Today – Exam#2 Review

- Exam #2 is Thursday March 13 in this room, BPS 1410
- Extra Credit Projects: Spring Break Story Contest
- The exam is 40 multiple choice questions. There are a few questions where you will have to use a formula and calculator.
- Bring your student ID
- You will have the full 80 minutes for the exam.
- You can bring one 8.5x11 inch sheet of notes (front and back)

Where are we?

- There are 4 known forces in nature (Gravity, weak, EM- electromagnetic , strong)
- Gravity does not fit well in our understanding with the others
  - It is very weak compared to the others. Why?
- Our current understanding of nature is by Quantum field theory: EM - quantum electrodynamics, EM+weak - electroweak theory, Strong - quantum chromodynamics).
- Our understanding of force involves the exchange of force carrying bosons between particles

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The particles of nature

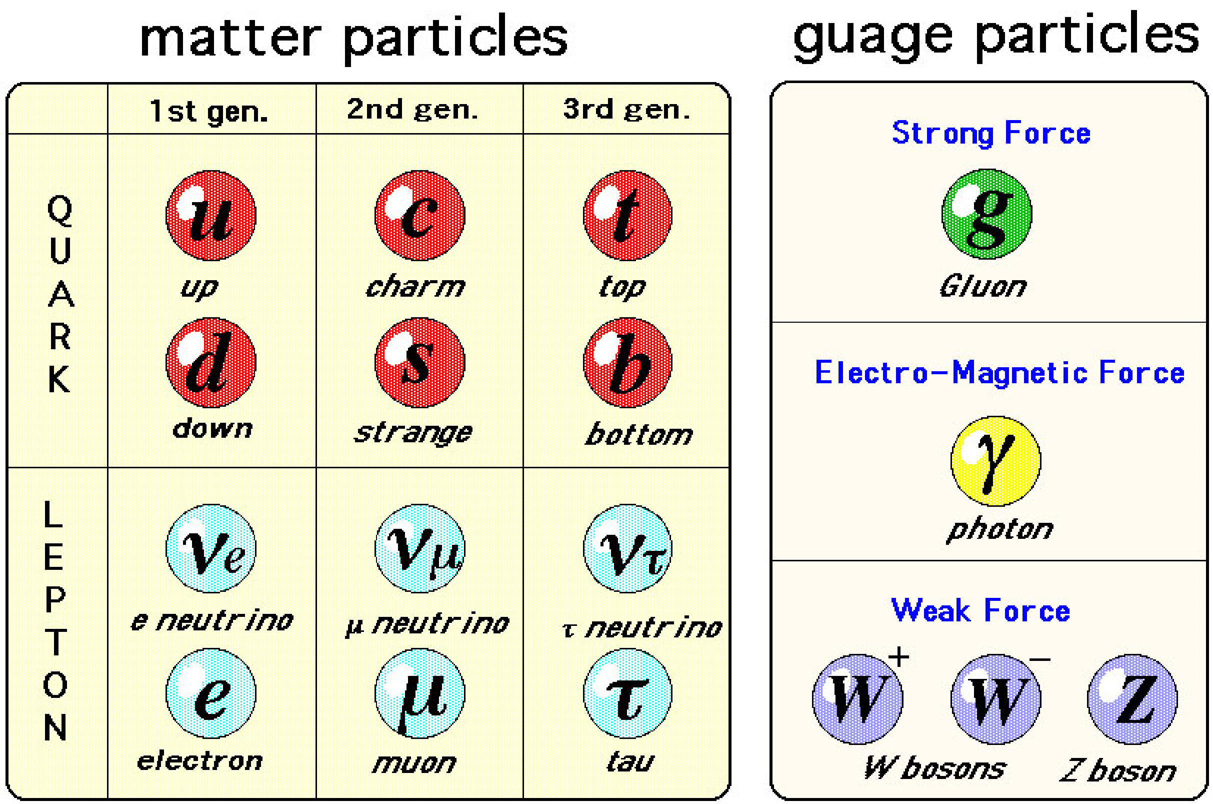
Charge

+2/3 →

-1/3 →

0 →

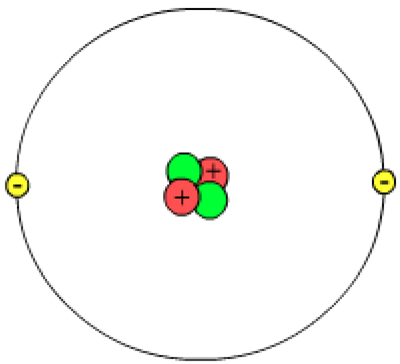
-1 →



anti-particles have opposite charge

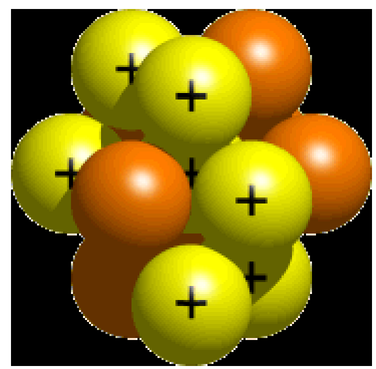
How nature is put together from the pieces…

Atoms



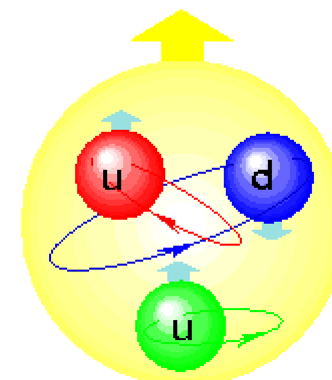
Made of nuclei and electrons. Size: 10^{-9}m

