I. Introduction

A. Introduce yourself as the instructor
B. Give Title of Lesson: *"Important Physical Forces & Emergency Vehicle Control"*
C. State Lesson Objectives

1. Write a brief description of the following terms, and state how they effect an emergency vehicle's operation.

   a) Velocity
   b) Centrifugal Force
   c) Inertia
   d) Friction

2. Indicate, on a drawing, the effects of acceleration, deceleration and turning on a vehicle's weight distribution.
3. State the primary cause of brake fade. Brake overheating is caused by:

   a) Driving too fast for conditions, necessitating heavy, continuous braking and resulting overheating.
   b) Brakes out of adjustment.

4. Describe the effects of weight transfer on an Emergency Vehicle.
5. Describe types of brakes used in the fire service today.

   a) Hydraulic – Shoe type as well as Disc
   b) Air – Shoe type (with "s" cams).
   c) Air – Disc type
   d) Air – Shoe type (wedge brakes).
   e) ABS – Antilock Brake System

II Vehicle Control

A. While driving, an operator can only control a vehicle's velocity and direction.

1. "Velocity Control" is control of the Emergency Vehicle's rate of motion or

speed. The key factors include **acceleration, deceleration and braking.**

2. "Directional control" is the control of the direction that the Emergency Vehicle will travel. This includes:

    a. Steering and turning, as well as tracking in the designed inclination of a curve. ("Tracking" in a curve is where the vehicle will follow the natural inclination of the curve. Most corners are banked in the direction of the turn. If the banking is incorrect or the vehicle crosses the crown in the road, then tracking must be corrected.)

(Have students think of examples where an operator could exceed the physical limits and lose control of a vehicle).

B. Several physical forces influence the amount of control the Operator has. If the limits created by the physical force are not exceeded, the Operator can fully control both the Emergency Vehicle's velocity and its direction. If the limits are exceeded, control will be lost.

1. Driving too fast for weather, road or tire conditions; accelerating too hard.
2. Braking inappropriately.
3. Changing direction too abruptly.
4. Tracking a curve at too high a speed.

C**.** The *key* for Emergency Vehicle Operators is to know the conditions under which these limits are reached, thus when the ability to control a vehicle will be lost.

III. WEIGHT TRANSFER

A. Every time an Emergency Vehicle accelerates, decelerates, or changes direction, the weight distribution of the vehicle shifts.

B. This shift of weight is called "weight transfer"

(Ask students to predict what will happen to the downward force of a vehicle when accelerating and braking.)

1. Weight transfer will keep you alive on the road.
2. In a moving vehicle, if the Emergency Vehicle operator changes the velocity, the

direction or both, weight can transfer to the front or rear, either side, or to any corner.
3. Just where the weight transfers **TO** depend on the kind of change the operator makes.

IV. EFFECTS OF CHANGING VELOCITY ON WEIGHT TRANSFER

Imagine a fulcrum under the vehicle's center of gravity.

A. Accelerating.

1. Downward force at **B** (rear) is increased.
2. More weight and traction at rear tires (unless wheels are spinning)

B. Braking or deceleration.

1. Downward force at A (Front) is increased.
2. More weight on front tires.

(Ask students to describe the forces which make a vehicle lean left in a right turn and right in a left turn.)

V. EFFECTS OF CHANGING DIRECTION ON WEIGHT TRANSFER

(If appropriate for this group, explain the special considerations applying to vehicles with a high center of gravity or with "live" loads.)

(Ask students what happens in a high speed, sharp right hand turn if the brakes are suddenly applied.)

Note: Reinforce the importance of storing equipment carried on apparatus as low as possible to reduce and lower the center of gravity!

A. We are all familiar with the way a vehicle "leans" in a curve. This lean is because of increased downward force on one side of the vehicle.

1. Centrifugal force and inertia "push" the vehicle away from the center of the curve. Thus, the vehicle leans to the outside of curve.
2. With a high center of gravity, the "lean" is more pronounced and the possibility of rolling over increased.
3. Vehicles with "live" loads (such as pumpers and tenders with unbaffled water tanks) can be pushed from the intended track as their loads shift. Because of the centrifugal force, most of the weight is on the left side tires.
5. When brakes are applied, still more of the vehicles weight transfers to the front.
6. Thus, most of the weight is on the front left tire. Two possibilities are as follows:

a. The left front tire can tear off the rim.
b. The left front tire will act like a pivot and the vehicle will spin out of control around that tire.

VI VEHICLE SUSPENSION AND WEIGHT TRANSFER

A. A vehicle's suspension system works to balance the forces (during a change in direction and/or velocity).

1. Distributes the weight transfer throughout the vehicle.
2. Keeps all four wheels firmly on the ground.
3. Keeps the vehicle level.

