Physics 105

Fall 2011

Lecture 3 Energy & Population

No Clicker Registered

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Top News story of the Week

Maryland uniforms

Love’m or Hate’m

1. Love them
2. They are OK
3. Take them or leave them
4. They look really good in the end zone
5. OMG – they’re horrible
Homework assignments & Reading

- Read Chapters 2 & 3 of Wolfson & Tragedy of the Commons article posted in the course document section of ELMS
- Assignment 3 =
  - Watch the youtube video (10 minutes)
    http://www.youtube.com/watch?
v=fTznEIZRkJg&feature=player_detailpage
  - Write a one paragraph summary of the main ideas presented.
  - Due 9/14 by midnight
- Assignment 4 =
  - BP article critical analysis - BP is sorry
  - Read the above linked news story, and complete a critical analysis. A worksheet for critical analysis is attached to elms
  - Due Sept 20
That Daily Show video was:

1. Funny
2. Rude
3. Insulting
4. Informative
5. Inappropriate

What is the best time scale for energy decisions?

1. 1 yr
2. 2 yr
3. 5 yr
4. 10 yr
5. 20 yr
6. 100 yr
7. 1000 yr
8. 10000 yr
9. 100000 yr
Discussion Question

According to the Pew Survey, the public and scientists identify their ideology as:

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<th>Public</th>
<th>Scientists</th>
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<tr>
<td>Conservative</td>
<td>37%</td>
<td>9%</td>
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<tr>
<td>Moderate</td>
<td>38%</td>
<td>35%</td>
</tr>
<tr>
<td>Liberal/Progressive</td>
<td>20%</td>
<td>52%</td>
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Questions:

Why are scientists more liberal than the public as a whole?

Is this likely to cause a bias in what scientists say and do?

Newton’s 1st Law

- An object in motion will move with a constant velocity unless acted upon by an outside force.

- e.g. – a bike moving on a flat road keeps moving straight except for friction which acts to slow it down

- When you are moving at constant speed in a car and go around a corner – do you experience a force?
Newton’s 2nd law

- acceleration = force/mass = \( f/m \)
- or \( f = ma \)
- To accelerate an object with more mass requires more force
- (Units force is Newtons = kg m/s\(^2\))
- Example \( f=10 \) N

\[ f = 10N \quad M=2kg \quad \ddot{a} = \ddot{f}/m = 5kg/(kg/m/s^2)= 5m/s^2 \]

\[ \ddot{v} = \ddot{a}t + v_0 = 5 \text{ t(sec)} + \ddot{v}_0 \]

Motion under constant acceleration (applet)
Gravity

- All objects near the earth fall at the same rate (when friction is unimportant) – Galileo
- They fall at a rate which increases with \( g = 9.8 \text{ m/s}^2 \)
- If all objects fall at the same rate the force must be proportional to mass (\( a = f/m \))
  - Force of gravity (near earth’s surface) is \( F_g = mg \) (downward)
  - also called weight
- Note: weight is a unit of force (Newtons) kilgroams are a unit of mass not weight – I have a mass of 84 kilograms, my weight is \( 84 \times 9.8 = 823 \text{ N} \) (185 pounds)

Inertial vs gravitational mass

- weight is due to attraction of gravity
- the \( m \) in \( f=ma \) is the inertial mass (they have the same value)
- If there is no gravity do things still have mass?
  - How do you tell if a sealed thermos bottle has liquid in it?
Work

- In physics, the definition of work is the application of a force through a distance
  \[ W = F \cdot d \]

- \( W \) is the work done
- \( F \) is the force applied
- \( d \) is the distance through which the force acts

Example – gravity –
- Force is \( mg \) (down) where \( m \) is the mass in kg and \( g \) is \( 9.8 \text{m/s}^2 \)
- If I lift an object a distance \( h \) then the work I do is
  \[ mg \cdot h \]
- If \( m \) were 1 kg and \( h = 5 \text{m} \)
- then force is \( mg \cdot (1 \text{kg} \times 9.8 \text{m/s}^2) = 9.8 \text{N} \)
- The work I did is \( 9.8 \text{N} \times 5 \text{m} = 49 \text{J} \)
- This is also the change in potential energy

Work

- If I let the object drop the same distance then gravity does the same amount of work
  - so gravity does 49N work and the object picks up kinetic energy

- Kinetic energy: \( E_{\text{kin}} = \frac{1}{2} m v^2 \)

- Work-Kinetic Energy Theorem: \( \Delta E_{\text{kin}} = W_{\text{net}} \)

- Remember its only the force that acts in the direction of motion counts towards work
Simple Machines

- Simple machines can allow you to do the same work with less force over larger distances
  - Work = f*d -> if we increase distance we can reduce force
- Levers

![Levers Diagram]

Simple Machines

- Pulleys
  - Distance is longer, force is smaller

![Pulleys Diagram]
**Conservative force**

- Work done is path independent for a conservative force like gravity
- If I am on the fourth floor of this building, the work done to get me there is independent of whether I took the elevator, the steps with a detour on the 3rd floor or went to the roof first and then back down
- So my potential energy (the energy I can get back by going down) is just a function of my height above the ground

**Friction is a Non-Conservative Force**

- The amount of work you do does depend on your path
- The amount of you do riding your bike depends on path
  - The further you go the more work it takes
  - The work against friction does NOT result in potential energy
- Where does the work go?
  - Thermal Energy
- Two types of friction
  - Static – between two non-sliding surfaces
  - Kinetic (sliding) – between surfaces moving wrt to each other
  - Static friction is bigger
- Sliding friction is independent of speed
- Air resistance (also a kind of friction) is proportional to $v^2$
  - The resistance your car feels at 60mph is 4 times that at 30!
Friction – microscopic view

- Individual molecules are sticky...
  - Friction is the sticking and unsticking of molecules
  - Depends on roughness
  - Actual materials (molecules) – why does oil reduce friction?

