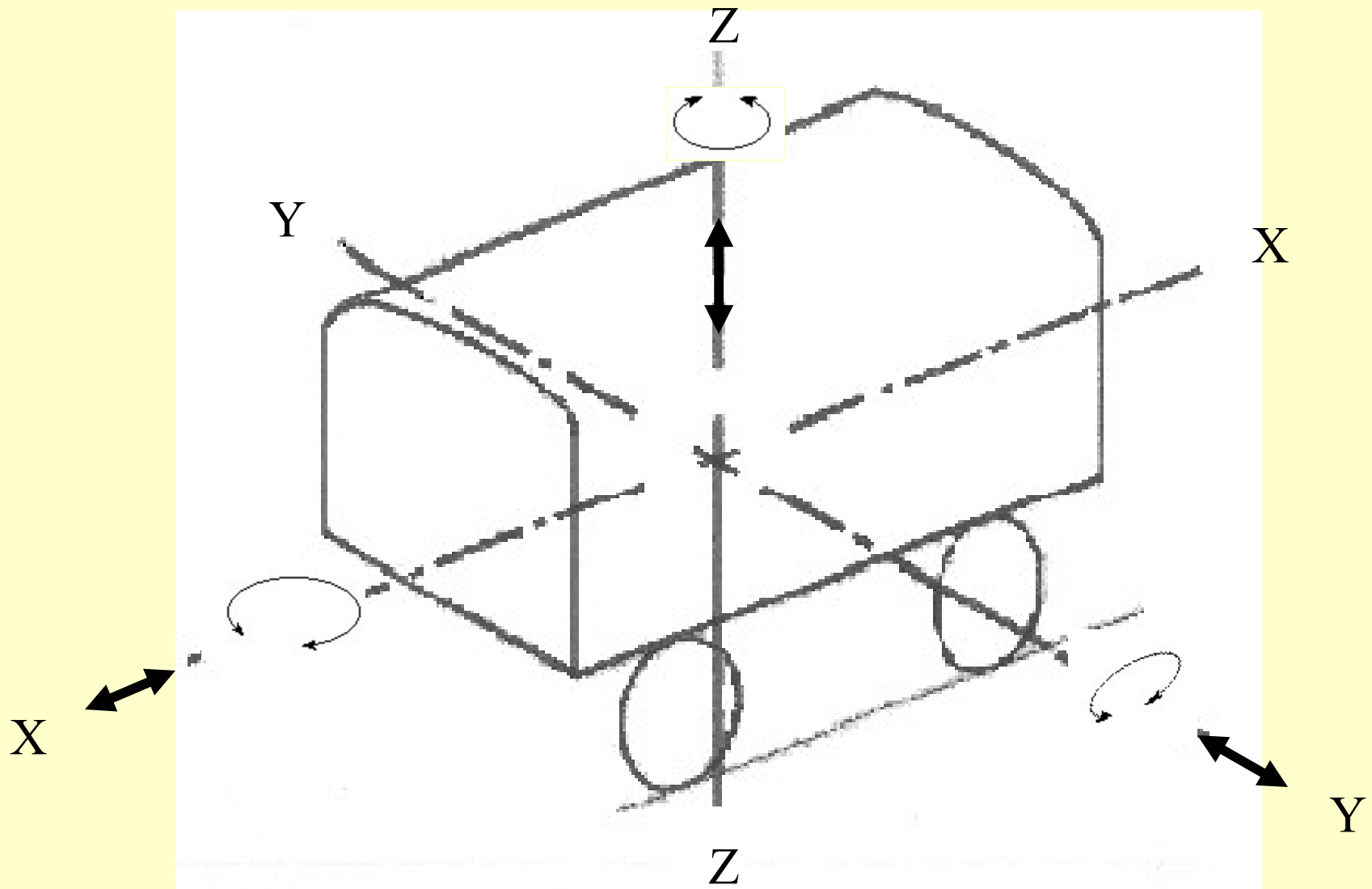




***ASSESSMENT OF STABILITY  
AND  
RIDING OF ROLLING STOCK  
ON  
INDIAN RAILWAYS***

