工業技術研究院
Industrial Technology
Research Institute

Briefing on Automotive NVH Technique

APMP TCAUV Workshop

The application of acoustics, vibration and ultrasound metrology in transportation industry

Bangkok, Thailand

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CMS/ITRI

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Agenda

1. NVH & Vehicle
2. Performance Targeting & Metrology
3. Experiences Sharing
   a. White body & Engine modal testing
   b. Cavity mode

What is NVH

- **Noise, Vibration, and Harshness (NVH) is the study and modification of the noise and vibration characteristics of vehicles.**
- **Designing for NVH is a process that requires the integration of customer product expectations with vehicle design and development process.**
  - **Customer, NVH is defined in terms of how the vehicle "feels" with regards to vibration level at the seat, toe pan, and steering wheel, and how the vehicle "sounds" with regards to the perceived loudness and quality of the interior noise.**
  - **Design Engineers, NVH is defined in terms of "measurable" tactile and acoustic response.**

More about NVH

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Competitiveness | **Company/product image** | **Subjective** | **Negative**

30 % performance complain come from NVH issues
NVH cost 20 % RD budget

Engine NVH

Car Body NVH

Chassis NVH

Aerodynamic NVH
HVAC NVH
Road ride NVH

Why NVH is necessary ?

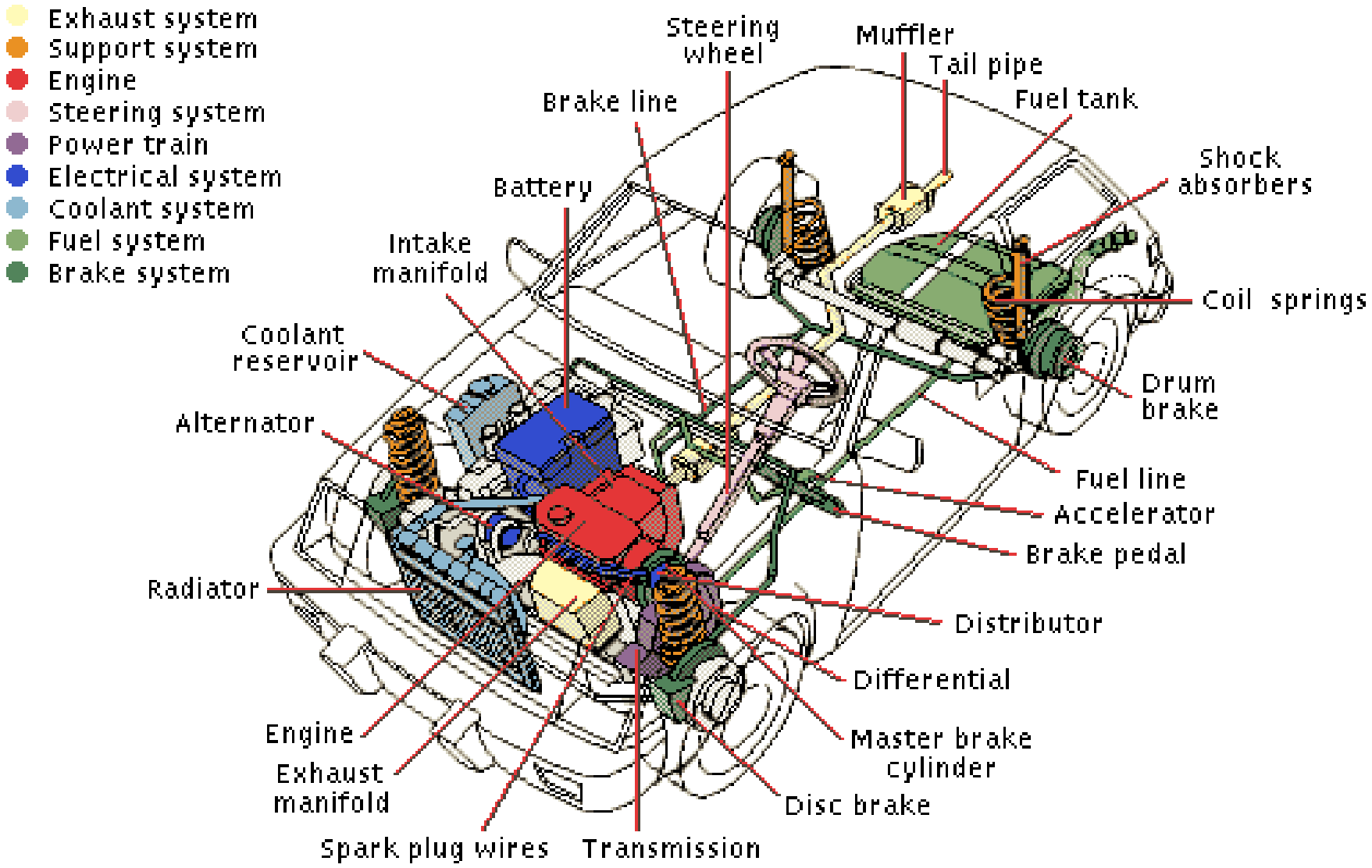
- Noise pollution
- Customer awareness of vehicle ride comfort
- Marketability
- Trend towards higher power and smaller size power trains
- Sound quality
- Design optimization
- Consistency in production
- Occupational hazard

The need to improve product quality and differentiate from the competition, concerns about human health and safety combined with stringent regulations, create a viable market for NVH.

