EMERGENCY VEHICLE OPERATOR

CLASS "B"

Module 3

Physical Forces

Skid Avoidance & Management

Rollover Prevention

Revised 5/10/21

OBJECTIVES

- To identify common conditions that lead to loss of vehicle control.
- To identify common driver errors that lead to loss of vehicle control.
- Discuss vehicle features and systems to assist with vehicle control.
- Differentiate between passenger vehicles and emergency vehicles
- Familiarization with actions to take to maintain or regain control

Motivation

Why is this necessary?

- ✓Service does not stop in bad weather
- ✓Emergency vehicle dynamics are different than a passenger vehicle
- ✓High speed – slow motion

Skid Avoidance

The ability to maintain control of the vehicle utilizing….
defensive driving skills and vehicle controls while…..
accounting for existing road and traffic conditions.

Class B vs. Passenger Vehicles

- Heavy Apparatus isn't a Passenger Car
  - Weight
  - Center of gravity
  - Steering system
- Heavy Apparatus isn't a Race car
  - Suspension
  - Tires

Energy of Motion

- Kinetic energy is the force that keeps the vehicle moving

Kinetic Energy = ½ (weight of vehicle)(starting speed^2 – final speed^2)

- Kinetic energy doubles as the weight doubles
- Kinetic energy quadruples as speed doubles
- Kinetic energy is dissipated as heat by the brakes during application of breaks

Friction

- Friction – resistance to motion between two moving objects that touch.
- Frictional force opposes the motion of the vehicle
- Frictional force occurs between:
  - the tire and the road surface when wheel rotation is locked by brakes
  - the brake pad/shoe and the rotor or drum
- The ability of a vehicle to stop depends on the coefficient of friction between the contacting surfaces.

Friction

- Maximum useable coefficient of friction occurs between the tire and road surface.
- The amount of energy that can be absorbed by the brakes depends upon
  - the coefficient of friction of the brake materials,
  - brake diameter,
  - brake surface area,
  - shoe geometry, and
  - the pressure used to actuate the brake.
- Stopping a vehicle suddenly means very high friction, resulting in high brake and tire temperature.

Vehicle Balance and Traction

When the vehicle is in motion:

- Sudden steering, braking and/or acceleration change vehicle balance and traction dramatically
- Sudden loss of vehicle balance causes traction loss and traction loss compounds crash results

Traction vs. Vehicle Movement

- Stationary (static) – A stationary vehicle parked on a flat surface with brakes set has greatest resistance to movement. A stationary tire has more traction than a sliding tire.
- Rolling (controlled dynamic) – A rolling tire has more traction than a sliding tire, thus it is important to not lock the brakes when trying to steer or stop a vehicle
- Sliding (uncontrolled dynamic) – A rolling tire can transition into a sliding tire under a variety of circumstances. The circumstances may or may not be predictable or controllable by the driver. A sliding tire offers little ability to change the path or speed of a vehicle.

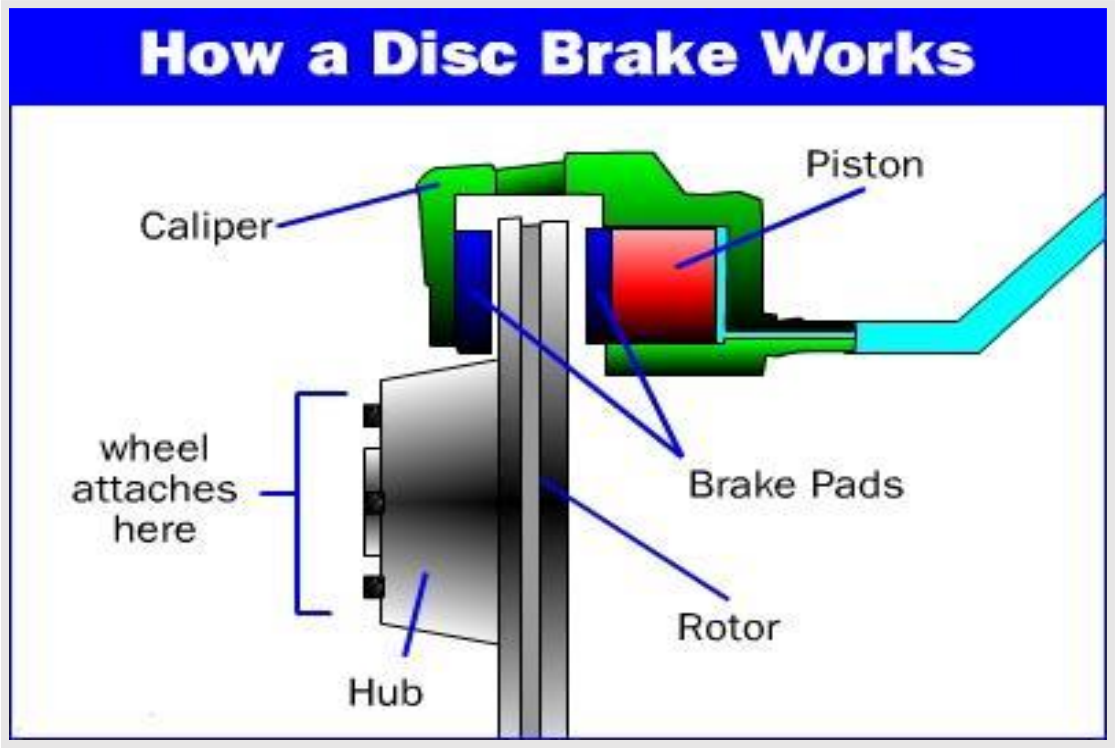
Traction

- Tire condition is critical to maintaining traction
  - Tread depth
  - Inflation
- Only about 10% of the tire's surface is in contact with the road at any time

