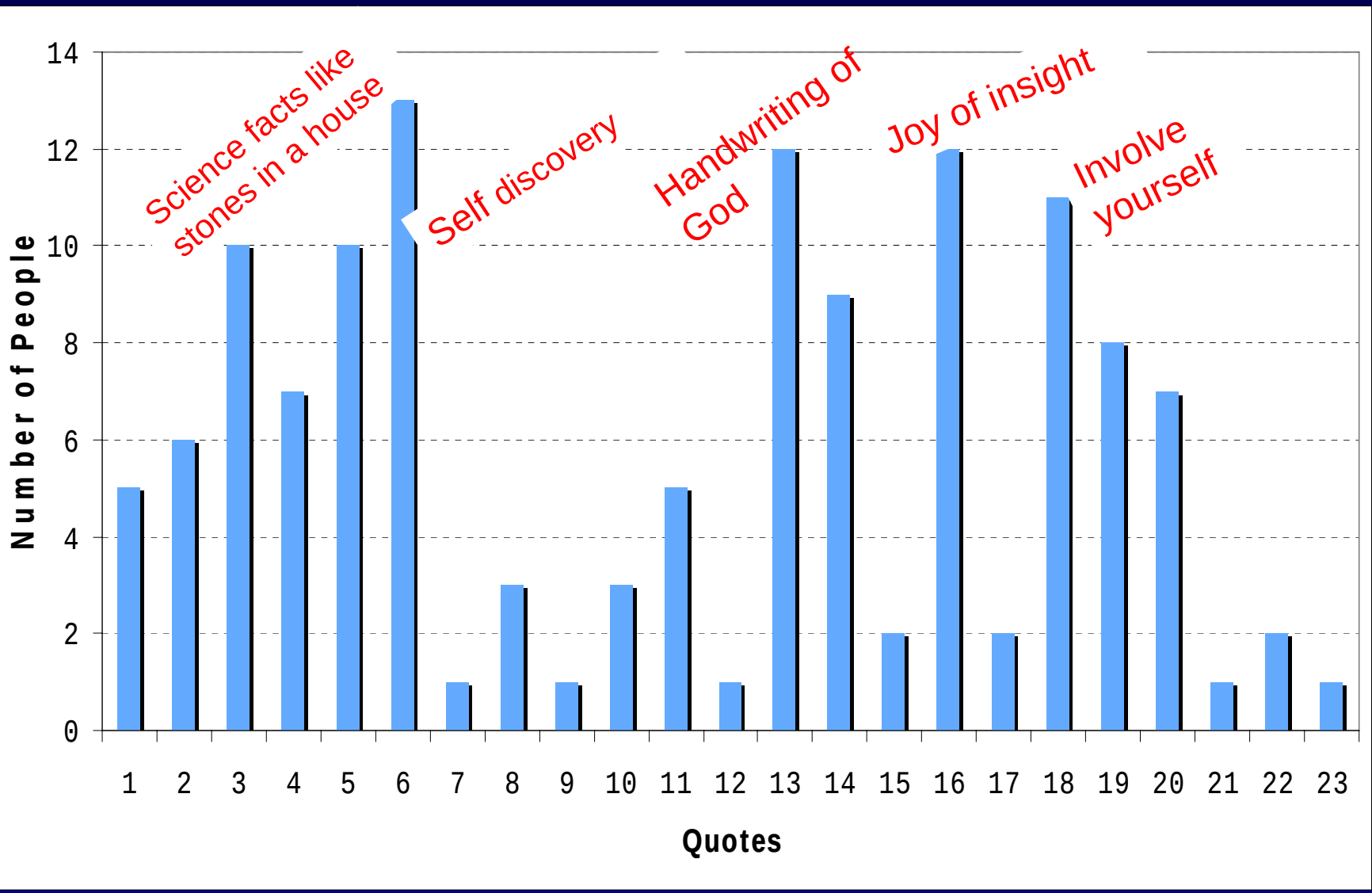
Topic #7
Overview of Newton's Laws of Motion & Momentum

QUOTE FOR TODAY:

Mathematical and mechanical principles are the alphabet in which God wrote the world.

~Robert Boyle

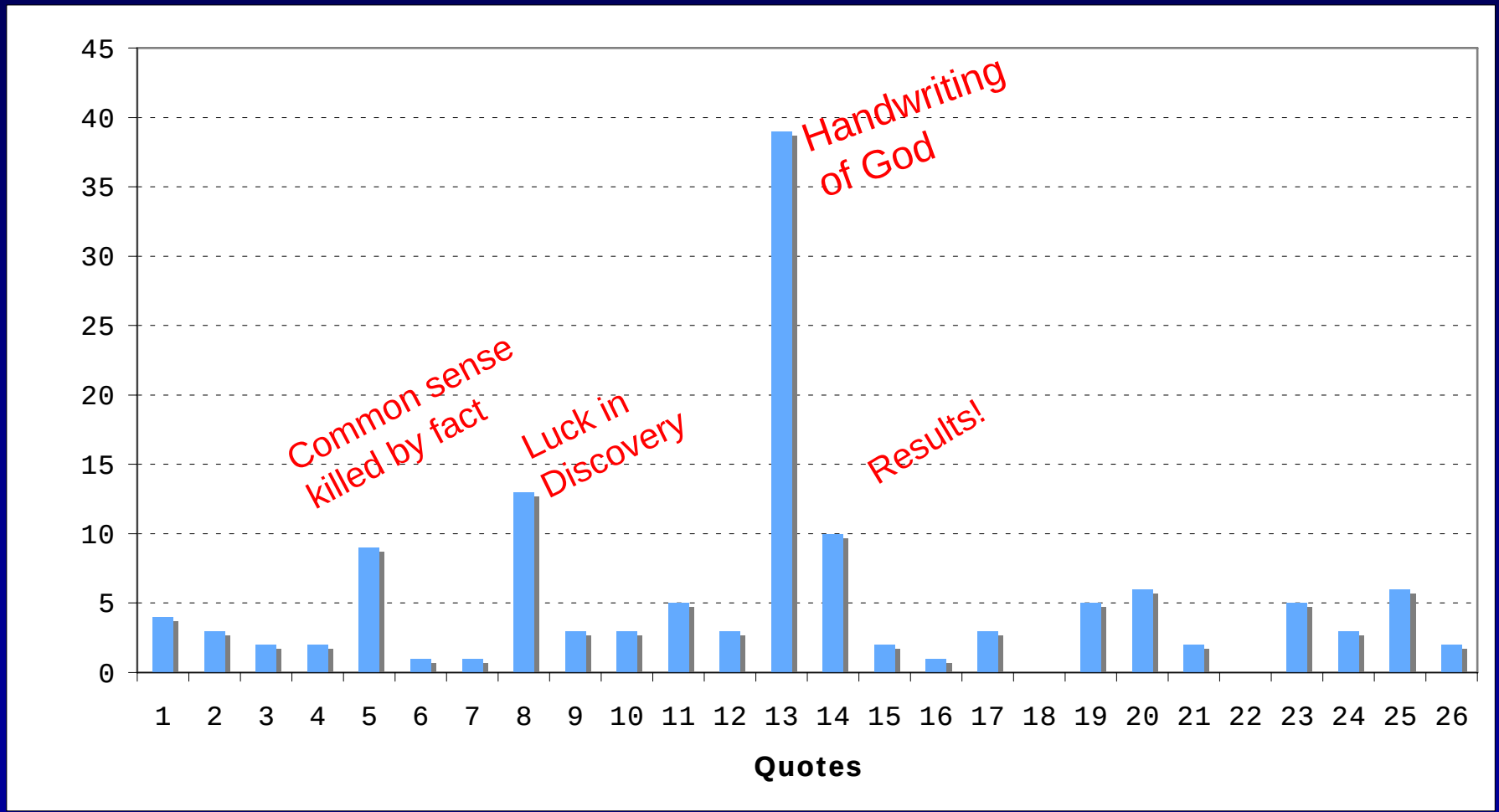
STUDENT'S FAVORITE QUOTES:



MOST INTRIGUING or SURPRISING QUOTES:

Flat out winner was Quote 13: *It is like finding the handwriting of God.*

Trend: The majority of students found it interesting that scientists, who base their work on fact, believe in something that has no proof.



Interested in Science & Theology? See forum: http://www.azstarnet.com/sn/printDS/146218

ANOTHER QUOTE FOR TODAY:

"If I have seen farther than other men, it is by standing on the shoulders of giants"

Sir Isaac Newton (1642-1727)

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Stand on the shoulders of giants

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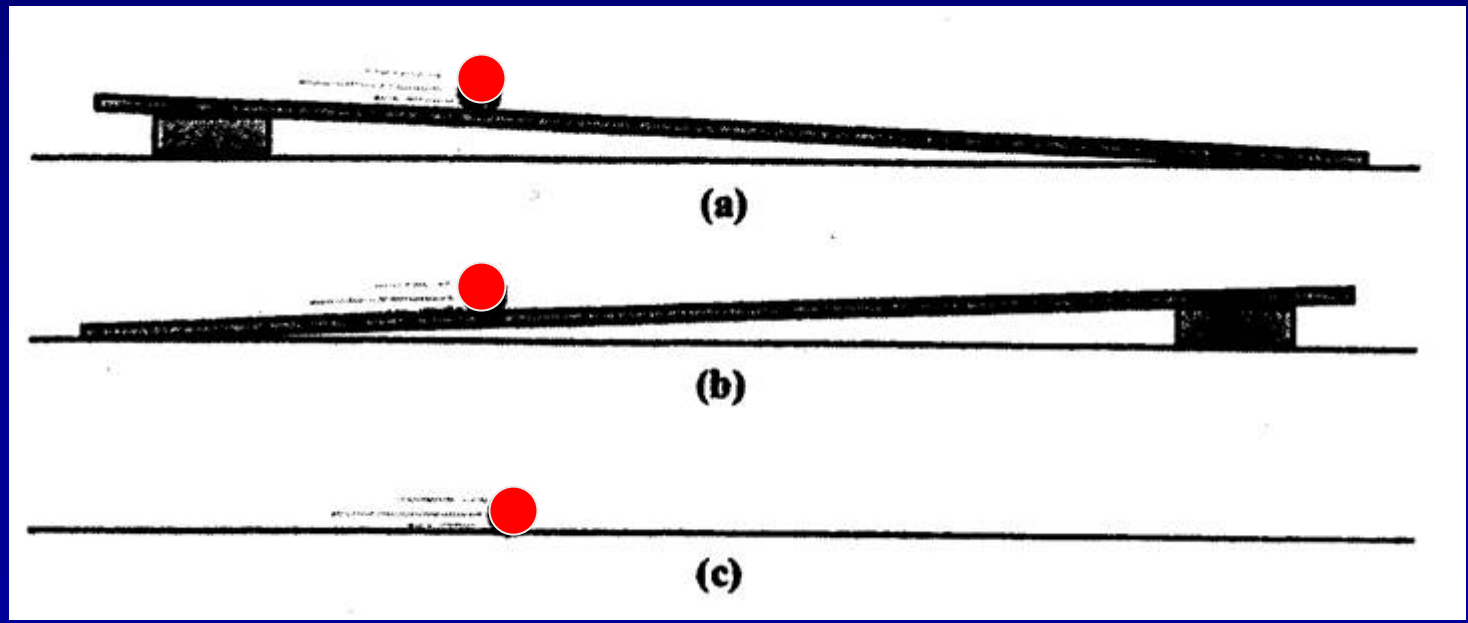
SCIENCE IS A CUMULATIVE ENTERPRISE

EVER-CHANGING NATURE OF SCIENTIFIC KNOWLEDGE

Galileo Galilei
(1564-1642)

- "Father of Experimental science"



Isaac Newton
(1642-1727)

Newton later expressed many of Galileo's ideas, observations and theories as formal "laws" which we know as "**THE LAWS OF MOTION**."

SOME DEFINITIONS WE NEED:

Force (F) = any influence that can cause a body to be accelerated.

(The common force unit is the *newton.* A force is an *action*, not a thing.)

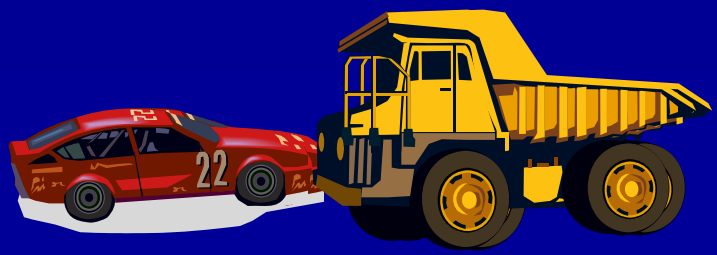
Every force is similar to a push or a pull.

Net force = the total, overall force on an object.

