Physics – Lecture 5

Dundas Valley Highschool Co-Op

Physics

Brydon Eastman

October 17, 2013

1. Acceleration Review

1. A cyclist on a ten-speed bicycle accelerates from rest to 2.2 m/s in 5.0 s in third gear, then changes into fifth gear. After 10.0 s in fifth gear, the cyclist reaches 5.2 m/s. Assuming that the direction of travel remains the same, calculate the magnitude of the average acceleration in the third and fifth gears.

2. A student throws a baseball vertically upward, and 2.8 s later catches it at the same level. Neglecting air resis- tance, calculate the following:

   - (a) the velocity at which the ball left the student’s hand (Hint: Assume that, when air resistance is ignored, the time it takes to rise equals the time it takes to fall for an object thrown upward.)
   - (b) the height to which the ball climbed above the student’s hand.

3. An athlete in good physical condition can land on the ground at a speed of up to 12 m/s without injury. Calculate the maximum height from which the athlete can jump without injury. Assume that the takeoff speed is zero.

4. The song question.

2. Forces

- List off any forces you might know
- Forces are everywhere
  - Force of gravity
  - Force of magnetism
  - Force of electricity
  - Force of friction
- Simply put, a force is a **push** or a *pull*.
- In Physics terms a force is something that causes *acceleration*.
- Forces are vector quantities, they act in a direction
- Example ISS orbiting earth

2 Forces – cont'd

- Gravity:

- Friction is another force that plays a role in our everyday lives.
  - Pushing things across a desk, sandpaper, etc.
- Normal force is the force the ground makes against your feet, preventing you from going through the ground.

3. Forces and Newton

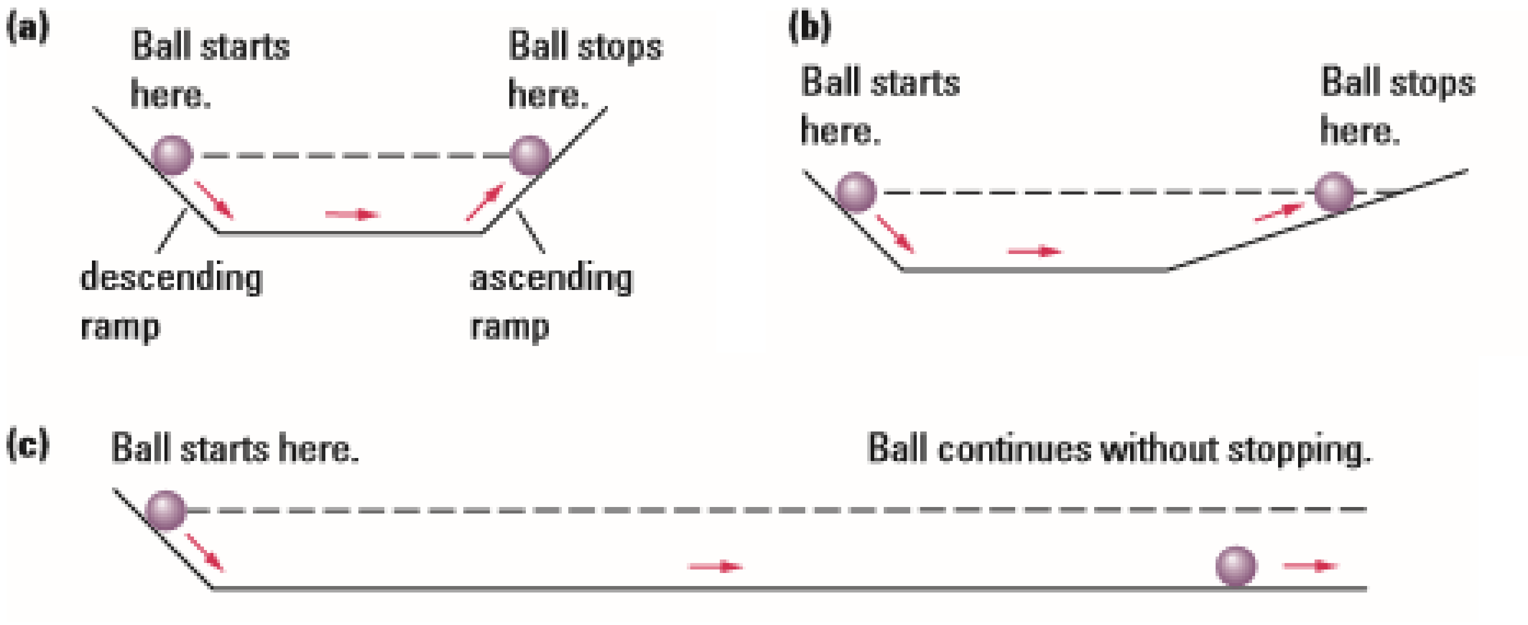
- Sir Isaac Newton is the father of forces
- Forces have units of $\mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}$ or Newtons (N)
- He invented calculus to, in part, explain the force of gravity (and model the movement of the moon).
- He's so important that Newton's Laws are fundamental to the understanding of forces.
- Previously we studied *kinematics* which is the study of motion. Now we will investigate *dynamics* which is the study of what causes motion.
- Newton has 3 "Laws of Motion" that we will now investigate one at a time.