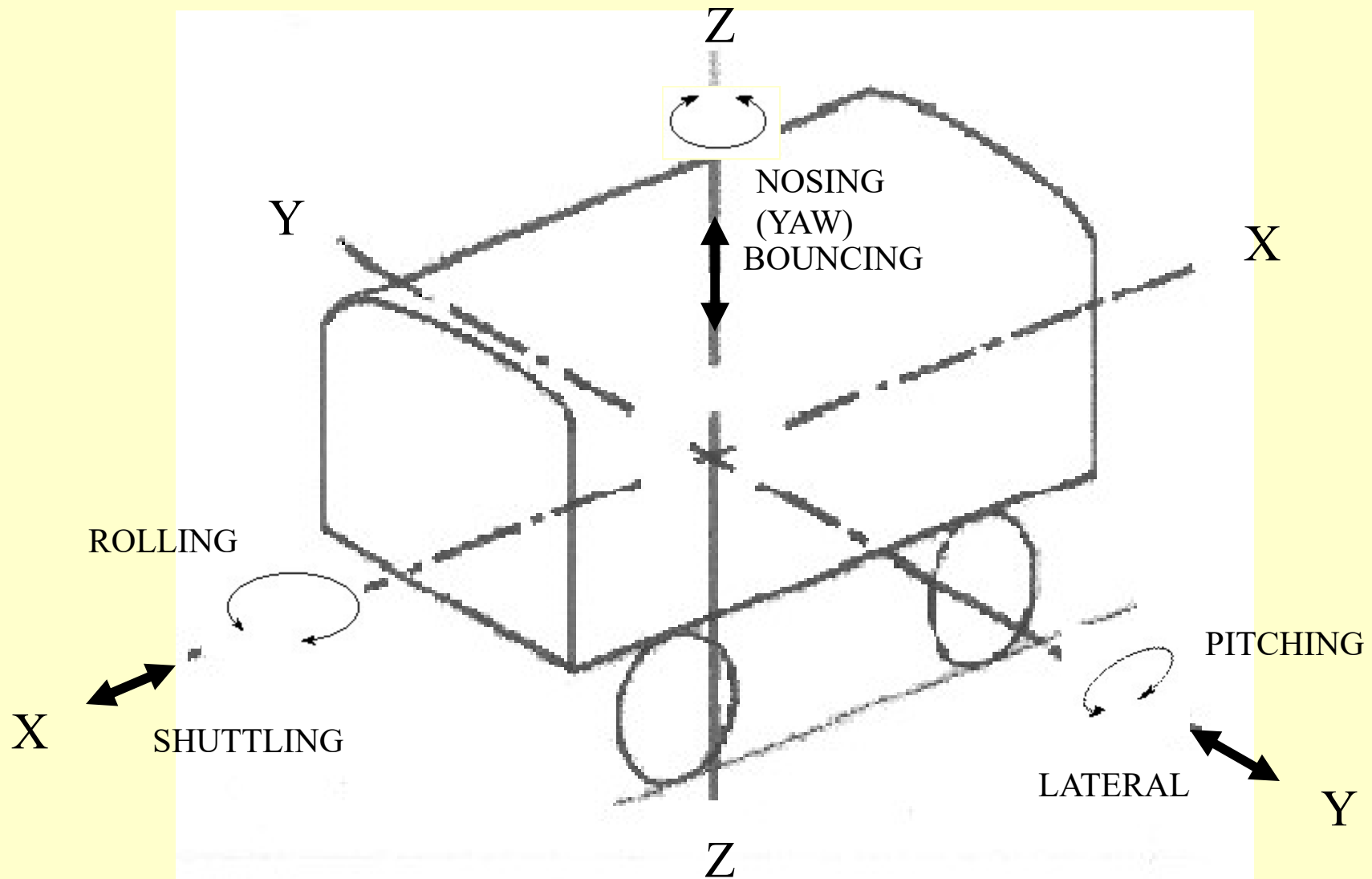
# Oscillation modes of vehicles

There are six modes of oscillations:



# Oscillation modes of body

There are six modes of oscillations:



# *Oscillation modes of vehicles*

Axis	Mode of oscillations	
	<u>Linear</u>	<u>Rotational</u>
X	Shuttling	Rolling
Y	Lateral	Pitching
Z	Bouncing	Nosing (also called 'Yaw')

The continued oscillation of 'Rolling' and 'Nosing' when violent is called 'Hunting'.

# *Oscillation modes of vehicles*

Generally the following track irregularities would generate the oscillations indicated against each:

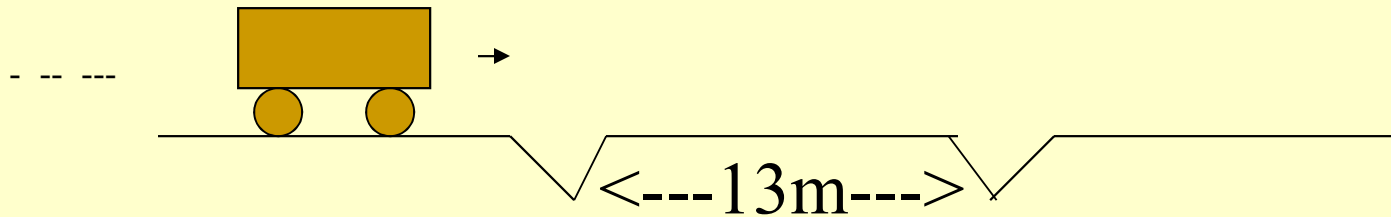
Track Irregularity	Mode of oscillation	Affects
a) Low joints, Unevenness loose packing, etc.	Bouncing, Pitching	Q
b) Alignment or Gauge faults	Lateral, Nosing	Y
c) Twist	Rolling	Q

# *Simplified rigid body dynamics*

- ◆ **Natural frequency** -
  - Every vehicle suspension has a natural frequency of oscillation in six modes stated earlier above.
  - When an external force creates an excitation and if the force is removed, the frequency with which it oscillates is called 'Natural Frequency'
  - Where an external forcing frequency in a particular mode equals the natural frequency in that mode, a phenomenon called resonance occurs.

# Resonance

- ◆ Example:



- ◆ Vehicle Travelling at 13m/sec > 1 Cycle/sec. } Frequency
- ◆ Vehicle Travelling at 26m/sec > 2 Cycles/sec. } of excitation
- } Pitching mode.
- ◆ THE ONLY WAY TO SAFEGUARD AGAINST THE ADVERSE EFFECTS OF RESONANCE IS TO ENSURE LOW NATURAL FREQUENCY & ADEQUATE DAMPING AT ALL TIMES.

# *Resonance*

- ◆ 13m rail joint frequency:

Speed (Km/h)	Forcing Frequency (Hz)
50	1.07
80	1.71
100	2.14



# *Critical speed*

- ◆ **Critical Speed**
  - Speed at which an initial oscillation just maintains its amplitude (without building up the oscillations).
  - This has to be higher than operational speed of a particular rolling stock.
- ◆ The maximum speed upto which a vehicle is tested and found stable may be taken as ‘critical speed’ and the ‘clearance speed’ is - normally kept 10 - 15% below critical speed. On Indian Railways ‘10% below’ is adopted.

# *Safety in coach design*

- ◆ Safety against derailment:
  - Derailment due to flange climbing.

NADAL's formula:

$$\frac{Y}{Q} \text{ Not greater than } \frac{\tan \beta - \mu}{1 + \mu \tan \beta}$$

***Y/Q should not be greater than 1.0 --- IR limit.***

Y = Flange force/lateral force for continuous Min.0.05  
(1/20) sec.

