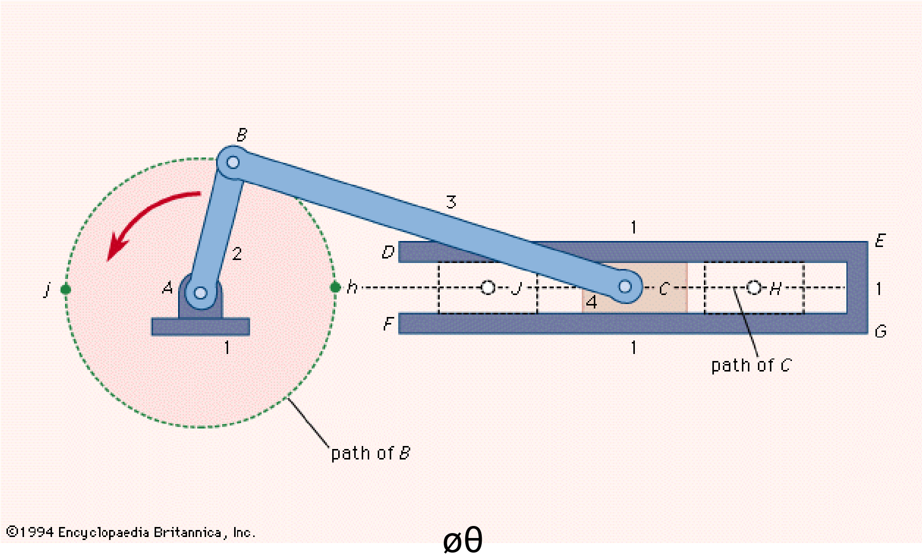
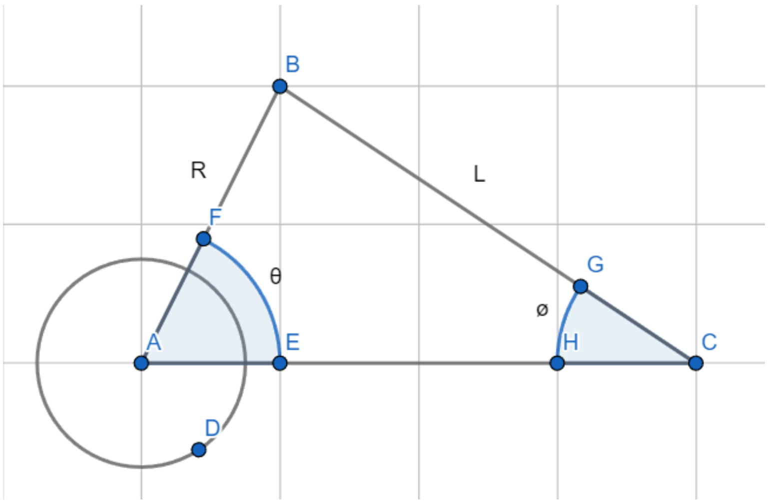
Slider Crank Mechanism



øθ

BC=L; AB=R; R/L=λ



$x = R\cos(\theta) + L\cos(\phi)$
$R\sin(\theta) = L\sin(\phi)$
$\lambda\sin(\theta) = \sin(\phi)$

$x = R\cos(\theta) + L(1-\sin^2(\phi))^{1/2}$
$x = R\cos(\theta) + L(1-\lambda^2\sin^2(\theta))^{1/2}$

Now, applying Binomial expansion of $(1-\lambda^2\sin^2(\theta))^{1/2}$

We get a expression of x/R, on double differentiating the equation and ignoring the higher order terms(of the order>=3), we get

