Purpose: Acquaint the student with some of the natural forces acting on a vehicle while stopping, maneuvering, and during a crash. Explain why certain features of a vehicle and maneuvers mitigate the effects of crash forces.

Section		Issue			Learning Objective	References
03.A	Natural forces affecting driving, general	03.A.01	**Natural forces, general, introduction**	03.A.01(1)	There are natural forces acting on your vehicle such as: (a) gravity, (b) inertia, (c) momentum, (d) kinetic and potential energy, (e) friction, and (f) centrifugal force. These forces affect how your vehicle handles, regardless of how well your vehicle is designed or how skilled you are at handling it.	CDH: p. 58
				03.A.01(2)	Understanding these forces will help you control your vehicle during turns, stops, and everyday driving conditions. Knowing how they affect driving your vehicle may also help you react appropriately to an emergency situation or avoid a collision.	
		03.A.02	**Natural forces, general, accidents caused by misjudging**	03.A.01(3)	The laws of nature and physics are present at all times and must be kept in mind while operating a vehicle. If you try to break them, you will end up losing control of your vehicle and perhaps cause an accident that could have been prevented.	
				03.A.02(1)	By misjudging natural forces, you can be pulled out of a curve and lose control. You may lose traction on wet pavement and be unable to stop or be traveling too fast to stop quickly in heavy traffic and cause an accident.	
03.B	The Force of Gravity	03.B.01	**Gravity, introduction**	03.B.01(1)	Gravity is the force that pulls all objects towards the center of the earth. Gravity also affects your speed of travel when going uphill and downhill.	

Section	Issue		Learning Objective	References
		03.B.01(2)	Traction is the result of friction between the road and your tires caused by the weight of the car pushing the tires to the road due to gravity. Traction is necessary for you to steer your car.	
03.B.02	**Gravity, driving uphill and downhill**	03.B.02(1)	When you are driving uphill, the force of gravity is working against you to slow you down and you may need to accelerate or change to a lower gear to maintain your speed.	
		03.B.02(2)	When you drive downhill, the reverse is true. Gravity will cause you to go faster and increase your stopping distance. You may need to shift to a lower gear or smoothly apply your breaks to slow to a safe speed and control your vehicle.	
03.B.03	**Gravity, parking on an incline**	03.B.03(1)	When you leave a vehicle parked on an incline, gravity works to pull your vehicle downhill.	CDH p.30
		03.B.03(2)	To keep your vehicle from rolling away, you should leave your vehicle in a low gear or in “Park” if it has an automatic transmission. You should always engage your parking brake and may even need to block your wheels by placing an object in front or behind of the tires.	CDH p.30
		03.B.03(3)	Just in case your parking brake fails, you should always turn the front wheels of your vehicle so that it will not roll into the traffic lane. The way you should turn your wheels depends on whether you are parked facing uphill or downhill and whether or not there is a curb.	CDH p.30
		03.B.03(4)	If you are parking facing downhill, you should always turn your front wheels towards the curb or side of the road.	CDH p.30

Section		Issue			Learning Objective	References
				03.B.03(5)	If you are parking facing uphill and there is a curb, you should turn your front wheels towards the middle of the road and allow the vehicle to roll back against the curb. If you are parking facing uphill and this is not a curb, you should turn your wheels toward the side of the road.	CDH: p.30
03.C	The law of Inertia	03.C.01	**Inertia, introduction**	03.C.01(1)	Objects that are moving tend to continue moving and objects that are not moving tend to remain at rest, unless acted upon by some other force. This is called the law of inertia. For example, vessels in space can move really far without much spent energy because there is very little air acting to slow them down. When you are waiting for a green signal on flat pavement at an intersection, you will not move unless you engage the engine or are otherwise pushed.	
		03.C.02	**Inertia, effect on driving**	03.C.02(1)	While driving, inertia keeps your vehicle moving, unless it is acted upon by something, such as your brakes, the road surface, a fixed object (such as a tree), or another vehicle.	
				03.C.02(2)	Inertia causes your body and loose objects in your car to keep moving forward when your vehicle stops suddenly.	
				03.C.02(3)	You may be injured because of the inertia and momentum of loose objects in your car that fly through the air during a sudden stop.	
				03.C.02(4)	When you are hit from behind while stopped, your head tends to stay in place due to inertia while the rest of your body is pushed forward by the seat. This causes whiplash. Using your headrest mitigates injuries due to whiplash.	

