南京邮电大学
Nanjing University of Posts and Telecommunications

物理实验教学中心

Physics Experiment Center

Forced vibration

Li Bin
NJUPT

Experimental Goals

- The resonance phenomena.
- The effect of different damping moments on the forced vibration.
- The amplitude-frequency (θ-ω/ω_0) and phase-frequency (φ-ω/ω_0) characteristics of the forced vibration.

Principles

This experiment adopts the balance wheel to study its forced vibration characteristics and electromagnetic torque elastic damping effect.

Forced vibration equation:

$$J\frac{d^2\theta}{dt^2} = -k\theta - b\frac{d\theta}{dt} + M_0\cos\omega t$$

$$\frac{d^2\theta}{dt^2} + 2\beta\frac{d\theta}{dt} + \omega_0{}^2\theta = m\cos\omega t$$

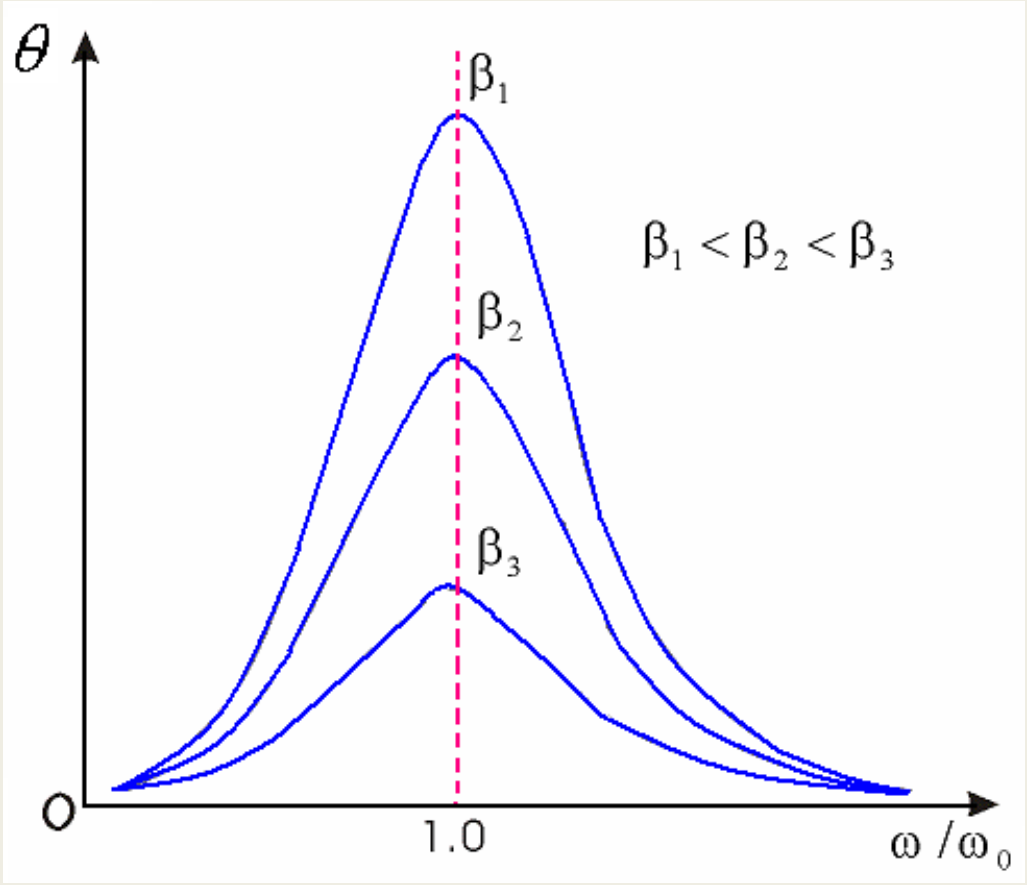
$$\theta = \theta_1 e^{-\beta t}\cos(\omega_f t + \alpha) + \theta_2\cos(\omega t + \varphi)$$

$$\theta_2 = \frac{m}{\sqrt{\left(\omega_0^2 - \omega^2\right)^2 + 4\beta^2\omega^2}}$$

