Lesson 4
Motion and Energy in Automobile Racing

Main Idea

Velocity, acceleration, forces, work and energy can be illustrated with examples from automobile racing.

Key Concepts

- Acceleration
- Bernoulli's principle
- Force
- Mass
- Power
- Velocity
- Watt
- Work
- Aerodynamics
- Downforce
- Kinetic energy
- Potential energy
- Thermal energy
- Venturi effect
- Weight

Racing Oral History Interview

- Carroll Shelby: Kinetic Energy and Brakes

Digitized Artifacts
from the Collections of **The Henry Ford**

Lesson 4 Motion and Energy in Automobile Racing

- Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)
- March 84C Race Car, 1984 (aerial view ID# THF69371)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (side view ID# THF69258) (aerial view ID# THF69260)
- Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472

Materials

- Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheets and digitized artifacts' images and descriptions
- Calculators
- Background Information Sheet for Students 4A: Motion and Energy in Automobile Racing
- Student Activity Sheet 4B: Distance, Velocity and Acceleration (Grades 4-5)
- Student Activity Sheet 4C: Distance, Velocity and Acceleration (Grades 6-8)
- Answer Key 4B/C: Distance, Velocity and Acceleration (Grades 4-5)/(Grades 6-8)

Duration 1 class period (45 minutes)

Instructional Sequence

1 Engagement

Discuss with students the concepts of distance, speed, velocity force and energy. Ask them to discuss the various speeds that they have experienced. Typical speeds are: 3-4 mph for walking, 10-20 mph for riding a bike, 25-40 mph in a car traveling locally and 70 mph for a car on the freeway. A cross-country train might travel at 100 mph, and a commercial airliner typically travels at 400 to 500 mph.

Continued...

Lesson 4 Motion and Energy in Automobile Racing Continued

2 Discovering Types of Motion and Energy in Automobile Racing

Distribute Background Information Sheet for Students 3A: Motion and Energy in Automobile Racing. If possible, access this sheet online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet. (See the Background Information for Teachers section below for additional information on formulas, speed and energy.)

Use the Background Information Sheet to review, read and discuss with students the question for analysis, concepts and information about motion and energy in automobile racing.

Encourage students to make their own observations, ask questions and offer other examples from life that illustrate motion and energy.

3 Background Information for Teachers

Formulas involving motion and energy:

Distance = velocity * time $d = v * t$

Velocity = change in distance / change in time $v = \Delta d / \Delta t$

Time = distance / velocity $t = d / v$

Acceleration = change in velocity / time $a = \Delta v / \Delta t$

Velocity = acceleration * time $v = a * t$

Work = Force * distance $W = F * d$

Power = Work / time $P = W / t$

One horsepower = 746 watts   1 hp = 746 watts

One watt = 1/746 hp = .00134 hp

Kinetic energy (KE) = $\frac{1}{2} m * v^2$

Note

Speed is a measure of distance traveled per time. Velocity is technically displacement per time, where displacement is distance and direction from the origin; velocity is speed and direction. For the purpose of this lesson, and for work with most students who are younger, speed and velocity can be used interchangeably.

In an automobile, chemical energy in gasoline or fuel is converted to thermal energy or heat energy. Thermal energy is then converted to mechanical energy. Mechanical energy is then converted to kinetic energy of motion.

Starting at a light, a car will be motionless because the engine force is balanced by the braking force, and the car remains at rest. The car will accelerate as long as the engine force is greater than all the friction forces (wind, tires on the road, moving parts in the engine, gears, etc.). If a car is accelerated to a cruising speed of 40 mph, then to continue at a constant 40 mph, friction forces will need to be balanced by the engine force. If on an expressway the driver presses harder on the accelerator, making the engine force greater than the friction forces, then when the car reaches and maintains a cruising speed of 70 mph, the engine force will again need to equal all the friction forces. When the engine force is reduced, the car will decelerate as the friction forces, including braking, become greater than engine force. If the driver presses firmly on the brake, friction forces will become greater than the engine force, and the car will decelerate to a stop.

