Unit 6

Newton's Laws

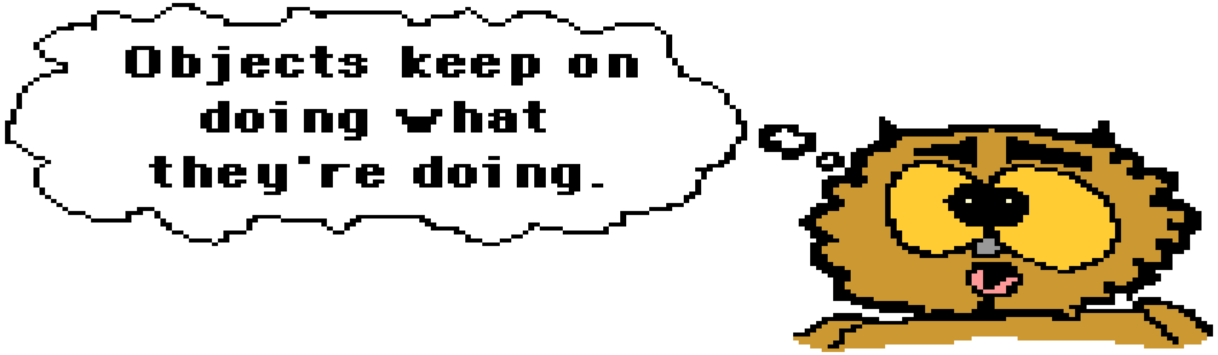
Vocabulary

- Mass – A measure of the amount of inertia.
- Inertia – The tendency of an object to resist change in motion; more specifically… to **resist change in acceleration**.

More mass = more inertia
Less mass = less inertia

Newton's First Law of Motion

- Objects at rest stay at rest until acted upon by an outside force.
- Objects in motion will stay in *straight line* motion until acted upon by an outside force.
- This is only true if the object is acted upon by forces that are zero or balanced.



What is a force?

- A force is a push or a pull on an object.

- There are two general kinds of forces.
  - Contact Force – requires two objects to touch each other
    - Pushing a sled, kicking a ball

  - Noncontact Force – does not require contact
    - gravity

Types of Forces

- F_g – <u>Force of Gravity</u> ("Earth on Mass")
  * Always present; points downward
  * Measurement of the **<u>weight of an object</u>**

- F_N – <u>Normal Force</u> ("Surface on Mass")
  * Need contact with a **<u>hard surface</u>**
  * Points perpendicular to surface

- F_f – <u>Force of Friction</u> ("Surface on Mass")
  * Opposes motion or an attempt at motion
  * Points parallel to surface

- F_A – <u>Applied Force</u>
  * A push or a pull
  * Examples: Tension, Spring, Thrust

Representing Forces

- Freebody (force) diagrams
- The object is represented by a small dot.
- The dots are surrounded by arrows that represent all of the forces that act on a given object.
- The length of the arrow represents the size of the force.
  i.e. A long arrow would have a larger force than a small arrow
- The direction of the arrow shows force is a vector!

Practice

- A book held in your hand at rest.
- A book is sliding across the desk at a constant velocity. *Assume **no** friction.*
- A book just after you removed your hand from underneath.
- A book pushed at a constant velocity across the desk by your hand. *Assume friction.*
- A book at rest on a desk when your hand is pushing down on it.

More Practice

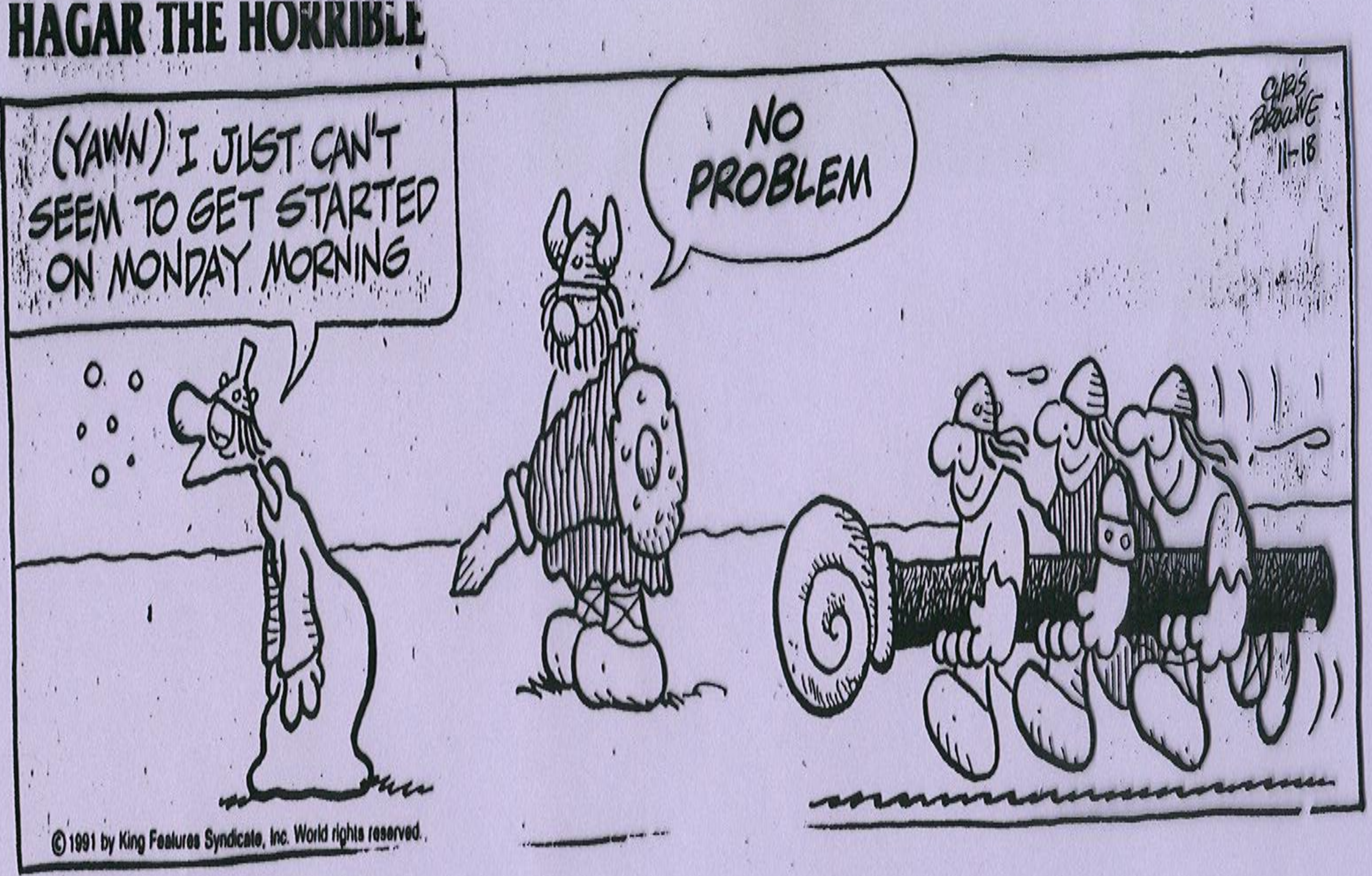
- Bob pushes a crate with a 10 N force to the right while Mark pushes to the left with a 5 N force. Draw a free body diagram for the crate.

- A boy is standing on the playground pulling a sled with 2 more boys on it. The weight of the sled is 200 N and the boy pulls with 100 N of force. Draw a free body diagram for the sled.