Amplitude-frequency characteristic curve

Resonance condition:

$$\omega_r = \sqrt{\omega_0^2 - 2\beta^2} < \omega_0$$

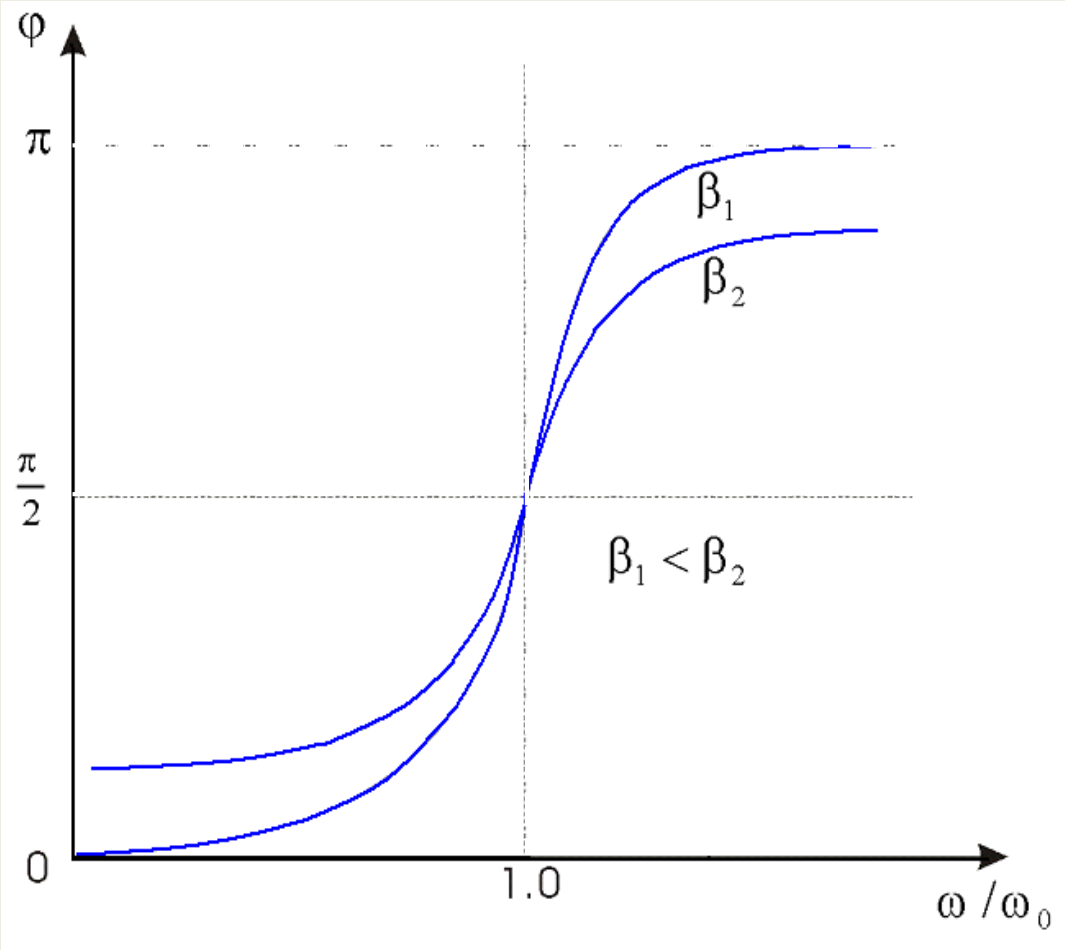


$$\varphi = \arctan \frac{2\beta\omega}{\omega_0^2 - \omega^2}$$

When resonance occurs:

$$tg\varphi_r \to \infty, \varphi_r \to \frac{\pi}{2}$$

Phase-frequency characteristic curve

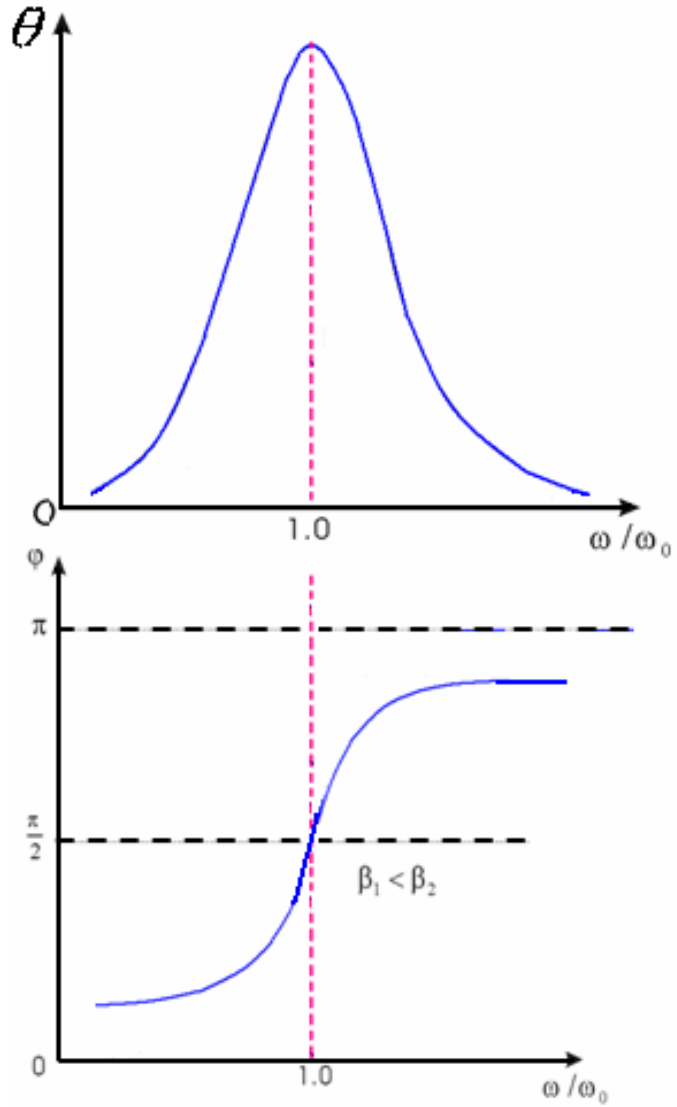


Free vibration: $T_0 \sim \theta$

Damping vibration: β :

Forced vibration: $\theta \sim \omega$

$\varphi \sim \omega$



TABLEs

TABLE I. Amplitude and period in free vibration

	1	2	3	4	5	6	7	8	9	10
Amplitude θ (°)										
Period T_0 (s)										

Draw T_0-θ curve.

TABLE II. Amplitude and period in damping vibration

*Damper position:*_____

No.	Amplitude θ / (°)	No.	Amplitude θ / (°)	$\ln \frac{\theta_i}{\theta_{i+5}}$
θ_1		θ_6		
θ_2		θ_7		
θ_3		θ_8		
θ_4		θ_9		
θ_5		θ_{10}		
Average value of $\ln \frac{\theta_i}{\theta_{i+5}}$				

$10T =$ _____s $\quad \bar{T} =$ _____ s $\quad 5\beta\bar{T} = \ln \frac{\theta_i}{\theta_{i+5}}$, $\quad \beta =$ _____

No.	1	……	5	6	7	……	10
Motor position							
Period T /s							
Phase j/ (^{0})							
Amplitude θ / (^{0})							
T_0 / s from Table I							
$\frac{\omega}{\omega_0} = \frac{T_0}{T}$							

Draw θ-ω/ω_0 and φ-ω/ω_0 curves.

END