~40 square inches of area

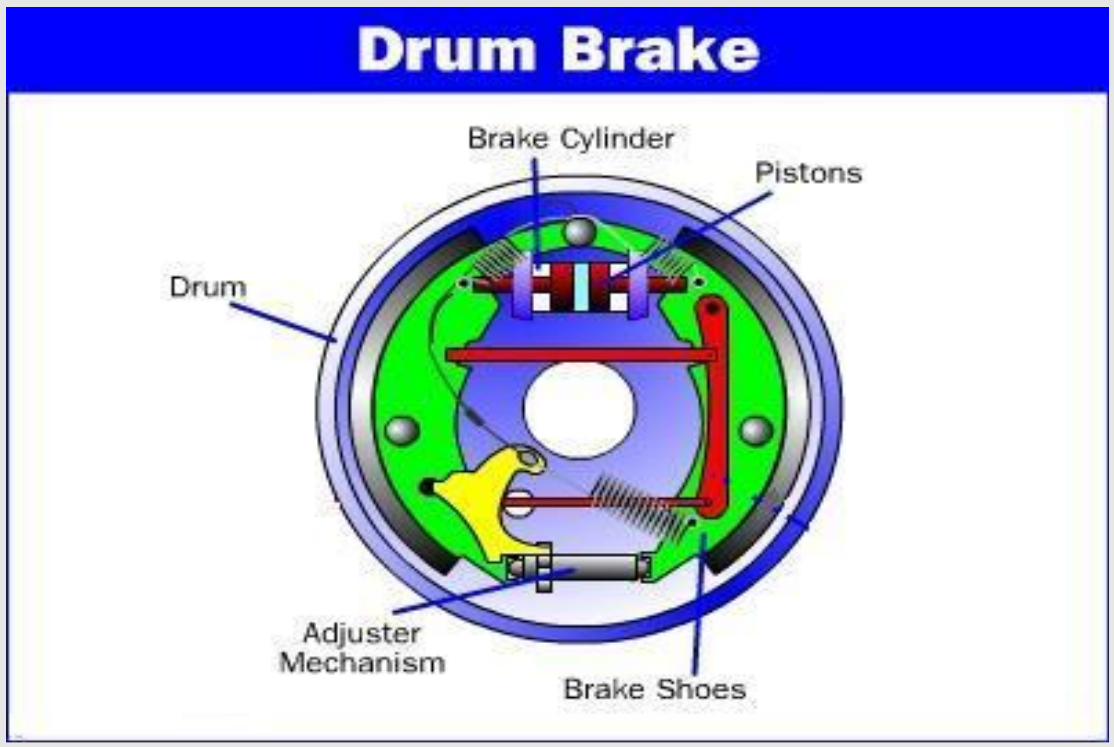
Vehicle Systems
Disc Brakes

- Generally shed debris, water, etc.
- Pads wear evenly
- Self cleaning
- Dissipate heat
- More easily inspected



Vehicle Systems
Drum Brakes

- Problem with debris, water, etc.
- Wears unevenly
- Builds up dirt
- Retain heat