Assessment

Assign students Student Activity Worksheet 4B/C: Distance, Velocity and Acceleration to assess their learning and understanding.

motion and energy in Automobile Racing

Motion and Energy

Automobile racing involves various forms of energy and various types of motion. Race car engineers and designers are constantly coming up with new innovations to make their cars travel faster and more safely.

Question for Analysis

How do we use the concepts of kinetic energy, work and power to evaluate automobile racing?

Concepts

Acceleration

The rate at which an object's velocity changes; $a = \Delta v / \Delta t$

Aerodynamics

The way the shape of an object affects the flow of air over, around or under it.

Bernoulli's principle

Air moving faster over the longer path on a wing causes a decrease in pressure, resulting in a force in the direction of the decrease in pressure.

Downforce

The aerodynamic force on a car that pushes it downward, resulting in better traction.

Force

Any push or pull.

Kinetic energy

Energy of motion. The formula for kinetic energy is $KE = \frac{1}{2} m v^2$, or ½ the mass times the velocity squared.

Mass

The amount of matter or substance in an object.

Potential energy

Energy due to position, or stored energy.

Power

Rate of doing work, or work divided by time; $P = W / t$

Speed

The distance an object travels divided by the time it takes to travel that distance.

Thermal energy

Heat energy.

Velocity

The speed of an object, including its direction. Velocity = change in distance over time, or $v = \Delta d / \Delta t$

Venturi effect

The effect produced by narrowing a passage of air as the air travels, causing an increase in the speed of the air, a drop in pressure and a force in the direction of the air passage.

Watt

A measurement of power. One watt is 1 joule of work per 1 second. A joule of work is 1 Newton of force acting through 1 meter.

Weight

The force of gravity pulling on an object, or the mass of the object times its acceleration due to gravity.

Work

The force on an object times the distance through which the force moves the object as the work is converted to energy of motion.

Continued...

Using the Racing Oral History Interview

View the oral history of Carroll Shelby as he talks about kinetic energy and brakes. Notice that he explains that the car's brakes can turn its kinetic energy of motion into heat energy.

Carroll Shelby: Kinetic Energy and Brakes

Speed, or Velocity, and Acceleration in Auto Racing

The speed of a car is measured by the distance the car covers in a certain amount of time. The formula for speed is s = d / t, or speed equals distance divided by time. A car that travels 100 miles in 2 hours would be traveling 50 miles per hour, since its speed = 100 miles / 2 hours = 50 miles / hour. Or, distance can be calculated by multiplying speed or velocity times time. So if a car is traveling 120 miles / hour, it will travel 360 miles in 3 hours. d=v * t, distance = 120 miles/hour * 3 hours = 360 miles.

Often, speed, or velocity, is measured in meters per second. A car that travels 200 meters in 8 seconds would be traveling 25 meters/second, since speed = 200 meters/8 second = 25 meters/second. If we work in meters per second, we can calculate the distance in meters. A car traveling at 40 meters/second for 10 seconds will travel 400 meters, since distance = 40 meters/second * 10 seconds = 400 meters.

Velocity is technically called displacement/time. Displacement is both distance and direction, while velocity is speed in a particular direction. Often, as in this Background Information Sheet, speed and velocity are used interchangeably.

Kinetic and Potential Energy

Kinetic energy is energy of motion. Kinetic energy is usually measured using meters and seconds. Kinetic energy equals one-half the mass of an object times its velocity squared ($KE = ½ m * v^2$). A toy car with a mass of 2 kilograms traveling at 10 meters/second will have 100 kilogram-meters^2/second^2, or what we call 100 joules; the unit of energy when measured in kilogram-meters^2/second^2 is the joule. So KE = ½ * 2 kilograms * (10 meters/second)^2 , or ½ * 2 * 10 * 10 = 100 kilogram-meters^2/second^2, or 100 joules.

A race car has a lot of kinetic energy. Look at the picture of the red #9 NASCAR race car [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 ID# THF69258]. The mass of this car is about 1,588 kilograms (3,500 pounds). If it travels at 180 miles/hour, or about 80 meters/second, its kinetic energy will be:

$KE = ½ m * v^2$ = ½ * 1,588 * 80 * 80 = 5,081,600 joules.

Potential energy is the energy due to the position of the object. A rock on the edge of a building's roof has the potential to fall and turn into kinetic energy. Potential energy can also be energy stored chemically, like the energy stored in gasoline.

Thermal energy is energy due to heat, or heat energy. When an automobile engine burns fuel, the potential energy in the fuel is turned into thermal energy – heat – that operates the pistons to change the thermal energy into kinetic energy, or energy of motion. The pistons then move a crankshaft that is attached to the wheels and makes them move.

Continued…

Work and Horsepower

The work done by the engine to create kinetic energy to move the car is measured differently than the way we normally think of work. The amount of work that a car engine can produce is measured in horsepower. The concept of horsepower was created by James Watt, who lived from 1736 to 1819. He measured the amount of weight a horse could move a certain distance in a given time and came up with 33,000 foot-pounds/minute, which he called 1 horsepower (1 hp). Thus an engine with 350 horsepower could do the work of 350 horses.

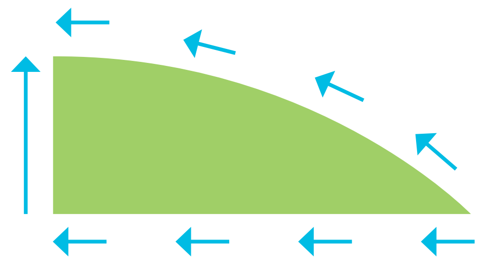
Work is measured by multiplying the amount of force on an object by the distance an object is moved by the force. Work equals force times distance ($W = F * d$). Work is measured in a unit called joules.

Power is a measure of how fast work can be completed. Power is work divided by time ($P = W / t$). Power is measured in watts, and 1 watt is 1 joule per second. One horsepower is equivalent to 746 watts.

Bernoulli's Principle and Energy

One of the most interesting aspects of automobile racing involves Bernoulli's principle. Fast-moving air produces a drop in air pressure and a force in the direction of the drop in pressure. If you look at a wing of an airplane, you will see that the top of the wing has a longer surface than the bottom of the wing (see Fig.1). The air has to travel faster over the longer upper surface. The faster-moving air produces a drop in pressure above the wing, giving the bottom of the wing comparatively higher pressure. There will be a force created from the pressure difference, and that force will push, or lift, the wing upward.

Fig. 1



Airfoils

Race car engineers use Bernoulli's principle to make winglike objects called airfoils. The "wing" of the airfoil is turned upside down so that the longer surface is on the bottom. The airfoil is attached to either the front or the back of the car to push down on it and gain better traction. Look at the airfoil on the Texaco Star race car [March 84C Race Car, 1984 (aerial view ID# THF69371)].

Air resistance can also be used to force a car down. Air hits the front of a race car that has a low front and continues over the top, actually pushing down on the front of the car and giving better traction. Look at the front of the red #9Ford Thunderbird [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)]. Notice that its low front causes the oncoming air to push down on the front of the car.

Designs of race cars are always being improved to allow the cars to travel faster.

Name

distance, velocity and acceleration
(Grades 4-5)

Formulas

Distance = velocity * time   d = v * t

Velocity = distance / time   v = Δ d / Δ t

Time = distance / velocity   t = d / v

Acceleration = change in velocity / time
a = Δ v / Δ t

Velocity = acceleration * time   v = a * t

Work = force * distance   W = F * d

1. During the Indianapolis 500, a winning driver can often cover the 500 miles in 3 hours. What would be his average velocity?

2. The land speed record set by the Goldenrod Racer [Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676] was 409 miles per hour (mph). A NASCAR racer can travel 180 mph. A bicycle racer can travel 30 mph. How long would it take each of the three to travel 500 miles?

3. During time trials, a NASCAR racer might reach 210 mph. How far could a NASCAR racer travel in 8 hours if he could continue at that speed?

4. The Willys “Gasser” drag-race car [Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)] could accelerate from 0 to 140 mph (about 63 meters/second) in 12 seconds. What would be its acceleration (measured in meters/second^2)?

5. How much work is done by the pit crew pushing a car with a force of 2,000 Newtons through a distance of 30 meters? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

Name

distance, velocity and acceleration
(Grades 6-8)

Formulas

Distance = velocity * time	d = v * t
Velocity = distance / time	v = Δ d / Δ t
Time = distance / velocity	t = d / v
Acceleration = change in velocity / time	a = Δ v / Δ t
Velocity = acceleration * time	v = a * t
Work = force * distance	W = F * d
Power = work / time	P = W / t
1 horsepower = 746 watts	1 hp = 746 watts

1. A race car makes 34 laps around the Daytona Speedway (1 lap is 2.5 miles). What would be the race car's average velocity if it makes the 34 laps in half an hour?

2. What would be the acceleration of a 1950s drag racer if the car accelerates from 0 to 130 mph (use 58 meters/second) in 12.8 seconds? See digitized artifact Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472.

3. How much work would be done by the engine in a NASCAR stock car that exerts a force of 1,600 Newtons for a 2.0-mile (3,200-meter) lap? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

4. A. What would be the power (in watts) of the car in Problem 3 if it takes 40 seconds to complete the lap?

   B. How many horsepower would be used?

5. If the Daytona 500 was won in a time of 2 hours and 40 minutes, what would be the winner's average speed? (Remember, there are 60 minutes in an hour.)

distance, velocity and acceleration
(Grades 4-5)

1. During the Indianapolis 500, a winning driver can often cover the 500 miles in 3 hours. What would be his average velocity?

   v = d / t = 500 miles/ 3 hours = 166.7 miles/hour

2. The land speed record set by the Goldenrod Racer [Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676] was 409 miles per hour (mph). A NASCAR racer can travel 180 mph. A bicycle racer can travel 30 mph. How long would it take each of the three to travel 500 miles?

   Goldenrod land speed racer:
   t = d / v = 500 miles/ 409 miles/hour = 1.22 hours or 1 hour 13 minutes

   NASCAR racer:
   t = d / v = 500 miles/ 180 miles/hour = 2.78 hours or 2 hours 47 minutes

   Bicycle racer:
   t = d / v = 500 miles/ 30 miles/hour = 16.67 hours or 16 hours 40 minutes

3. During time trials, a NASCAR racer might reach 210 mph. How far could a NASCAR racer travel in 8 hours if he could continue at that speed?

   *d=v * t = 210 miles/hour * 8 hr = 1,680 miles*

4. The Willys "Gasser" drag race car [Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)] could accelerate from 0 to 140 mph (about 63 meters/second) in 12 seconds. What would be its acceleration (measured in meters/second^2)?

   a = Δ v / Δt = 63 meters/second / 12 seconds = 5.25 meters/second^2

5. How much work is done by the pit crew pushing a car with a force of 2,000 Newtons through a distance of 30 meters? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

   *Work = F * d = 2,000 Newtons * 30 meters = 60,000 joules*

distance, velocity and acceleration
(Grades 6-8)

1. A race car makes 34 laps around the Daytona Speedway (1 lap is 2.5 miles). What would be the race car's average velocity if it makes the 34 laps in half an hour?

   Distance =
   *# laps * 2.5 miles = 34 laps * 2.5 miles/lap = 85 miles*

   Velocity = d / t = 85 miles/ 0.5 hour = 170 miles/hour

2. What would be the acceleration of a 1950s drag racer if the car accelerates from 0 to 130 mph (use 58 meters/second) in 12.8 seconds? See digitized artifact Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472.

   Acceleration = Δ v / Δ t = 58 meters/second/ 12.8 seconds = 4.53 meters/second^2

3. How much work would be done by the engine in a NASCAR stock car that exerts a force of 1,600 Newtons for a 2.0-mile (3,200-meter) lap? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

   *W = F * d = 1,600 Newtons * 3,200 meters = 5,120,000 joules*

4. A. What would be the power (in watts) of the car in Problem 3 if it takes 40 seconds to complete the lap?

   Acceleration = Δ v / Δ t = 58 meters/second/ 12.8 seconds = 4.53 meters/second^2

   B. How many horsepower would be used?

   *128,000 watts * 1 hp/ 746 watts = 172 hp*

5. If the Daytona 500 was won in a time of 2 hours and 40 minutes, what would be the winner's average speed? (Remember, there are 60 minutes in an hour.)

   s = d / t = 500 miles/ 2.67 hour = 187.3 miles/hour