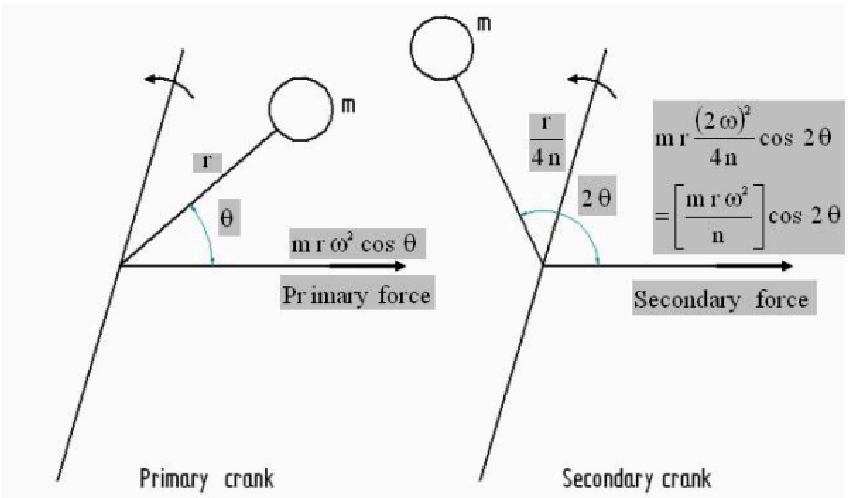
$(X^{\circ\circ})/R = a/R = -w^2[\cos(\theta) + \lambda\cos(2\theta)]$ (w = angular velocity of rotation of AB)
Unbalance Force = $m_{rec}a = -m_{rec}Rw^2[\cos(\theta) + \lambda\cos(2\theta)]$
(m_{rec} is the net mass of the reciprocating mechanism)

Unbalance Force = $F = -m_{rec}Rw^2[\cos(\theta) + \lambda\cos(2\theta)]$
$\theta = wt$

$F = \underbrace{m_{rec}Rw^2\cos(wt)}_{\text{Primary unbalance}} + \underbrace{m_{rec}Rw^2\lambda\cos(2wt)}_{\text{secondary unbalance}}$

Primary Unbalance - The reciprocating mass (piston, piston rings, connecting rod) moving up and down translates to a force acting along the axis of the cylinder. This force creates a primary unbalanced force when resolved into components along the direction of crank rotation.
Occurs once per revolution of the crankshaft (at crank positions 0° and 180°)
Secondary Unbalance - Due to the connecting rod's finite length, the reciprocating mass doesn't perfectly follow a straight path but has a slight sideways movement. This creates a secondary unbalanced force acting perpendicular to the cylinder axis.
Occurs twice per revolution of the crankshaft (at crank positions 0°, 90°, 180°, and 270°)
Generally smaller than the primary force due to the factor (1/λcos(θ)) where n is typically 4-5.

$F = m_{rec}Rw^2\cos(wt) + (\lambda m_{rec}/4)R(2w)^2\cos(2wt)$
$n=1/\lambda$



$F = m_{rec}Rw^2\cos(wt) + m_{rec}(R/4n)(2w)^2\cos(2wt)$
Thus, we can say that to balance the unbalance forces in a crank shaft mechanism we need to put a mass m_{rec} at a distance R, rotating with angular velocity w. But, this only balances the primary unbalance.

To get rid of the secondary unbalance we need to put a mass m_{rec} at a radius (R/4n), rotating with angular velocity 2w.

Elimination of Unbalance

1. Engine Design:

Multi-cylinder Engines: By arranging cylinders at specific angles (e.g., V8 engines), the primary unbalanced forces from different pistons can cancel each other out.

2. Counterweights:

Crankshaft Design: The crankshaft is designed with counterweights on its throws (opposite the crank pin) to create a moment that counteracts the unbalanced forces from the reciprocating masses.

Firing Order

The firing order in an engine refers to the specific sequence in which the cylinders ignite fuel and air mixture. It dictates the order in which the power strokes occur within the engine's cylinders.

Importance of Firing Order

Smooth operation: A well-defined firing order helps distribute the combustion events evenly throughout the engine cycle.This reduces vibrations and makes the engine run smoother.

Balanced power delivery: The firing order ensures a consistent flow of power to the crankshaft. This helps maintain a steady power output and prevents jerky acceleration.

Reduced vibration: Certain firing orders can help cancel out natural vibrations that occur within the engine. This contributes to a more comfortable driving experience and reduces wear and tear on engine components.