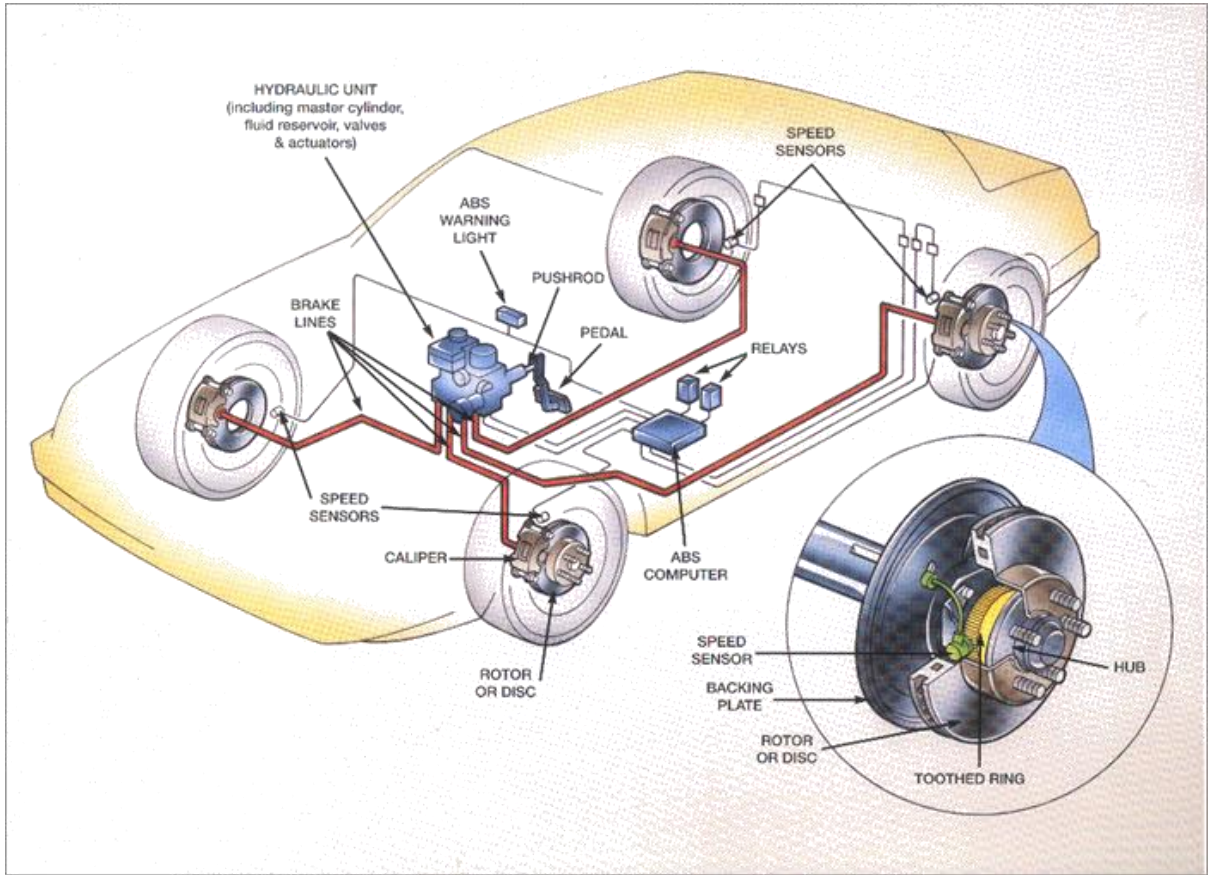
Braking Systems

- Electronic Braking Control Systems brake by wire
- Anti-lock Braking Systems (ABS)
- Secondary or Auxiliary Braking Systems
  - Driveline Retarder
  - Compression or Engine Brake
  - Exhaust Brake
  - Automatic Transmission Retarder

Anti-Lock Brake Systems

- Electric control over hydraulic or air brakes
- Generates micro-pulses in the brake activation
  - Replaces pumping the brake pedal
- Senses wheel rotation speed to identify when lock-up is occurring

ABS Video



Brake Fade

- Most of the heat created goes into the brake drum or disc during braking.
- Under severe use, brake drums may reach 600 degrees F.
- Coefficient of friction within the brake system is much lower at these high temperatures so that additional pedal pressure is required.
  - Repeated severe stops or after holding the brakes on a long down hill grade result is nearly no friction between the shoes/pads and the drum/rotor. This condition is called brake fade.
- Drum and disc expand during braking
  - Drum brakes: diameter of the drum increases with heat. The shoe no longer matches the drum and hence lining-to-drum contact surface becomes smaller, creating less friction area and even more heat.
  - Disc brakes: expansion of disc has little effect on braking because the pads apply braking force on the side of the disc and hence braking surface area remains constant.

Skid Causes

- ☒ The need for speed
- ☒ Improper braking (including auxiliary brakes)
- ☒ Improper acceleration
- ☒ Improper steering
- ☒ Excessive weight transfer
- ☒ Poor roadway conditions

Speed

- Speed directly correlates to the kinetic energy of the vehicle
  - Energy increases *exponentially* as speed increases
- Energy is neither created or destroyed – it just changes forms
- Higher energy has the following effects:
  - Brakes must convert the energy to heat – the more kinetic energy the more heat gets generated
  - Center of gravity shifts are more significant as momentum tries to keep the vehicle moving
  - Better tire adhesion to the road surface is required to work in conjunction with the brakes

What Causes a Braking Skid?

Brake pedal applied

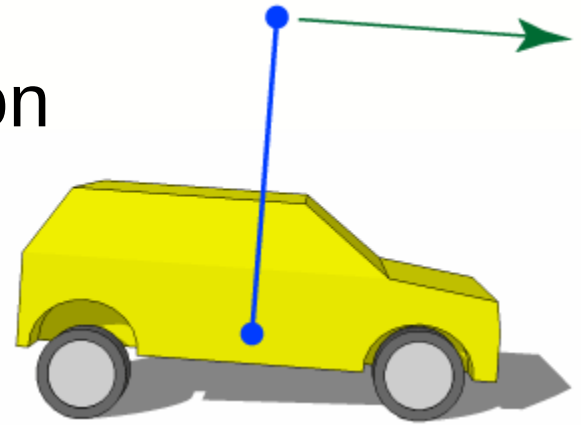
Brake system creates friction to slow the rotation of the wheels

Friction between the tires and the road surface allow the tires to grab as the rotation of the wheel slows

A skid occurs when the friction of the brake system is more than the friction of the wheels grabbing the road surface

Vehicle Balance and Traction
Braking

- When brakes are applied:
  - Weight or center of mass transfers to the front of the vehicle
  - Causes a noticeable drop of the front of the vehicle and a rise in the rear
  - Occupants feel a forward movement
- Results in the front wheels needing more traction and the front brakes working harder than the rear



Brake Balance

- The braking of a vehicle occurs at ground level
- Vehicle weight and kinetic energy of the vehicle act through center of gravity, which are above ground level
- This causes the vehicle to pitch forward as the brakes are applied.
  - some of the vehicle weight is effectively transferred from the rear wheels to the front wheels. Consequently, the front brakes must absorb more kinetic energy than the rear brakes.
- By design, the front brakes lock up slightly ahead of the rear brakes. The intent is for the vehicle to slide straight ahead and to not spin out.

Effective Braking

- Braking and Stopping
  - Hydraulic – Pump brake pedal
  - Air – Firmly and steadily press brake pedal, release if wheels lock
    - “threshold” braking
  - Anti-Lock Braking System (ABS) – Apply firmly and hold down for duration
  - Disc vs. Drum - Differences
- Auxiliary Braking Systems
  - Adjust use of retarders/engine brakes during inclement weather or when the road surfaces are slippery.
    - Manufacturer recommendations vary.
  - Using these systems with poor traction could result in loss of control of the vehicle.