Noise, Vibration and Harshness

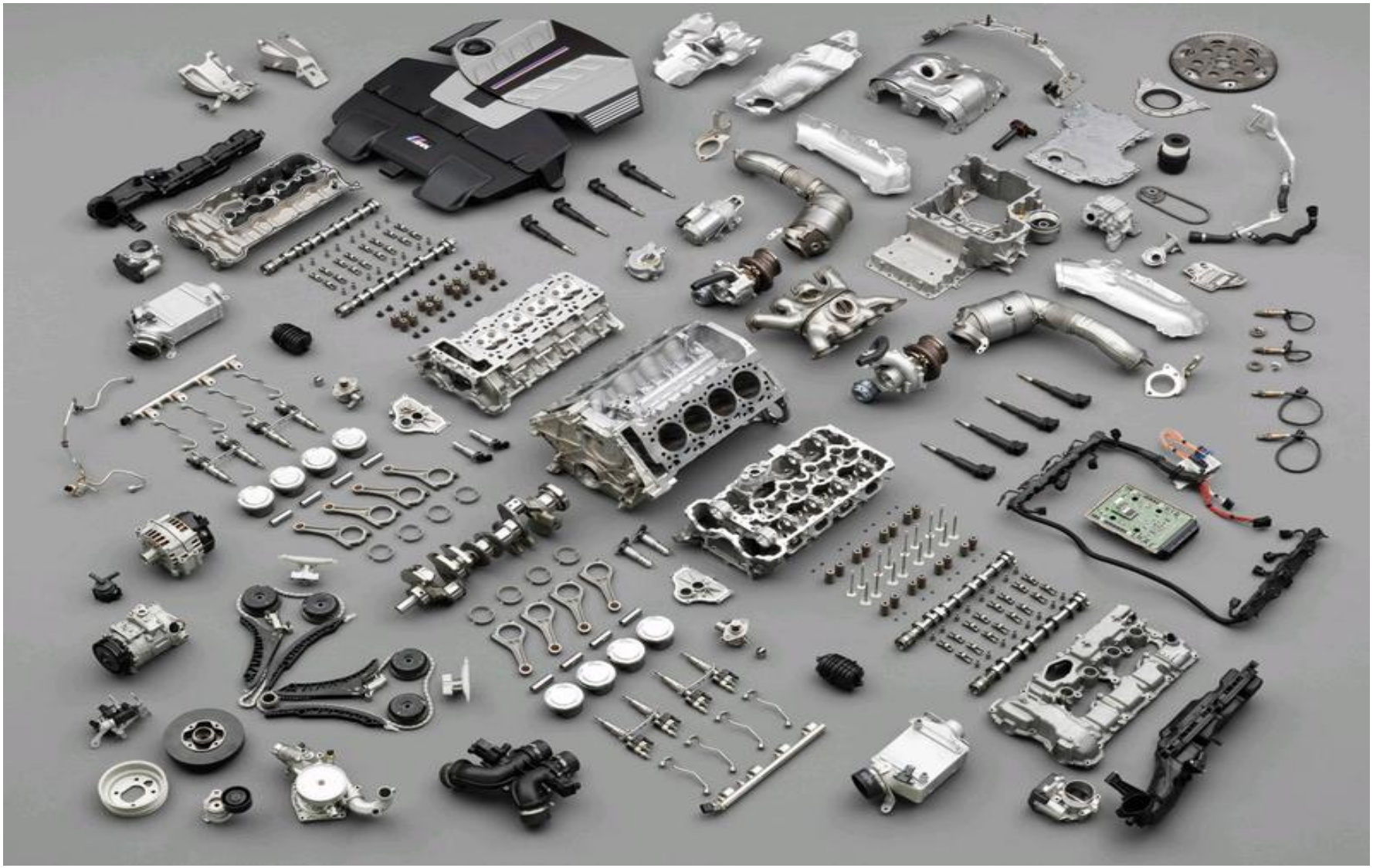
- **Noise**
  - a audible sound generated in vehicle or any other system including engine, driveline, tire contact patch and road surface, brakes, clutches, gearbox, cooling fan etc.
- **Vibration**
  - They are very low frequency energy propagations through a medium, produced in the driveline and the medium of vibration can be any part of a vehicle.
- **Harshness**
  - Harshness is a combination of Noise and Vibration which creates an uncomfortable feeling in occupants of that vehicle.
  - They just can be felt and can be JURY evaluated.

