Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Clicker Practice

- Please set your clickers to channel #18
  - (press Channel-18-Channel)
- After I open polling, please press ‘D’
  - We should see all D’s on the results
- This time, after I open polling, first press ‘D’
- Now, press ‘A’
  - We should see all A’s on the results

Introductions I

- Where are you from?

A. Iowa
B. Other state in U.S.A.
C. Outside of U.S.A.
D. Another planet

Introductions II

- What is your major?

A. Physics
B. Astronomy
C. Math
D. Physics and …
E. Other

About Me



SPACE SCIENCES LABORATORY
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Newton's Laws

Newton's Laws

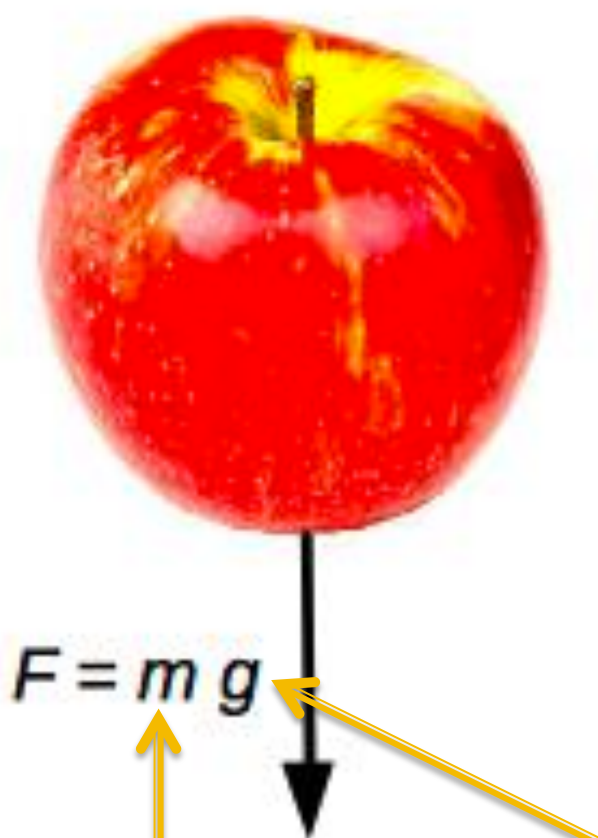
1. A body will remain at rest, or moving at a constant velocity, unless it is acted on by an unbalanced force.
2. The force experienced by an object is proportional to its mass times the acceleration it experiences:

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

3. If two bodies exert a force on one another, the forces are equal in magnitude, but opposite in direction:

$$\vec{F}_{12} = -\vec{F}_{21}$$

Force of Gravity Near Surface



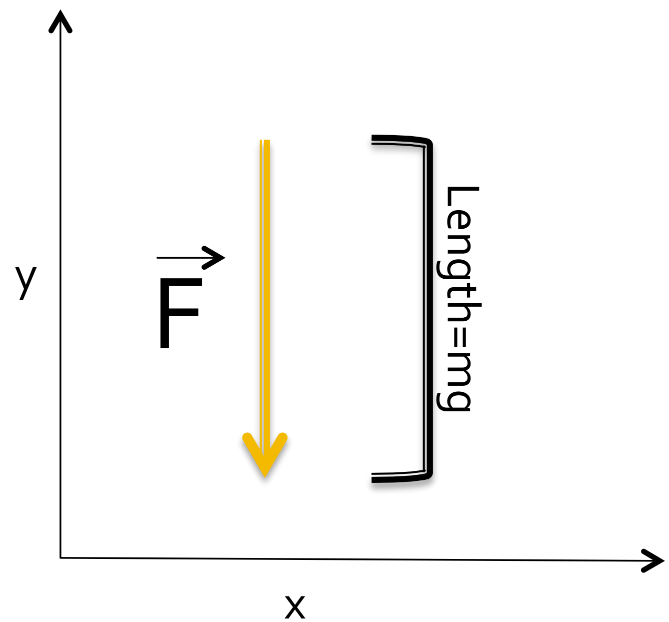
Force

mass (inertia)

gravitational acceleration
(9.8 m/s² at surface of Earth)

Force of Gravity in Vector Form

- The force of gravity can be written in vector form as follows (defining g as a positive constant, and the y axis upward):
  - $\vec{F} = -mg\,\hat{y}$