Q = Instantaneous wheel load

$\beta$  = Flange angle (68 degree)

$\mu$  = Co-efficient of friction between wheel and rail (0.25)

- **Y/Q=1.4**

# *Safety in coach design*

- ◆ Safety against derailment:
  - Derailment due to track distortion:  
Prudhomme's Limit:  
Lateral force (limit)  
 $H_y$  should not be greater than  $(1 + P/3)p$

$P$  = axle load in tons

$p$  = Co-efficient to take care of track maintenance, layout of tracks etc.

=0.85

*Lateral force applied for min.2m length of the track.*

# *Safety in coach design*

- ◆ **Ride comfort:**

## Sperling Ride Index

$$V = 0.896 \sqrt[10]{(b^3/f) F(f)}$$

where,

V = numerical value indicating Ride Index

b = mean acceleration in cm/sec.<sup>2</sup>

f = frequency in Hertz.

F(f) = correction factor allowing for the effect of frequencies

**Ride index values associated with ‘comfort’ are considerably lower than those associated with ‘safety’.**

# *Safety in coach design*

## ◆ Relation bet. Passenger comfort & R.I.

Ride Index	Appreciation	Fatigue Limit
1.0	Very good )	
1.5	Almost very good )	Over 24 hours.
2.0	Good )	
2.5	Neatly good	13 hours.
3.0	Passable	5.6 hours.
3.5	Still passable	2.8 hours.
4.0	Able to run	1.5 hours.
4.5	Not able to run	45 minutes
5.0	Dangerous	15 minutes.

# *RDSO's Oscillation Trials*

## *Policy Circular No.6*

This deals with “PROCEDURE FOR CERTIFICATION OF MAXIMUM PERMISSIBLE SPEED FOR ROLLING STOCK”.

- ◆ Sanctioning speeds of new designs of rolling stock.
- ◆ Determination of provisional speed by RDSO.
- ◆ Determination of final maximum permissible speed by RDSO for new designs.
- ◆ Multiple operation of motive power units.
- ◆ Application for sanction by Zonal Railways.
- ◆ Recommendation by CRS/CCRS.
- ◆ Movement of newly designed rolling stock.
- ◆ Sanctioning speed for tests on new rolling stock.

# *RDSO's Oscillation Trials*

## *Policy Circular No.6 (contd...)*

- ◆ Reducing the speed of existing rolling stock restoring the same.
- ◆ Increasing the speed of existing rolling stock by making improvements.
- ◆ Sanction of speed of nominated trains on specified routes-
  - a) Speed above 105 kmph and upto 110 kmph on BG.
  - b) Speed above 110 kmph on BG and 75 kmph on MG.
- ◆ importance of Temporary/Permanent speed restrictions by Zonal Railway System.
- ◆ Maximum speed for trains.

# ***RDSO's Oscillation Trials***

## *Criteria for Assessment of Stability / Riding of rolling stock in Indian Railways*

### 1. DIESEL & ELECTRIC LOCOMOTIVES:

- ◆ The lateral/transverse forces lasting more than 2 meters shall not exceed  $0.85 (1+P/3)$  tons, where P is the axle load in tons.
- ◆ Isolated peak values exceeding the above limit are permissible provided the record shows a stabilizing characteristics of the locomotive subsequent to the disturbances.
- ◆ A simultaneous assessment of the lateral force exerted by the adjacent axles at a point where a high lateral force is exerted by a particular axle.



