1. (i) Figure 1 shows a mechanism where link 2 is driving link 4 with the help of a rigid, uniform coupler of negligible mass. The angular velocity $\omega_2$ at the instant shown is 10 rad/s. If a moment $M$ of magnitude 500 N-m is applied on 2, as shown, determine the acceleration of link 2. The moments of inertia of links 2 and 4 about $O_2$ and $O_4$ are 0.5 kg.m$^2$ and 1.0 kg.m$^2$, respectively. Given $O_2O_4 = 25$ cm, $AO_2 = 35$ cm, and $BO_4 = 50$ cm.

(ii) What will be the acceleration of link 2 if the coupler has a mass 2 kg and the mechanism is in a horizontal plane?

![Figure 1](image)

2. For the mechanism shown in Fig. 2, the sliding blocks weigh 45 N each. Both connecting rods are uniform, each being 50.8 cm long. The length of the crank is 15.3 cm and is rigid with a mass 10 kg at its end. All links weigh 172 N/m. (i) If a force of 450 N is applied to the slider A as shown in the figure, what will be the acceleration of the slider B at the instant when the force is applied, assuming the mechanism to be initially at rest? (ii) Instead of being at rest, if the crank possesses an angular velocity of 300 rad/s in the counter-clockwise direction, what will be the acceleration of the slider B at the instant?

3. (i) Figure 3 shows a four-bar mechanism in the vertical plane and stationary at the instant indicated. The input and output members $0_2A$ and $0_4B$ are rigid but of a negligible mass. The coupler AB is a rigid, uniform rod of length 50 cm, its total mass being 15 kg. A torque $M$ acts on the crank $0_2A$, as shown, causing this crank to move with an angular acceleration 50 rad/s$^2$ in the direction of $M$. Determine the magnitude of $M$.

(ii) What will be the magnitude of $M$ when the input member rotates with an angular velocity of 150 rad/s (CCW) at the same instant as in Problem (i)?
4. A slotted-lever quick-return mechanism is shown in Fig. 4. The crank is balanced and its moment of inertia about $O_2$ is 0.15 $kg.m^2$. The moment of inertia of the slotted lever about its CG, $G_4$, is 2.5 $kg.m^2$, and that of the sliding block about $G_3$ is 0.01 $kg.m^2$. The masses of the block and the slotted lever are 15 kg and 60 kg respectively. Neglecting gravitational effects and friction, determine the total force on the pin $O_4$.

5. In a slider-crank engine mechanism when the crank angle is $\theta$ from the outer dead-centre position, the gas pressure $p$ is suddenly applied on the piston. The mechanism was initially at rest. Prove that the angular acceleration of the crank at the instant when the pressure is applied will be

$$\alpha \approx \frac{pA\sin(\theta + \phi)}{J_r \cos\phi + m_{rec}r^2(\sin\theta + \frac{1}{2}\sin(2\theta))\sin(\theta + \phi)}$$

where
- $A =$ cross-sectional area of the piston,
- $r =$ crank length,
- $\lambda = \frac{r}{l} \ (l \text{ being the length of the connecting rod}),$
- $\phi =$ angle made by the connecting rod with the line of stroke at this instant,
- $m_{rec} =$ mass of the reciprocating parts, and
- $J_r =$ moment of inertia of the crank about the axis of rotation.

6. Fig. 5 shows a slider-crank mechanism for an offset engine. Show that the acceleration of the piston towards the crankshaft can be approximately expressed (for a small offset $h$) as
Note that with the proper amount of offset, the overall frictional loss between the cylinder and the piston can be reduced.

7. The data given for a vertical offset engine are $r = 6.3$ cm, $l = 24.1$ cm, $h = 2$ cm, diameter of the cylinder = 9 cm, speed of the engine = 2400 rpm, and mass of reciprocating parts = 1.35 kg. Determine the turning moment when the crank has rotated through $60^\circ$ from the top dead-centre position and the net gas pressure on the piston is 112 $N/cm^2$.

8. A horizontal gas engine running at 210 rpm has a bore of 220 mm and a stroke of 440 mm. The connecting rod is 924 mm long and the reciprocating parts weigh 20 kg. When the crank has turned through an angle of $30^\circ$ from the inner dead centre, the gas pressures on the cover and the crank sides are 500 $kN/m^2$ and 60 $kN/m^2$ respectively. Diameter of the piston rod is 40 mm. Determine
   i) turning moment of the crank shaft
   ii) thrust on the bearings.
   iii) acceleration of the flywheel which has a mass of 8 kg and radius of gyration of 600 mm while the power of the engine is 22 kW.

9. The crank and connecting rod of a vertical petrol engine, running at 1800 rpm are 60 mm and 270 mm respectively. The diameter of the piston is 100 mm and the mass of the reciprocating parts is 1.2 kg. During the expansion stroke when the crank has turned $20^\circ$ from the top dead centre the gas pressure is 650 $kN/m^2$. Determine the
   (i) net force on the piston
   (ii) net load on the gudgeon pin
   (iii) thrust on the cylinder walls
   (iv) speed at which the gudgeon pin load is reversed in direction.
10. The following data relate to a horizontal reciprocating engine.
   Mass of reciprocating parts = 120 kg
   Crank length = 90 mm
   Engine speed = 600 rpm
   Connecting rod:
   Mass = 90 kg
   Length between centres = 450 mm
   Distance of centre of mass from big end centre = 180 mm
   Radius of gyration about an axis through centre of mass = 150 mm
   Find the magnitude and the direction of the inertia torque on the crankshaft when the crank has
   turned 30° from the inner dead centre.

11. The piston diameter of an internal combustion is 125 mm and the stroke is 220 mm. The connecting
rod is 4.5 times the crank length and has a mass of 50 kg. The mass of reciprocating parts is 30 kg. The centre of mass of the connecting rod is 170 mm from the crank-pin centre and the radius of gyration about an axis through the centre of mass is 148 mm. The engine runs at 320rpm. Find the magnitude and the direction of the inertia force and the corresponding torque on the crankshaft when the angle turned by the crank is 140° from the inner dead centre.