Newton's 1st Law Summary

- If the sum of the forces **equals zero, or is balanced** (the object is said to be in **equilibrium**)…
  - The object is at **rest ($v = 0$ m/s)**
  - The object is moving at **constant velocity**

- If the sum of the forces does **not equal zero**…
  - The object is **accelerating**
  - The object's **velocity or direction is changing!**


HAGAR THE HORRIBLE
(YAWN) I JUST CAN'T SEEM TO GET STARTED ON MONDAY MORNING
NO PROBLEM
CHRIS BROWNE 11-18
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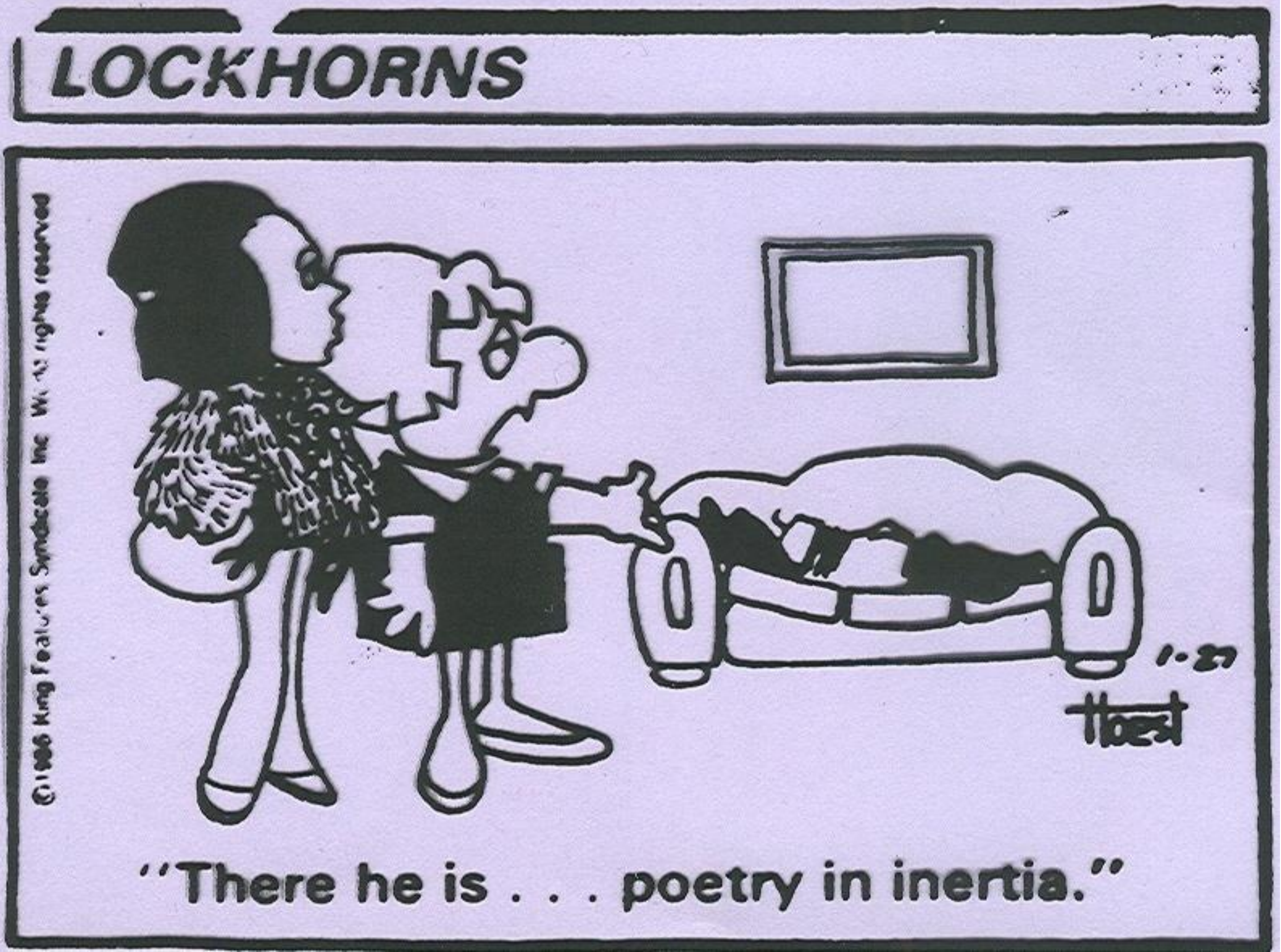
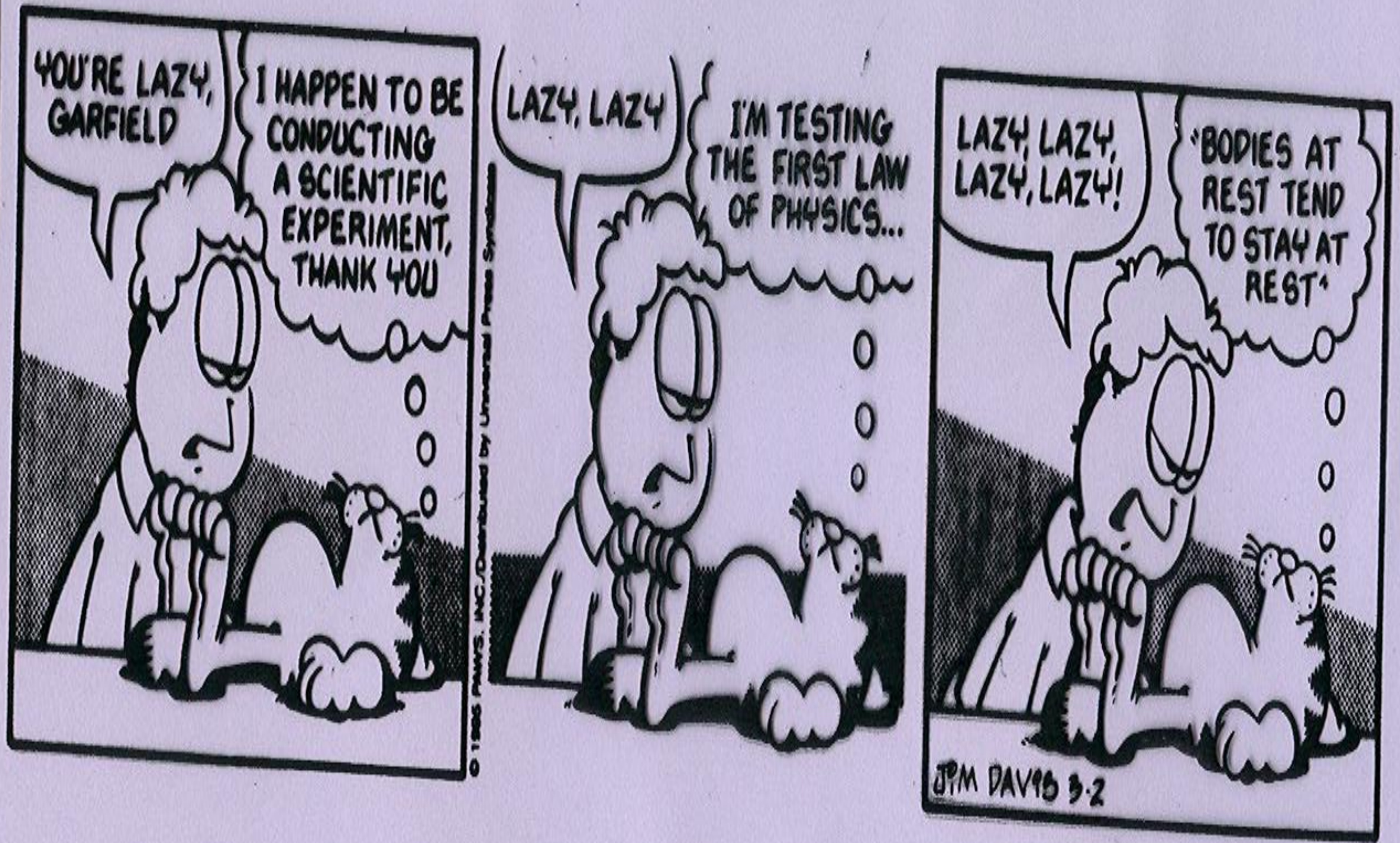


"There he is . . . poetry in inertia."