B. When changing the vehicle direction, good drivers work **WITH** the suspension, not against it.

1. They avoid abrupt changes in direction or velocity that could shift the vehicle's weight suddenly and cause the suspension to overact (possible loss of control).
2. They slow down or widen the track if the vehicle is leaning too much.

VII. MAJOR PHYSICAL FORCES

A. The most important physical forces for Emergency Vehicle control are **friction, momentum, inertia, and centrifugal force.**
B. Friction; what is it?

1. Friction is the resistance to slipping.
2. Friction occurs whenever two surfaces "rub" together.
3. Friction occurs throughout the Emergency Vehicle
4. Operator's hands on steering wheel.
5. Engine parts rubbing together.
6. Gears meshing.
7. Tires and the road surface.
8. Brake shoes or pads rubbing on drums or discs.

(Use writing board and have students think of examples of friction in the Emergency Vehicle)

(Point out that without friction, vehicle control is impossible. Friction enables the Emergency Vehicle to stop, accelerate and change direction.)

C. For vehicle control, the most important areas of friction are:

1. Between the tires and the road.
2. Between the brakes and the wheels.

D. Friction between the tires and the road.

1. If there is no friction between the tires and the road surface, vehicle control tasks will be impossible
2. The amount of friction between the tires and road depends on several factors: Tire size, tread, type, and inflation. Follow the vehicle manufacturer's specifications to ensure optimum footprint (area of the tire in contact with the road surface).
3. Tires must roll in order for a driver to control a vehicle's operation.
4. Friction can be classified in three conditions:

    a. *Greatest* – When the wheels and the vehicle are stationary.
    b. *Very Good* – When the wheel is rolling on a dry, smooth road.
    c. *Least* – When the wheel is locked or spinning.

E. Brake Friction

1. Shoes pressing on drums or pads clamping the disc create friction and slow the wheel.
2. The friction at the brake surfaces generates heat. As heat increases, braking ability diminishes.
3. Brake Fade is one of the worst consequences of heat due to excessive, hard braking.

    a. When sustained (hard) braking heats the brakes sufficiently, the pedal force requirements go up dramatically. In extreme cases, during hard application of the brakes, the brakes may suddenly "disappear". The vehicle will continue

forward as if no brakes were being applied.

b. At best, this is a scary situation. At worst, it is DEADLY.

c. Brake fade can occur in a variety of ways. In all cases, however, the cause is EXCESSIVE HEAT.

VIII. EMERGENCY BRAKING

A. If there is not enough room to stop, or if no escape route is available, emergency braking may be one way to avoid a collision or minimize the consequences.

***GOAL** – Produce shortest possible stopping distance without locked wheels or loss of control. The best method for accomplishing this is*

1. Hydraulic Brakes:

   a. Hard pressure to the brake pedal without locking the wheels is accomplished by one of two methods:

      (1) Quick, firm jabs on the brake pedal when the pavement is dry and non-slippery condition is present (ONLY ON NON-ABS brake systems is jabbing effective)

      (2) Short, steady pressure; release and repeat when the roadway is slippery or less control is possible;

      RELEASE; REPEAT

   b. IF WHEELS LOCK, *RELEASE BRAKE PEDAL.* Re-apply with less pressure.

   c. The best braking method is somewhat dependent on whether the vehicle has ABS, and whether it is equipped with drum or disc brakes.

2. Air Brakes:

    a. Air Brakes should be applied with a steady pressure at the beginning of a stop and then eased off as the vehicle comes to a complete stop. Brakes should be released to avoid jerk and rebound and then applied again to hold the vehicle while it is stopped.
    b. Air brakes should not be fanned (alternatively applied and released), except on slippery pavement where this type of braking gives a shorter stop.

Fanning brakes wastes air pressure and serves no useful purpose. Fanning will also contribute to brake fade, due to excessive heat buildup.

Special note: *Disc brakes can take more sustained hard braking since they cool off more effectively and are less likely to fade.*

(If you have specific information about the Emergency Vehicle your students will drive, go into some detail about braking.)

3. Rapid deceleration could cause a rear-end collision.

    a. In some cases, a rear-end collision is preferable to the alternative (e.g., hitting a pedestrian). Each case must be judged independently.

IX. UNDERSTANDING BRAKE TYPES

A. Drum Brakes – Almost 90% of the total drum surface is in contact with the brake shoe at one time. Thus, only about 10% of the surface can be cooling off at one time. The brake drums can heat up and expand to the point where it is impossible for the shoes to make good contact with the drums.

B. Disc Brakes – Since the pad makes contact with only about 15% of the disc surface, about 85% of the disc surface is cooling. Disc brake design permits much more cooling. Even if the disc were to get hot, it usually expands, thereby making <u>better</u> contact with the disc pads.

1. The biggest cause of brake fade in disc brakes is worn pads. Disc pads that are 50%

worn have a 300% greater chance of causing fade.
2. In extreme cases, the heat can cause the disc to warp, leading to uneven braking.
3. Disc brakes do NOT hold as well with the parking brake as do shoe-type brakes. Using wheel chocks is even more important with disc brakes.

C. *SYSTEMS* – Vehicles may have different types of braking systems. Those systems include hydraulic brakes, air brakes, air over hydraulic, vacuum brakes and vacuum over hydraulic. Each system requires the driver to understand the principles of the braking system.

1. The *hydraulic system* is simply a closed system using hydraulic fluid (brake fluid) and foot pressure. The harder the foot is pressed against the brake pedal, the greater the hydraulic pressure on the braking system.
2. The *air system* uses compressed air to operate the vehicle's service and parking brakes. The system requires a minimum air pressure of 70 pounds per square inch (psi) and a maximum pressure of 120 psi. In the event the air pressure falls below 60 psi, the maxi-brakes shall automatically be applied, the rear wheels will lock up, and the vehicle will skid to a stop. This will cause severe damage to the apparatus. The Driver must be aware of the vehicle's air pressure at all times. Vehicles should be equipped with a low-air pressure light and alarm. These devices are designed to activate at 10 psi above Maxi-brake lock up. In the event either warning device activates, the vehicle should immediately be stopped and the cause of the failure determined.
3. *Air over hydraulic* uses air pressure to operate the hydraulic system. Some of the systems will have Maxi-brakes; others will use shaft brakes as the parking brake.
4. *Vacuum brakes* are found on vehicles with gasoline engines. This system utilizes the

vacuum created in the intake manifold to assist in the operation of the master cylinder.

5. *ABS (Anti-lock Brake System)* There are several types of Anti-lock Brake Systems on vehicles.

    a. The most basic is the two-wheel ABS, designed to prevent the rear wheels from locking up. In this system, found on trucks and vans more than a few years old, it is still possible to lock the FRONT wheels and loose steering control
    b. The other type of system is the four-wheel ABS, which is designed to prevent lock-up on all four wheels. This system uses electronic sensors to compare tire speeds at all 4 wheels. It automatically reduces brake pressure to the wheel(s) that are locking up. The advantage to this over the two wheel system is that it enables the Operator to stop as quickly as possible while retaining steering control.
    c. When making an emergency stop with and ABS equipped vehicle, the Operator should *maintain pedal pressure, even if the pedal begins to pulsate.* This pulsation is the system "pumping" the brake at the wheel(s) that are trying to lock up. It does this at a rate of 6-20 times per second. There can be a corresponding sound synchronous with the pulsations. Some ABS systems do not give the pedal or sound feedback at all; in such vehicles, the Operator must remember to keep a steady pressure on the pedal while attempting an emergency stop.
    d. ***IT IS IMPORTANT TO KEEP IN MIND THAT ON A DRY, SMOOTH SURFACE, A SKILLED OPERATOR CAN OUT-BRAKE AN ABS SYSTEM BY 10-20% DISTANCE. THE ABS SYSTEM WILL HELP KEEP THE VEHICLE UNDER STEERING CONTROL WHILE STOPPING, <u>NOT</u>***

SHORTEN THE STOPPING DISTANCE.

e. It is important for an Operator to know if their vehicle is ABS equipped and, if so, with what type of ABS system.

f. ABS CAN FAIL. In such an event, the Operator must recognize this and resort to their unaided emergency braking skills.

X. AUXILIARY BRAKING DEVICES

Note:
A "Jake Brake" is one form of a compression-type braking device. "Jake Brake" is a commercial brand name for an engine compression braking system.

A. Vehicle retarders can be added to diesel engines to increase the stopping capacity of a vehicle's service brakes. There are two types of retarders:

1. Engine brakes simply stop the injection of fuel into the engine and turn the vehicle's engine into a compressor. This result is greater compression and greater stopping power.
2. Exhaust brakes, probably the most common of the retarders used; work on the principal of a mechanical restriction of the exhaust system which creates more back pressure in the exhaust system than normal, which results in greater compression.
3. In the hydraulic retarder system, a control valve is actuated which introduces a fluid into a cavity through restricted passages providing a retarding effect to the vehicle's rear wheels.
4. The electric retarder, when switched on, provides a powerful drag force by using electromagnets which exert a drag on iron discs attached to the vehicle's drive line.
5. Automatic transmission retarders are an integral part of some transmissions. It uses a rotor which works against transmission fluid in a manner similar to the Hydraulic Retarder. The results are increased backpressure in the transmission which converts to the type of compression which slows the vehicle. There are two types:

a. Input retarder.
b. Output retarder.

B. Retarders are meant to be used as an auxiliary braking device. On long hills and steep grades, they can assist in the braking action and reduce the heat build-up in the regular braking system.

C. When NOT to use the retarders:

1. Some communities restrict the use of several types of retarder systems. Public Ordinance often prohibits those that create an increased exhaust system noise and are termed as “Exhaust Brakes”.