Section		Issue		Learning Objective	References
	03.C.03	**Inertia, counteracting with seatbelts**	03.C.03(1)	Wearing a seatbelt while driving will stop the forward momentum of your body if you have a collision. It will prevent you from hitting the windshield, steering wheel, and other parts of the interior of your vehicle.	CDH p 46
03.D Potential energy	03.D.01	**Potential energy, introduction**	03.D.01(1)	Potential energy is the energy that an object possesses because of its position or form. For example, a book on a table has the "potential" energy to fall to the floor, whereas a book that is already on the floor does not have this potential energy.	
	03.D.02	**Potential energy, effect on driving and parking**	03.D.02(1)	When you are parked on a hill, gravity causes your car to have potential energy. This energy is converted to kinetic energy (motion) if it breaks loose and rolls down the hill.	
			03.D.02(2)	There is also potential energy built up in the components of your car's suspension system that may cause you to swerve when you come out of a turn.	
03.E Kinetic energy	03.E.01	**Kinetic energy, introduction**	03.E.01(1)	Kinetic energy is the energy a body possesses because it is in motion. For example, the potential energy had by a book on a table is converted to kinetic energy (motion) when it falls. The book lying flat on the floor does not have this same potential or kinetic energy.	
	03.E.02	**Kinetic energyeffect on driving**	03.E.02(1)	As you increase your driving speed, both your body and your vehicle acquire kinetic energy which eventually must be: (a) absorbed by your brakes, engine compression forces, or other friction in a controlled stop, or (b) absorbed by your body, your vehicle's body, and the objects you hit if you are involved in a crash.	

Section		Issue			Learning Objective	References
				03.E.02(2)	The kinetic energy of your body while it is in motion, of loose objects in the car, and of the car itself, all increase with weight and the square of your speed so that: (a) if you increase your speed from 10 MPH to 20 MPH, you are dealing with four times the amount of kinetic energy, and (b) if you increase you speed from 10 MPH to 50 MPH you have to deal with 25 times the amount of kinetic energy.	
				03.E.02(3)	The kinetic energy of your moving vehicle determines your ability to stop the car. In addition to the distance traveled due to your reaction time, your stopping distance will be (a) five times further if you increase your speed from 10 MPH to 20 MPH, and (b) 25 times further if you increase your speed from 10 MPH to 50 MPH.	CDH: p.40
				03.E.02(4)	Gravity decreases your kinetic energy when you are driving uphill and increases it when you are driving downhill. Therefore, the force of gravity will make it (a) easier to stop your car if you are going uphill, and (b) more difficult to stop your car if you are going downhill.	
				03.E.02(5)	Braking to a stop converts kinetic energy into heat energy in your brakes through friction. 03.E.02(6) If you and your vehicle are involved in a collision, the kinetic energy is still converted into heat through friction, but not in your brakes (ouch!).	
03.F	Momentum	03.F.01	**Momentum, introduction**	03.F.01(1)	The force of a moving object is called momentum. The momentum of an object is proportional to its weight and speed. For example, a brick traveling at 10 MPH has more momentum (force) than a chunk of Styrofoam traveling at the same speed.	

