cam rotation; dwell for 60° cam rotation; return stroke with UAM, for 90° cam rotation; dwell for the remaining period. Determine max. velocity and acceleration during out stroke and return stroke if the cam rotates at 1200 rpm in clockwise direction.
9. **Draw the cam profile for following conditions:**
Follower type = flat faced follower, in line; follower rises by 20mm with SHM in 1200 of cam rotation, dwells for 300 of cam rotation; returns with SHM in 1200 of cam rotation and dwells during the remaining period. Base circle radius = 25mm.
10.) **Draw the cam profile for following conditions:**
Follower type = roller follower, in line; roller dia. = 5mm; follower rises by 25mm with SHM in 1800 of cam rotation, falls by half the distance instantaneously; returns with Uniform velocity in 1800 of cam rotation. Base circle radius = 20m.

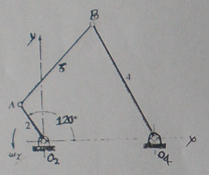
THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 4 Velocity Analysis

VELOCITY DIAGRAM (assume missing data)

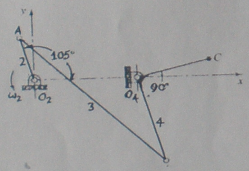
1. The velocity of point B linkage Shown in the figure40 m/sec find the velocity of A and angular velocity of link 3.



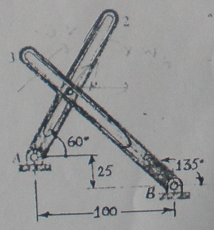
2. The mechanism shown in the figure is driven by link 2 at angular velocity 45 rad/sec find the angular velocities of link 3 and 4. (AO_2 =10 mm, AB=25 mm O_2O_4 =30 mm.)



3. Find the velocity of point c on link 4 of the mechanism shown in the figure if crank 2 is driven at angular velocity 48 rad/sec ccw. What is angular velocity of link 3 ?(AO_2 = 8cm, AB =32 cm, O_2O_4=16 cm, BO_4=16cm)



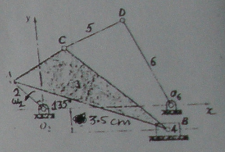
4. Slotted link 2 and three are drive independently at angular velocity of link 2 is 30rad/sec cw and angular velocity of link 3 is 20 rad/sec respectively. Find the absolute velocity of centre of pin carried on two slots.



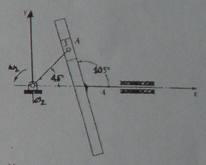
Rudra Ghimire

THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 4 Velocity Analysis

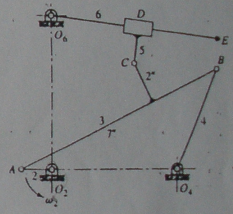
5. The angular velocity of the link 2 mechanism shown in the figure is 10 rad/sec . Find the angular velocity of link 6and velocities of point B, C and D.(AO_2 =2.5cm AB= 10cm, BC = 8cm, AC=DC= 4 cm, O_6O_2 =8 cm and DO_6= 6cm)



6. The figure shows variation of scotch yoke mechanism. It is driven by crank 2 at angular velocity 36 rad/sec ccw. Find the velocity of cross head link 4. AO_2



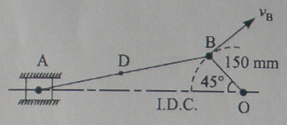
7. Make the complete velocity analysis of the linkage shown in the figure for angular velocity 72 rad/sec ccw.
(AO_2=DC=1.5 cm, AC=10.5 cm, O_2O_4=6cm, BO_4 =5cm, O_2O_6=7 cm, EO_6=8cm)



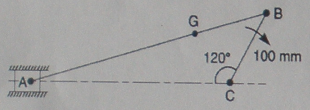
Rudra Ghimire

(Assume missing data)

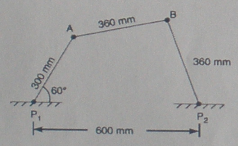
1. The crank of a slider crank mechanism rotates clockwise at a constant speedof 300 rpm. The crank is 150 mm and the connecting rod is 600 mm long. Determine **a.** linear velocity and acceleration of the midpoint of the connecting rod, and **b.** angular velocity and angular acceleration of the connecting rod, at a crank angle of 45° from inner dead center position.