THE INTELLIGENCER ♦ THE RECORD Thursday, March 2, 1995 Page D-7

GARFIELD



Newton's 1st Law Review

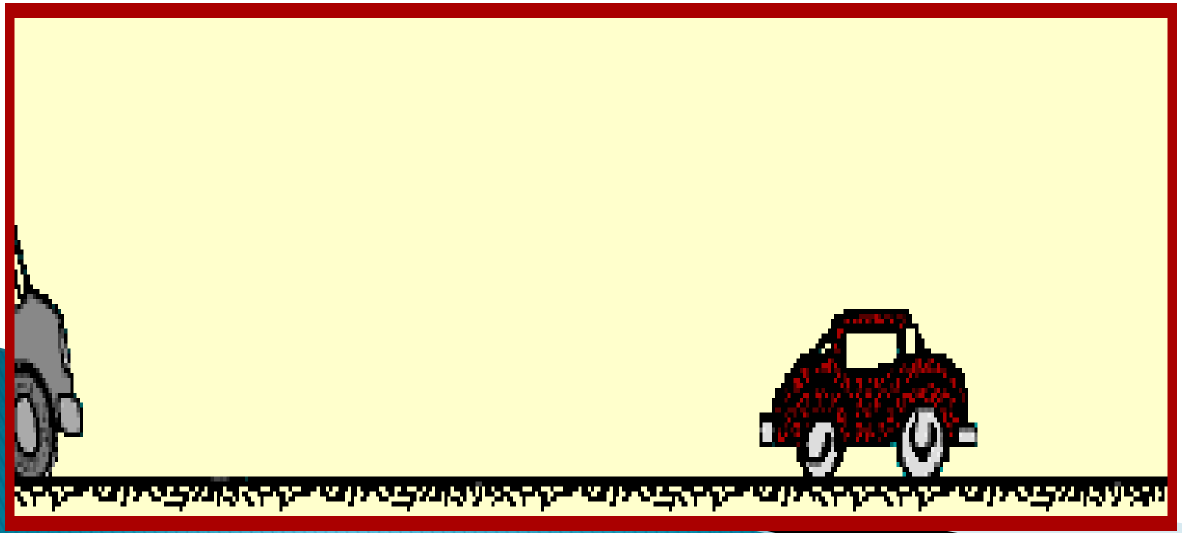
- Check Your Understanding with Physics Classroom :
  [Newton's Laws – Lesson 1]

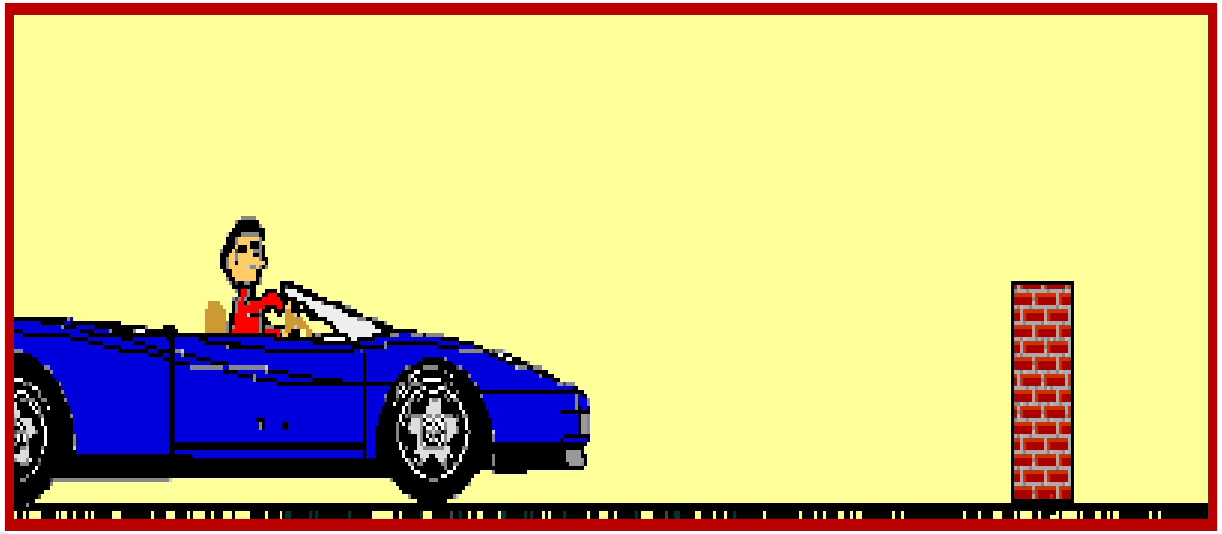
Newton's Law Animations

Remember…

If the sum of the forces does **not equal zero**…
* the object is **accelerating**

If the sum of the forces **equals zero**…
* the object is at **rest** -OR-
* the object is moving at **constant velocity**





Net Force

- If the forces up/down & left/right balance…

  net F = 0

  * This is an example of *rest* or *constant velocity*

- If the forces up/down & left/right do not balance…

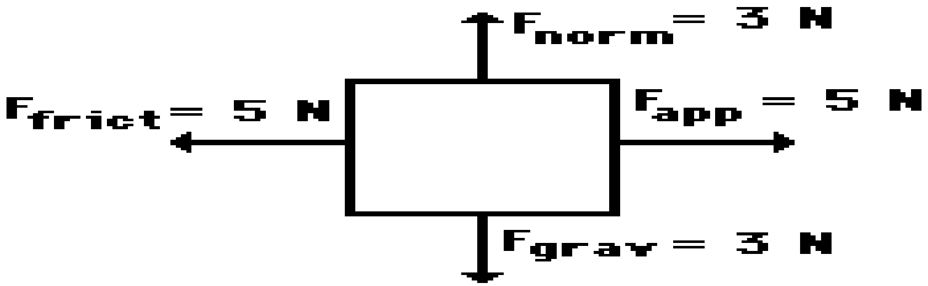
  net F ≠ 0

  * This is an example of *acceleration*

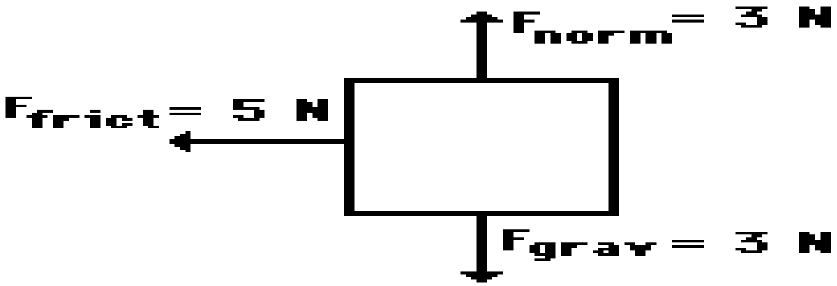
Examples of Net Force

- In each situation below…
  a) determine the net force
  b) decide if the object is at rest/constant velocity or accelerating