Acceleration Skid

Accelerator pedal applied

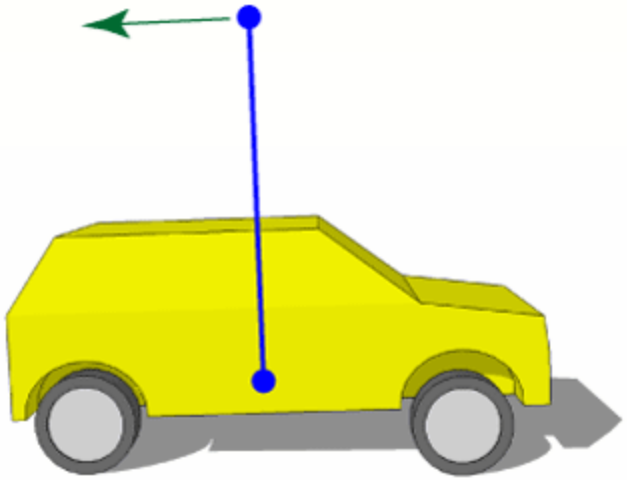
Power train applies torque to rotate the wheels faster

Friction between the tires and the road surface allow the tires to grab as the rotation of the wheel increases

Acceleration skid occurs when the torque applied to the wheels is more than the friction of the wheels grabbing the road surface

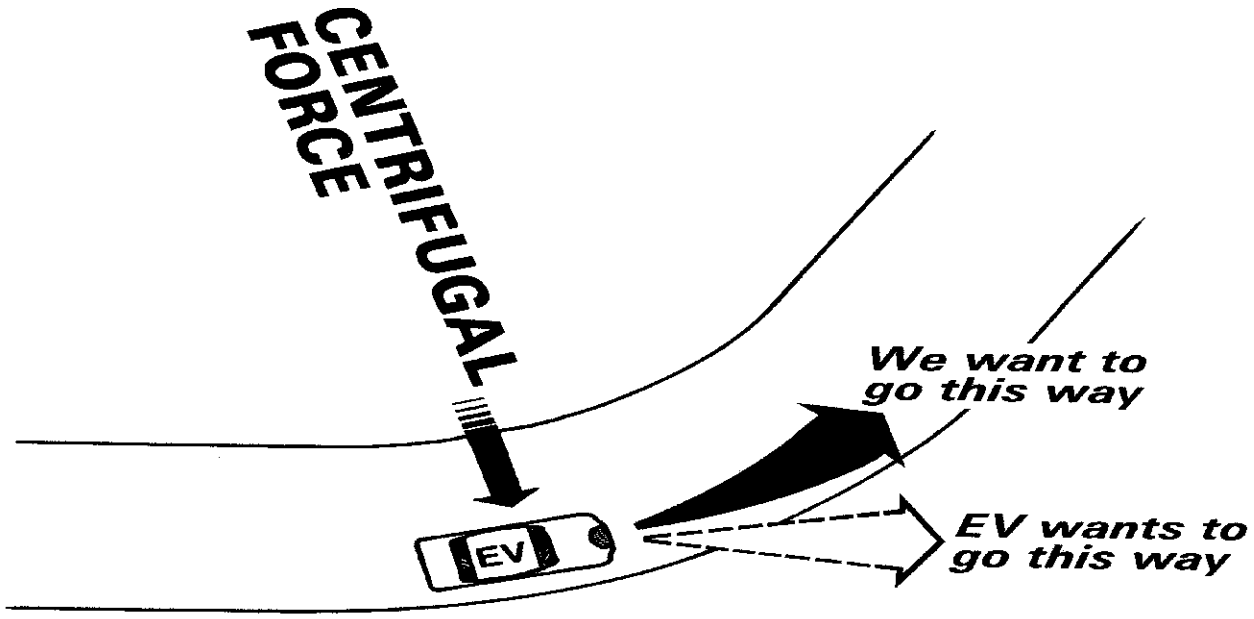
Acceleration Skid
Vehicle Balance and Traction

- When acceleration is applied:
  - Weight or center of mass transfers to the rear of the vehicle
  - Causes a noticeable rise to the front of the vehicle and a drop in the rear of the vehicle
  - Occupants feel a rearward movement
- Results in the rear wheels getting more traction
- Results in front wheels having less traction for steering



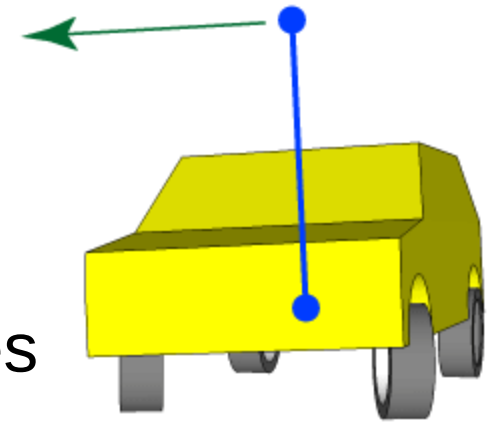
Steering Skid

- An object moving in a straight line wants to remain in a straight line
- Factors contributing to a steering skid:
  - Speed
  - Weight and weight transfer
  - Surface traction
  - Tire height, condition, inflation
  - Radius of the turn