Section		Issue		Learning Objective	References
	03.F.02	**Momentum, effect on driving**	03.F.02(1)	When you are driving, both you and your vehicle have acquired momentum which is proportional to the weight of your vehicle and its speed. If you increase your speed from 10 MPH to 20 MPH, you double your car's momentum, and if you increase your speed from 10 MPH to 50 MPH, you increase your car's momentum five times.	
			03.F.02(2)	When you make a controlled stop, the momentum of your vehicle must be overcome by (a) the friction force of your brakes (b) the friction force between your tires and the road, and (c) the compression force of your engine.	
			03.F.02(3)	When you are in a crash, the momentum and kinetic energy of your vehicle and body must be absorbed, which results in heat, the deformation of your vehicle, and possible injury to your body.	
03.G The force of friction	03.G.01	**Friction, introduction**	03.G.01(1)	Friction is a force caused by the contact of one surface on another. It results in the resistance of an object moving over a surface. For example, it is easier to move your hand over fine sandpaper than over rough sandpaper because there is less friction caused by the surface of the fine sandpaper.	
			03.G.01(2)	Friction is (a) increased by the weight of your vehicle, (b) decreased if your tires are over-inflated or are worn smooth, (c) increased if your tires are under-inflated, (d) affected by the material used to construct the road, and (e) affected by the condition of the surface of the road (including factors due to weather).	
			03.G.01(3)	Friction occurs (a) between your tires and the road, (b) in your brakes when applied, and (c) in many parts of your engine and transmission (including the clutch, when engaged).	

Section		Issue		Learning Objective	References
	03.G.02	**Friction, effect on stopping**	03.G.02(1)	Because friction is increased by the weight of your vehicle, a fullyloaded truck has more stopping power than does an empty one because it is heavier. The weight aides in stopping the vehicle by producing more friction between the tires and the road surface.	CDH: p. 50
			03.G.02(2)	The kinetic energy of your moving vehicle is converted into heat during braking because of the friction of your brakes against your wheels and the friction of your tires against the road.	
	03.G.03	**Friction, effect of roads and tires**	03.G.03(1)	Worn or over-inflated tires will reduce the friction between your tires and the road surface, reducing the traction needed to: (a) start smoothly, (b) stop quickly, and (c) pull out of a turn or curve without losing control.	
			03.G.03(2)	Road surface changes due to: (a) ice, (b) rain, (c) snow, (d) oil and diesel fuel buildup, or (e) sand or dirt will reduce the traction of your tires. This could result in you losing control of your vehicle.	CDH: p. 59
	03.G.04	**Friction, effects on braking**	03.G.04(1)	Skidding while braking is caused by the friction of your brakes being stronger than the friction force between your tires and the road, which causes you to lose traction.	
			03.G.04(2)	The kinetic energy of your vehicle cannot be converted into friction in your brakes (heat energy) when your brakes are locked as they are in a locked-wheel skid.	
			03.G.04(3)	If the components of your brakes become too hot, they cannot release any more heat and will fail to absorb any more kinetic energy (such as when traveling down a steep hill and using your brakes a lot).	

Section		Issue			Learning Objective	References
				03.G.04(4)	The purpose of anti-lock brakes is to prevent your wheels from locking during a quick stop so that your brakes can continue to absorb energy and you can maintain traction.	
				03.G.04(5)	The loss of traction in a stop or turn can be avoided by (a) driving slower, and (b) properly using your brakes. (See Unit 6 and 8.)	
		03.G.05	**Friction, effects on vehicle components**	03.G.05(1)	The friction that the clutch creates when released can: (a) cause loss of traction if released improperly (peeling out), (b) slow your vehicle down by engaging a lower gear, and (c) allow the vehicle to move regularly.	CDH: p.58
				03.G.05(2)	The friction on your brakes and clutch results in brake and clutch wear. If used improperly, excessive wear to the brake pads and clutch can occur. To avoid this: (a) do not ride your brakes, (b) do not drive with your clutch partially engaged (depressed), and (c) use your lower gears to slow the vehicle on downhill grades (downshift).	
				03.G.05(3)	Improper lubrication of your engine and transmission will cause excessive friction which will result in mechanical failure. You could be left stranded or lose control of your vehicle as a result. (See Unit 6 for more detail.)	
03.H	Centrifugal force	03.H.01	**Centrifugal force, introduction**	03.H.01(1)	Centrifugal force is the tendency for objects to be pulled outward when rotating around a center.	
			Centrifugal force, effect on turns	03.H.02(1)	In a turn, your car is subject to centrifugal force which is pulling your car away from the direction you want to turn and into a straight line. Traction is necessary to keep from losing control in a turn.	CDH: p. 62