Atomic Nucleus



Made of neutrons and proton. Size 10^{-14} m

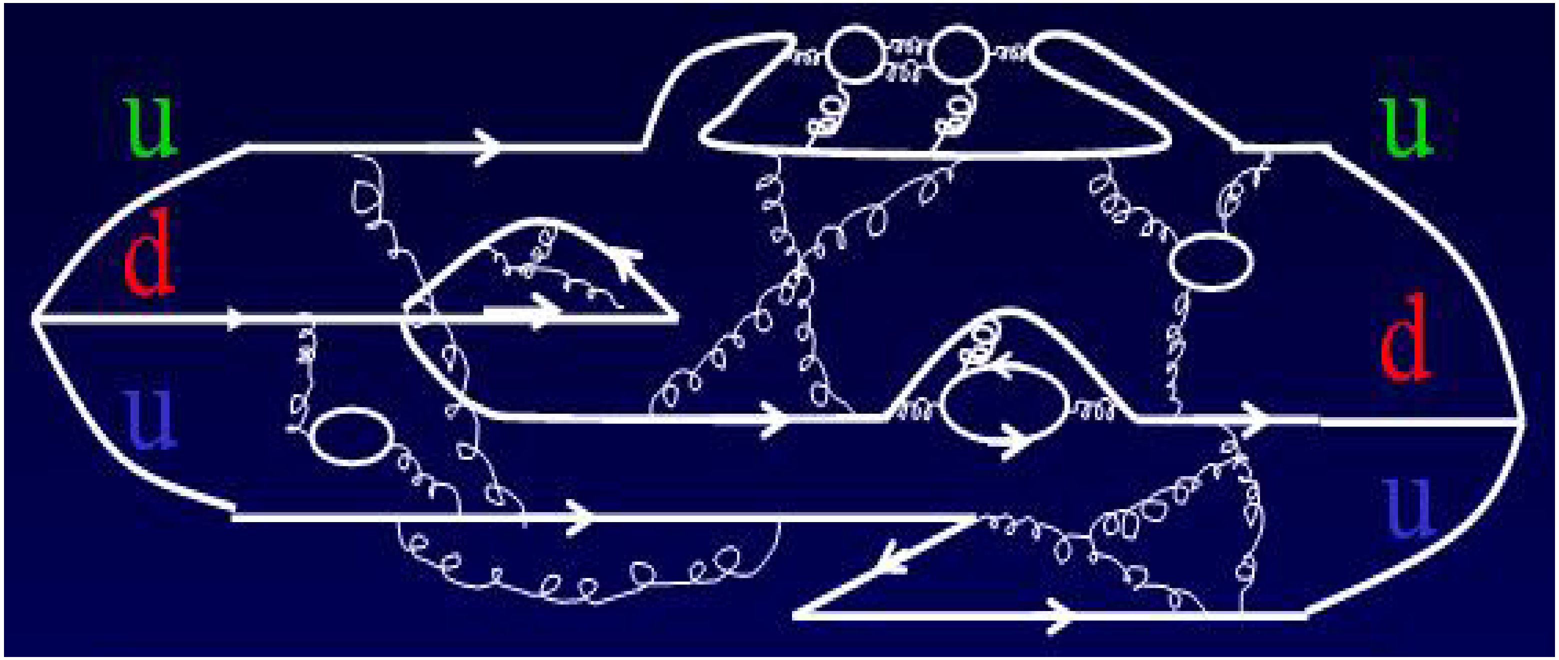
A proton (uud)



Made of quarks: Size 10^{-15} m

A neutron has ddu

Closer to what a proton really looks like



http://www.gwu.edu/~cns/theory/theory_webpage/proton2_qcd.jpg

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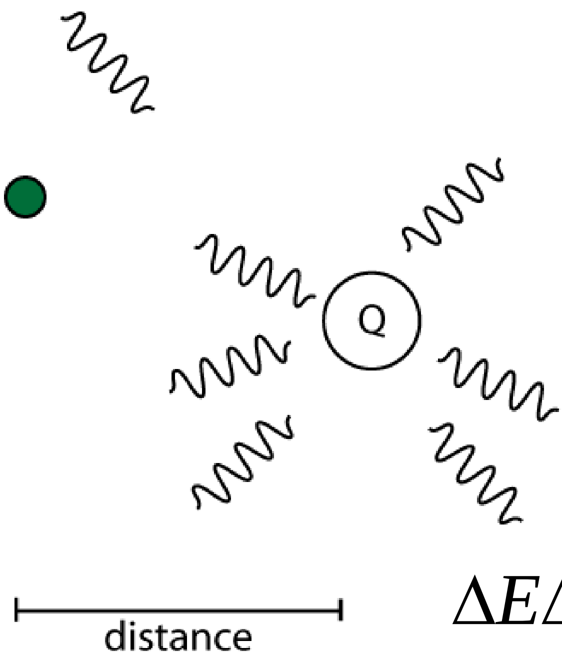
A summary of the forces of nature

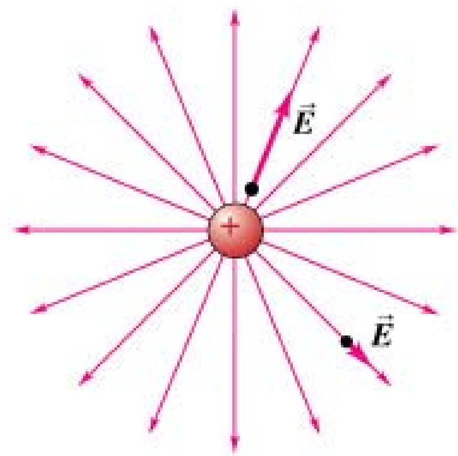
Force	Strength	Carrier	Acts on	Range (m)
Strong	1	Gluon, g	quarks	10^{-15} size of a proton
Electromagnetic	1/137	photon	anything with charge	infinite
Weak	10^{-6}	Vector Bosons W^{+}, W^{-}, Z^{0}	quarks, electrons (leptons) , neutrinos	10^{-18} Only 0.001 width of proton
Gravity	$6x10^{-39}$	Graviton (?)	anything with mass	infinite