Automotive Systems



Automotive Parts

Engine Parts



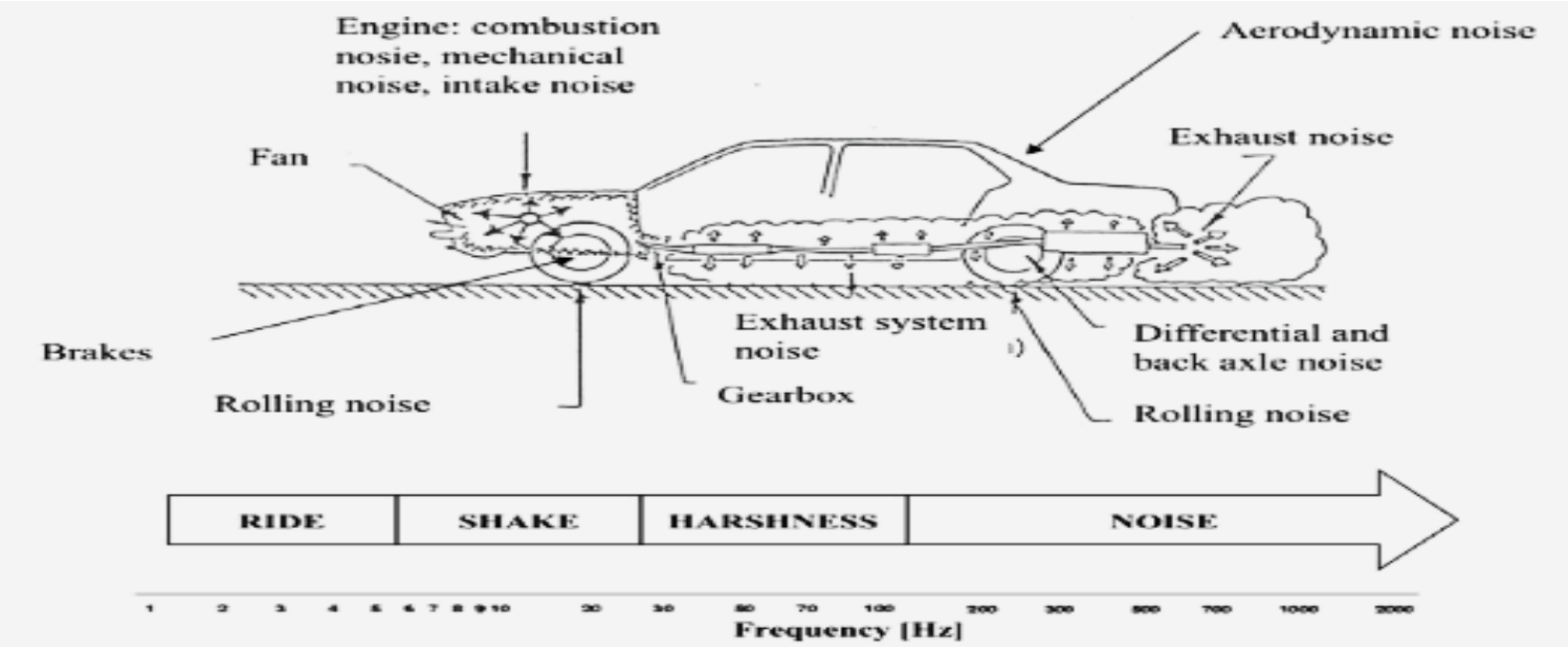
NVH Classification

- **Noise type**
  - Road NVH, Wind Noise, Powertrain/Driveline NVH, Squeak / Rattle
- **Vehicle Systems**
  - Body NVH, Chassis NVH
- **Vehicle Components**
  - Climate control system, wipers, Seat motors, Switches

Typical NVH issues and frequencies

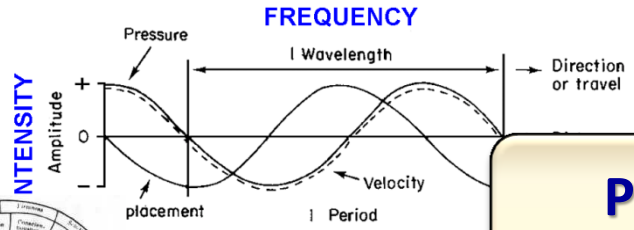
NVH Characteristic	Frequency Range (Hz)
Ride	<5
Shake	5 – 25
Harshness, Boom	25 – 100
Moan	100 – 150
Noise	150 – 300

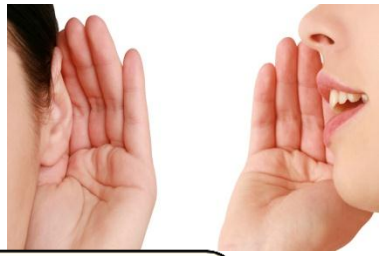
Noise and Vibration Source

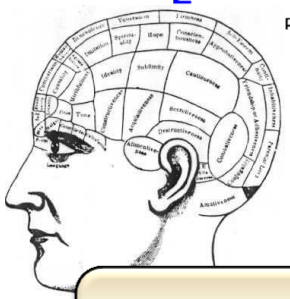


Noise contributions from various systems		
	Fan and Radiator assembly	10%
	Driveline	14%
	Engine	21 %
	Intake System	14%
	Exhaust System	32%
	Structural Components	10%
	Miscelleneous	3%