Section		Issue			Learning Objective	References
				03.H.02(2)	Banked roadways improve your traction in turns. They help in overcoming the centrifugal force that is pulling you away from the direction in which you want to turn.	
				03.H.02(3)	In order to keep a vehicle in a turn without allowing centrifugal force to pull the car out, you should: (a) decelerate before the curve, (b) brake gently and gradually while turning, and (c) downshift (manual transmission).	CDH: p. 62
				03.H.02(4)	Centrifugal force can be partly overcome by leaning toward the inside of the turn when driving a motorcycle or riding a bicycle.	
03.I	Forces in a crash	03.I.01	**Forces in a crash, introduction**	03.I.01(1)	In a crash: (a) the kinetic energy of your vehicle and body must be dissipated, (b) the forces needed to dissipate this energy are lower if the time period over which your vehicle moves during the crash is longer, and (c) if the car suddenly stops, the forces will be very high.	
		03.I.02	**Forces in a crash, head-on collisions**	03.I.02(1)	The forces that stop your car during a crash will be greatest if you have a head-on collision with another vehicle or large immovable object, such as a bridge abutment, wall, or a tree, because the momentum and kinetic energy of your car must be absorbed almost instantaneously.	

Section		Issue		Learning Objective	References
			03.I.02(2)	If two vehicles are involved in a collision moving at the same rate of speed, the vehicle that weighs less will take the greater impact. The larger and heavier the vehicle, the greater the energy and momentum. The smaller and lighter vehicle will have greater deceleration and may even be pushed in the reverse direction of travel. In some cases the smaller and lighter vehicle may be crushed as in: (a) a semi-truck against a sedan and (b) a train against a semi-truck The impact of a train against a vehicle can be compared to the impact of a vehicle on an aluminum can.	
	03.I.03	**Forces in a crash, reducing them**	03.I.03.(1)	You can reduce the forces on you and your car during an unavoidable crash if you are able to redirect your path toward objects that will cause your car to stop over a greater distance, such as: (a) bushes rather than trees, (b) snow, (c) soft dirt, and (d) sand barrels placed in front of freeway abutments.	CDH: p. 59
			03.I.03.(2)	The purpose of barrels filled with sand in front of an abutment (such as a support for a highway over pass) is to reduce the forces on your vehicle by allowing your vehicle to travel farther than if it hit the abutment directly.	

Section	Issue	Learning Objective	References
	03.I.03.(3)	Modern vehicles have a number of features that reduce the forces on your body during a crash by absorbing energy and increasing the distance over which the impact occurs. These include: (a) crush zones (areas of the vehicle designed to absorb impact by crushing in without harming the passenger area of the vehicle), (b) I-beam construction in the frame and doors to give the vehicle more rigidity, (c) air bags, (which allow the momentum of your body to be absorbed over a slightly greater distance than if it hit the steering wheel or windshield), (d) energy-absorbing bumpers that reduce the effect of the kinetic energy during a front or rear-end collision, (e) padded dashboards, and (f) safety glass windows and windshields designed to crumble into small dull-edged pieces to reduce lacerations.	CDH: p. 48
	03.I.03.(4)	If the force of impact is excessive, such as during a head on collision with another vehicle, the above safety features may still not be enough to prevent serious injury or death.	
	03.I.03.(5)	Your seatbelt is the best protection against injury if you have in an accident.	CDH: p. 46