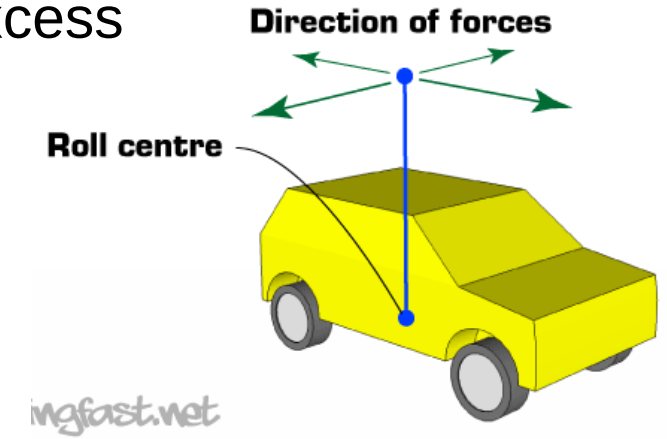
Steering Skid
Vehicle Balance and Traction

- When steering is applied:
  - Weight or center of mass transfers to the front right or left of the vehicle
  - Causes a noticeable drop and tilt of the front of the vehicle and a rise and tilt of the rear of the vehicle
  - Occupants feel a movement forward to the corner of the vehicle
- Places the vehicle in an imbalanced position with one tire having more of the load
- Braking while steering further shifts the center of mass
- Best to gain and lose speed in a straight line where the tires share the load!



Excessive Weight Transfer

- Transfer occurs every time the vehicle accelerates, slows, or changes direction
- Amount of transfer is dependent upon weight, height of the center of gravity, and the rate of acceleration/deceleration
  - Which factor do you control?
- Effects of weight transfer
  - Too little weight and the rubber doesn't stick to the road
  - Too much weight causes it to stick too hard and creates excess heat
  - Damage to suspension
- Slope or grade of road surface
- Water tanks



Excessive Weight Transfer
Water Influence

- Liquid movement creates force forward, rearward, and sideways
- Baffles dampen the effect forward and aft
- Actively changing center of gravity
- Tankers
  - Easy to roll over
  - Can turn over at posted speed limits
  - On & off ramps should be driven slower

3,000 gallons of H_2O = 24,000lbs of H_2O

Excessive Weight Transfer
Aerial Ladders

Aerial devices create a high center of gravity

Surface Conditions

- Friction must exist between the tire and the road for braking and steering to occur
- Anything that interferes with the contact area between the tire and the road surface can cause skidding
  - Rain – hydroplaning
  - Snow/Ice
  - Gravel, Sand, Dirt
  - Leaves
  - Rough surface
  - Road slope/grade

Specific Conditions

- "One tire in mud, other on roadway"
  - All power to wheel of least resistance
- Shocks/springs cause vehicle to ride level even if banked roadway
- If tire cannot get traction to go forward, it will go sideways
- Access ramps
  - Roadway radius stays constant or tightens
  - Do not attempt to accelerate through a curve
    - Gain and lose speed in straight lines
  - Cannot go in fast and come out faster

Surface Conditions

Shaded areas – Shady parts of the road will remain icy or wet long after open areas

Bridges – When the temperature drops, bridges will freeze before the road will. Be especially careful when the temperature is close to 32 degrees Fahrenheit

Melting Ice – Slight melting will make ice wet. Wet ice is much more slippery than ice that is not wet.

Black Ice – Black ice is a thin layer that is clear enough that you can see the road underneath it. It makes the road look wet.

Black Ice Video

Surface Conditions

Just After Rain Begins – Right after it starts to rain, the water mixes with oil left on the road by vehicles. This makes the road slippery. If the rain continues, it will wash the oil away.

Raining/Wet – Water collected on the road may cause tires to lose their contact with the road and have little or not traction and your vehicle may hydroplane.

Leaves & Debris – Following a storm or during the Fall leaves or other debris collect on the road. Leaves can be as slippery as ice.

Surface Conditions

Excessive Heat – Heat can soften the road surface or even cause buckling. The surface aggregate can peel away as a tire tries to grip.

Dirt/Gravel/Sand – Any loose material between the tire and a hard surface reduces traction. Frequently these conditions are combined with uneven surfaces.

Pitted or Potholed – vehicle suspension and tires may not adjust to the unequal surfaces and allow traction to be lost as the vehicle “bounces”.

Driving Errors

Vehicle begins to slide, driver panics

- ☒Locks the Brakes
- ☒Loses steering control

Driver responds by:

- ☒Correcting steering too late
- ☒Under correcting
- ☒Using improper throttle control
- ☒Combination of all above