SOUND ENGINEERING







Physics

Acoustics

Communication Engineering

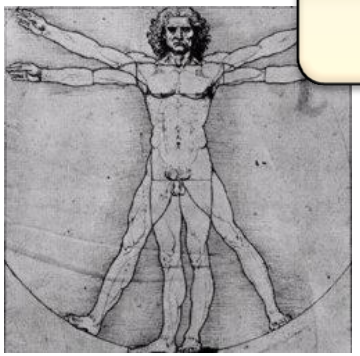
Psychology

Sound Engineer

Mechanical Engineering

Physiology

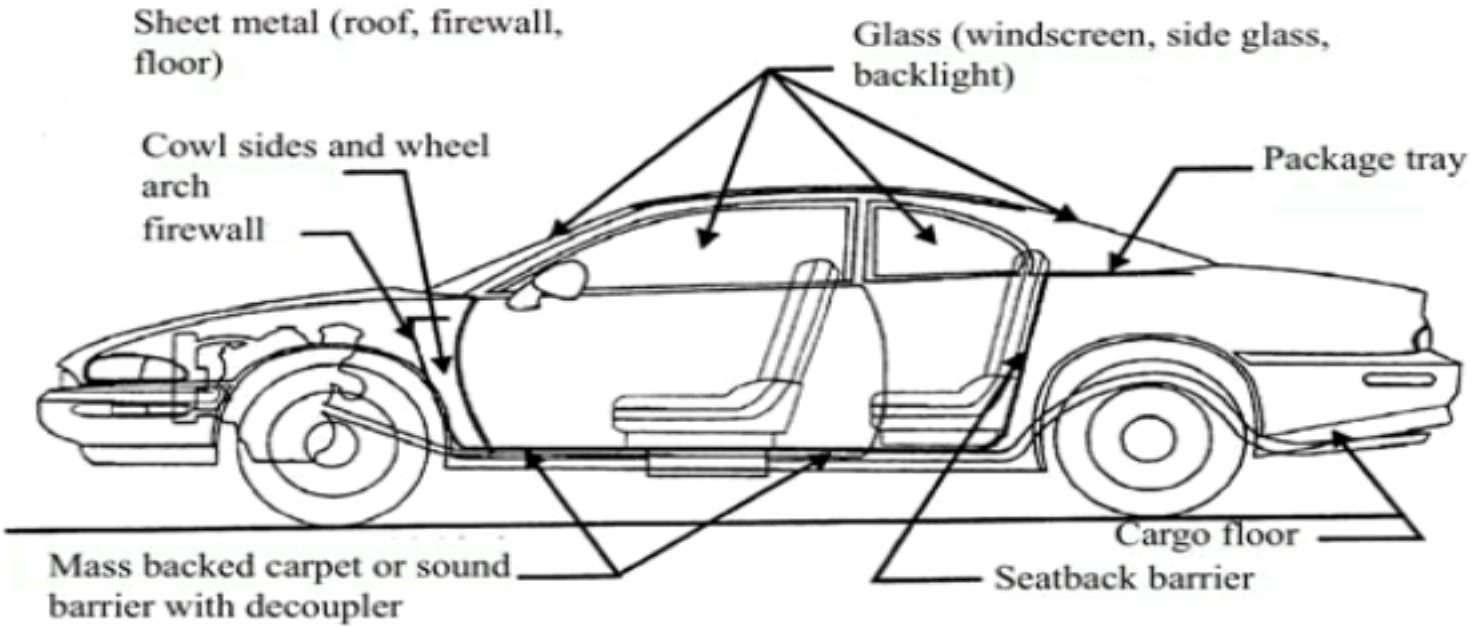
Musicology



Marketing

Noise

- Reducing the source strength, as in making a noise source quieter with a muffler, or improving the balance of a rotating mechanism;
- Interrupting the noise or vibration path, with barriers
- Absorption of the noise or vibration energy, as for example with foam noise absorbers.



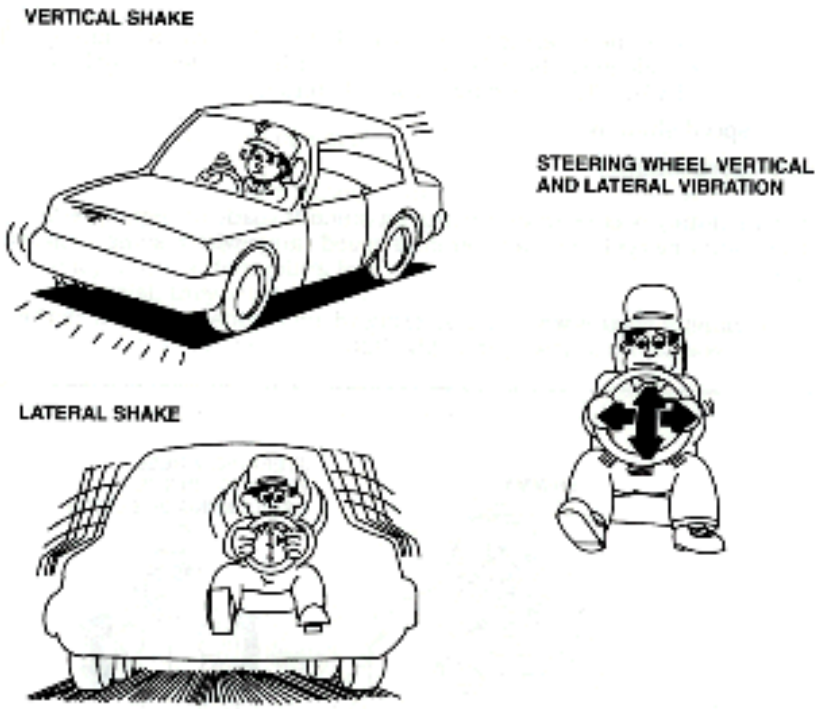
Vibrations

- Vibration refers to mechanical oscillations about an equilibrium point.
- The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road.
  - Type of Vibration
    - Free Vibration
    - Forced Vibration
  - Vibration Characteristics
    - Ride Comfort
    - Shake
    - Shimmy
    - Brake Shudder

Shake

- Vibrations felt in the steering wheel, seat or floor
- Two types of shake are:
  - Vertical
  - Lateral
  - Generally has a frequency between 10 to 30 Hz.

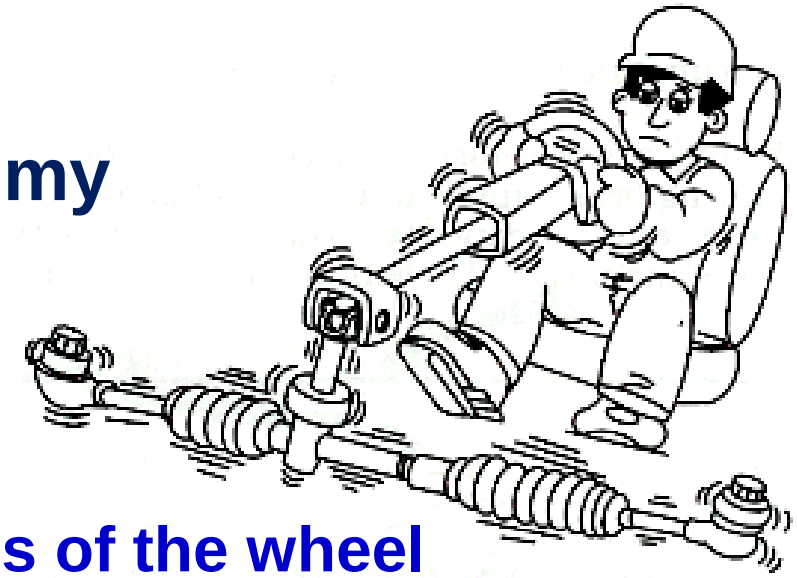
- Possible Caused of a Shake
  - Roughness of the road
  - Tire imbalance
  - No-uniform tires
  - Bent or out of roundness of wheels
  - Driveline
  - Engine



Shimmy

- Vibration that causes the steering wheel to oscillate.
- Typically has a frequency between 5 and 15 Hz
- The two main types of shimmy are:
  - Low speed shimmy
  - High speed shimmy

