Applied Mechanics - Newton's Law

Newton's Laws of Motion

First Law: A body at rest or in uniform motion will remain at rest or in uniform motion unless some external force is applied to it

Second Law of Motion: When a body is acted upon by a constant force, its resulting acceleration is proportional to the force and inversely proportional to the mass,

$$a = \frac{F}{m}$$

Where,

a=acceleration, m/s^2

F=force, N

M=mass of a body, kg

Third Law of Motion: It states that to every action force there is an equal and opposite reaction force.

Motion:

Displacement

$$S = V_0 t + \frac{1}{2} a t^2$$

Velocity

$$V = V_0 + at$$

Acceleration

$$a = \frac{dv}{dt} = \frac{d^2 S}{dt^2}$$

Where, S=distance covered by a moving body in time t, m

V=Velocity of a moving body, m/s

A =acceleration of a moving body, m/s^2

V_0= initial velocity of a moving body, m/s

T=time of movement, s

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Newton's Law of Gravitation

Any two bodies attract each other with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them

$$F \alpha \frac{m_1 m_2}{d^2}$$

or

$$F = G \frac{m_1 m_2}{d^2}$$

where,

F=force of attraction, N

m_1=mass of body one, kg

m_2=mass of body second, kg

d=distance between two bodies, m

G=Newtonian constant of gravitation

$$= 6\ 66 \times 10^{-11} \frac{m^3}{kgs^2}$$

Inertia

The inertia of a body may be defined as that property of a body which tends to resist a change in its state of rest or motion.

Mass is defined as a quantitative measure of inertia.

Moment of Inertia of Areas

$$I_x = \int y^2 dA \qquad I_y = \int x^2 dA$$

$$I_z = \int r^2 dA = I_x + I_y$$

where,

I_x=moment of inertia of cross-sectional area about X-axis

I_y=moment of inertia of cross-sectional area about Y-axis

I_z=moment of inertia of cross-sectional area about Z-axis.

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Moment of inertia of areas

Mass moment of inertia (I_m) of a body is given by:

$$I_m = \int r^2 dm$$

Mass moment of inertia for different shapes of body

Rectangle

$$\bar{I}x = \frac{bh^3}{12}$$

$$Ix = \frac{bh^3}{3}$$

$$\bar{J} = \frac{bh}{12}\left(b^2 + h^2\right)$$

Triangle

$$\bar{I}x = \frac{bh^3}{35}$$

$$Ix = \frac{bh^3}{12}$$

$$Ix = \frac{bh^3}{4}$$

Circle

$$\bar{I}x = \bar{I}y = \frac{\pi r^4}{4}$$

$$\bar{J} = \frac{\pi r^4}{2}$$

Ellipse

$$\bar{I}x = \frac{\pi ab^3}{4}$$

$$\bar{I}y = \frac{\pi a^3 b}{4}$$

$$\bar{J} = \frac{\pi ab}{4}\left(a^2 + b^2\right)$$

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Circular Cylindrical Shell

$I_z = mr^2$ where *m*= mass, *r* = radius

Right Circular Cylinder

$$I_z = \frac{1}{2}mr^2$$

$$I_x = \frac{1}{12}m\left(3r^2 + 4l^2\right)$$

where *m*= mass, *r* = radius

Semi cylinder

$$I_z = \left(\frac{1}{2} \times 2mr^2\right)$$

$$= \frac{1}{2}mr^2$$

where *m*= mass, *r* = radius

Hemisphere

$$I_x = I_z = \frac{1}{2}\left(\frac{2}{5} \times 2mr^2\right)$$

$$= \frac{2}{5}mr^2$$

where *m*= mass, *r* = radius

Rectangular Parallelopiped

$$I_z = \frac{1}{12}m\left(a^2 + b^2\right)$$

$$I_x = \frac{1}{12}m\left(4l^2 + a^2\right)$$

Uniform Slender Rod

$$I_{center} = \frac{mL^2}{12}$$

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Right Circular Cone

$$Iz = \frac{3}{10}mr^2$$

$$Ix = Iy = \frac{3}{5}m\left(\frac{r^2}{4} + h^2\right)$$

Elliptical Cylinder

$$Iz = \frac{1}{4}m\left(a^2 + b^2\right)$$

Hemispherical Shell

$$Ix = Iz = \frac{2}{3}mr^2$$

Torus (complete)

$$Iz = m\left(R^2 + \frac{3}{4}a^2\right)$$

Applied Mechanics – Density

Density

$$\rho = \frac{M}{V}$$

$$Pw = \frac{W}{V}$$

Where,

ρ=density, g/cm^3

Pw=weight density, N/cm^3

M=mass, g

V=volume, cm^3

W=weight, N

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Applied Mechanics – Vibrations

Vibrations

1. **Simple Harmonic Motion**

$$T=\frac{1}{n}$$

where,

T=period of a vibration, s

n=frequency or vibration per unit time, 1/s

2. **Spring Pendulum**

$$T=2\pi\sqrt{\frac{m}{k}}$$

where,

T=period, s

M=mass of pendulum

K=spring

3. **Simple Pendulum**

$$T=2\pi\sqrt{\frac{l}{g}}$$

where,

l=length of the pendulum

g=acceleration due to gravity

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4. **Wavelength**

$$V=n\lambda$$

where,

V=total distance traveled in one second

λ=length of one wave

η=number of waves per second

5. **Speed of sound**

$$V=V_o+0.61t_c$$

where,

V=speed of sound at temperature t_c˚C, m/s

V_o=speed at 0˚C, m/s

t_c=temperature, ˚C.

6. **Beat Notes**

$N=n_2-n_1$

where,

N=beat frequency, i.e., number of beats per second

N_1, n2=frequencies of two sources producing the sound, vibrations/s

7. **Doppler Effect**

$$N_o=n_s\frac{V\pm v_o}{V\pm v_s}$$

where,

N_o=frequency heard by the observer

n_s=frequency of the source

V=velocity of sound

V_s=velocity of source

V_o=velocity of the observer

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8. **Intensity of sound**

$$E=\frac{E_o}{d^2}\ (\text{Inverse square law})$$

where,

E=intensity of sound at any distance d, microwatts/cm^2 or decibels

E_o=intensity of sound at unit distance, decibels

9. **Vibrating Strings**

$$V=n\lambda$$
$$V=\sqrt{F/m}$$
$$\lambda=2L$$
$$n=\frac{V}{\lambda}$$

where,

V=velocity of sound, m/s

N=frequency or number of waves passing by per second

λ=length of one wave or wavelength

F=tension in a rope or string, N

M=mass of string per unit length, kg/m

L=distance between two consecutive nodes, m

10. **Sound Wave Through Gas**

$$V=\sqrt{k\frac{p}{\rho}}$$

where,

V=wave velocity, cm/s

P=gas pressure, dynes/cm^2

ρ=gas density, g/cm^3

K=proportionality constant

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