Our Picture of Force

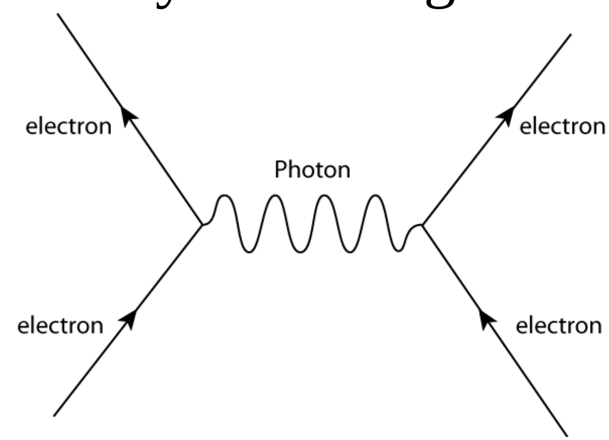
A charge creates a field…



Picture of the field



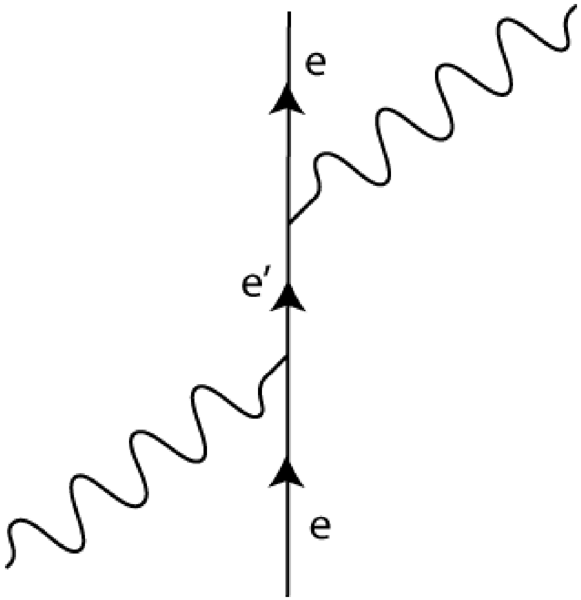
Feynman diagram



$$\Delta E \Delta t \ge \frac{h}{4\pi}$$

Virtual particles can exist for a short time.

Why is the sky blue? Feynman Diagram



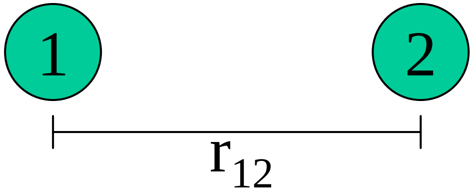
The process is more likely if the photon energy is higher. Hence blue light scatters more than red light.

Coulombs Law

- Charge comes in units of 1.6E-19C.

- The force between two charges is:

$$F = \frac{kq_1q_2}{r_{12}^2}; k = 8.99\times10^9 \frac{Nm^2}{C^2}$$

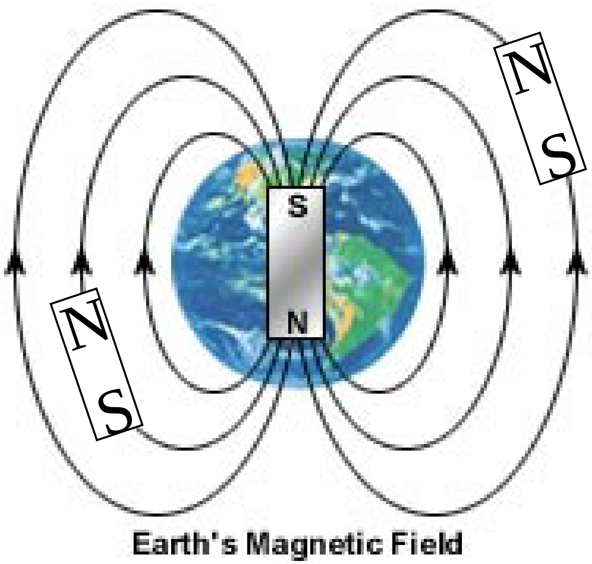


- Example (inverse square law): 4 times the distance

$$F_{4d} = \frac{kq_1q_2}{(4r_{12})^2} = \frac{1}{4^2}\frac{kq_1q_2}{r_{12}^2} = \frac{1}{16}\frac{kq_1q_2}{r_{12}^2} = \frac{1}{16}F_d$$

The Earth behaves as a large magnet

The Earth is like a large magnet with a south magnetic pole at the North geographic pole.



T/F   A-true B-false

- **T** North pole of a compass points north in northern hemisphere
- **F** North pole of a compass points south in southern hemisphere
- **T** North pole of a compass points towards the north in the southern hemisphere