# *RDSO's Oscillation Trials*

## *Criteria for Assessment of Stability / Riding of rolling stock in Indian Railways-Loco*

*(contd...)*

- ◆ Derailment coefficient should be worked out in the form of ratio between lateral force ( $H_y$ ) and wheel load ( $Q$ ) continuously over a period of 1/20th second, value of  $H_y/Q$  shall not exceed 1.
- ◆ Values of acceleration recorded at a location as near as possible to bogie pivot shall be limited to 0.3g both in vertical & lateral directions. Peak value upto 0.35g may be permitted, if records do not indicate a resonant tendency in the regions of peak value.
- ◆ General indication of stable running characteristics of locomotive as evidenced by movement of bogie on straight & curved track, and by acceleration readings & instantaneous wheel load variation.
- ◆ In the case of such locos where measurement of forces is not possible, evaluation shall be in terms of ride index which shall not be greater than 4, a value of 3.75 is preferred.

# *RDSO's Oscillation Trials*

## *Criteria for Assessment of Stability / Riding of rolling stock in Indian Railways (contd...)*

### 2. CARRIAGE:

- ◆ Ride Index shall not be greater than 3.5; a value of 3.25 is preferred. For EMU & DMU type of stock, ride index shall not be greater than 4.0.
- ◆ Values of acceleration recorded as near as possible to the bogie pivot shall be limited to 0.3g both in vertical and lateral directions. A peak value upto 0.35g may be permitted, if records do not indicate a resonant tendency in the region of peak value.
- ◆ A general indication of stable running characteristics of the carriage as evidenced by the movement of the bogie on a straight and curved track and by the acceleration readings and instantaneous wheel load variations/spring deflections.

# *RDSO's Oscillation Trials*

## *Criteria for Assessment of Stability / Riding of rolling stock in Indian Railways (contd...)*

### 3. WAGONS:

- ◆ Lateral/transverse forces lasting more than 2 meters shall not exceed  $0.85 (1+P/3)$  tons, where P is the axle load in tons.
- ◆ Isolated peak values exceeding the above limit are permissible provided the record shows a stabilizing characteristics of the locomotive subsequent to the disturbances.
- ◆ A simultaneous assessment of the lateral force exerted by the adjacent axles at a point where a high lateral force is exerted by a particular axle.

# *RDSO's Oscillation Trials*

## *Criteria for Assessment of Stability / Riding of rolling stock in Indian Railways (contd...)*

- ◆ Derailment coefficient should be worked out in the form of ratio between lateral force ( $H_y$ ) and wheel load ( $Q$ ) continuously over a period of 1/20th second, value of  $H_y/Q$  shall not exceed 1.
- ◆ General indication of stable running characteristics of wagon as evidenced by movement of bogie on straight & curved track, and by acceleration readings & instantaneous wheel load variations/spring deflections.
- ◆ In the case of such wagons where measurement of forces is not possible, evaluation shall be in terms of ride index which shall not be greater than 4.5; a limit of 4.25 is preferred.

# *RDSO's Oscillation Trials*

- ◆ Normal parameters measured on coaching stock -
  - Vertical acceleration } on floor above
  - Lateral acceleration } the pivot.
  - Spring deflections:
    - Primary
    - Secondary
  - Bolster swing - In case of two stage suspensions.
  - Bogie rotation.

# *RDSO's Oscillation Trials*

## ◆ Values adopted for Ride Index:

	Indian Railways	British Railways
Coaches	< 3.5 3.25 preferred. < 4.0 for EMU/DMU.	< 3.25 Later reduced to 2.75 3.25 for suburban coaches.
Wagons	< 4.5, 4.25 preferred where assessment of forces is not possible	4.25 Mean 5.00 Max.
Locos	< 4.0 3.75 preferred where measurement of force is not possible.	< 3.7

# *RDSO's Oscillation Trials*

- ◆ Acceleration levels:

	Indian Railways	British Railways
Coaches	0.3g max. normal. 0.35g Max. isolated	
Wagons	-	< 0.25g mean vertical <0.44g max. vertical < 0.2g mean lateral < 0.35g max. lateral
Locos	0.3g max. normal 0.35g max.isolated	0.25g (lateral) max. 0.4g (vertical) max.