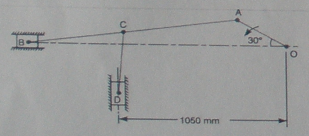
2. An engine mechanism is shown in Fig. 8.5. The crank CB = 100 mm and theconnecting rod BA = 300 mm with center of gravity G, 100 mm from B. In the position shown, thecrankshaft has a speed of 75 rad/s and an angular acceleration of 1200 rad/s2. Find:**a.** velocity ofG and angular velocity of AB, and **b.** acceleration of G and angular acceleration of AB.



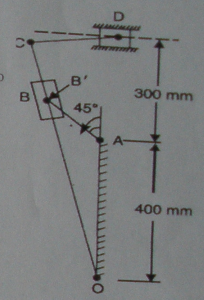
3. The dimensions and configuration of the four bar mechanism, shown infigure are as follows:P_1A = 300 mm; P_2B = 360 mm; AB = 360mm, and P_1P_2 = 600 mm.The angle AP_1P_2 = 60°. The crank P_1A hasan angular velocity of 10 rad/s and an angularacceleration of 30 rad/s2, both clockwise. Determine the angular velocities and angular accelerations of P2B, and AB and the velocity and acceleration of the joint B.



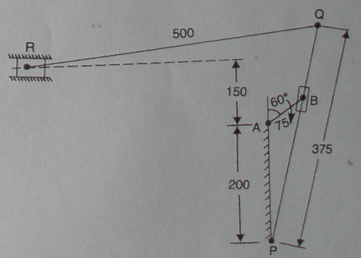
4. In the mechanism, as shown in Figure, the crank OA rotates at 20 rpm.ccw and gives motion to the sliding blocks B and D. The dimensions of the various links are OA = 300 mm; AB = 1200 mm; BC = 450 mm and CD = 450 mm.



5. A mechanism of a crank and slotted lever quickreturn motion is shown in Fig. 8.28. If the crank rotates counter clockwiseat 120 r.p.m., determine for the configuration shown, the velocity andacceleration of the ram D. Also determine the angular acceleration ofthe slotted lever.Crank, AB = 150 mm ; Slotted arm, OC = 700 mm and linkCD = 200 mm.



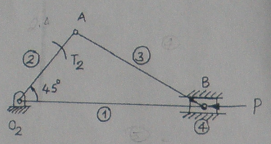
6. The driving crank AB of the quick-return mechanism, as shown in Fig. 8.30,revolves at a uniform speed of 200 r.p.m. Find the velocity and acceleration of the tool-box R, in theposition shown, when the crank makes an angle of 60° with the vertical line of centres PA. What isthe acceleration of sliding of the block at B along the slotted lever PQ ?



THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 6 Force Analysis

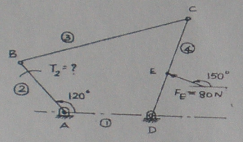
1. ***Slider crank mechanism***

Figure shows a slider crank mechanism in which the resultant gas pressure 8 x 104 Nm-2 acts onthe piston of cross sectional area 0.1 m2. The system is kept in equilibrium as a result of thecouple applied to the crank 2, through the shaft at O2. Determine forces acting on all the links(including the pins) and the couple on 2.