If acting in the in the SAME direction = the (vector) sum of the two forces

If acting in the OPPOSITE direction = the (vector) difference between the two forces:

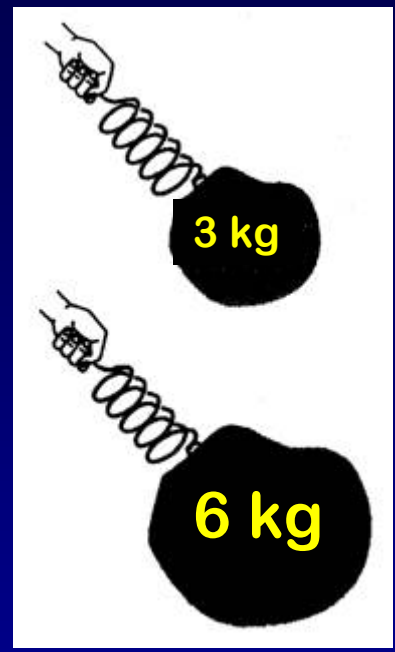
Net force acts in the direction of the <u>stronger</u> force:



SOME DEFINITIONS WE NEED:

Inertia = The tendency of a body to resist a change in motion;

. . . or a body's ability to stay at rest or to maintain an unchanging velocity



(A body's INERTIA is its degree of resistance to acceleration, in other words: its MASS)

Mass = the quantity of matter in a body, a measurement of the inertia or sluggishness that a body

SOME DEFINITIONS WE NEED:

Mass vs. weight

Mass = the quantity of matter in a body, a measurement of the inertia or sluggishness that a body

Weight = The force *due to gravity* upon a body.

(More specifically: the net gravitational force exerted on it by all other bodies.)

The astronaut in space depicted at right finds it just as difficult to shake the "weightless" anvil as it would be on earth.

Q1: If the anvil is more massive than the astronaut, which shakes more:

1 = the anvil

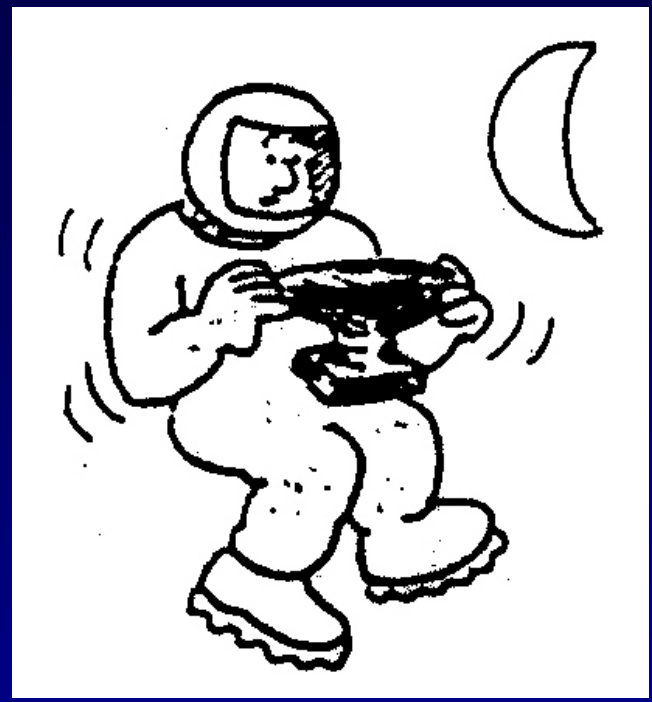
2 = the astronaut

3 = neither shakes more than the other

Explain your answer, using the terms weight, mass, and inertia.

ANSWER =

2 = the astronaut



Explain your answer, using the terms ***weight, mass,*** *and* ***inertia:***

Both the anvil and astronaut are weightless, but the anvil has more MASS, hence the anvil has more inertia and shakes less.

1st Law of Motion
(Law of Inertia)

A moving object will continue moving in a straight line at a constant speed . . .

. . . and a stationary object will remain at rest . . . unless acted on by an unbalanced force.

Other ways of stating Law #1:

- **Every body continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it. (MH text)**

or

- **All bodies have inertia.**

Newton's Laws in everyday life:

1st LAW =

The LAW of INERTIA!

EASY WAY of remembering the 1st Law:

The key word is **"continue."**

If a body is at rest, it **continues** to stay at rest; if moving, it **continues** to move in a straight line.

It can't start or stop moving on its own without some external force, i.e. "a body does not accelerate itself."

2nd Law of Motion
(Newton's Law of Motion)

The acceleration (a) produced on a body by a force (F)

is proportional to:
the magnitude of the force (F)

and inversely proportional to:
the mass (m) of the object.

$a = F / m$ or $F = ma$

2nd Law: F= ma

Acceleration $\propto$ net force / mass

$\propto$ = "is proportional to"