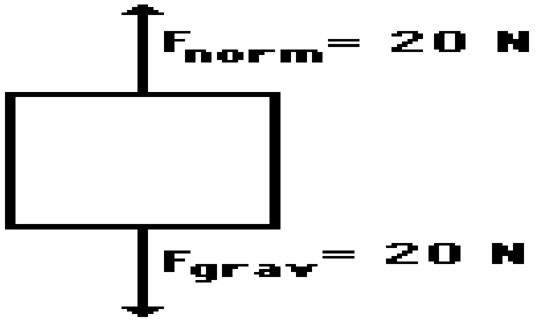
Situation A



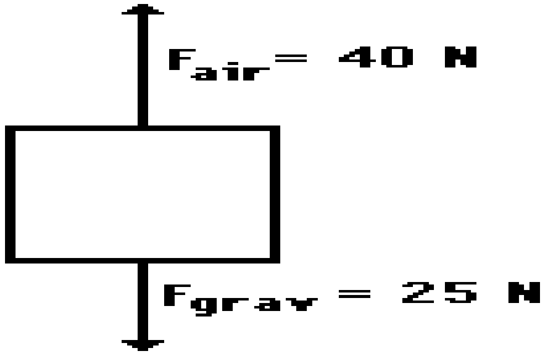
Situation B



Situation C



Situation D



Mass & Weight – $F_g = ma_g$

- **Mass** – symbol: m, units: kg
  - An intrinsic property of matter that does not change as an object is moved from one location to another.
- **Weight** – symbol: Fg, units: N
  - The force of gravity acting on the object and can vary from one location to another.
- Mass and weight are different quantities. They cannot be interchanged when solving problems!

Practice

- A rightward force of 60 N is applied to a book so that it moves with a constant velocity. Friction is present.

A) Draw the freebody diagram.

B) If the book has a mass of 45 kg, calculate its weight.

C) What is the normal force?

D) What is the frictional force?

Newton's Second Law

- Net F = ma

- The acceleration of an object is dependent upon the following:

1) **the net force acting on an object.**
   If the mass is held constant, acceleration is directly proportional to net force.

2) **the mass of an object.**
   If the net force is held constant, acceleration is inversely proportional to mass.

Practice – Newton's 2nd & Constant Acceleration

1

A bike has a mass of 18 kg. Someone pushes sideways with a force of 20 N to cause the bike to move to the left. The frictional force along the floor is 12 N.

a) Draw a free body diagram with labeled force values.

b) What is the acceleration of the bike?

c) What is the coefficient of kinetic friction?

Practice – Newton's 2^{nd} & Constant Acceleration

2

An applied force of 30 N is used to accelerate an object that weighs 60 N to the right across a frictional surface. The object encounters 15 N of friction. Draw a diagram and determine the following:

a) the normal force
b) the net force
c) the mass
d) the acceleration of the object
e) the coefficient of kinetic friction

Practice – Newton's 2nd & Constant Acceleration

3

A 873-kg dragster, starting from rest, attains a speed of 26.3 m/s in 0.59 s.

a) Draw a free body diagram.

b) Find the average acceleration of the dragster during this time interval.

c) What is the average net force on the dragster during this time?

Practice – Newton's 2nd & Constant Acceleration

4

After a day of testing race cars, you decide to take your own 1550-kg car onto the test track. While moving down the track at 10.0 m/s, you uniformly accelerate to 30.0 m/s in 10.0 s. What is the average net force that the track has applied to the car during this time? *Draw a labeled FBD first!*

Practice – Newton's 2nd & Constant Acceleration

5

A ball has a mass of 2 kg. Someone pushes sideways with a force of 5 N to cause the ball to move to the right. The coefficient of kinetic friction between the surface and the ball is 0.15.

a) Draw a free body diagram with labeled force values.
b) What is the acceleration of the ball?

Practice – Newton's 2nd & Constant Acceleration

6

A race car has a mass of 710 kg. It starts from rest and travels 40.0 m in 3.0 s. The car is uniformly accelerating during the entire time. What is the net force exerted on it?

Practice – Newton's 2nd & Constant Acceleration

7

The propellers of a small airplane produce a forward thrust of 62,000 N on the plane which has a mass of 28,000 kg. Assume that air resistance is negligible.

a) If the plane is flying horizontally, what isthe lift (upward force of air) on the plane?
b) What is the plane's forward acceleration.

Practice – Newton's 2nd & Constant Acceleration

8

A girl in a canoe uses a paddle to push the canoe at rest from a dock giving it a speed of 0.30 m/s. If the paddle is in contact with the dock for 0.75 seconds, what is the average net force on the canoe? (The mass of the canoe is 27 kg and that of the girl is 52 kg.)

Practice – Newton's 2nd & Constant Acceleration

9

For a warm up drill, the soccer coach asks the players to dribble the 1.5-kg ball at constant velocity. The players must apply an 5 N force to the ball. Assume friction is present between the ball and the grass.

a) Draw a free body diagram with labeled force values.

b) What is the coefficient of kinetic friction?

c) What is the acceleration of the ball?

Practice – Newton's 2nd & Constant Acceleration

10

A 65-kg swimmer jumps off a 10.0-m tower.

a) Find the swimmer's velocity as he hits the water.
b) The swimmer comes to a stop 2.0 m below the surface. Using your above answer as v_i, along with other variable you can determine from this description, find the net force exerted by the water.

Practice – Net F to Solve for Individual Forces

1

A 75-kg person is standing on a bathroom scale in an elevator going up! Starting from rest, the elevator accelerates at $+2.0\ m/s^2$ for 2 s, then continues at a constant speed. What is the scale reading (what is the apparent weight of the rider) during the acceleration?

Practice – Net F to Solve for Individual Forces

2

A tow rope is used to pull a 1750-kg car, giving it an acceleration of 1.35 m/s^2. If the frictional force is 600 N, what force does the rope exert?

Practice – Net F to Solve for Individual Forces

3

A 50-kg bucket is being lifted by a rope. The rope is guaranteed not to break if the tension is 500 N or less. The bucket started at rest, and after being lifted +3.0 m, it is moving at 3.0 m/s. Assume the acceleration is constant.

a) What is the tension (F_A) in the rope?

b) Is the rope in danger of breaking?

Practice – Net F to Solve for Individual Forces

4

The instant a skydiver pulls his parachute he accelerates up at 3.0 m/s^2 for 3 s. If this diver has a mass of 75 kg, what is the frictional force (force due to air resistance) exerted on the diver? *Draw a labeled FBD first!*

Practice – Net F to Solve for Individual Forces

8

The Rock 'n Roller Coaster at Disney's Hollywood Studios has a mass of 1800 kg. It starts from rest and travels 110.0 m in 7.0 s. An applied force of 8744 N is required to accelerate the coaster during this time.

a) What is the force of friction the car experiences from the track?

b) What is the coefficient of kinetic friction between the track and coaster?

Practice – Net F to Solve for Individual Forces

5

In bench pressing 100 kg, a weight lifter applies a force of 1040 N. How large is the upward acceleration of the weights during the lift?

Practice – Net F to Solve for Individual Forces

6

The maximum force a Gap clothing bag can withstand and not rip is 130 N. If 12.0-kg of clothing (jeans, sweaters, etc.) is lifted from the ground to the trunk of your car with an acceleration of 5.5 m/s^2, will the bag hold?

Practice – Net F to Solve for Individual Forces

7

A 60 kg bucket is being lifted by a rope. The rope is guaranteed not to break if the tension is 670 N or less. The bucket started at rest, and after being lifted 3.5 m, it is moving at 2.75 m/s. Assuming that the acceleration is constant, is the rope in danger of breaking?