Newton's First Law of Motion

A body is either at rest or moves with a constant velocity unless acted upon by an outside force.

4 Newton’s First Law

- Newton’s First Law might seem obvious to us now, but it wasn’t always so.
- People used to think that it required a constant force to keep an object moving at a constant velocity.
  - Why might they have thought like this?
- Galileo was one of the first to question this



  - Air track

4 Newton’s First Law and Inertia

- Newton called this tendency for an object to stay in motion “inertia”
- Inertia is a property of matter
- The more mass the more inertia
- Inertia is like “grumpiness”
- Things with more inertia *hate* acceleration
- Pushing a car – harder to get it moving than to keep it moving
- Free Body Diagrams
  - Draw all the forces acting on a body, in the right directions
- Example:
  - A weight lifter holds a weight above his head by exerting a force of 1.6 kN [↑]. The force of gravity acting on the weight is 1.6 kN [↓]. Draw a system diagram and an FBD of the weight, and state the net force on the weight at that instant.

4. Newton's First Law

- Free Body Diagram:
  - Pushing a stapler across a desk.
  - Four forces involved: applied force, normal force, gravitational force, frictional force.
- Net Forces
- To cause a change in velocity, the net force on an object must not be zero; that is, two equal opposing forces acting on an object will not change its velocity.
- Objects at rest remain at rest unless acted upon by a net external force greater than zero.
- Moving objects continue to move in a straight line at a constant speed unless acted upon by a net external force greater than zero.
- Example: Whiplash
- Example: Turning a car while moving at high speeds

4. Newton’s First Law – Final Summary

- Objects at rest tend to stay at rest
- Objects in motion tend to remain in motion
- If the velocity of an object is constant, the net external force acting on it must be zero.
- The net force is the vector-sum of all forces acting on an object.
- If the velocity of an object is changing in either magnitude or direction or both, the change must be caused by a net external force acting on the object

- Example: State the net force acting on an object that is (a) at rest and (b) moving with constant velocity.

5. Newton’s Second Law

Newton’s Second Law

If the net external force on an object is not zero, the object accelerates in the direction of the net force. The magnitude of the acceleration is pro- portional to the magnitude of the net force and is inversely proportional to the object’s mass.

$$\vec{F}_{net} = m\,\vec{a}$$

Example:
A net force of 58 N [W] is applied to a water polo ball of mass 0.45 kg. Calculate the ball’s acceleration.

5. Newton’s Second Law

1. In an extreme test of its braking system under ideal road conditions, a Toyota Celica, travelling initially at 26.9 m/s [S], comes to a stop in 2.61 s. The mass of the car with the driver is 1.18 × 103 kg. Calculate (a) the car’s acceleration and (b) the net force required to cause that acceleration.

2. Does Newton’s Second Law agree with his first law?

3. Determine the mass of a regulation shot in the women’s shot-put event if a net force of 7.2 × 102 N [fwd] is acting on the shot, giving the shot an average acceleration of 1.8 × 102 m/s2 [fwd].

4. Assume that during each pulse a mammalian heart accelerates 21 g of blood from 18 cm/s to 28 cm/s during a time interval of 0.10 s. Calculate the magnitude of the force (in newtons) exerted by the heart muscle on the blood.