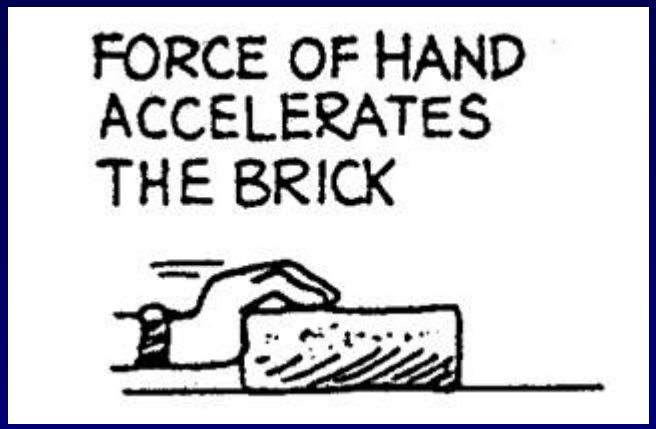
or

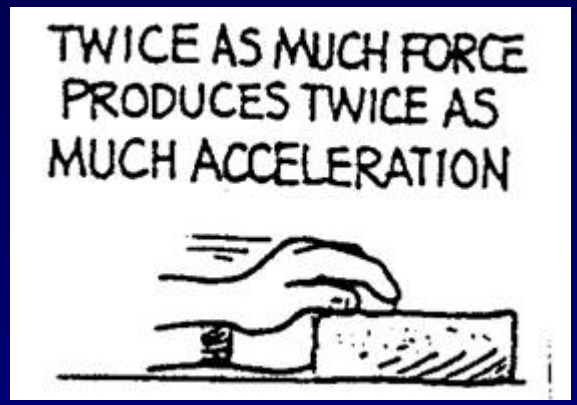
$$a \propto F/m$$

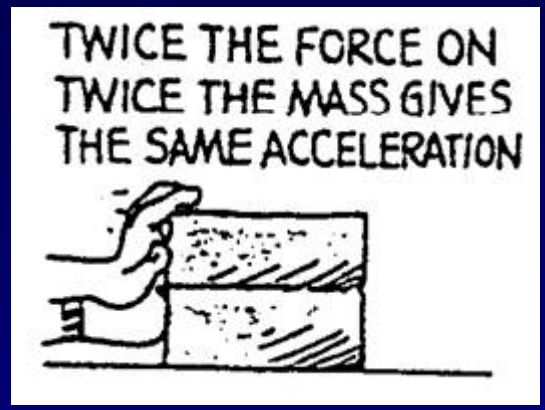
$$a = F/m$$

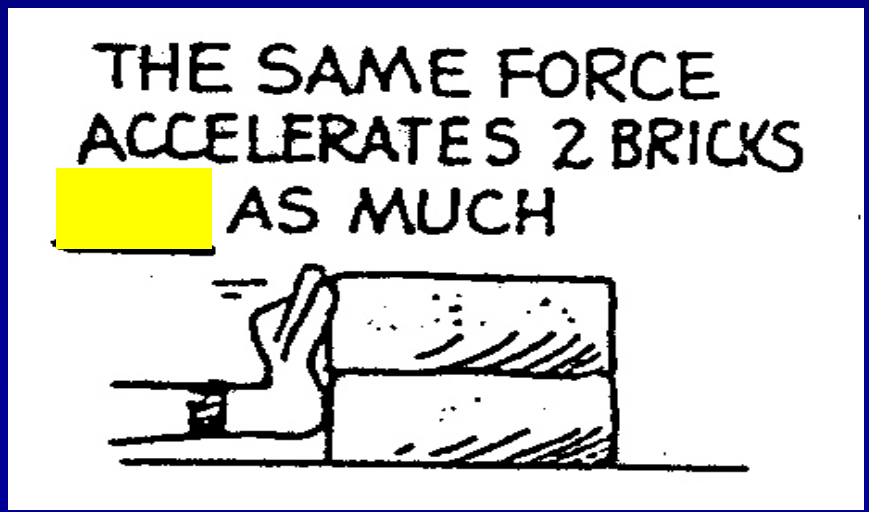
(with appropriate units of m/s^2 for a, newtons for F, kilograms for m)

F = ma


FORCE OF HAND
ACCELERATES
THE BRICK

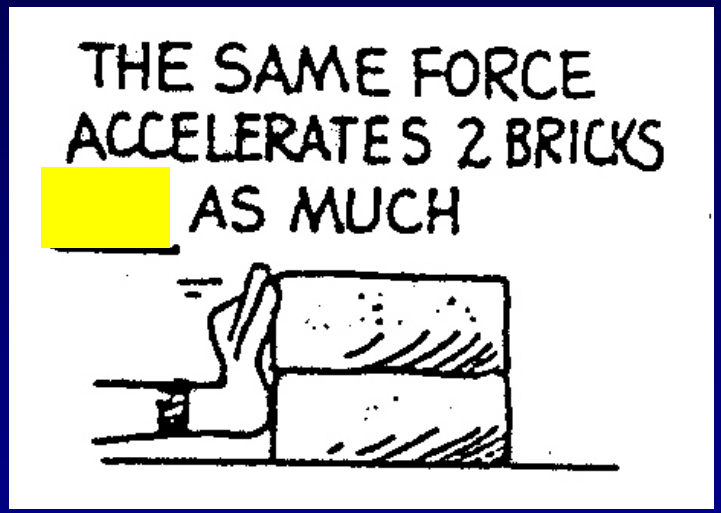

TWICE AS MUCH FORCE
PRODUCES TWICE AS
MUCH ACCELERATION

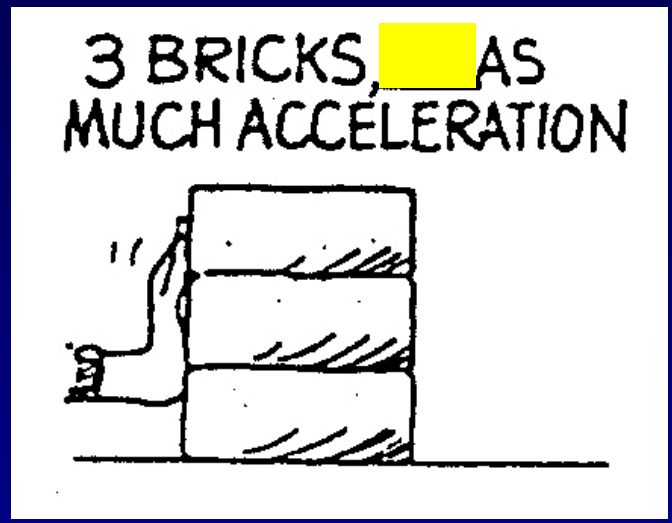

TWICE THE FORCE ON
TWICE THE MASS GIVES
THE SAME ACCELERATION


THE SAME FORCE
ACCELERATES 2 BRICKS
AS MUCH

F = ma

Q2: Fill in both blanks





CHOICES FOR ABOVE:

A = 1/2

B = twice

C = 1/3

CHOICES FOR ABOVE:

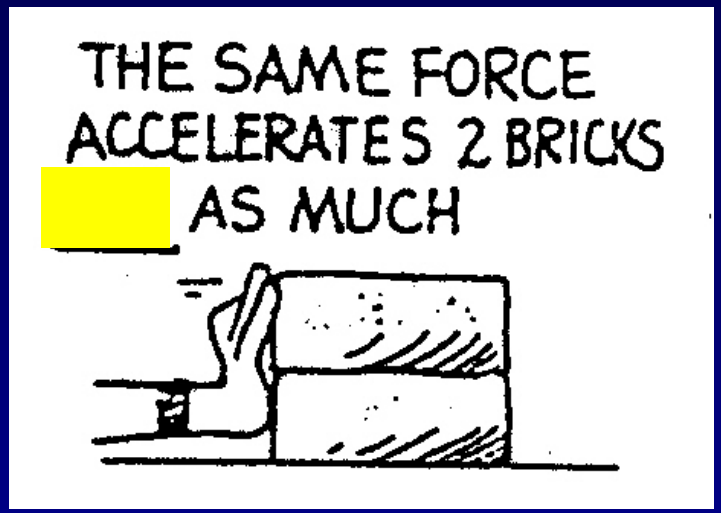
D = 3 times

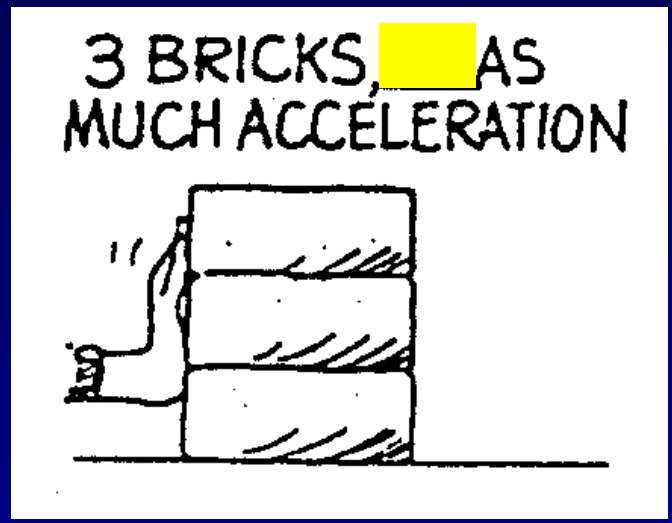
E = 6 times

F = 1/3

F = ma

Q2: Fill in both blanks





CHOICES FOR ABOVE:

A = 1/2 ←

B = twice

C = 1/3

CHOICES FOR ABOVE:

D = 3 times

E = 6 times

F = 1/3 ←

3rd Law of Motion
(Law of Force Pairs)

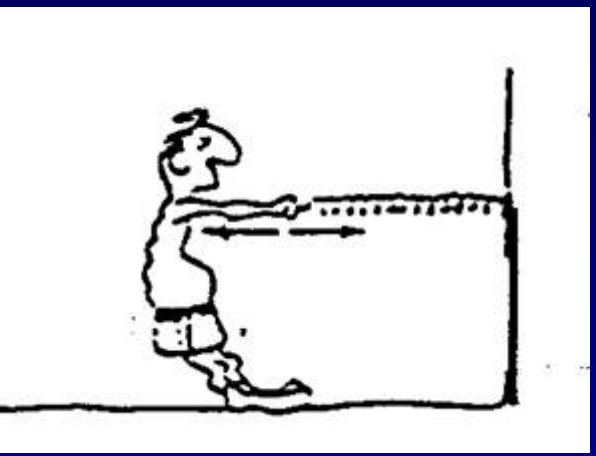
For every action there is an equal and opposite reaction.

3rd Law = "Law of Force Pairs"

- **Forces always occur in pairs**; an **action** and a **reaction**. To every action force there is an equal and opposite reaction force;

- whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first body.

- The two forces are equal in strength but opposite in direction. **There is never only a single force in any situation.**

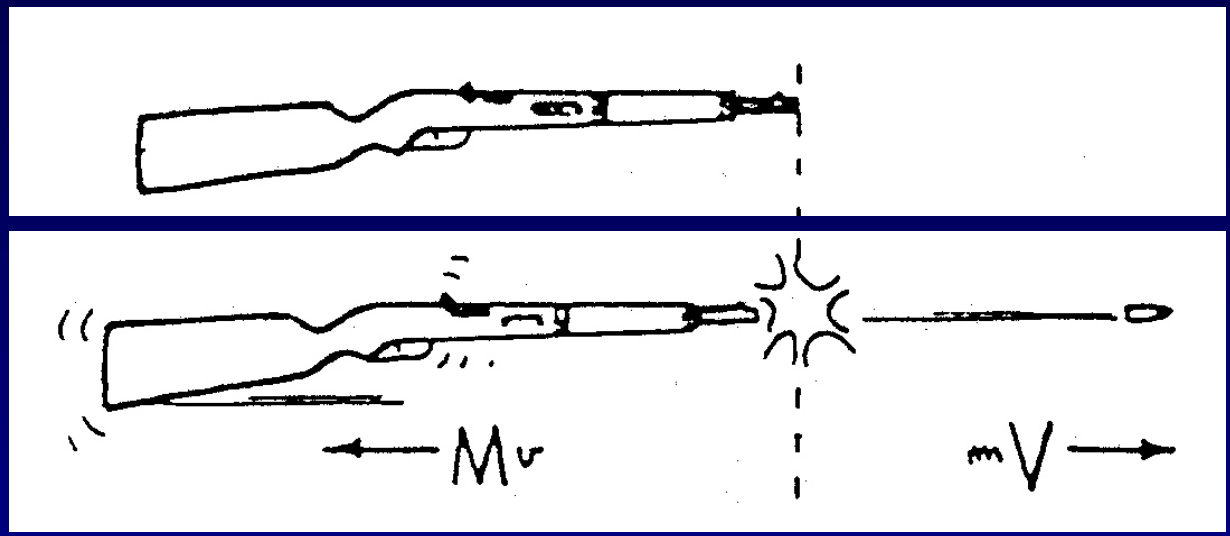


ACTION: Man pulls on spring

REACTION : _____ pulls on _____

String pulls on man

3rd Law: Force exerted on the bullet is exactly equal to the force exerted on the rifle, hence the rifle kicks back.



2nd law reminds that mass is involved!

Acceleration of bullet is large
(due to small mass of bullet)

$$\frac{F}{m} = a$$

Acceleration of recoiling rifle is smaller
(due to larger mass of rifle)

$$\frac{F}{m} = a$$

Remember this quote?

Newton's passage from a falling apple to a falling moon was an act of the prepared imagination.

~ John Tyndall (1820-1893)

Isaac Newton's Apple Tree in Lincolnshire, England

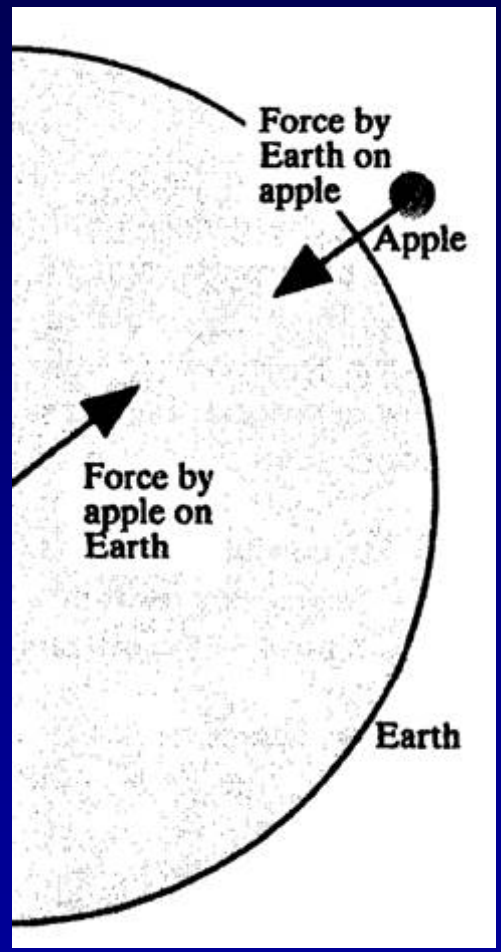
➔ Inspiration emerges from a well-informed mind!