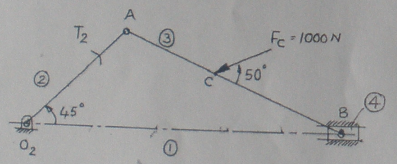


2. **Four link mechanism.**

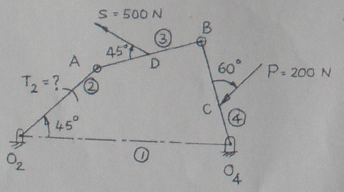
A four link mechanism is acted upon by forces as shown in the figure. Determine the torque T2 to be applied on link 2 to keep the mechanism in equilibrium. AD=50mm, AB=40mm, BC=100mm, Dc=75mm, DE= 35mm,



3. Determine T2 to keep the mechanism in equilibrium
AC=70mm,
AB=150mm,
O2A= 40mm



4. Determine the torque T2 required to keep the given mechanism in equilibrium.
O2A= 30mm, = AB =O4B, O2O4 =60mm
AO2 O 4= 60°, BC = 19mm, AD=15mm.



Rudra Ghimire

THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 4 Acceleration Analysis(corolious)

1 The mechanism as shown in Figure 1 is a marine steering gear, called Rapson's slide. *O2B* is the tiller and *AC* is the actuating rod. If the velocity of *AC* is 25 mm/min to the left, find the angular velocity and angular acceleration of the tiller. Either graphical or analytical technique may be used.
[Ans. 0.125 rad/s; 0.018 rad/s2]

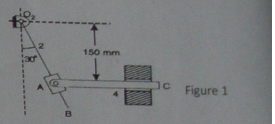


Figure 1

2 In the oscillating cylinder mechanism as shown in Figure 2, the crank OA is 50 mm long while the piston rod AB is 150 mm long. The crank OA rotates uniformly about O at 300 r.p.m. Determine, for the position shown : 1. velocity of the piston B relative to the cylinder walls, 2. angular velocity of the piston rod AB, 3. sliding acceleration of the piston B relative to the cylinder walls, and 4. angular acceleration of the piston rod AB
[Ans. 1.5 m/s ; 2.2 rad/s (anticlockwise) ; 16.75 m/s2 ; 234 rad/s2]

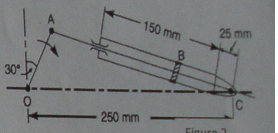


Figure 2

3 Figure 3 shows a quick return motion mechanism in which the driving crank OA rotates at 120 r.p.m. in a clockwise direction. For the position shown, determine the magnitude and direction of 1, the acceleration of the block D ; and 2. the angular acceleration of the slotted bar QB.
[Ans. 7.7 m/s2 ; 17 rad/s2]

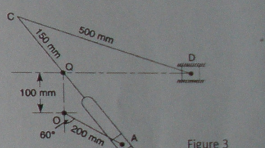


Figure 3

4 In a quick return mechanism, as shown in Figure 4, the driving crank OA is 60 mm long and rotates at a uniform speed of 200 r.p.m. in a clockwise direction. For the position shown, find 1. velocity of the ram R ; 2. acceleration of the ram R, and 3. acceleration of the sliding block A along the slotted bar CD.
[Ans. 1.3 m/s ; 9 m/s2 ; 15 m/s2]

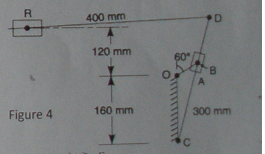


Figure 4

5 In the toggle mechanism, as shown in Figure 5, D is constrained to move on a horizontal path. The dimensions of various links are : AB = 200 mm; BC = 300 mm ; OC = 150 mm; and BD = 450 mm. The crank OC is rotating in a counter clockwise direction at a speed of 180 r.p.m., increasing at the rate of 50 rad/s2. Find, for the given configuration 1. velocity and acceleration of D, and 2. angular velocity and angular acceleration of BD.
[Ans. 1.3 m/s ; 9 m/s2 ; 15 m/s2]

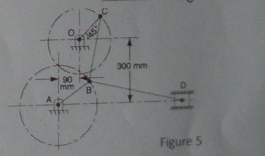
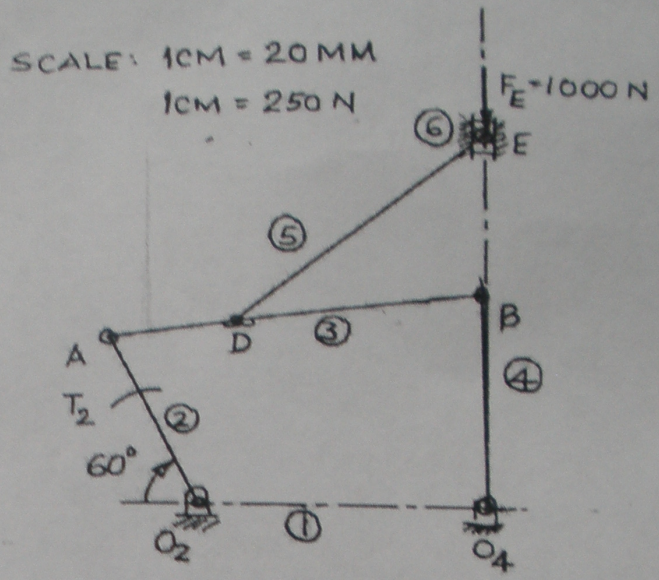


Figure 5

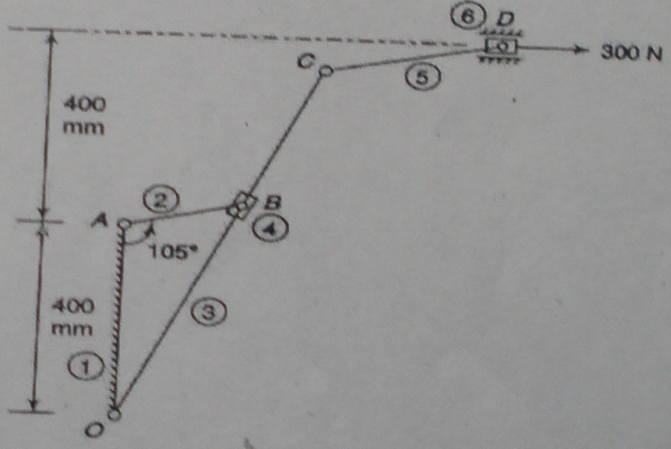
Rudra Ghimire

THEORY OF MECHANISM AND MACHINE-I
TUTORIAL 6 Force Analysis

5. Determine the torque T_2 required to overcome the force F_E along the link 6.
AD=30mm, AB=90mm, O_4B=60mm,
DE=80mm, O_2A=50mm, O_2O_4=70mm

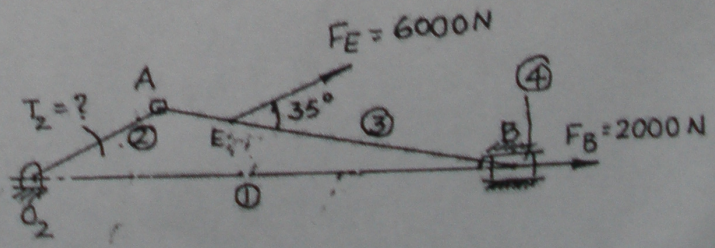


6. For the static equilibrium of the quick return mechanism shown in fig.
(a) determine the input torque T_2 to be applied on link AB for a force of 300N on the slider D. The dimensions of the various links are OA=400mm, AB=200mm, OC=800mm, CD=300mm



1CM = 50 MM

Determine T_2 to keep the body in equilibrium.
O_2A =100mm, AB=250mm,
AE=50mm, O_2AO B = 30mm
<AO2B=30'



Answers:

1. 1100 Nm CW 2. 18.78 N-mm CCW 3. 4. 1150 N-mm CW
5. 65000 N-mm CW 6. 48 360 N-mm CCW 7. 116000 N-mm CCW