Ground Vehicle (GV) Fundamentals
- Not Vehicle Design anymore
- Old course was more like “GV Design Methodology”
- Now kind of like “GV Mechanisms (with a few extras)”

GV Functions
- Traverse the ground
- Transport
  - People
  - Equipment
  - Cargo
- Operations in transit/at destination
  - Comfort
  - Communications
  - Industrial functions
  - Medical functions
  - Military functions

GV Values
- Available
- Safe
- Timely
- Convenient
- Exciting (internal self-expression)
- Attractive (external self-expression)

GV Functions covered in 4430
- Traverse the ground
  - Accelerate
  - Decelerate
  - Turn
  - Follow terrain
- Transport/support
  - Crew
  - Passengers
  - Payload
  - Mechanisms
GV Functions not covered in 4430

- Mechanism control
- Communications
  - Internal
  - External
- Electromagnetic compatibility
- Comfort
  - Hotel functions
  - Thermal comfort
  - NVH
- Acoustics
- Poisonous emissions
- Style
- Lighting
- Manufacturing

Types of GV covered by 4430 (i.e., wheeled, steered, vehicles)

- Open road vehicles
- Closed road vehicles
- Off road vehicles
- Roll stabilized vehicles (i.e., two wheels)
- Track stabilized vehicles (i.e., three or more wheels, not in a line)

Types of GV not covered by 4430

- Wheeled, non-steered vehicles
  - Rail
  - Industrial carriages
- Non-wheeled, steered vehicles
  - Air cushion vehicles
  - Tracked vehicles
    - Military
    - Earth-moving
  - Walking machines
- Non-wheeled, non-steered vehicles
  - Maglev

Your basic, typical, run-of-the-mill 4430 subject vehicle

- Four wheels (box pattern)
• Front wheels steered
• Pneumatic tires

Basic vehicle physical decomposition

• Acceleration system
  o Propulsive force generation (tires/tyres)
  o Torque distribution
    ▪ Transfer (driveline)
    ▪ Proportioning (differentiation)
  o Torque/speed transduction (transmission)
  o Power/torque generation (stored to kinetic energy transduction – combustion, electro-motive force)
    ▪ Architecture
      • Combustion
      • Electric
      • Hybrid
        ▪ Stored energy delivery (fueling, air path, power management)
        ▪ Waste heat rejection (cooling)
        ▪ Waste product rejection (exhaust)
        ▪ Noise attenuation (silencing/muffling)
        ▪ Friction management (lubrication circulation, filtering, cooling)
        ▪ Control/command interface (set point, engine control, power management)
  o Energy storage/delivery (fuel, charge)

• Deceleration system
  o Retarding force generation (tyres/tires)
  o Foundation brakes (disk, drum)
  o Braking power generation (hydraulics, anti-lock braking system)

• Turning system
  o Lateral force generation (tires/tyres)
  o Steering force transmission (tie rods, steering arms)
  o Control input transduction (steering rack, steering drive)

• Terrain-following system
  o Motion control
    ▪ Control arms (A-arms, trailing arms)
    ▪ Compliance (bushings)
  o Motion attenuation
    ▪ Spring (springs, torsion bars, leaf springs, flexible control arms)
    ▪ Damping (shock absorption)

• Structural system
  o Operating load transmission
- Drivetrain
  - Suspension
    - Hazard load transmission
      - Impact
      - Deformation
    - Support
      - Crew functions (biomechanics)
      - Payload (biometrics)
- Aerodynamic effects
  - On acceleration (drag)
  - On turning (downforce)
  - On heat rejection (internal cooling circuits)

Outline of the ideal 4430
- Tires
  - Tire patch, shape, pressure distribution
  - Construction
  - Designation
  - Stiffness
    - Vertical
    - Lateral
    - Yaw
  - Rolling resistance
  - Magic formula
  - Noise
  - Compliant road
  - Case studies
- Brakes
  - Friction pairs
  - Mechanisms
  - Member forces
  - Heating
  - Power
  - Hydraulic systems
- Wheelset architecture
  - Bearings
  - Motions
  - Forces
  - Compliance
  - Mechanisms
- **Suspension**
  - Springs
  - Dampers
  - Compliance and joints
  - Motion arcs
  - Member forces
  - Corner properties
  - Roll center
  - Roll bars
  - Pitch center

- **Steering**
  - Mechanisms
  - Steer angles
  - Ackermann
  - Steering forces
  - Suspension following
  - Member forces
  - Feedback
  - Compliance

- **Driveline**
  - Flexible joints
  - Motions
  - Member forces
  - Differentials
  - Efficiency

- **Powertrain**
  - Energy storage and delivery
    - Liquid fuel systems
      - Pumps
      - Tanks
      - Slosh
      - Circuits
    - Batteries
  - Torque generation
    - Combustion
    - Electric
    - Hybrid
    - Braking regeneration
  - Clutching
  - Speed transmission
- Heat rejection
  - Not: electromagnetics, lubrication, exhaust, air path
- Structure
  - Loads
  - Cases
  - Types
  - Analysis
  - Crash
  - Deformation
  - Regulation
- Ergonomics
  - Biometrics
  - Biomechanics
- Aerodynamics
  - Form
  - Friction
  - Parasitic
  - Wheels
  - Force/moment
    - Drag
    - Yaw/sway
    - Downforce
  - Internal flows (cooling)
    - Ducts
    - Fans
    - Circuits
- Mass properties
  - Bill of materials & decomposition
  - Frames of reference & measurement
  - Subsystem multipliers & uncertainty
  - Mass
  - Center of mass vector
  - Moment of inertia tensor

Links between 4430 and 4420
- 4430 provides the GV characteristics
- 4420 turns the characteristics into performance
- Example: roll stiffness and mass properties from 4430, rollover dynamics from 4420
- Example: pitch center from 4430, pitch oscillation on a washboard road from 4420
- Example: tire patch orientation from 4430, resulting yawing (turning) motion from 4420
• Example: driveline torque and tire friction from 4430, resulting acceleration trace from 4420

More 4430 outline – things not covered in 4420
• Energy usage
  o Power matching
  o Driving profile
  o Well-to-wheels analysis