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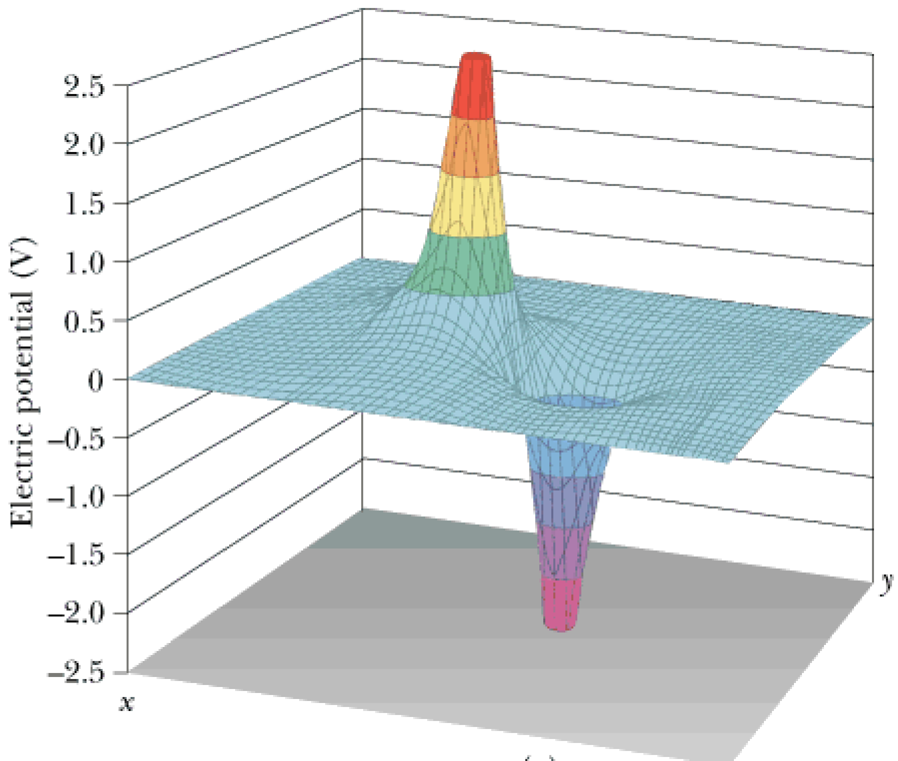
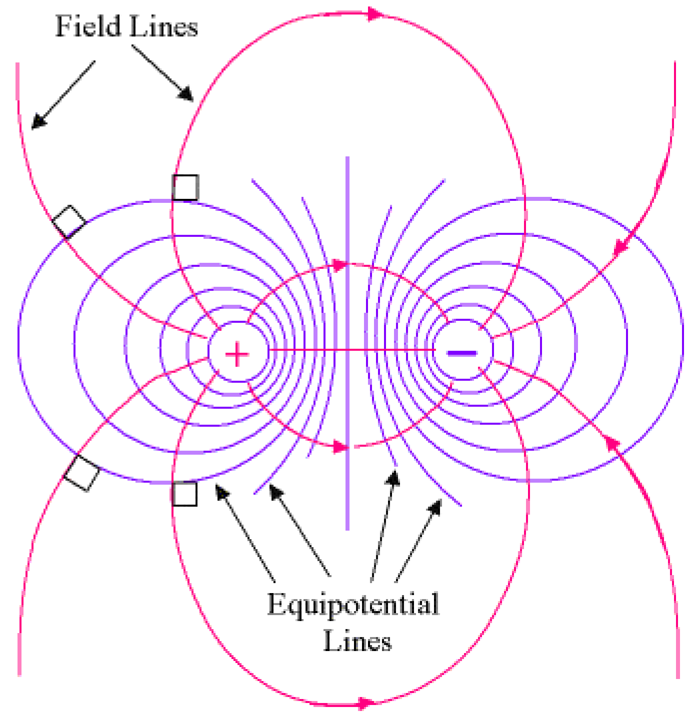
Map for the Electric Field



(a)

Serway, Physics for Scientists and Engineers, 5/e
Figure 25.8a Harcourt, Inc.

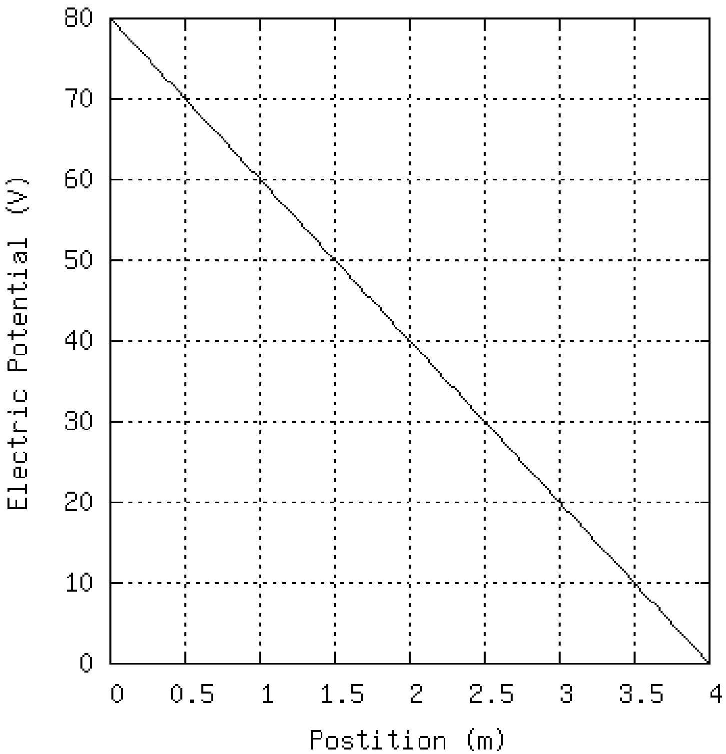


Note: we could make similar maps for all the fields in nature (gravity, weak, EM, strong).