5. Newton's Second Law and Driver's Ed

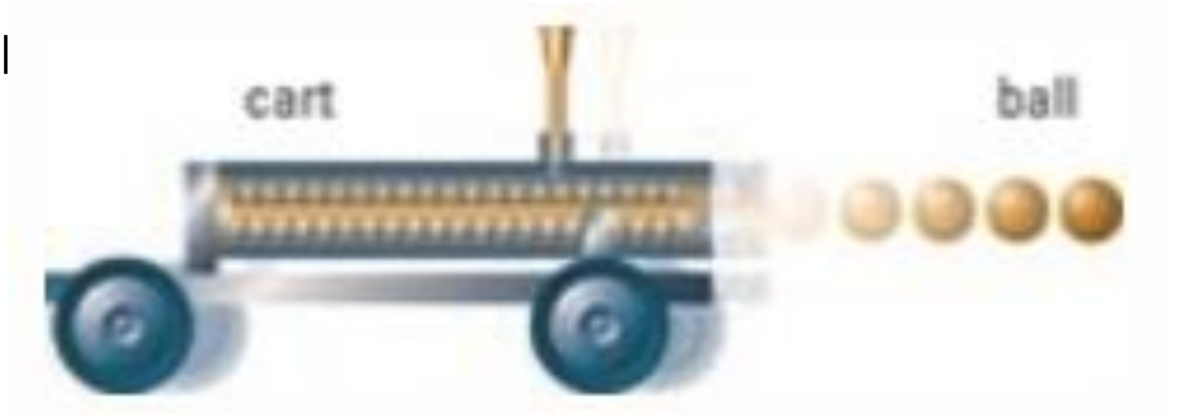
- The Ontario driver's handbook says a car should be at least 2.0s behind another car in order to safely stop in time in the event of an emergency. Assume that a 1.2×10^3-kg car is travelling 72 km/h [S] when the truck ahead crashes into a northbound truck and stops suddenly.
  - If the car is at the required safe distance behind the truck, what is the separation distance?
  - If the average net braking force exerted by the car is 6.4×10^3 N [N], how long would it take the car to stop?
  - Determine whether a collision would occur. Assume that the driver's reaction time is an excellent 0.09 s.

6. Newton's Third Law

Newton's Third Law of Motion

For every action there is an equal and opposite reaction.

- Example: astronauts in space
- Example: Skating rink
- Imagine a ball shot horizontally out of the tube of a toy cart on wheels, as shown in the picture. When the ball is pushed into the cart, a spring becomes compressed. Then, when the spring is released, the spring (and thus the cart) pushes forward on the ball. We call this force the action force. At the same instant, the ball pushes backward on the spring (and thus the cart).We call this the reaction force of the ball on the cart. The action and reaction forces are equal in size but opposite in direction, and act on different objects.



6. Newton's Third Law

- Draw the free body diagram of the ball in the previous example as it is still in the chamber but is being pushed by the spring.

- Do action-reaction forces exist on stationary objects?

- What is the action reaction force in swimming?

6. Questions

- An airplane is travelling with constant speed, heading east at a certain altitude. What forces are acting on the airplane? What is the net force on the airplane
- A football player kicks a 410-g football, giving it an acceleration of magnitude 25g for 0.10 s. (a) What net force is imparted to the ball? (b) Name and state the magnitude of the reaction force.
- Apply Newton's first law of motion to explain the danger in travelling too quickly on a curve of an icy highway.
- One of the world's greatest jumpers is the flea. For a brief instant a flea is estimated to accelerate with a mag- nitude of 1.0 × 103 m/s2. What is the magnitude of the net force a 6.0×10^{-7}-kg flea would need to produce this acceleration?