NEWTON'S INSPIRATION = apple & moon!

Earth pulls on apple (gravity)

but . . .
THE APPLE ALSO PULLS ON THE EARTH!

(so small it cannot be measured -- but it is there)



➔ Newton likened the force pairs between the apple & earth
to the moon & the earth!

One more concept . . . .

Momentum = inertia in motion; or more specifically, the product of mass of an object and its velocity.

Momentum = mass x velocity

or $P = mv$

To change the momentum of something requires force and time
(HOW LONG THE FORCE ACTS)

Force * time interval = IMPULSE

IMPULSE (Ft) changes momentum

Force * time interval = change in (mass X velocity)

Ft = (change in) mv

"an external force is required to change the momentum of a body"

Take notes

Principle of Conservation of Momentum

When no external net force acts on an object or a system of objects, no change of momentum takes place.

No external net force ➔ no change in momentum

Hence, the momentum BEFORE the event (involving internal forces) is equal to the momentum AFTER the event:

Quick Review: Forms of Energy

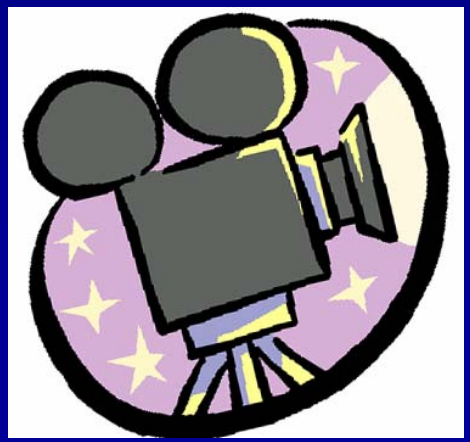
- **Kinetic** (KE or KinE) = energy of *motion*; the ability of a mass to do work.

KE = ½ (mass x velocity^2) or KinE = (1/2) ms ^{2}

- **Potential** (PE) = energy a system possess if it is capable of doing work, but is *not* doing work now
  - Includes: **gravitational, elastic, chemical, electrical, and magnetic**

"Understanding Car Crashes It's Basic Physics"

As you watch the video, fill in the blanks on pp 47-48 in CLASS NOTES.



G-3 YOUR CAR & GLOBAL CHANGE

(Part 1)

SAFETY vs. ENVIRONMENT??

What kind of car do you drive???

Dr H and her hummer

??????????

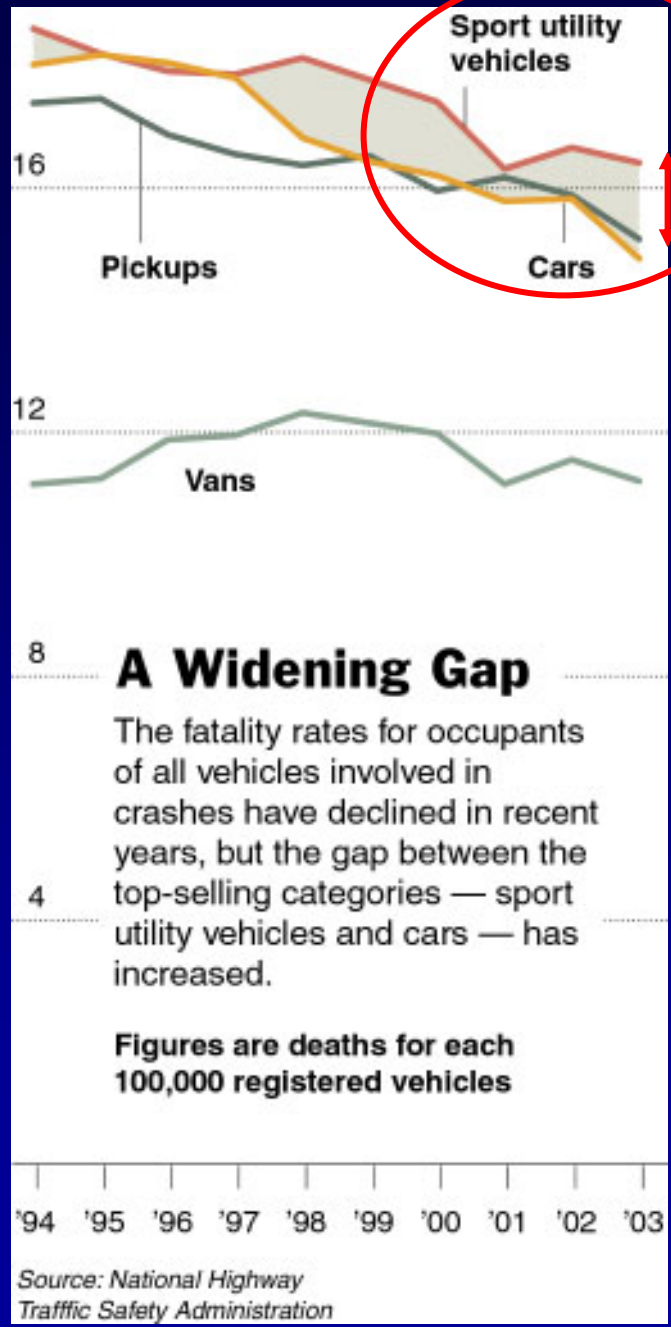
Wow! Six SUVs in a row! Is this a ski resort or hunting lodge?

No....it's a suburban apartment complex in FLORIDA!!!

G-3 Your CAR & GLOBAL CHANGE

Fatality Rates for occupants of all vehicles involved in crashes

(deaths per 100,000 vehicles)




CAN YOU BELIEVE
GAS IS OVER T
BUCKS A GAL
GREED
'N
GO
FOSSIL
FOOL
ON
BOARD
PLUNDER
THE
PLANET
PIG
SWIG
Chevron
SELF-
CONTRO
CLOSED
THRILLIN'
GUZZLEGUY
HUGGED
IG TODAY?