Practice

- In a supermarket parking lot, an employee is pushing 10 empty shopping carts, lined up in a straight line. The acceleration of the carts is 0.05 m/s2. The ground is level, and each cart has a mass of 26 kg.
  a) What is the net force acting on any one of the carts?

  b) Assuming friction is negligible, what is the force exerted by the 5^{th} cart on the 6^{th} cart?

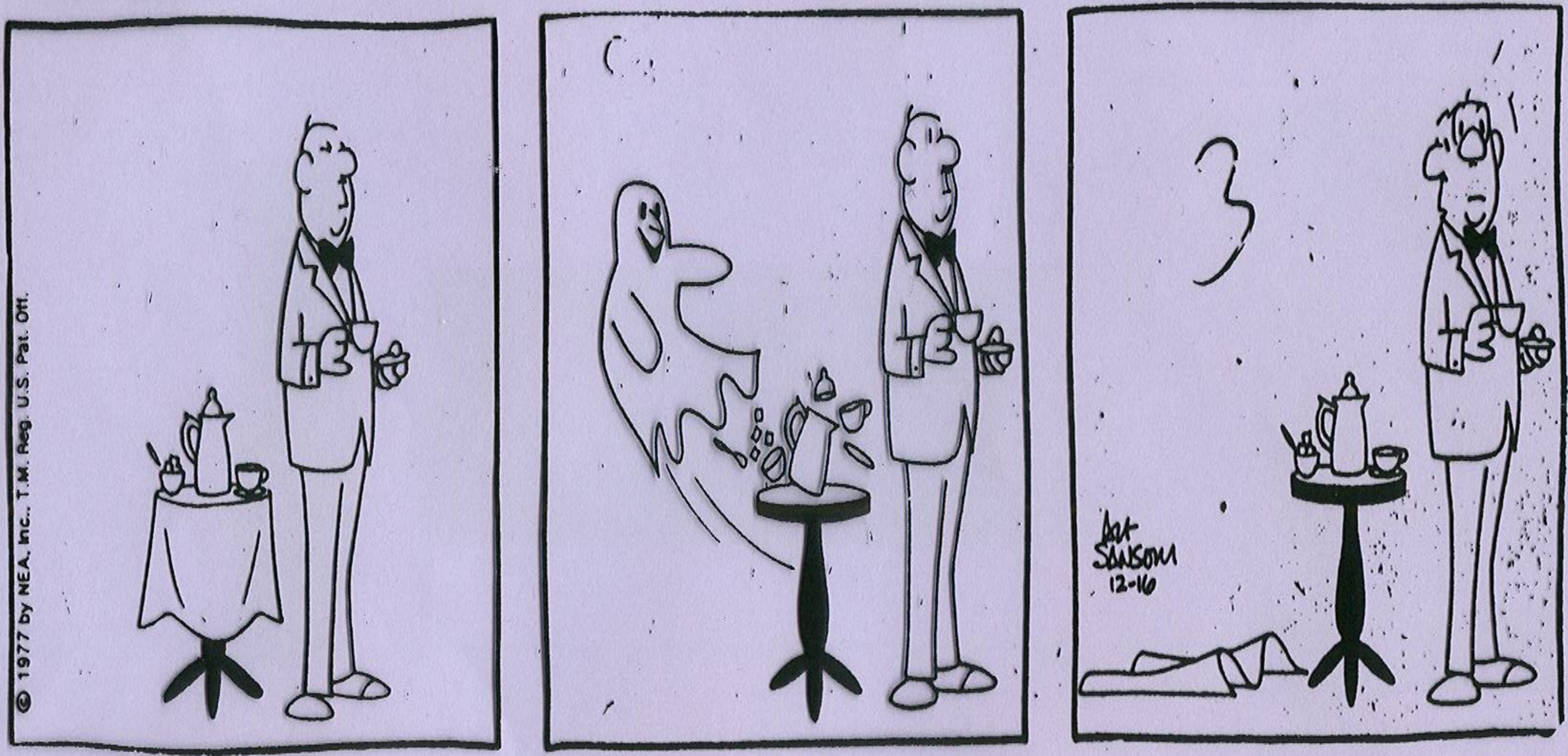
Practice

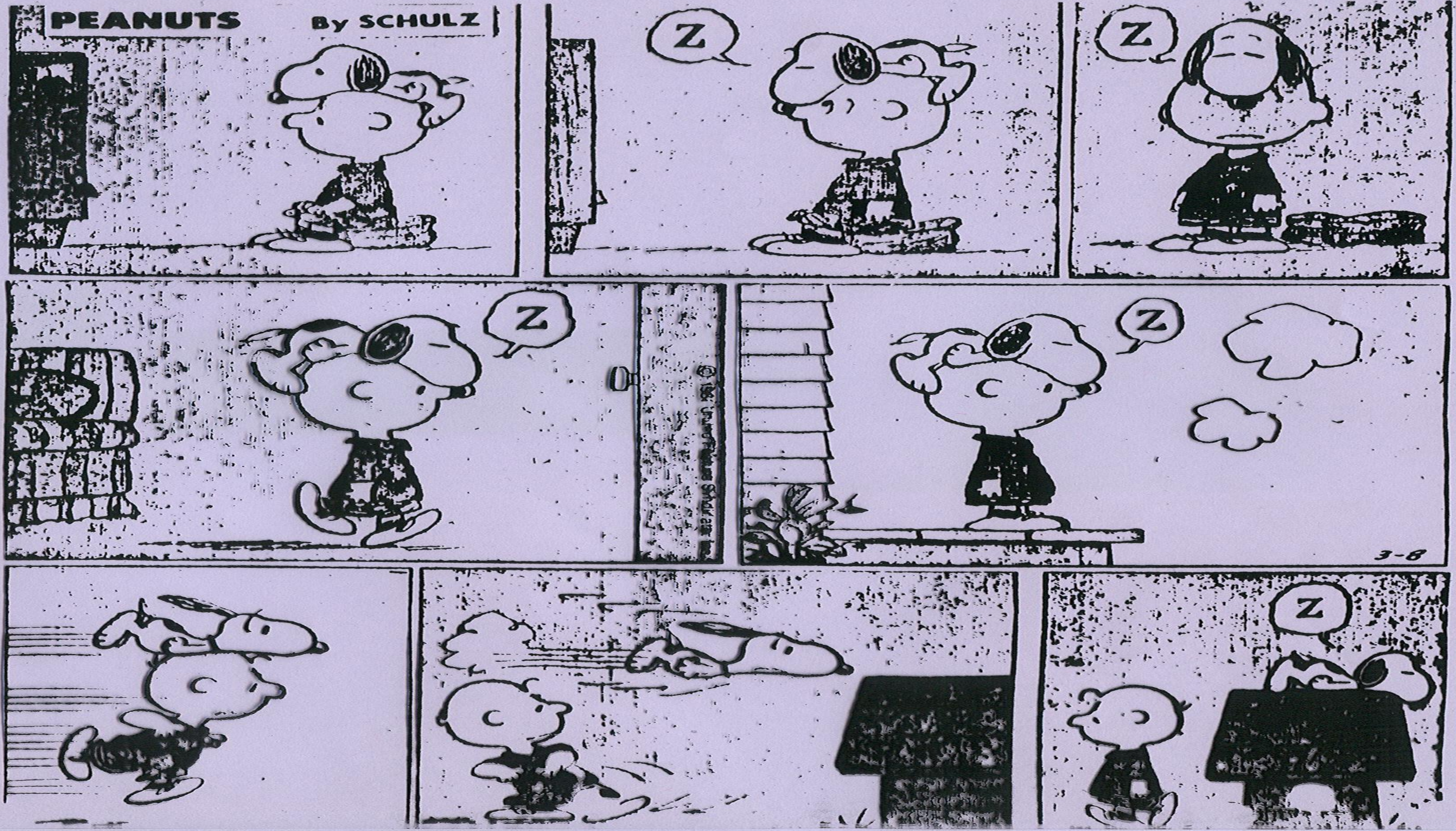
- A car is towing a boat on a trailer. The driver starts from rest and accelerates to a velocity of +11 m/s in a time of 28 s. The combined mass of the boat and trailer is 420 kg. The frictional force acting on the trailer can be ignored. What is the tension in the hitch that connects the trailer to the car?