Kind of like velcro

In a moving car is the wheel on the road undergoing

1. Static friction?
2. Kinetic friction?
Friction continued

- Why do we have anti-lock brakes?
- Why do we have to apply the gas when driving on a level highway?

Summary of Energy

- Energy is conserved
  - Cannot be created or destroyed - just transformed or transferred
- Work = $f \cdot d$ in the direction of force
- Work Energy Theorem $\Delta E_{\text{kin}} = W_{\text{net}}$
- Kinetic energy = $1/2 \cdot mv^2$
- Gravitational Potential Energy = $mgh$
- Friction converts kinetic energy into thermal energy
**Power**

- Rate of doing work
  - I can run up a 3m flight of stairs in ~5 s
  - \( Mgh = 66 \text{ kg} \times 10 \text{ m/s}^2 \times 3 \text{ m} = 2000 \text{ J} \)
  - Power = \( \frac{2000 \text{ J}}{5 \text{ s}} = 400 \text{ Watts} \)
  - Average power - 2000 kcal/day - ~80 kcal/hr = 360 kJ/h = \( \frac{360,000 \text{ J}}{3600 \text{ s}} = 100 \text{ W} \)
  - Basal Metabolic (resting) Rate ~0.6 kcal/h/kg so for me
  - BMR = \( 66 \times 0.6 = 40 \text{ kcal/h} \) ~45W So that is how much heat I produce while doing nothing
  - If I rest for 1/3 day then my average power output while awake is: 100 W = \( \frac{1}{3} \times 45 \text{ W} + \frac{2}{3} \times P \)
    - \( P = \frac{3}{2}(100 \text{ W} - 15 \text{ W}) = 127 \text{ W} \)

**Population**

The power of population is infinitely greater than the power in the earth to produce subsistence for man. – Malthus – 1798
How many people are on the Earth? (pick the closest)

1. 1 Million
2. 10 Million
3. 100 Million
4. 1 Billion
5. 10 Billion
6. 100 Billion

Energy and Population?

Why does population matter in a class on the energy crisis?
http://www.bit.ly/n5DjaC
Population

- Currently there are 6.7 billion people on earth ($6.7 \times 10^9$)
- The rate at which population grows is proportional to the existing number of people
  - The number of people born depends on the number of potential parents
  - At the current rate of growth the population doubles every 35 years (as people live longer this gets shorter)
  - If you (and a partner) have 2 children by 35 and they do the same when you are 70 there will be six of you.
  - Then assuming you die off (which having kids can cause) the population has gone from 2 when you where <35 to 4 when you are gone at 70...
- This is exponential growth

Birth vs. death

- Current Birth Rate : 4.3 people/second
- Current Death Rate: 1.8 people/second
- Net population growth rate: 2.5 people/second

- During this class:
  - 19,350 will be born
  - 8,100 will die

In the US:
- Someone is born every 7.4 sec
- Someone dies every 12.2 sec
- Someone immigrates every 23.6 sec
Exponential vs. linear growth

- **Linear growth**
  - increase by a fixed amount each interval
  - E.g.: You make $20,000 and get a $2,000 raise each year
  - After 20 years - salary = $20,000 + 20 X 2,000 = $60,000

- **Exponential Growth**
  - Increase by a amount proportional to what is already there
  - E.g.: you make $20,000 and get a 10% raise each year
  - After 20 years:
    - Year 1: $20,000 + 0.1 ($20,000) = $22,000
    - Year 2: $22,000 + 0.1 (22,000) = $24,200
    - ...
    - Year 20: \((1.1)^{20}\) X $20,000 = $134,549

After 50 years: linear - $120,000; exponential: $2,347,817!
Estimates of Human Population

Fire, tool-making

Industrial revolution

Green revolution

The Plague

Rome falls

Agricultural Revolution

Human Population (millions)

Years Before Present

Human Population (millions)
If we agree we need to reduce population growth we should:

1. Public information campaign
2. Free birth control
3. Remove any incentives
4. Tax extra children
5. Outlaw (fine) extra children
6. Forced sterilization
Which do you believe?

1. Constant fertility
2. High variant
3. Medium variant
4. Low variant

Some countries (e.g. France) are experiencing negative population growth. They are offering incentives to families who have many children. Is this right?

1. Oui
2. Non
Fertility Declining Faster Than Expected

Rule of thumb for exponential growth

Amount doubles in:

\[ t = \frac{70}{\text{growth rate} \, (\%)} \]

If population is growing at 2%/year, it doubles in 35 years...

\[ P(t) = (1 + g)^n p(0) \sim e^{ng} p(0) \]
Linear vs. exponential growth

Both curves have same increase in first year

Exponential growth

- Two Bacteria in a jar at 11 AM
- Double population every minute
- Jar is full at noon
Exponential growth

• When is the jar half full?
  • 11:59 AM

• When does it seem empty (1/16)?
  • 11:56 AM

Clicker question

Some enterprising bacteria escape and discover 3 more jars, quadrupling the total amount of space. How much longer will they have until everything is full?

1. 4 hours
2. 1 hour
3. 4 minutes
4. 2 minutes
Exponential Growth

Carrying Capacity

How many people can the Earth hold?