6. Questions

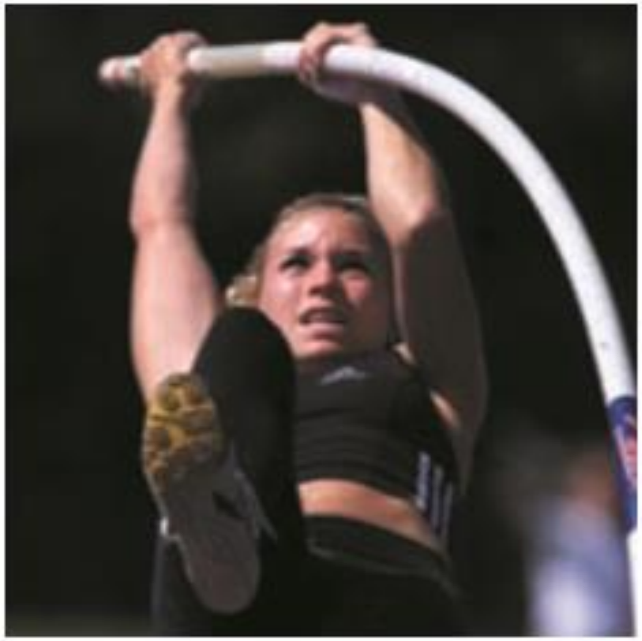
- Draw a free-body diagram to determine the net force acting on the object in italics in each of the following situations:
  - Two teenagers are pushing a dirt bike through a freshly plowed field. One exerts a force of 390 N [W] on the bike while the other exerts a force of 430 N [W]. Frictional resistance amounts to 810 N.
  - A water-skier is being pulled directly behind a motorboat at a constant speed of 20.0 m/s. The tension in the horizontal rope is 520 N.
  - An elevator, including passengers, has a mass of 1.0×10^3 kg. The cable attached to the elevator exerts an upward force of 1.2×10^4 N. Friction opposing the motion of the elevator is 1.5×10^3 N

7. Gravity and Friction

- Things still fall
  - Demonstration
- What’s harder to do: push one textbook across a desk? Or push 10 textbooks across a desk?
- The force of gravity is greater in the second case.
- The force of friction is also greater in the second case.
- Clearly there’s some relationship there.
- Gravity keeps us on the planet, which is nice.
- Friction keeps us on the roads, which is also nice.
- Takeaway: Knowledge of physics makes you a better driver.

7. Gravity and how to Cheat the Olympics

- In 1968 the Olympics were hosted in Mexico City, a very mountainous region about 2300 m above sea level
- That year many records were absolutely shattered
- The pole vaulting record was exceeded by over 30 cm.
- The elevation caused a measurably smaller force of gravity
  - Pole vault
  - Short races
  - Jumping & Throwing events
- However the reduction in oxygen from the altitude negatively affected some athletes stamina
- The gravitational force falls off with distance
- Though when we are close to the surface of the earth we can model the gravitational force as $\vec{F}_g = m\vec{g}$



7. British Puns and American Idiocy

- The maximum train load pulled through the Chunnel (the train tunnel under the English Channel that links England and France) is 2434 t. Determine the force of gravity on this huge mass. (Note: 1t = 1000 kg)
- Weight is a term we commonly use instead of mass, though the two are vastly different. (Blame the Americans)
  - Mass is the quantity of matter in an object
  - Weight is the force of gravity on an object
- If you went to the moon what would be different? Your mass? Your weight?

Table 2 Variation in $\vec{g}$ with Latitude (at sea level)

Latitude (°)	$\vec{g}$ (N/kg [↓])	Distance from Earth's centre (km)
0 (equator)	9.7805	6378
15	9.7839	6377
30	9.7934	6373
45	9.8063	6367
60	9.8192	6362
75	9.8287	6358
90 (North Pole)	9.8322	6357

7. 1 Quick Tip for Weight Loss

- What is the weight of a 70 kg mountain climber at the top of Mount Everest?
- What would his weight be in Toronto?
- Bathroom scales are *liars*.

Table 3 Variation in $\vec{g}$ with Altitude (at similar latitudes)

Location	Latitude (°)	$\vec{g}$ at sea level (N/kg [↓])	Altitude (m)	$\vec{g}$ (N/kg [↓])
Toronto	44	9.8054	162	9.8049
Mount Everest	28	9.7919	8848	9.7647
Dead Sea	32	9.7950	–397	9.7962

7. Pun about Building Blocks

- Let's slowly work through an example.
- Three blocks are placed as in the diagram below. The 6 kg block has a pulling force exerted on it of 24 N (right). What is the acceleration of the system? What is the tension in the cord? What force is exerted by the 1 kg block on the 2 kg block?