Practice

- A fisherman is fishing from a bridge and is using a "45-N test line." In other words, the line will sustain a maximum force of 45 N without breaking. What is the mass of the heaviest fish that can be pulled up vertically when the line is reeled in…
  a) at a constant speed?
  b) with an acceleration of 2.0 m/s^2

BORN LOSER




PEANUTS
By SCHULZ
Z
Z
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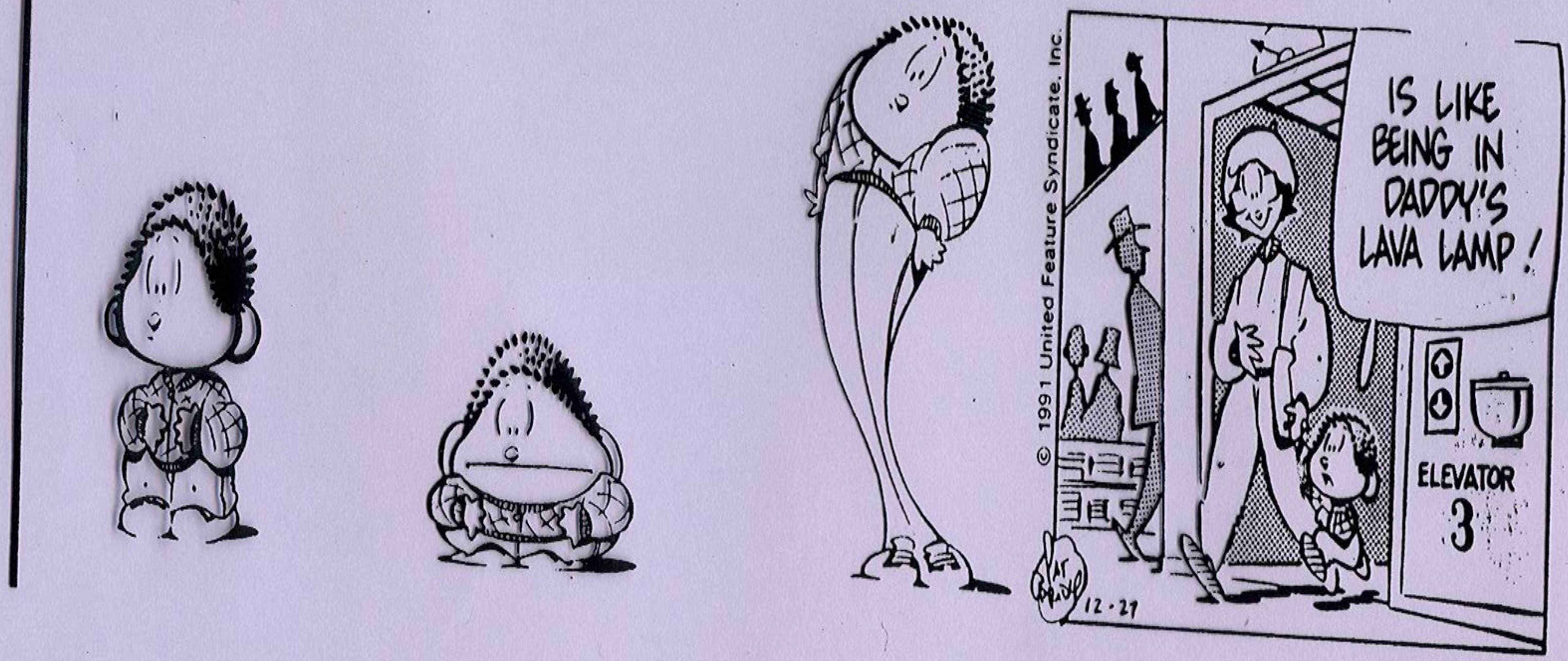
3-8

ROSE IS ROSE


IS LIKE BEING IN DADDY'S LAVA LAMP!
ELEVATOR
3
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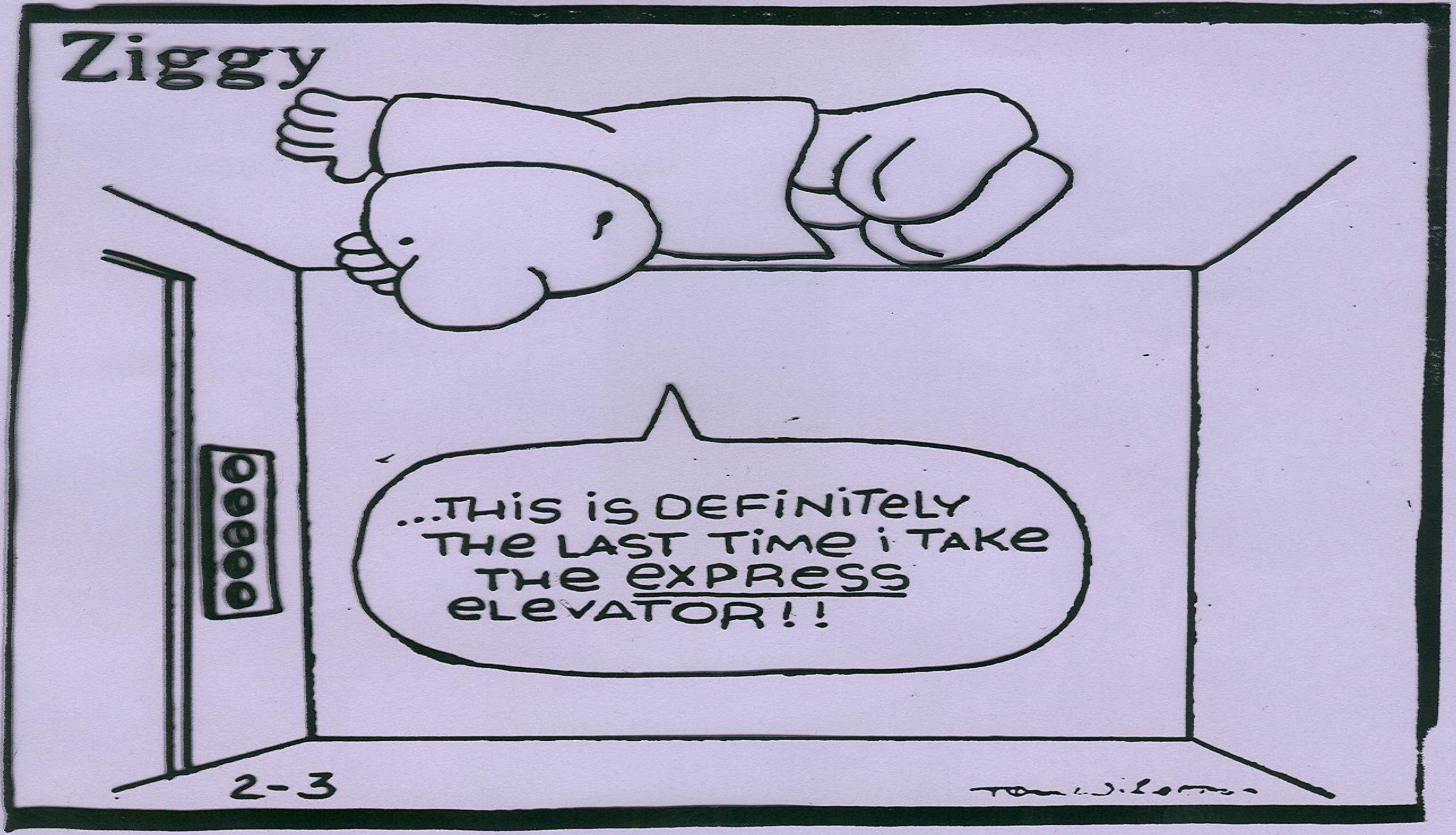
12·27


Ziggy
...THIS IS DEFINITELY THE LAST TIME I TAKE THE EXPRESS ELEVATOR!!
2-3

An 80-kg man is leaving work for the day and gets on the elevator from his 10^{th} floor office in the city. He first speeds up at 4.5 m/s^2, then achieves constant velocity before finally slowing down at 4.0 m/s^2.

Draw a motion map for his entire trip down to the ground floor. Include velocity, acceleration and net force.

Draw a force diagram for each part of the trip and include the values for each identified force.

An 15-kg child gets on an elevator with his mom. They are going to the doctor's office on the 3rd floor. The elevator first speeds up at 3.0 m/s^2, then achieves constant velocity before finally slowing down at 4.0 m/s^2.

Draw a motion map for the entire trip down to the 3rd floor. Include velocity, acceleration and net force.

Draw a force diagram for each part of the trip and include the values for each identified force.

Imagine a bug getting hit by a car…

- If the car is moving with some velocity v_C, and hits a bug that is stationary (at rest), who feels more force, the bug, the car, both are the same, both feel nothing?

- If the car is at rest and the bug has velocity v_B, who feels more force, the bug, the car, both are the same, both feel nothing?

- If they both have velocity towards each other, who feels more force, the bug, the car, both are the same, both feel nothing?

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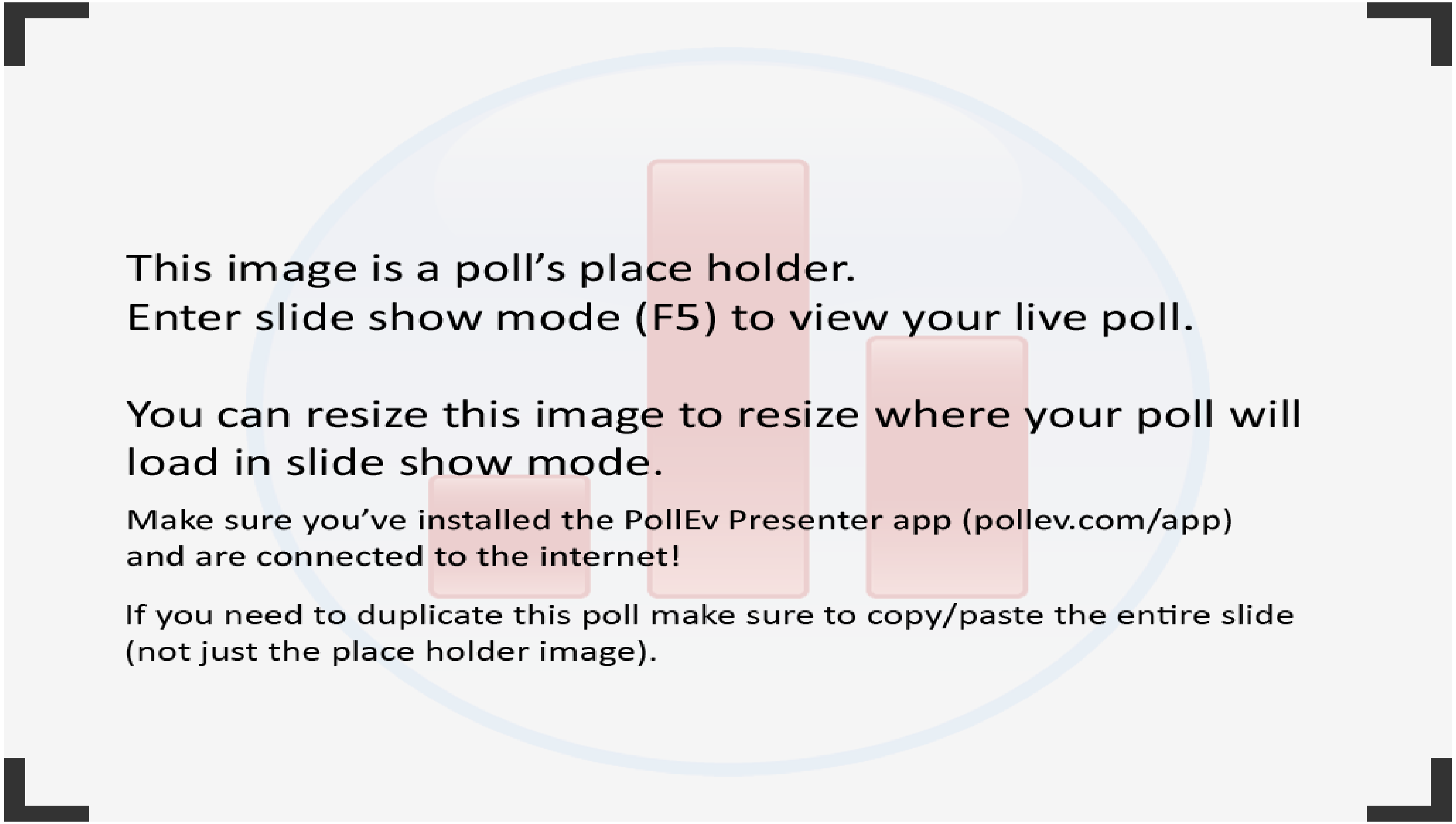
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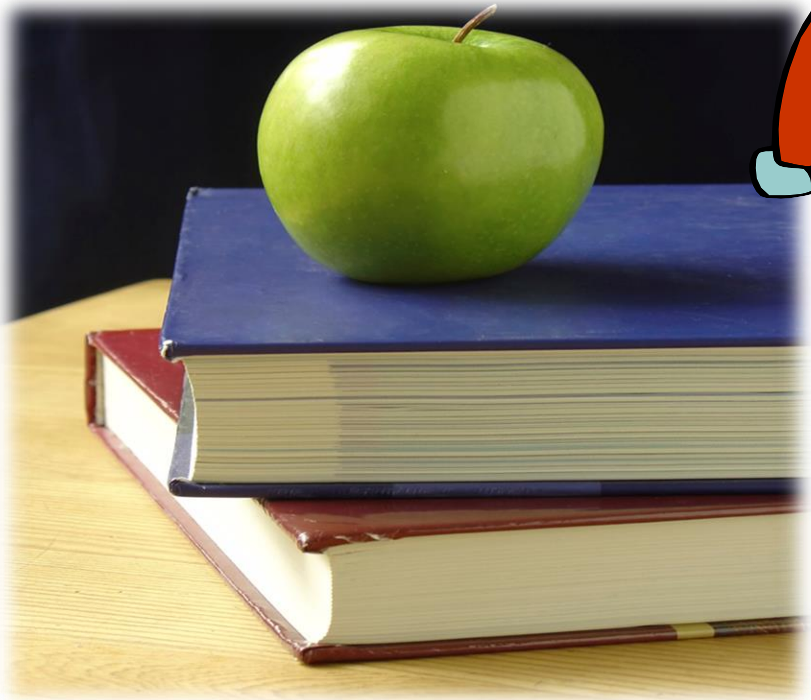
Newton's 3rd Law

- Involves the interaction of 2 masses and 2 forces

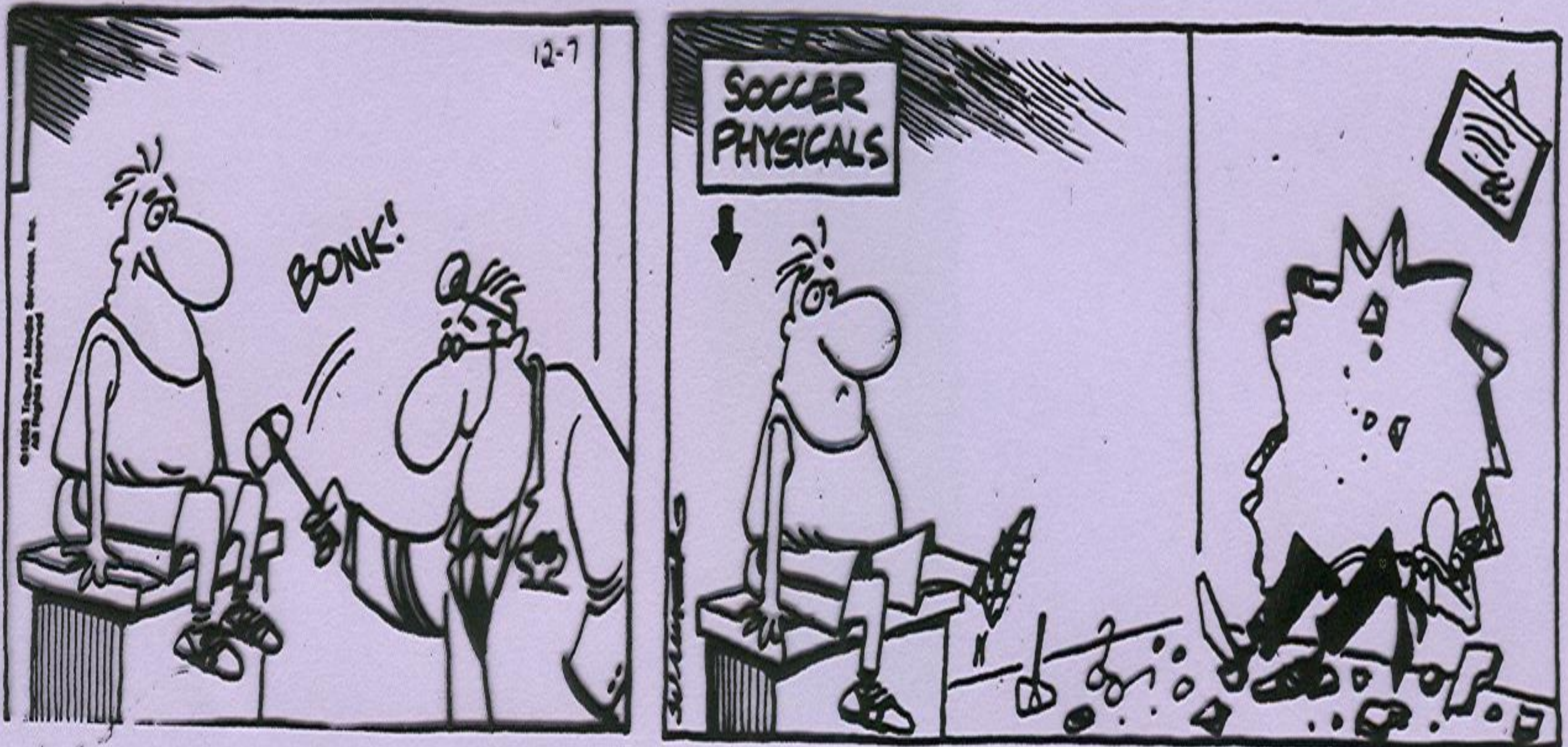
- For two objects in contact with each other, when object A acts on B with a force, object B acts on A with an equal (in size) and opposite (in direction) force.

For every action there is an equal and opposite reaction!

Examples



BOUND & GAGGED



PEANUTS

ALL I HAVE TO DO IS KICK IT, RIGHT?
RIGHT
WHAT IF IT KICKS ME BACK?
9-21

BLOOM COUNTY

Friction – *lab results*

- The **force of friction** is directly proportional to the **normal force.**

- Friction is affected by:
  - Normal Force
  - Surface material (texture)

- Friction is NOT affected by:
  - Surface area (amount of surface in contact)
  - Speed

Static Friction (F_{Fs}) –

the friction that exists when a force is applied to an object, but it is not great enough to cause motion between the two surfaces in contact.

$$0 \leq F_{F\,s} \leq \mu_s * F_N$$

Kinetic Friction (F_{Fk}) –

the friction that exists once two surfaces begin sliding (moving) over one another.

$$F_{F\,k} = \mu_k * F_N$$

Coefficient of Friction

Practice with Friction

- A 120-kg crate is being pushed at a constant velocity. If the coefficient of kinetic friction is 0.2, what is the frictional force exerted on this object?

Practice with Friction

- A 59-kg skier is standing motionless on a horizontal patch of snow. She is holding onto a horizontal tow rope, which is about to pull her forward. The coefficient of static friction between the skis and snow is 0.14. What is the magnitude of the maximum force that the tow rope can apply to the skier without causing her to move?

Practice with Friction

- A block whose weight is 45.0 N rests on a horizontal table. A horizontal force of 36.0 N is applied to the block. The coefficients of static and kinetic friction are 0.650 and 0.420 respectively. Will the block move under the influence of the force, and, if so, what will be the block's acceleration? Explain your reasoning.

Momentum

- The headlines declare “Philadelphia Phillies Gaining Momentum."

- The coach *pumps* up his team at half-time, saying "You have the momentum; the critical need is that you use that momentum and bury them in the third quarter."

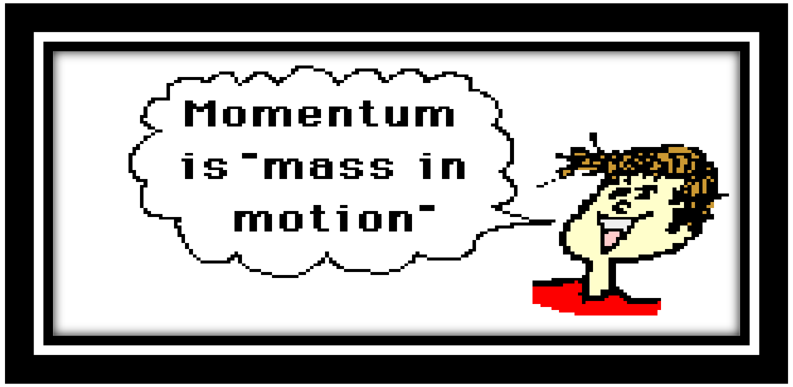
Momentum

If an object is moving it has momentum.

Momentum = mass • velocity

$$p = m \cdot v$$

$$(kg \cdot m/s) = (kg) \cdot (m/s)$$



Momentum

Determine the momentum of a ...

- a. 60-kg halfback moving eastward at 9 m/s.
- b. 1000-kg car moving northward at 20 m/s.
- c. 40-kg student moving southward at 2 m/s.

Momentum

A car possesses 20 000 units of momentum. What would be the car's new momentum if ...

- a. its velocity were doubled.
- b. its velocity were tripled.
- c. its mass were doubled (by adding more passengers and a greater load).
- d. both its velocity were doubled and its mass were doubled.