- Main Causes of a Shimmy
  - Roughness of road
  - Tire Imbalance
  - Non-uniform tires
  - Bent or out of roundness of the wheel

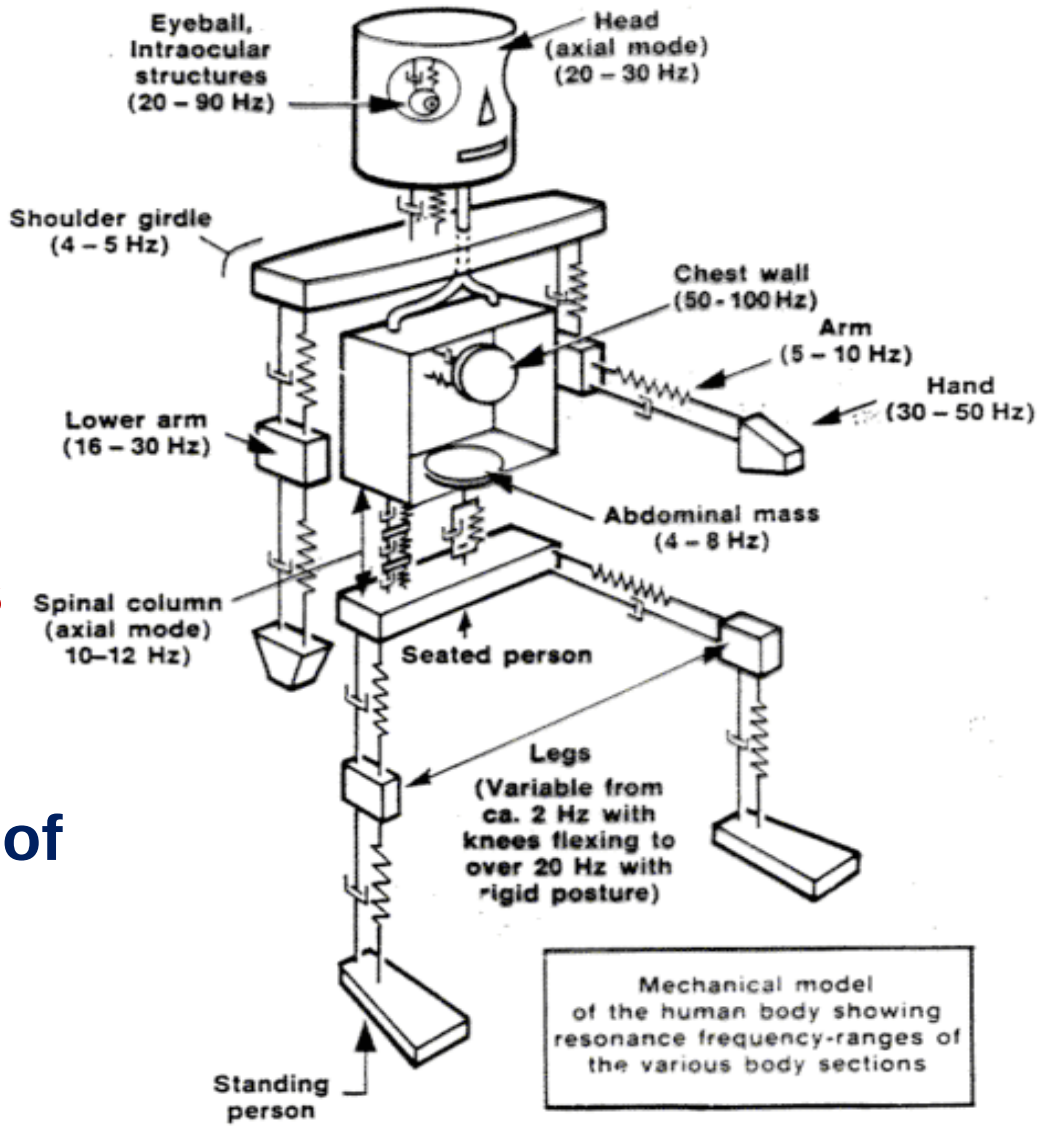


Brake Shudder

- Causes the instrument panel, steeling wheel, and sometimes the entire body to vibration vertically back and forth.
- Peaks at 50 to 80 kph and has frequency of 5 to 30 Hz
- The major sources of shudder are:
  - Brake rotor run out
  - Non uniform thickness
- Certain operating conditions can greatly affect these vibrations:
  - Extended periods where the vehicles is not in operation.
  - Brake disc surface irregularities caused by foreign substances (saltwater, antifreeze, etc)
  - Deformation of brake drum cause by poor installation.

Harshness

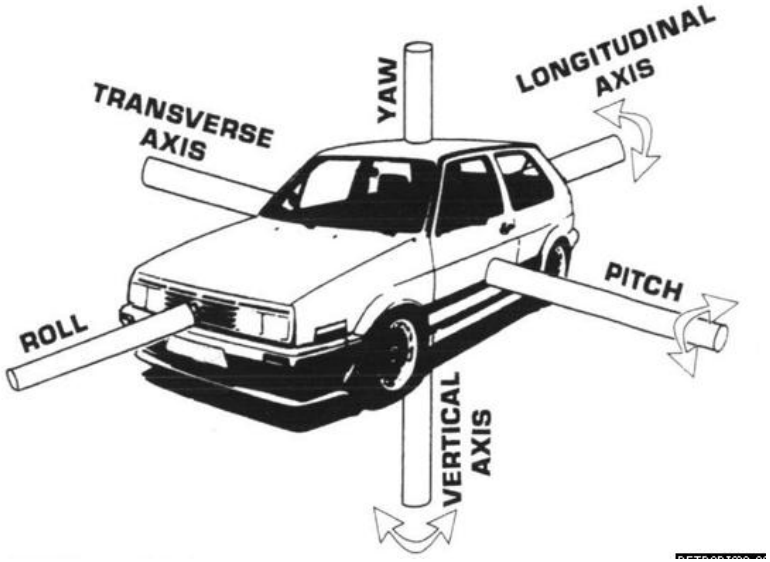
- Many customer use the word “harshness” to describe ride comfort concerns.
- Occurs when a vehicle vibrates when moving across road joints, projections, depressions or stepped paved road surfaces.
- Typically has a vibration of 30 to 60 Hz.