The relation between electric and magnetic fields

- Charge creates an electric field (and potential, V)
- Moving charge creates a magnetic field
- The photon is responsible for transmitting both the electric and the magnetic forces
- Maxwell's equations describe the relationship
  - Charge makes electric fields
  - Changing magnetic field makes electric fields
  - Changing electric fields make magnetic fields
  - Magnets always come with a north and a south pole
  - EM waves travel at the speed of light (in a vacuum)

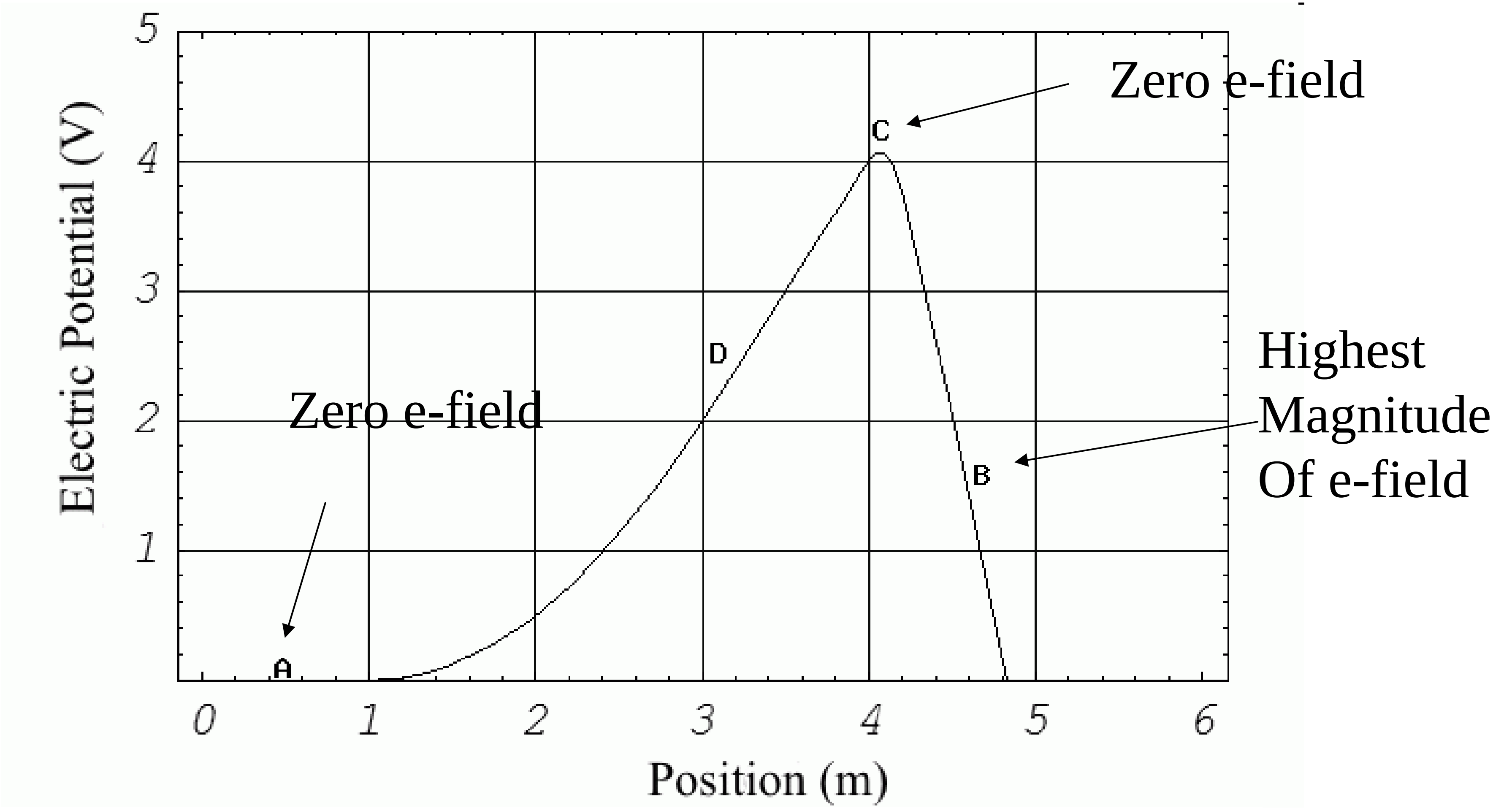
Sample Problem



What is the magnitude of the electric field at 2.0 m?

$$E = -\frac{\Delta V}{\Delta x} = -\frac{(0V - 80V)}{(4m - 0m)} = 20.0\frac{V}{m} = \boxed{20.0\frac{N}{C}}$$

Sample Problem



Electric field is the rate of change of potential with position.

Simple Problem

$$\mathbf{F = E\ q}$$

If a charge of 1.5 C is placed on an electric field of 15.5 V/m, what is the magnitude of the force on the charge?

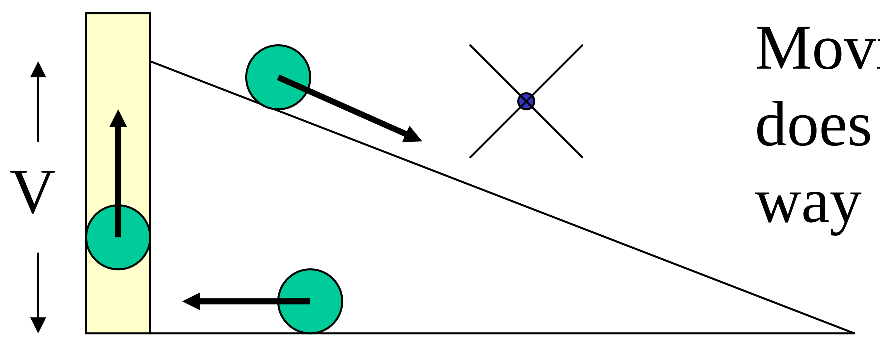
Answer:

F = 15.5 N/C x 1.5 C = 23.3 N

Flow of Charge - Current

- Batteries are like pumps that lift charge to a higher potential. The charge flows down the hill to the other side of the battery.

A battery is like a pump.



Moving Charge does work on the way down

Energy, Work, etc.

- Two kinds of energy: Kinetic – energy of motion, Potential – energy of position
- Energy is measured in Joules, J
- Power = Energy/time . The unit is Watts = J/s
- Energy is always conserved. Energy conservation can be used to find how high something will go.
- Work = force x distance, converts energy from one form to another.

Chemical Energy

- 1 Calorie = 4184 J
- How many Calories are used by a person to lift 200 kg 1m? Assume people are 10% efficient in converting chemical energy to work.

Work = mgh = 200 x 9.81 x 1 = 1962 J

Chemical energy=Work/eff=1962J/.1=19620.

#Calories = 19620 J/(4184 J/Cal) = **4.69 Cal**

Which of the following is correct concerning temperature?

A. **The average kinetic energy of molecules in a gas increases at the temperature is increased.**
B. Thermal motion Is highly organized
C. As a gas is cooled, the molecules more more rapidly.
D. Temperature is a measure of the average potential energy of atoms.
E. Temperature is not related to energy.

Entropy

Entropy is a measure of the number of possible ways to arrange a system. Which is correct?

A. Molecules in a gas usually are moving together in the same direction.

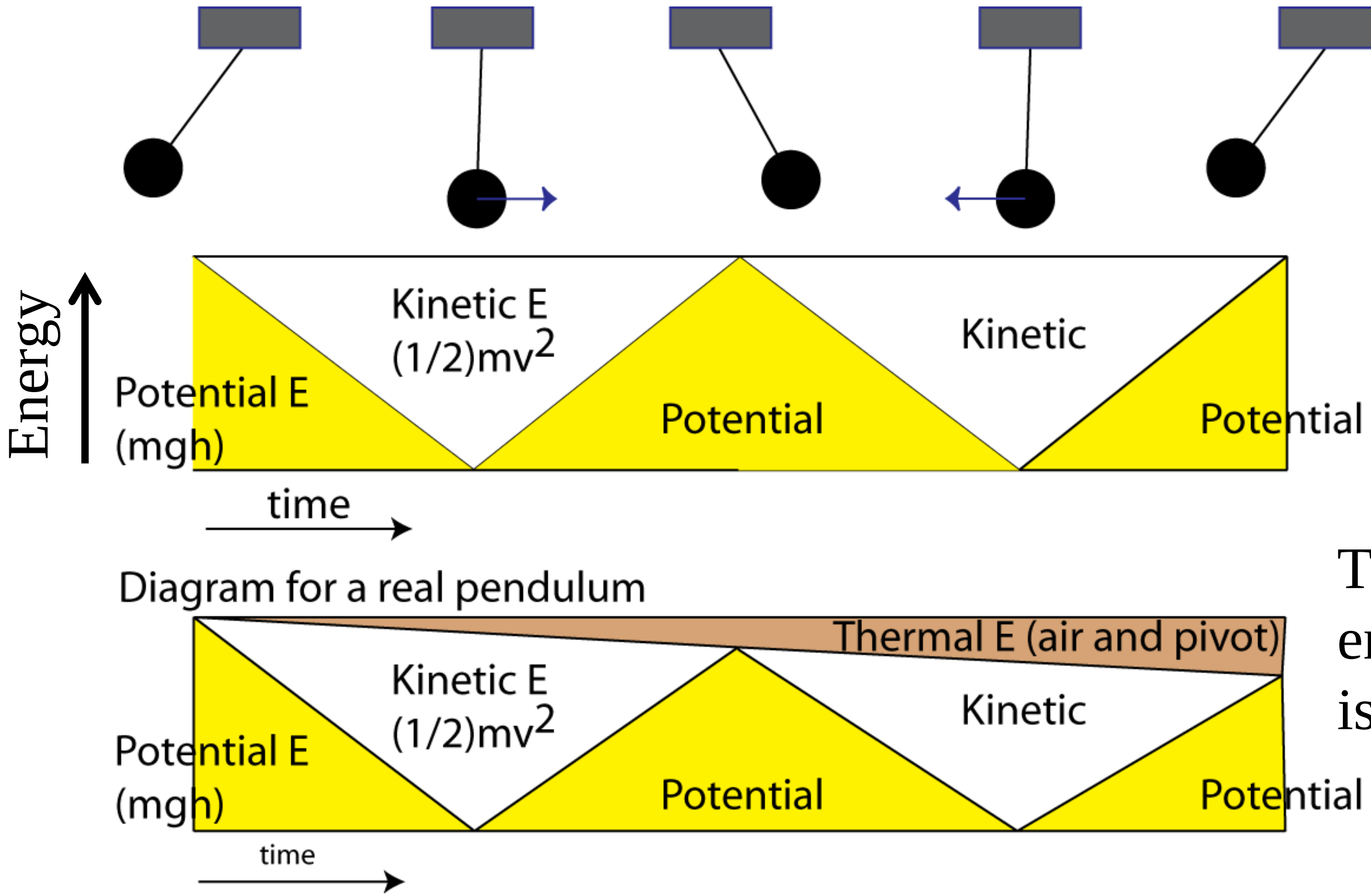
B. The entropy of 10 heads is higher than the entropy of 5 heads and 5 tails.

C. **In all closed systems the entropy never decreases in any process.**

D. We can reduce entropy by adding heat.

E. We can reduce entropy by adding more coins to a pile.

Energy and Entropy - Pendulum Example



The thermal energy (heat) is “lost”

The Second Law of Thermodynamics

Which of the following are a statement of the second law of thermodynamics?

- Energy is conserved in a closed system
- The entropy of a system could decrease by external influences
- With no external influence, entropy is conserved
- **With no external influence, entropy always increases**
- With no external influence, entropy always decreases

Quantum Mechanics Review

- Light can be described as an electromagnetic wave or a little bundle of energy (a photon). Light has particle and wave character.
- Waves can overlap – this is called interference
- Particles, for example electrons, have wave and particle properties.
- The thing that is waving in the case of a particle is probability. The square of the height of the wave (wave function) is a measure of the probability density.
- All objects (atoms, molecules, etc.) exist in defined states of energy. The energy is quantized (quantum mechanics)

The Uncertainty Principle

What is the meaning of the Uncertainty Principle?

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

A. The entropy of a closed system always increases.
B. **It is not possible to know the exact position and momentum of a particle at the same time.**
C. It is not possible to ever know the exact position of a particle.
D. Small objects have a wave function.
E. Energy is conserved in a closed system.

Antiparticles and Antimatter

- All particles have a corresponding anti-particle with opposite quantum numbers. We write the anti-particle with a bar over the top, e.g. proton – p anti-proton $\bar{p}$
- Antimatter (matter made of anti-particles) is very difficult to make. It can artificially be produced only at large particle accelerators ("atom smashers").
- Matter and anti-matter are created naturally in pairs
- So far the total amount of antimatter ever produced by humankind is a few grams.

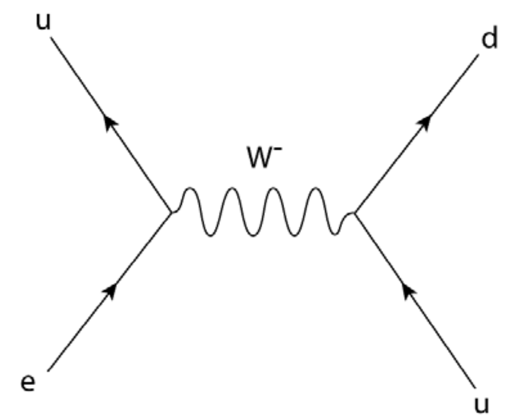
Neutrinos

- Neutrinos are subatomic particles that do not have charge. They only interact via the weak force.
- These are very unusual particles and we still don't know much about their properties. **They have a mass**, but it is so small we have not been able to measure it.
- They account for about 2% of the universe but interact weakly. One light-year of lead would have only a 50% chance of stopping one.

Equations – sort of

Rules for Feynman Diagrams:

1). The number of leptons and baryons must be conserved.



Not allowed

2). Charge must be conserved.

Some examples

Is the following allowed? Production of a quark and anti-quark by a collision of an electron and an anti-electron.

Name	Charge	Lepton	Baryon
Up quark	-1/3	0	1/3
Down quard	2/3	0	1/3
electron	-1	1	0
neutrino	0	1	0

Before	After
electron + anti-electron	quark + anti-quark

Some examples

	Before	After
	Electron + anti-electron	Quark + anti quark
Baryon	0 + 0	1/3 + (-1/3)
Lepton	1 + -1	0 + 0
Charge	-1 + 1	1/3 + (-1/3)

Name	Charge	Lepton	Baryon
Up quark	-1/3	0	1/3
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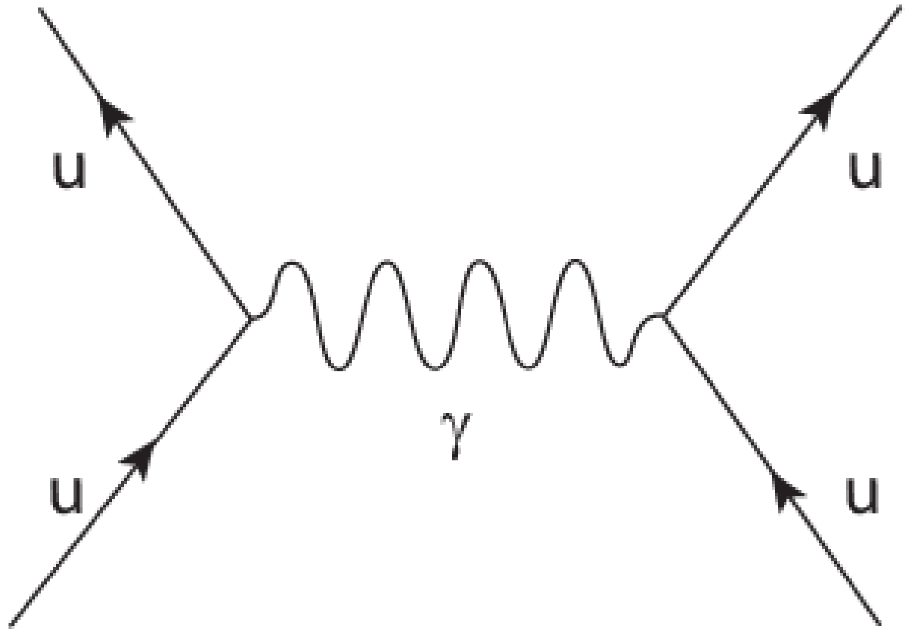
electron	-1	1	0
neutrino	0	1	0

allowed

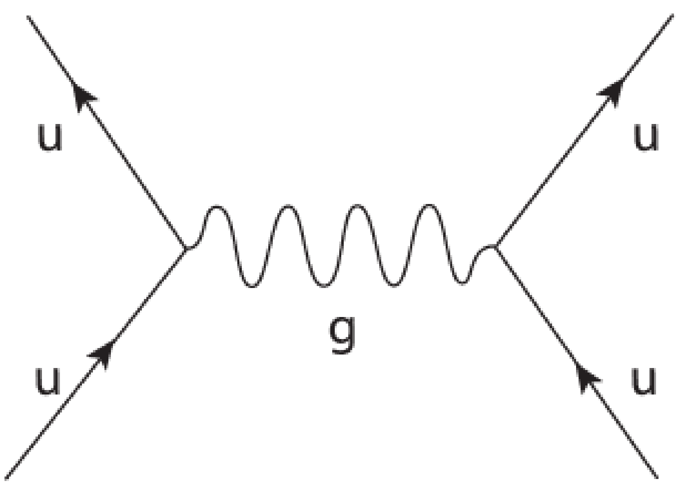
Is this possible?



Yes, it is two quarks interacting via the electromagnetic force.
Up quarks have electric charge of +2/3.

Force Carriers

- Stong – Gluons – g
- Weak – Intermediate vector bosons – Z,W
- Electromagnetic – photon - γ



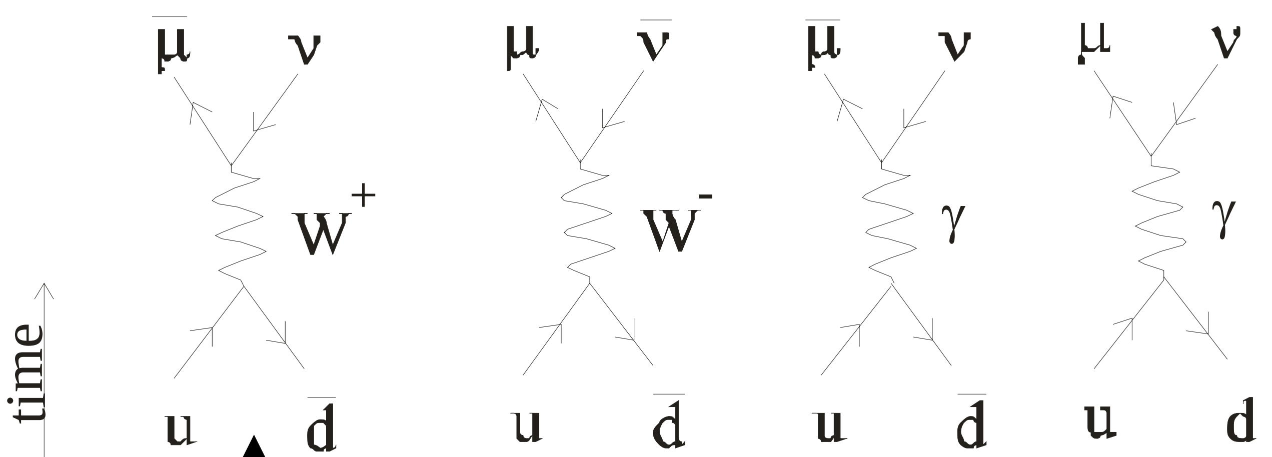
Two quarks interacting via the strong force

Feynman Diagrams and rules

Charge, baryon number, and lepton number are conserved

Consider the decay of a +pion into an antimuon by the Weak force. Which diagram describes this process?

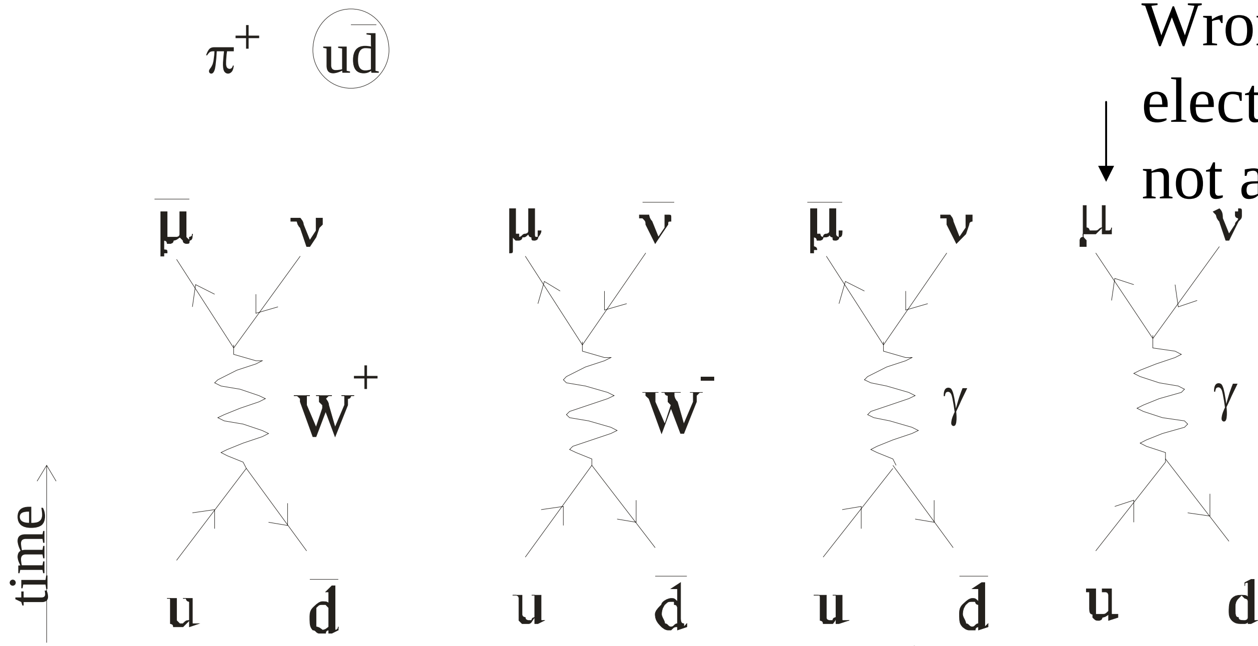
π^+ $u\bar{d}$



correct

Other Examples

Wrong because electric force does not act on neutrinos



Baryon and lepton not conserved

Decay of pion

Charge of W is not correct

Wrong because electric force does not act on neutrinos