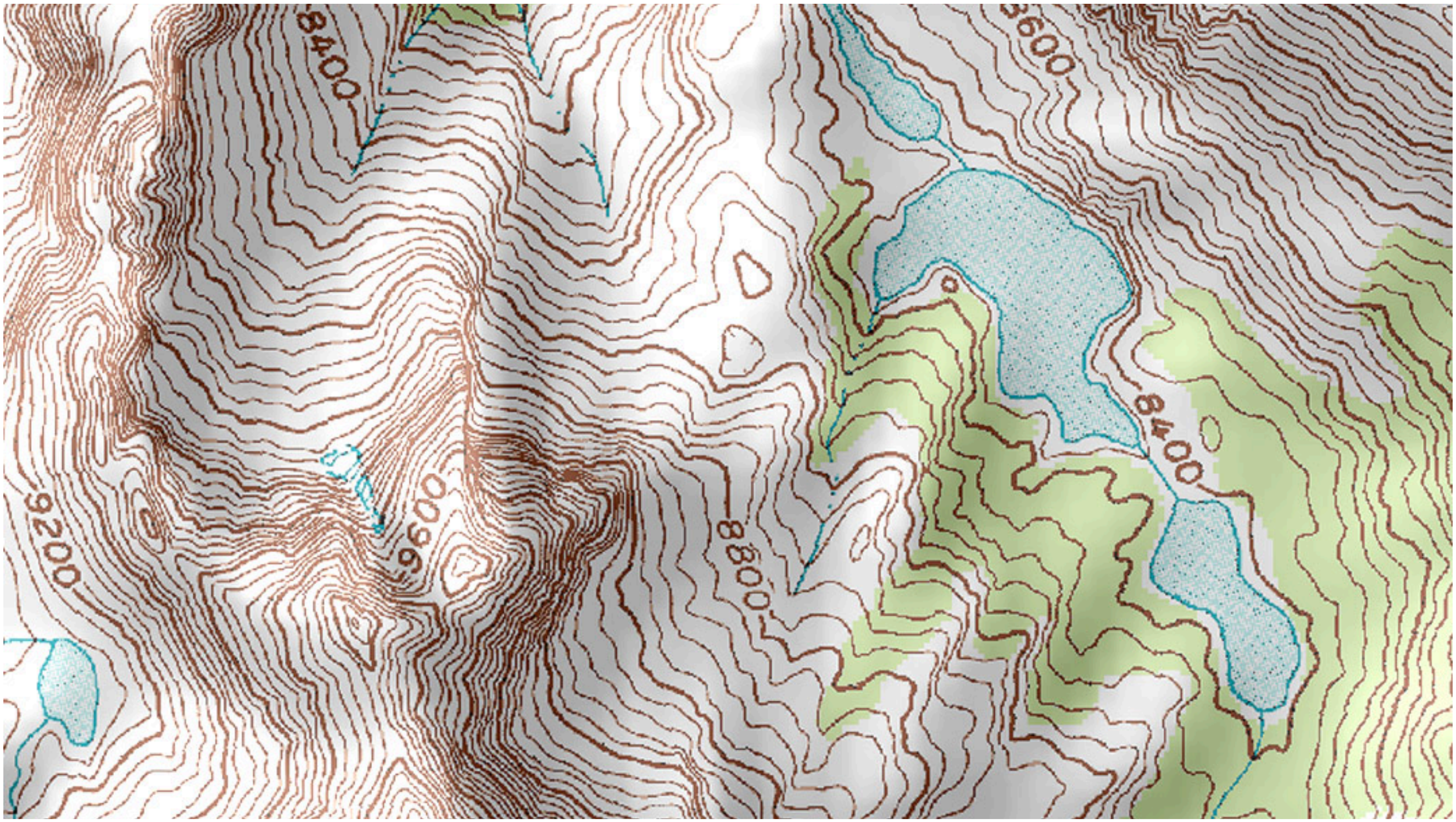
What is a Field?

- A field is a physical quantity that has a value for each point in space and time (according to Wikipedia)
  - A field is just a fancy name for a function of vector coordinates (could also depend on time)

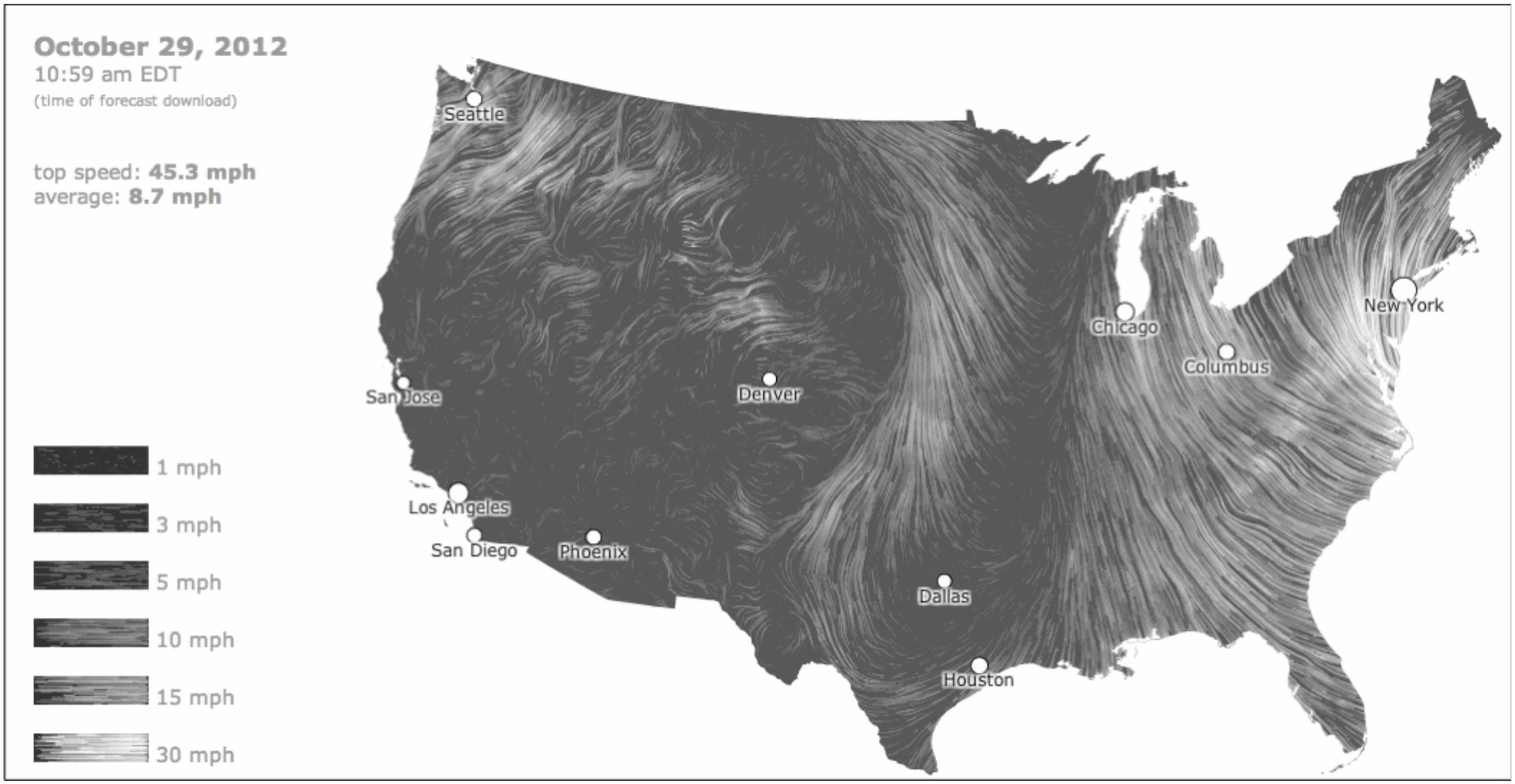
- Scalar field $F = F(x,y,z) = F(\vec{r})$

- Vector field $\vec{F} = \vec{F}(x,y,z) = \vec{F}(\vec{r})$

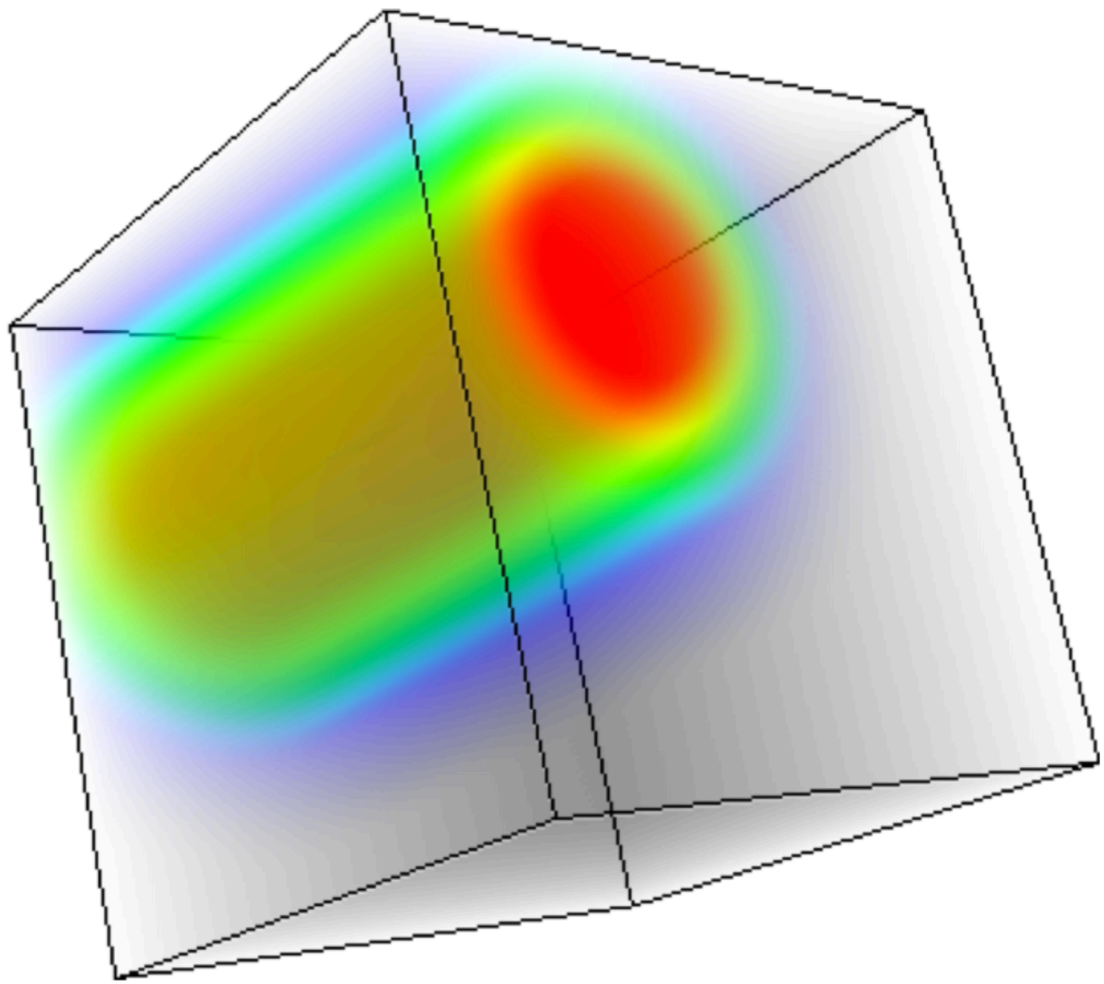
Constant Scalar 2-d field



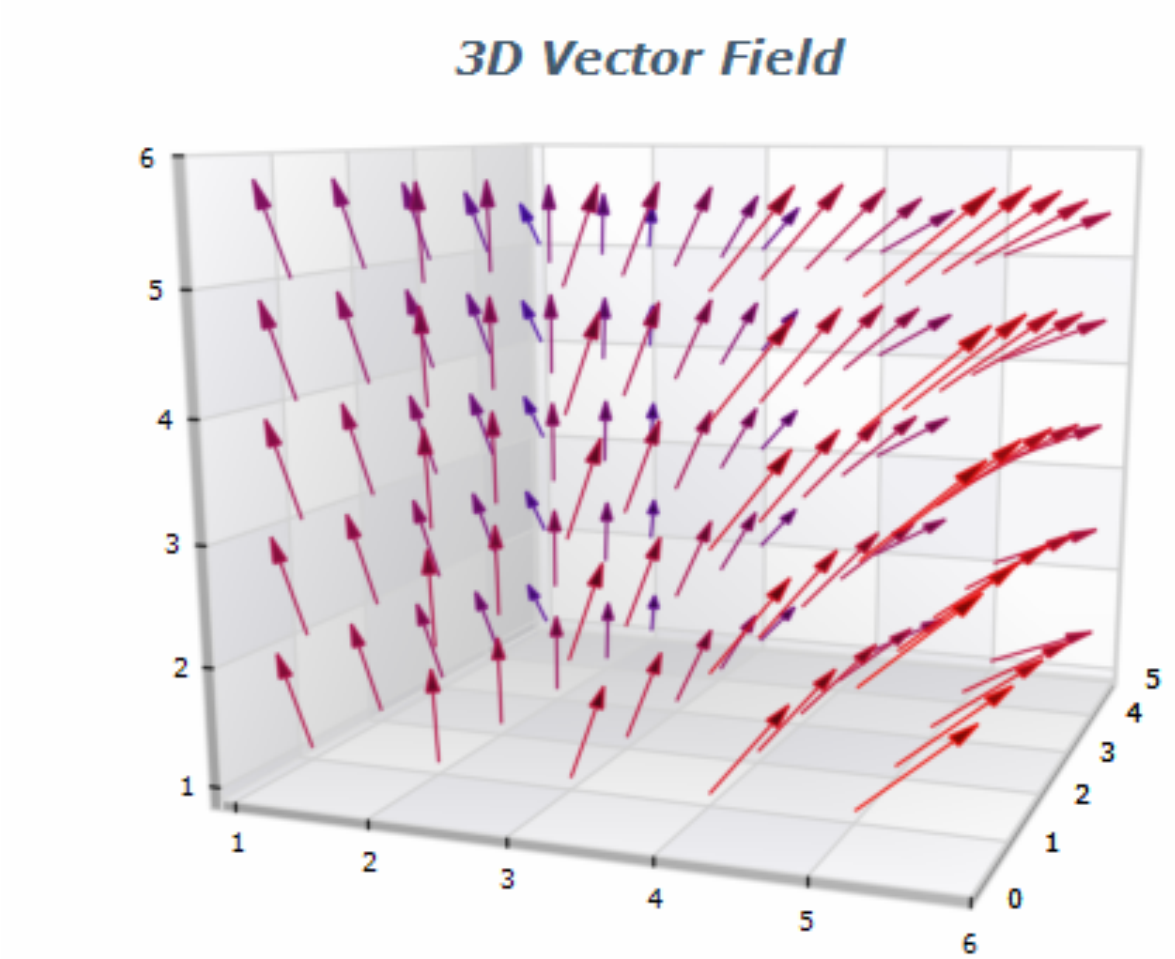
Time-Varying Vector 2-d Field



3-d Scalar Field



3-d Vector Field



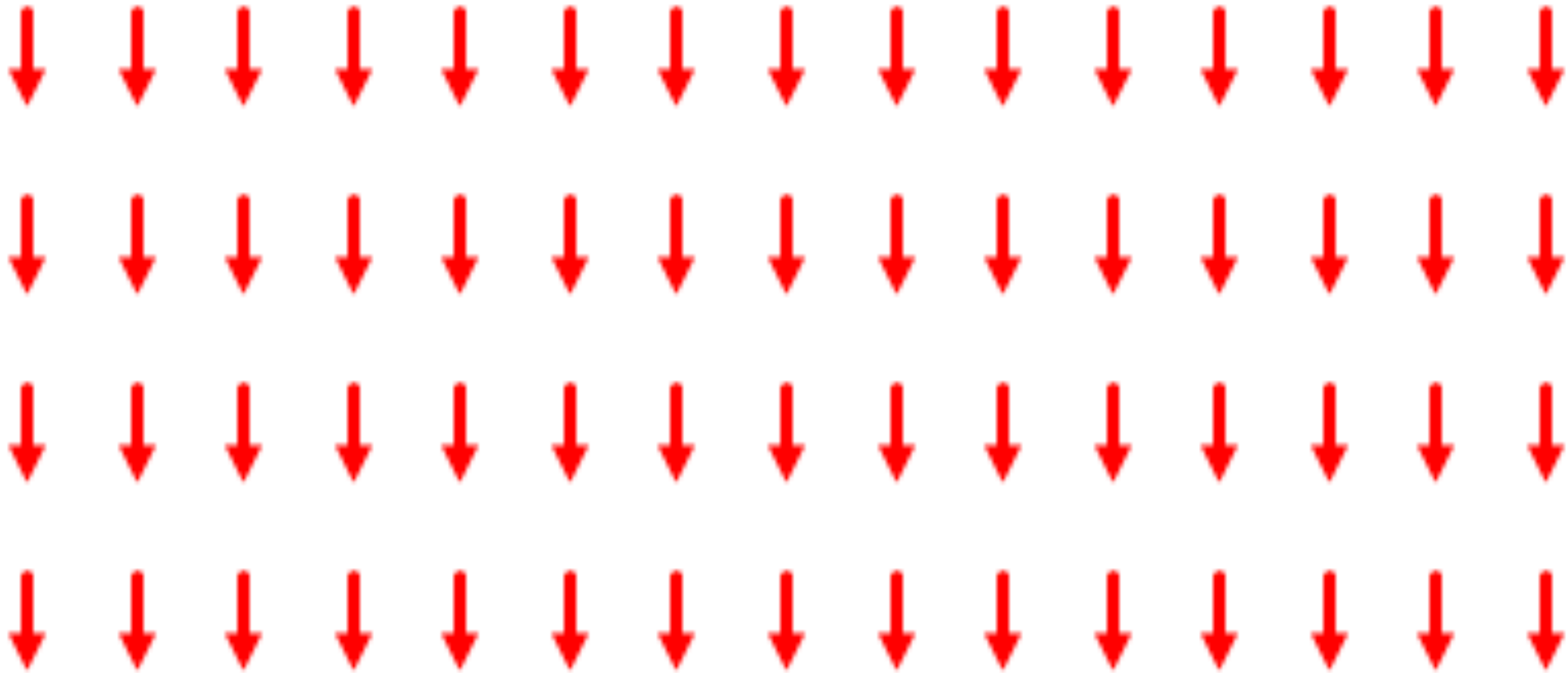
Gravitational Field Near Surface

- We will define the gravitational field as the gravitational force per unit mass

- Near the surface, the gravitational field is constant and equal to the gravitational acceleration g times a downward vector

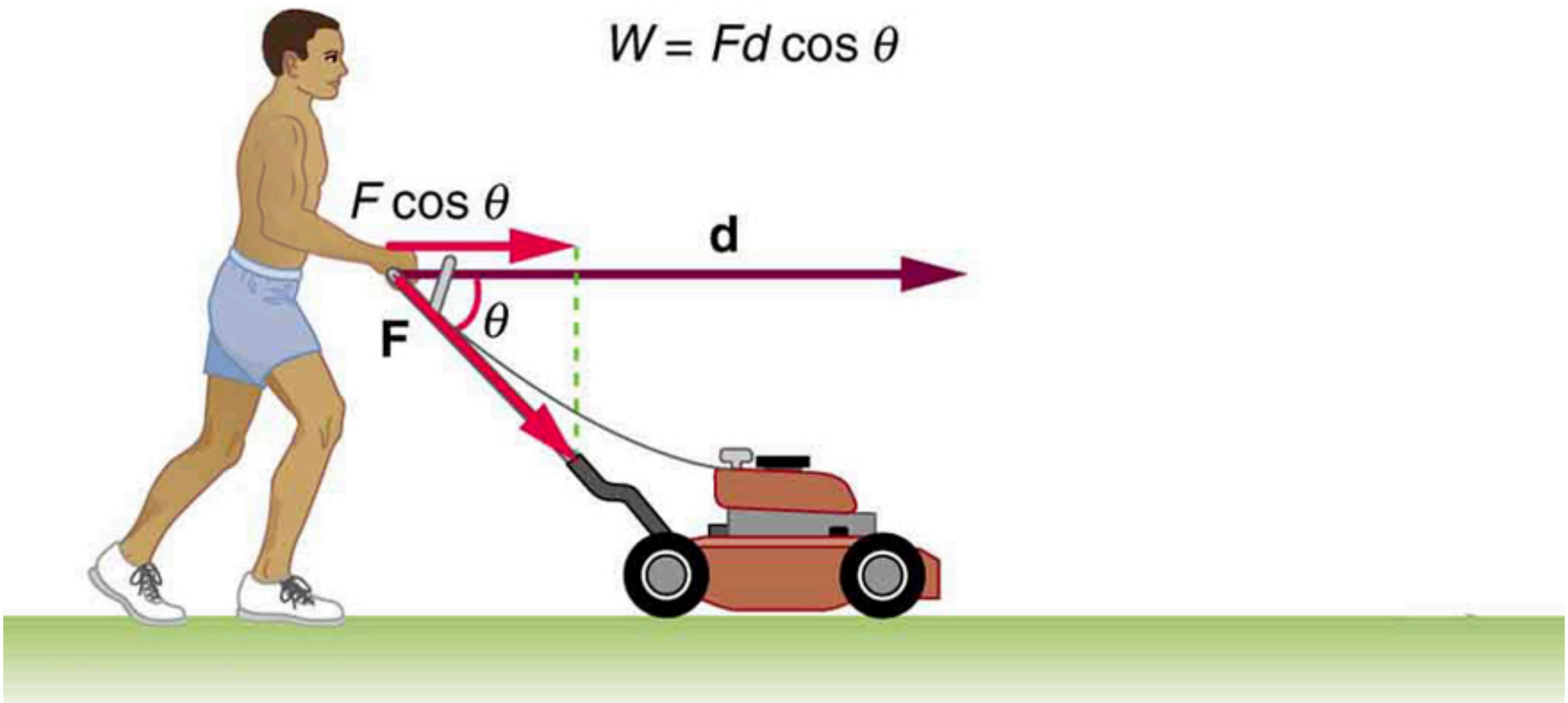
  - $\vec{g} = -g\,\hat{y}$

Gravitational Field Near Surface



Convention: Length of arrows proportional to magnitude of field

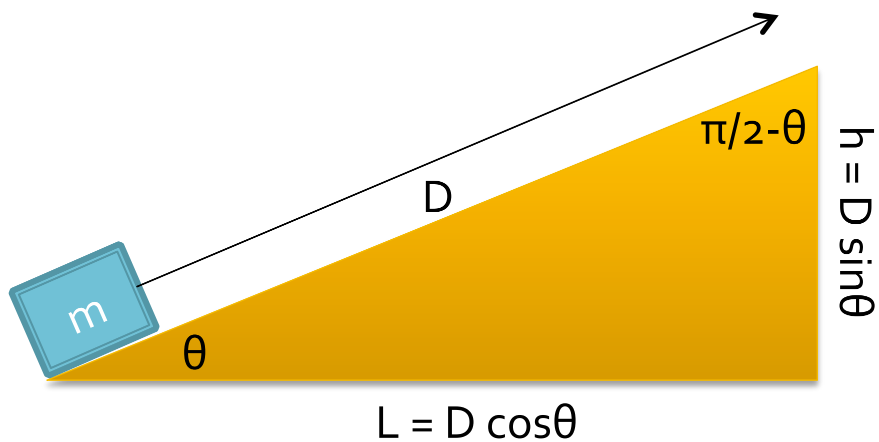
Work



Work Done by Gravity

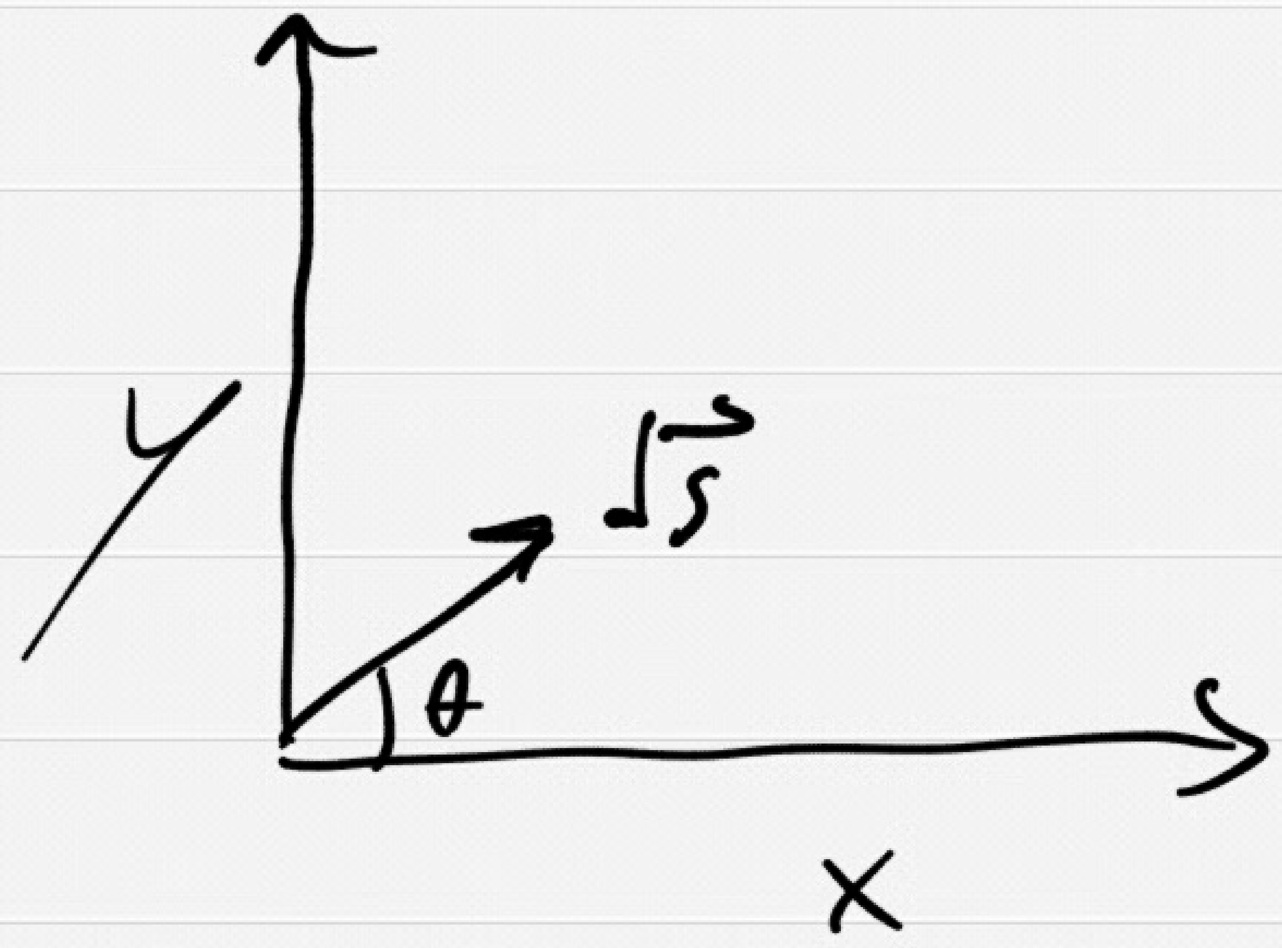
- How much work does gravity do on a box of mass m as you push it up the ramp of length D shown below?

A. -mgL
B. -mgD
C. mgD
D. -mgh
E. mgh



Path integral along ramp:

$$\vec{F} = -mg\hat{j}$$



$$d\vec{s} = ds\,(\cos\theta\,\hat{i} + \sin\theta\,\hat{j})$$

↑ unit vector along ramp

$$|d\vec{s}| = ds\sqrt{\cos^2\theta + \sin^2\theta}$$
$$= ds$$

$$\int \vec{F}\cdot d\vec{s}$$

$$= \int -mg\hat{j}\cdot ds\,(\cos\theta\,\hat{i} + \sin\theta\,\hat{j})$$

$$= \int -mg\sin\theta\, ds$$

$$-mg\sin\theta\, s\Big|_a^b = -mg\sin\theta\, D$$

$$= -mgh$$

What about taking a different path?

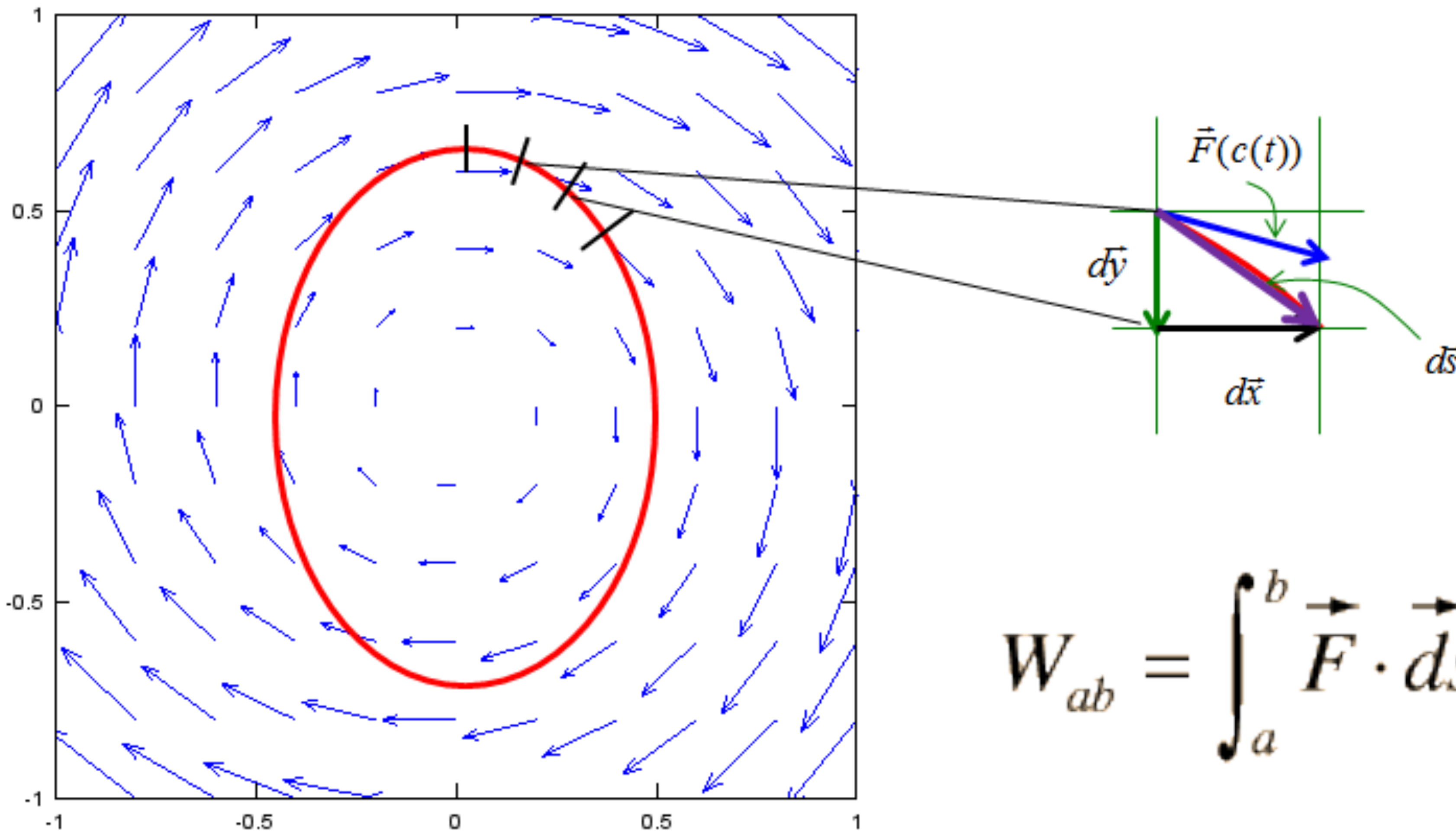
Break into two parts:

$$W_1 = \int -mg\hat{j} \cdot \hat{i}\, ds$$
$$= 0 \quad \text{since } \hat{j} \cdot \hat{i} = 0$$

$$W_2 = \int -mg\hat{j} \cdot \hat{j}\, ds$$
$$= \int -mg\, ds = \int -mg\, dy$$
$$= -mgy \Big|_0^h$$
$$= \boxed{-mgh}$$

Would be same for any path!

Path Integrals



$$W_{ab} = \int_a^b \vec{F} \cdot \vec{ds}$$

Potential Energy

- For gravity, the work done along any path between two points is the same, regardless of path
  - This is equivalent to stating that gravity is a potential force
  - For any potential force, we can define a potential energy:
    - $\Delta U = -W$

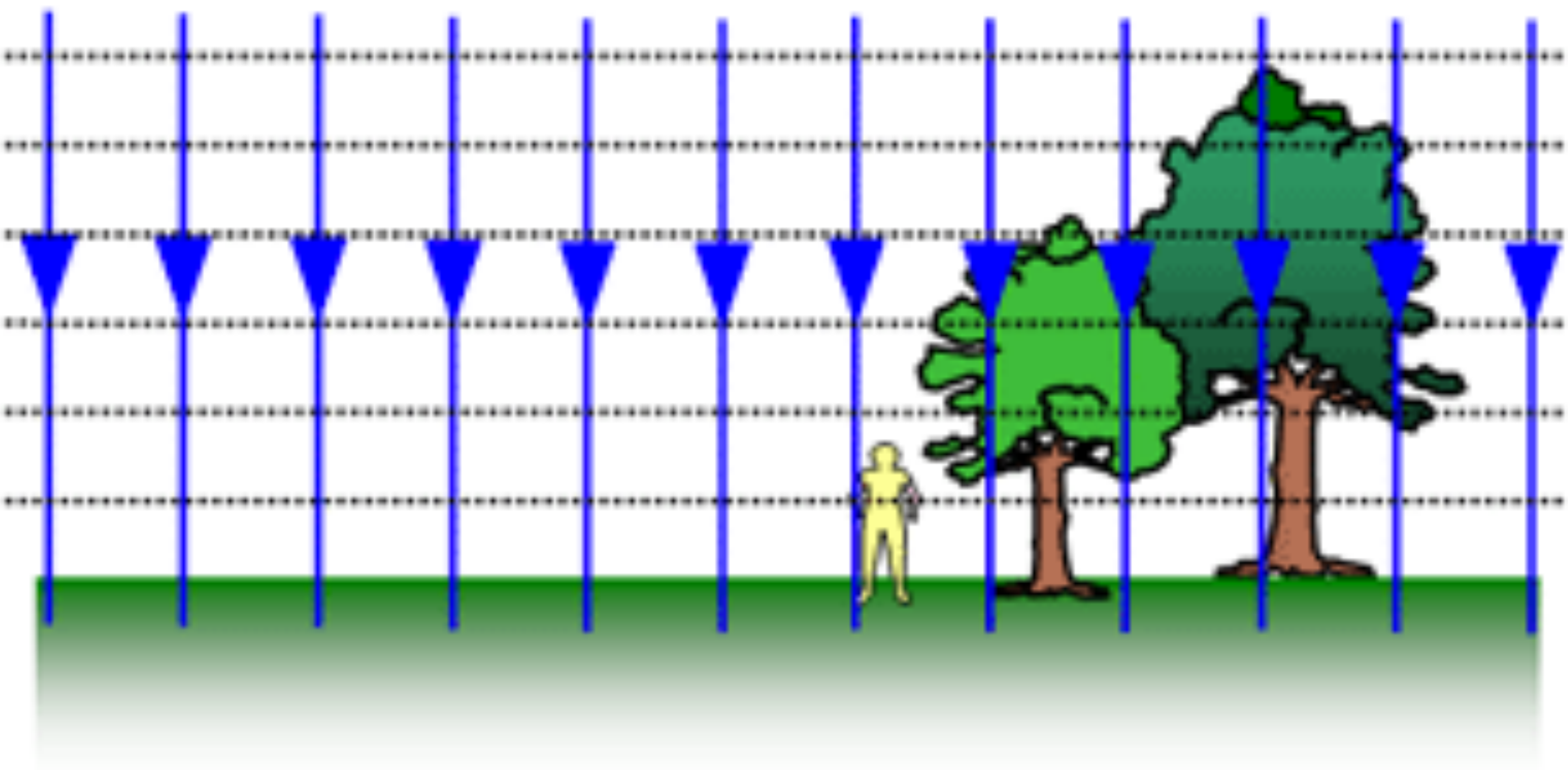
Work-Energy Theorem and Conservation of Energy

- The work energy theorem tells us:
  - $\Delta KE = W$
- For a potential force, this implies:
  - $\Delta KE = -\Delta U$
- Can instead write:
  - $\Delta KE + \Delta U = 0$
  - This is conservation of total mechanical energy

Gravitational Potential Energy Near Surface

- $W = -mg\Delta y$
- $\Delta U = -W = mg\Delta y$
- The zero of potential energy is arbitrary
- If you set potential energy equal to zero at $y = 0$, then:
  - $U = mgy$

Gravitational Equipotentials



Note that the gravitational potential is also a field – a scalar field