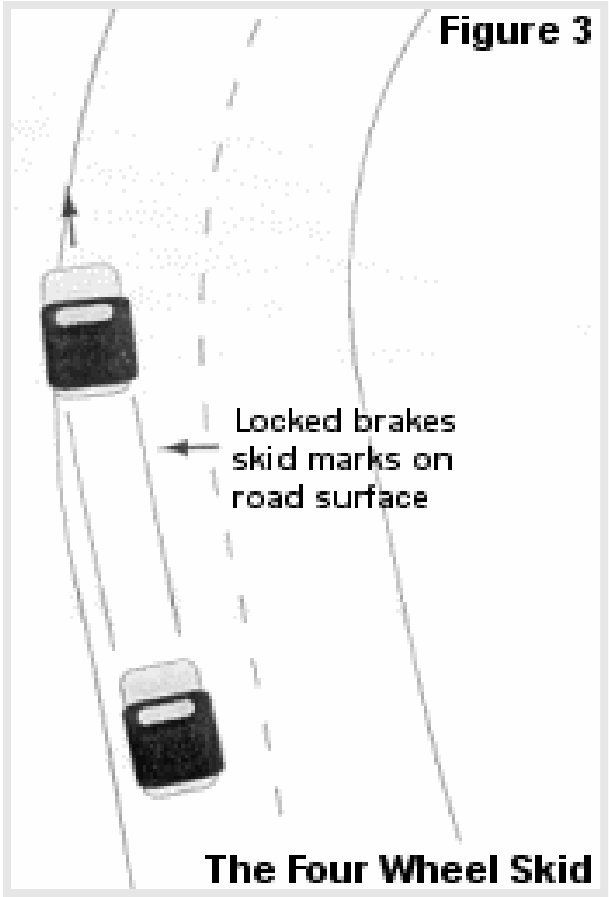
Six Deadly Skids

- All-wheel braking skid
- Front wheel braking skid
- Rear wheel braking skid
- Power skid
- Hydroplaning

Front and Rear Wheel Skid Video

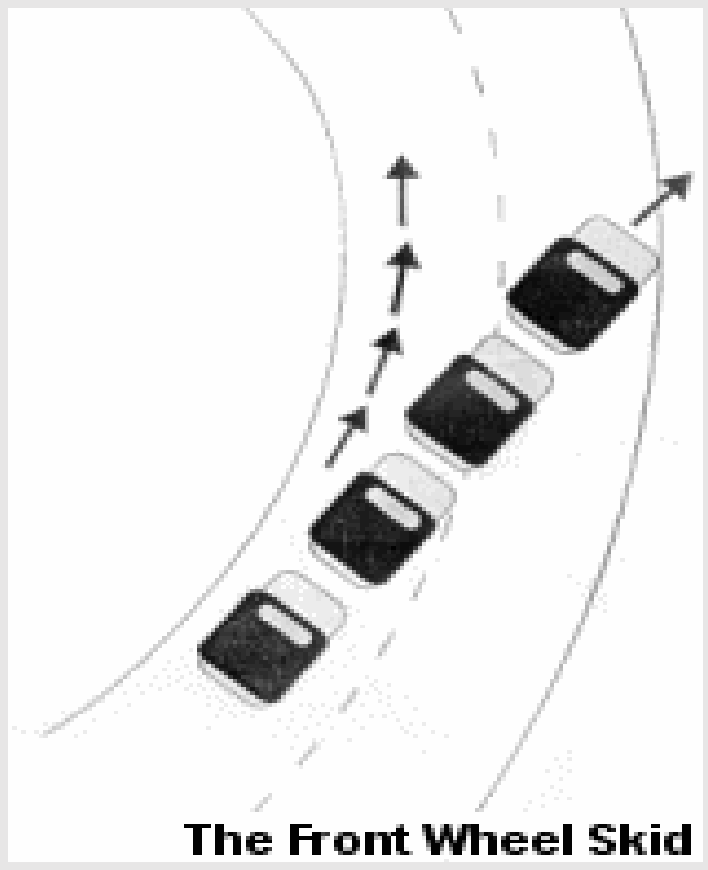
Skids
All-Wheel

- Often start as front or rear skids and turn into all-wheel
- No steering control
- Vehicle will travel in straight line until other forces or friction act upon it
  - If the car was going straight it will continue straight
  - If the car was going around a curve, the car will slide sideways in the path it had at the moment when traction was lost
- Front locks first
- Regain Control
  - Must release brakes so wheels begin to roll again
  - Rolling friction vs. sliding friction



Skids
Front Wheels

- Excess speed upon entry into a curve or while avoiding a hazard, or
- Braking sharply while turning to avoid a hazard
- Vehicle does not respond to steering
- Vehicle tracks in line with the rear wheels until the front wheels regain traction

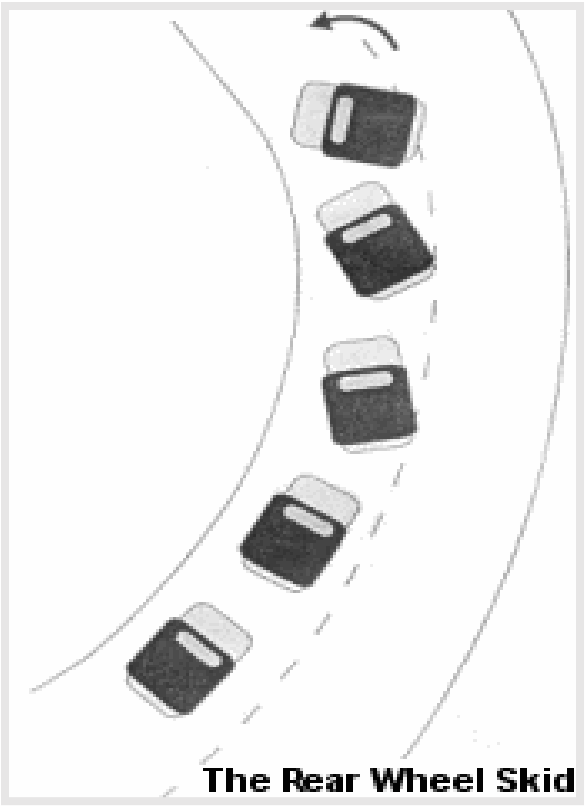

The Front Wheel Skid

Skids
Front Wheels

- Behavior/Performance
  - At 27mph front lock – rear rotates, one more time
  - At 65 mph front lock – rear rotates nine more times
  - Cause of vehicle turning sideways
  - Car should slide straight ahead
- Regaining Control
  - Decelerate to recover steering control of vehicle
  - Keep steering inputs to a minimum until tires regain traction