JIM BRENEMAN
CINCINNATI ENQUIRER ©2005
SELECT PRICE YOU'RE WILLING TO PAY:
DEEPER INVOLVEMENT IN MIDDLE EAST
IRREPARABLE DAMAGE TO PRISTINE WILDERNESS
TAKE PUBLIC TRANSPORTATION
DOWNSIZE TO FUEL EFFICIENT VEHICLE

GLOBAL CHANGE LINK:

For every gallon of gas you use, you add ~ 22 pounds of CO_2 to the atmosphere.

Recall Newton's 1st and 2nd Laws.

Now consider the mass (and acceleration capabilities) of a large SUV (sport utility vehicle) vs. a small sedan and answer the following:

Q3: An SUV and a small sedan are both at rest at a stop light. Which vehicle has a greater inertia?

Q3 Choices:

1 = The SUV has a greater inertia because it has a greater mass and resistance to acceleration.

2 = The sedan has a greater inertia because it has a greater ability to accelerate.

3 = Since both are at rest, their inertia is the same.

Q3: An SUV and a small sedan are both at rest at a stop light. Which vehicle has a **greater** <u>inertia</u>?

1. The SUV has a greater inertia because it has a greater mass and resistance to acceleration.
2. The sedan has a greater inertia because it has a greater ability to accelerate.
3. Since both are at rest, their inertia is the same.

Q4: If the mass of the SUV is three times that of the sedan,

the same amount of force (via consumption of gasoline) **will accelerate the SUV ____ as much as the sedan (all other things being equal in the two engine designs)?**

Q4 Choices:

1 = 3 times

2 = 1/3 ←

3 = nine times

Now imagine that the two vehicles are moving down the freeway side by side at equal velocities of 75 mph.

Suddenly, after rounding a curve, the drivers encounter a large semi-truck at a standstill that has jacknifed across both lanes.

If the two vehicles have comparable brakes, which one is most in danger of smashing into the truck ahead? _____

Explain why, using the term **momentum.**

CLASS DISCUSSION BACKGROUND:

-- Many people own SUVs because they feel safer in them and personal safety for oneself and one's family is clearly an extremely important consideration when buying a vehicle.

--- At the same time, some SUV's have notoriously low gas mileage and hence contribute much more CO_2 to the atmosphere than smaller and more fuel efficient cars.

-- For years SUV's, pickups & minivans were held to less stringent emissions controls than regular passenger cars. In March 2006, the government finalized new regulations for SUVs, minivans and pickup trucks, calling for modest improvements in fuel efficiency in SUVs, pickups and minivans.

CAFE = Corporate Average Fuel Economy

- **1975 Energy Policy and Conservation Act of 1975 established Corporate Average Fuel Economy [CAFE] standards for passenger cars and light trucks.**

- **passed in response to the 1973-74 Arab oil embargo.**

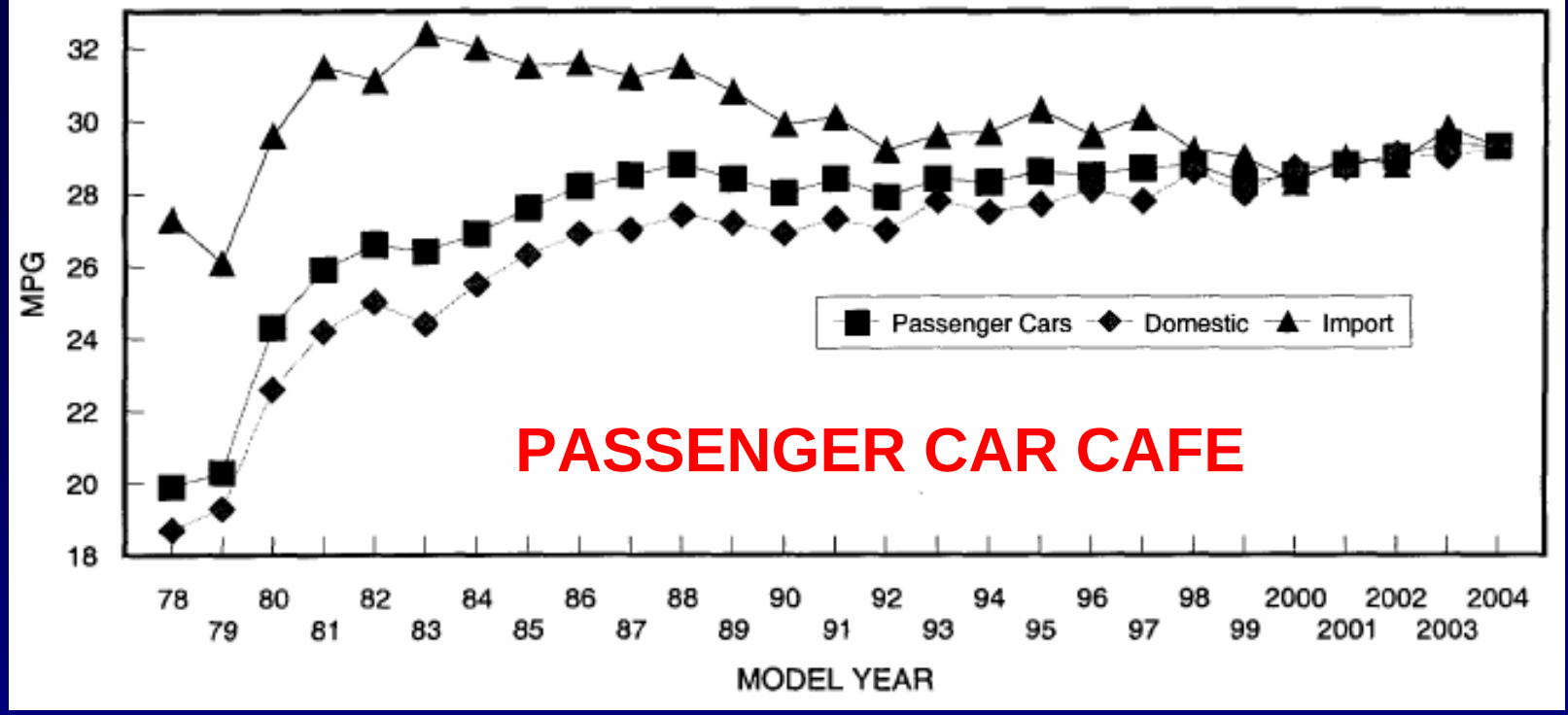
- **stated near-term goal was to double new car fuel economy by 1985**