Ride Comfort

When unsprung components start to resonate with sprung components.

- Pitching
- Rolling
- Bouncing



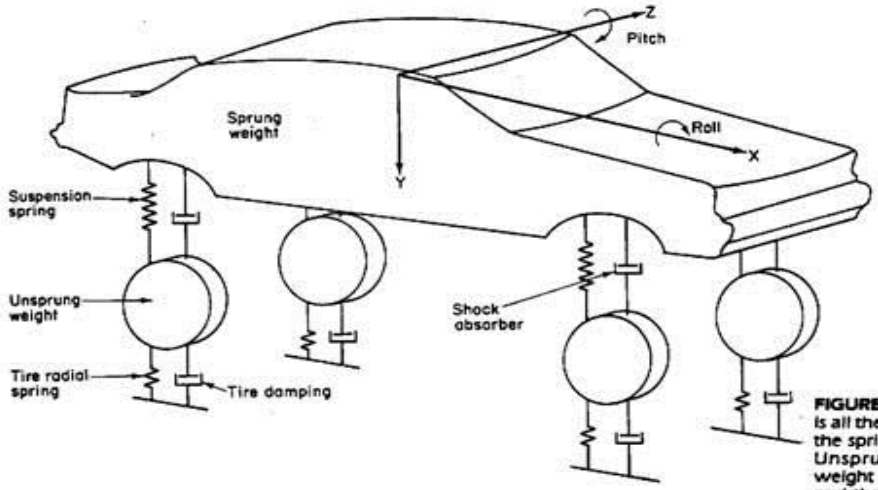
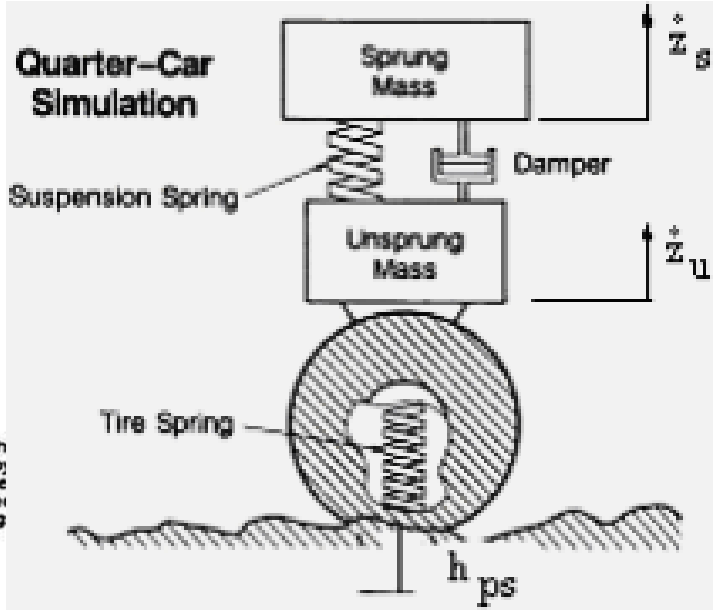


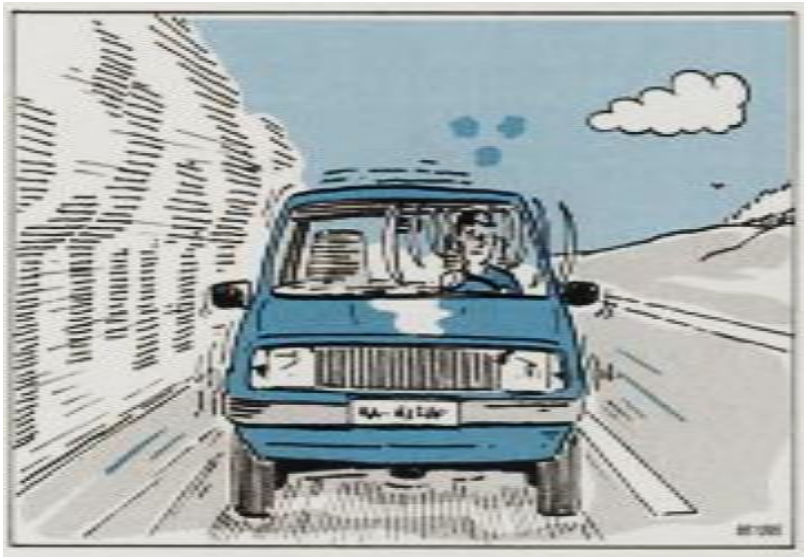
FIGURE Sprung weigh is all the weight supported by the springs and road surface Unsprung weight is the weight between the spring and the road surface.

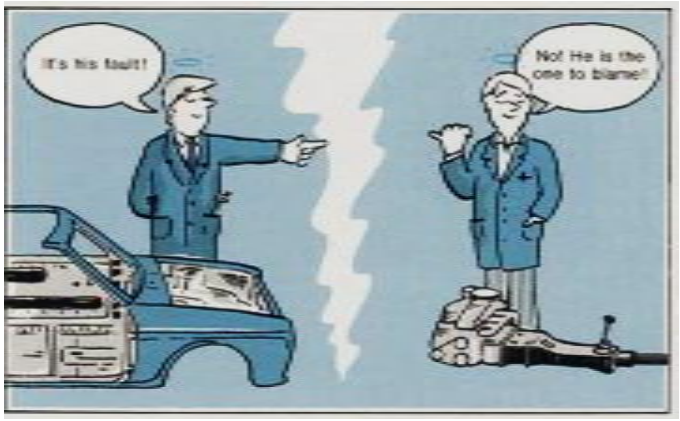


Vehicle Ride Comfort

- Ride comfort in a vehicle is a subjective perception normally associated with level of comfort experience during traveling in a vehicle.
- Perceived ride is cumulative effect of many factors.
- In the vibration spectrum,
  - Ride 0- 25 Hz
  - Noise 25 Hz – 20 kHz
- Ride is a tactile and visual vibrations.

NVH Strategy for Engineer





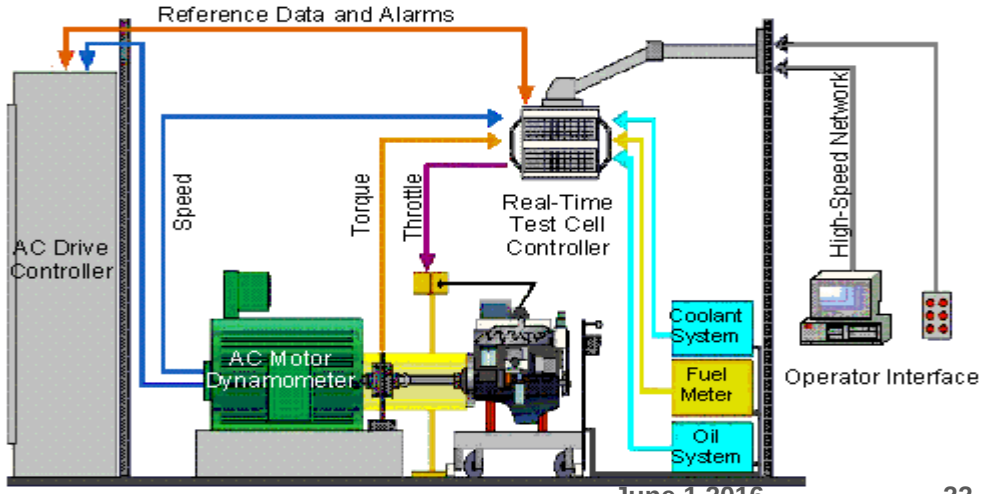
Source	Engine, Power train, Drive train, Tire-road interaction, aerodynamic
Path	Drive Train, Car Body, Engine mounts, Chassis, Suspension
Radiation media	Windshield, Toe-pedal, Steering wheel, Seat, Floor, Interior Noise
Perception	Environmental regulation, Quality assessment, Custom complain

Root Cause Analysis

Contribution Analysis

Instruments Needed

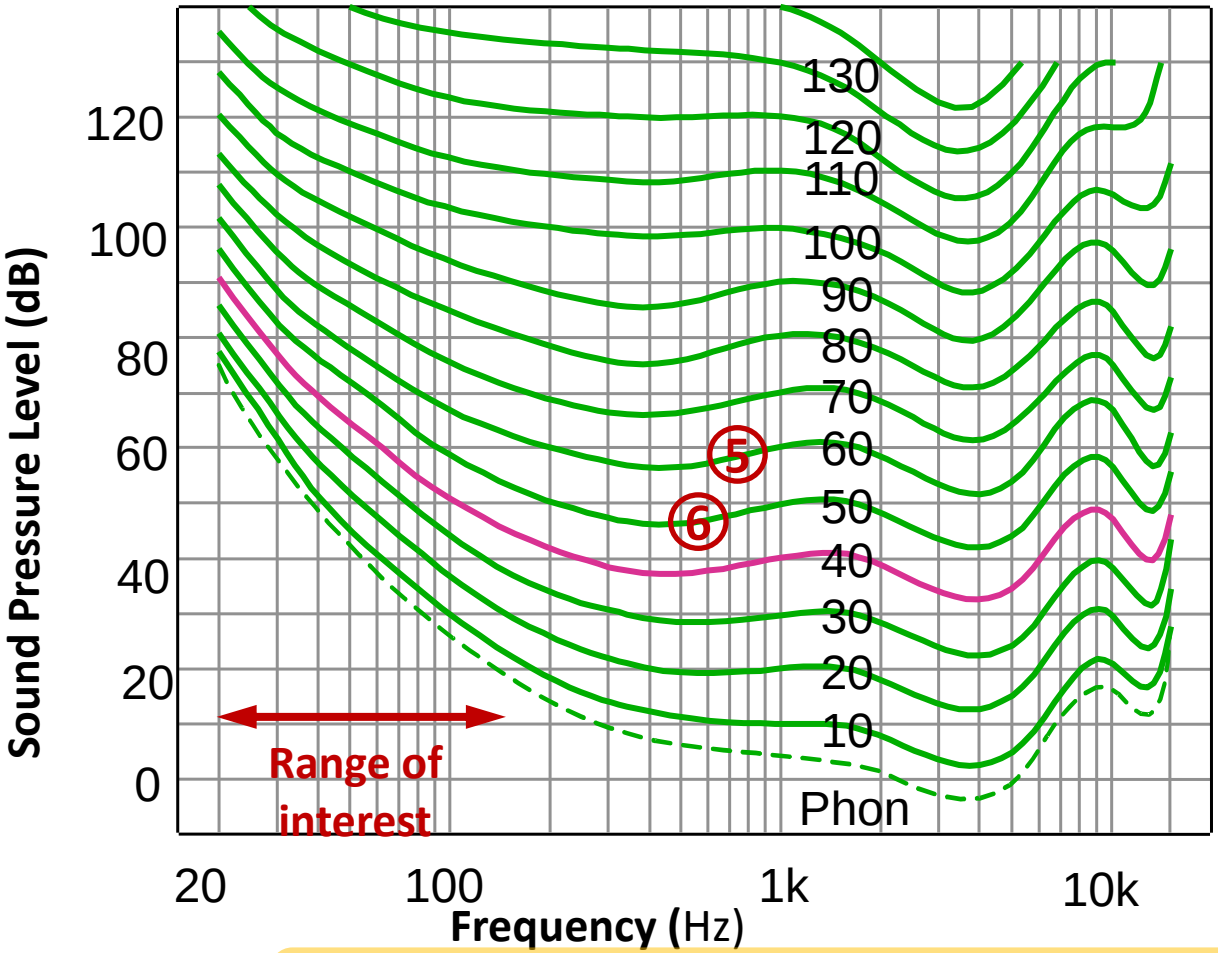
- **Sensors**
  - Microphone
  - Accelerometers
  - Motion, position
  - …..
- **Data Acquisition Devices**
  - Analog-to-digital converter (ADCs)
  - Anti-aliasing filters
  - Signal conditioning
  - …..



SAE 10-point rating system

1	2	3	4	5	6	7	8	9	10
Unacceptable				Borderline	Acceptable				
Condition Noted By									
All Observes		Most Observers		Some Observers	Critical Observers		Trained Observers		Not Observed
1	2	3	4	5	6	7	8	9	10

Human Sensitivity to pure tones



- a listener perceives a constant loudness when presented with pure steady tones
- Nonlinear effect on the human ear to hearing perception

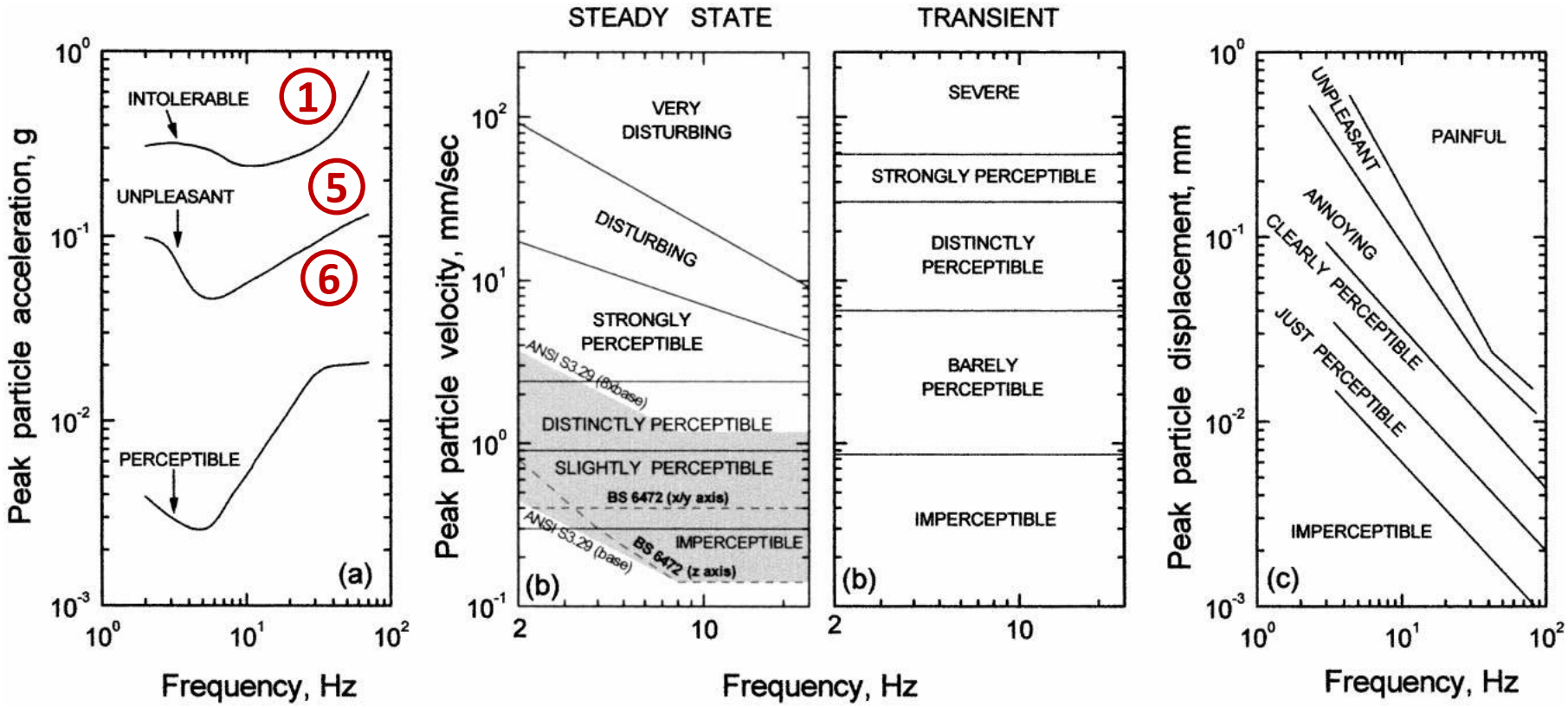
Tactile rating equation

SR = (-0.175) * SPL +13.6

SR is the subjective rating, and

SPL is the A-weighted sound pressure level in dB

Threshold vibration criteria for Various degrees of human discomfort



(a) Acceleration (b)Velocity (c) displacement

Tactile rating equation

SR = 8.19 – 4.34 * log (V)

SR is the subjective rating, and

V is the tactile velocity level in mm/s

The difficulties on Vehicle NVH design

No sound system, no sound product, no acoustic environment can be design by a calculator. Nor a computer, nor a cardboard slide rule, nor a Ouija board. There are no step-by-step instructions a technician can follow: that's like Isaac Newton going to the library and asking for a book on gravity. Design work can only be done by designers, each with his own hierarchy of priorities and criteria. ***His three most important tools are knowledge, experience, and good judgment.***

~ Ted Uzzle ~

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