Skids
Rear Wheels

- Improper throttle control
- Excessive weight transfer
- Rough or “jerky” steering
- Improper brake adjustment
- Parking or Emergency brake engaged
- Transmission – low gear
- Auxiliary braking systems engaging on slippery surfaces


The Rear Wheel Skid

Skids
Rear Wheels

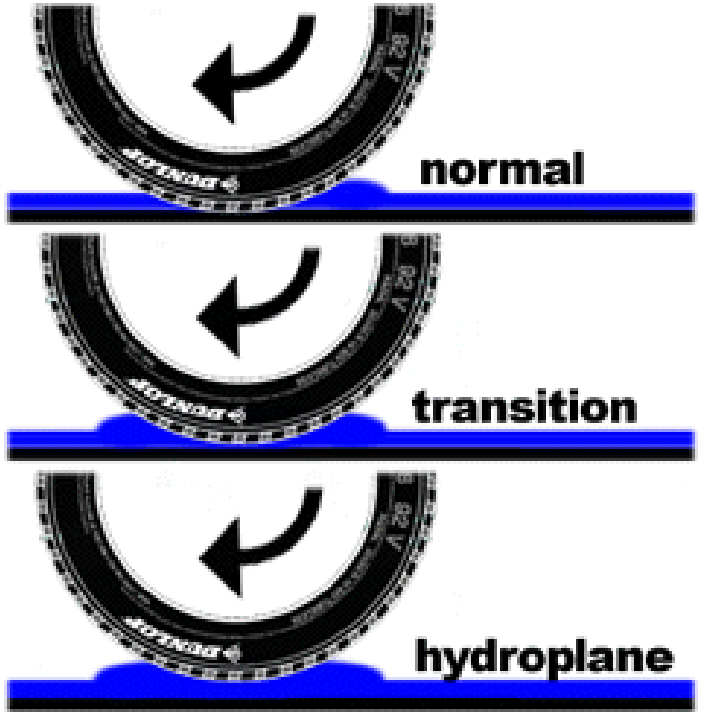
- Turn steering in direction of skid
  - Amount of steering required to correct for slide, must be equal to the degree of slide
- Once vehicle swings out of line more than 25 degrees, steering correction will not be effective
- Driver fails to respond to the slide properly, either in timing or in the degree of correction, the vehicle will continue to slide out of control
  - When correction and the driver steers more than the degree of the slide (over correct), the primary slide will stop.
  - Vehicle will experience a severe weight transfer. Will induce a secondary slide in the opposite direction.

Skids
Power

- Application of too much power for the road conditions.
- Accelerating too fast around a curve
  - Exceeding the critical speed of a curve
- Excessive power causes driving wheels to break traction
- “Fishtailing” is a characteristic
- Regaining Control
  - Reduce acceleration until the car stabilizes
  - Counter steer as needed

Skids
Hydroplaning

- Occurs due to water or slush build-up on the road surface
- Lifts the vehicle off the road surface
- Speed is too great for the tire tread to shed the water on the road surface



Hydroplaning Description Video

Hydroplaning Video

Hydroplaning

- Partial Hydroplaning -counter steering, light application of brakes
- Total Hydroplaning – release accelerator and ride out the skid
  - Front wheels are riding on water, making track for rear wheels
  - Vehicle reacts the same as rear wheel skid.
- Counter-steer to keep the rear from swinging around
- Rolling tires eventually shed the water and regain traction
  - Avoid locking up the brakes or steering sharply

ROLLOVER

Rollovers are almost always preceded by one or more of the following

- Skidding
- One or more tires leaving the paved or improved road surface
- Collision with another vehicle or object
- Mechanical failure

Rollover
Uncontrollable Factors

- Vehicle specifications
  - Height
  - Weight and weight distribution
  - Width and wheelbase
  - Center of gravity
- Vehicle suspension and tires
- Road surface and configuration
  - Soft shoulders
  - Road surface slope
- Weather

Rollover
Controllable Factors

- Speed & Steering
- Driver attentiveness
- Vehicle condition
- Improper recovery/panic
  - Over-steering
  - Uncontrolled braking or accelerating
- Water tank levels

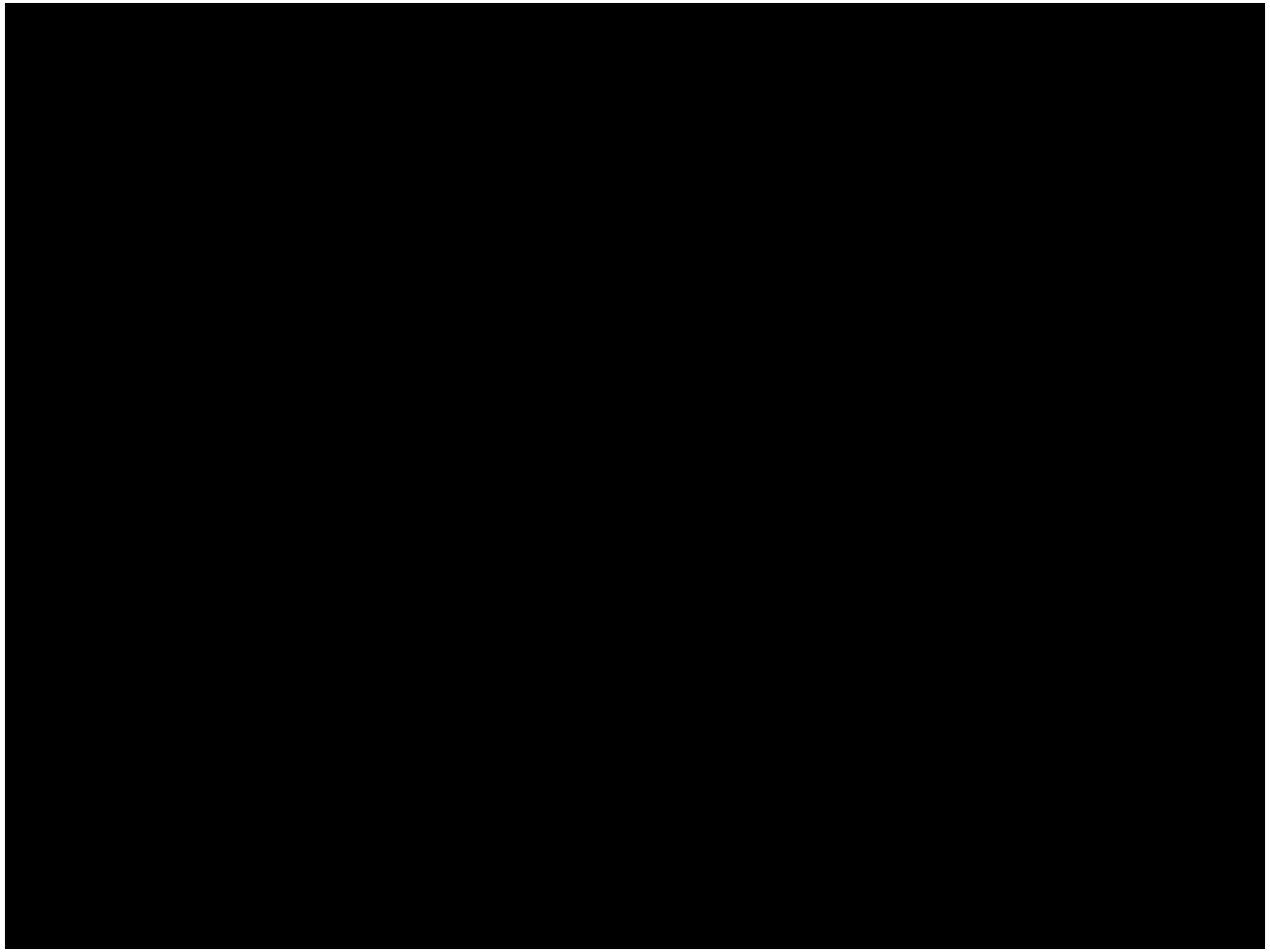
VFIS “Rollover Prevention” DVD

Rollover Actions

- When you sense your vehicle is about to overturn it may be too late to recover
- Stop accelerating
- Start braking gently – avoid additional weight transfer
- Both hands on the wheel at 9 and 3
- If your tires leave the paved surface:
  - Do not jerk the steering wheel to attempt to correct
  - Allow the vehicle to slow down
  - Re-enter the roadway one tire at a time – gradual merge

ROLLOVER

- Raleigh, NC
- July 10, 2009
- Going on a “box”
- Response started while “on the air”



Other Vehicle Systems

- **Automatic Traction Control (ATC) - video**
  - Applies the service brake to a spinning wheel so torque can be transferred through the differential to the wheel that has traction.
  - If both sets of drive axle wheels are spinning this system reduces engine torque until traction is sensed.
- **Roll Stability Control (RSC) - video**
  - Integral to the anti-lock braking system
  - Becomes active when the vehicle senses lateral acceleration that exceeds acceptable thresholds.
  - Works in stages by reducing engine torque, engaging the engine brake or retarder, and then applying the service brakes until lateral acceleration falls below thresholds.
- **Electronic Stability Control (ESC) - video**
  - Stabilizes the vehicle during cornering by detecting loss of steering control
  - Applies brakes to individual wheels and may reduce engine power until steering control is regained.

Collision Forces
Phoenix E18 – April 2019

- 3 civilians killed
- 3 firefighters injured
- Civilian vehicle turned in front of the engine at an intersection
- Engine was estimated to be going 69mph
  - Posted speed limit was 40mph
  - Policy restricted speed to 10mph over posted limit

Collision Forces
Phoenix E18 – April 2019

- Kinetic energy of the apparatus was over 6,400,000 ft-lbs
  - 69mph and assuming a vehicle weight of 40,000lbs
  - Same vehicle at 40mph would be 1/3 the energy (2.1M ft-lbs)
- Pickup truck landed **250 feet** from the initial point of impact
- Commercial disc air brakes apply about 23k ft-lbs of torque at maximum application
- At 69mph, the apparatus would need approximately **500 feet** to come to a controlled stop

Collision Forces
Phoenix E18 – April 2019

- What was the main focus of the news story?
  - The civilian driver or the apparatus operator?
  - Burden of a professional driver
- What was the headline?
  - Unlicensed impaired civilian driver mistake or apparatus speed?
- What is a reasonable speed on a straight 3-lane 40mph road in dry weather?
  - 40mph = 59 feet/second
  - 69mph = 101 feet/second
- How does the story change if E18 was going 50mph?

SUMMARY

- Heavy apparatus does not handle like a passenger vehicle
- Forces associated with heavy apparatus are far greater than passenger vehicles
- Drive in a manner that limits the reaction forces on the vehicle due to stopping and turning
- Once a heavy vehicle starts to skid it will tend to remain in a skid
- When you skid, you are OUT OF CONTROL

HOMEWORK

For next night session, review Case Study #1 and be prepared to discuss.