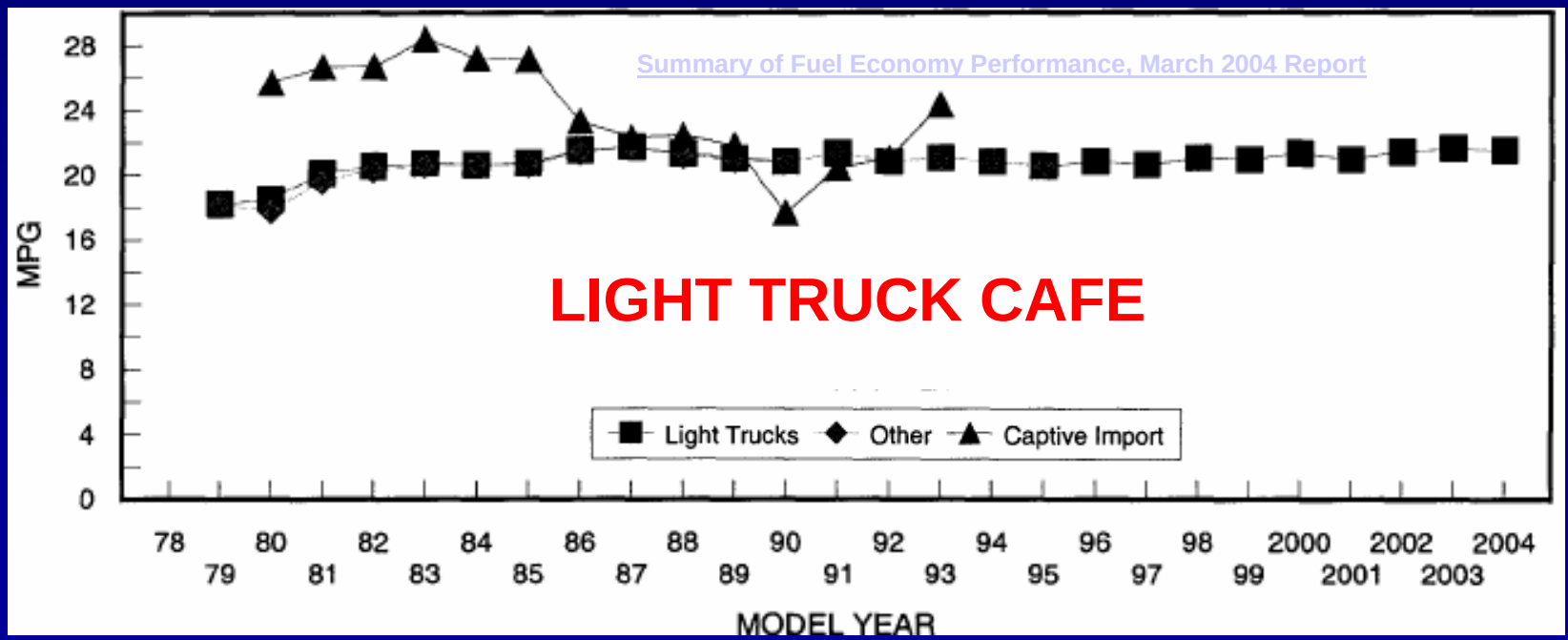
- **passenger cars & light trucks required to meet CAFE standards**

- **standards applies on a fleet-wide basis for each manufacturer**
  entire line of passenger cars: avg = 27.5 mpg
  light trucks (including vans & SUVs): avg = 20.7 mpg. (2003-04)

- **manufacturers earn "credits" for exceeding CAFE standards; can be used to offset fuel economy shortfalls over +/- 3 model yrs**

- **Total fleet fuel economy peaked in 1987 at 26.2 mpg when light trucks made up a mere 28.1 percent of the market. In 2004, light trucks made up more than 50 percent of new vehicle sales!**


MPG
32
30
28
26
24
22
20
18
Passenger Cars
Domestic
Import
PASSENGER CAR CAFE
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 2000 2001 2002 2003 2004
MODEL YEAR


Summary of Fuel Economy Performance, March 2004 Report
MPG
28
24
20
16
12
8
4
0
Light Trucks
Other
Captive Import
LIGHT TRUCK CAFE
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 2000 2001 2002 2003 2004
MODEL YEAR

• **April 2003: National Highway Traffic Safety Administration promulgated a final rule establishing the average fuel economy standards for light trucks that will be manufactured in the 2005-2007 model years (MYs).**

The 2003 standards for all light trucks manufactured were set at:

- **21.0 mpg for MY 2005**
- **21.6 mpg for MY 2006**
- **22.2 mpg for MY 2007**

See: http://www.fueleconomy.gov/

New "Reformed" standards put forward in Mar 2006: http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.d0b5a45b55bfbe582f57529cdba046a0/

MY 2008: From 26.8 mpg for the smallest vehicles to 20.4 mpg for the largest;
MY 2009: From 27.4 mpg for the smallest vehicles to 21.0 mpg for the largest;
MY 2010: From 27.8 mpg for the smallest vehicles to 20.8 mpg for the largest;
MY 2011: From 28.4 mpg for the smallest vehicles to 21.3 mpg for the largest.

Claimed Differences Between the Proposed and Final CAFE Light Truck Rule

Proposed CAFE Light Truck Rule (August 2005)	**Final CAFE Light Truck Rule (March 2006)**
"Six" Size Categories With Their Own Miles Per Gallon Target	**Stronger Miles Per Gallon Target for All Light Trucks**
Largest SUVs Not Included	**Largest SUVs Included**
Average Miles Per Gallon: 24	**Average Miles Per Gallon: 24.1 (24 with Largest SUVs included)**
9 Billion Gallons of Fuel Saved*	**10.7 Billion Gallons of Fuel Saved**

QUESTION:

Is it environmentally irresponsible to own an SUV or pickup truck that gets mileage of LESS than 20-21 mpg?

The McLaughlin GROUP

http://www.mclaughlin.com

Eleanor Clift

John McLaughlin

Tony Blankley

Pat Buchanan

Mort Zuckerman

McLaughlin's Question:

Suppose the traffic accident mortality rate goes up because cars are made smaller to preserve fuel.

Is that a good trade-off . . . bodies for barrels?

G-3 Part A:

(will take place in your groups after the GROUP TEST on Thursday Sept 14)

"GC McLaughlin Group" DISCUSSION

QUESTION #1: Is it environmentally irresponsible to own an SUV or pickup truck that gets mileage of LESS than 20 mpg? **Yes or No & why/why not**

QUESTION #2: Suppose the traffic accident mortality rate goes up because cars are made smaller to preserve fuel. Is that a good trade-off? **Yes or No & why/why not**

QUESTION #3: Frame your group's OWN Question, answer it & discuss it: