College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Kinematics Equation #4

$$v^2 = v_0^2 + 2a\Delta x$$

1/2 m *[$v^2 = v_0^2 + 2a\Delta x$]

$\boxed{\text{Work - Energy}}$

$$v^2 = V_0^2 + 2a\Delta x$$

$$\frac{1}{2}mv^2 = \frac{1}{2}mV_0^2 + ma\Delta x$$

$$ma\Delta x = \frac{1}{2}mV^2 - \frac{1}{2}mV_0^2$$

$$F_{net}\Delta x = \frac{1}{2}mv^2 - \frac{1}{2}mV_0^2$$

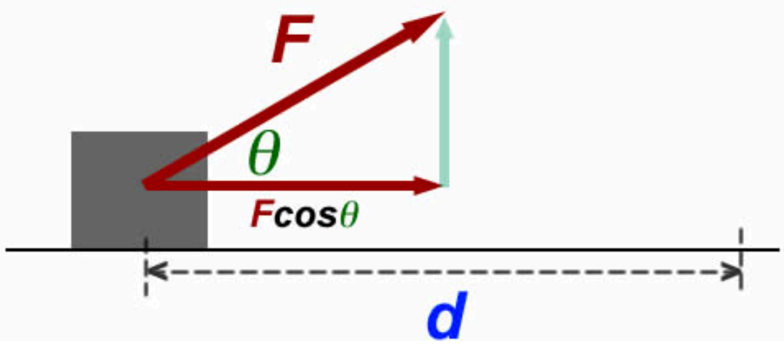
Work = Change in Kinetic Energy

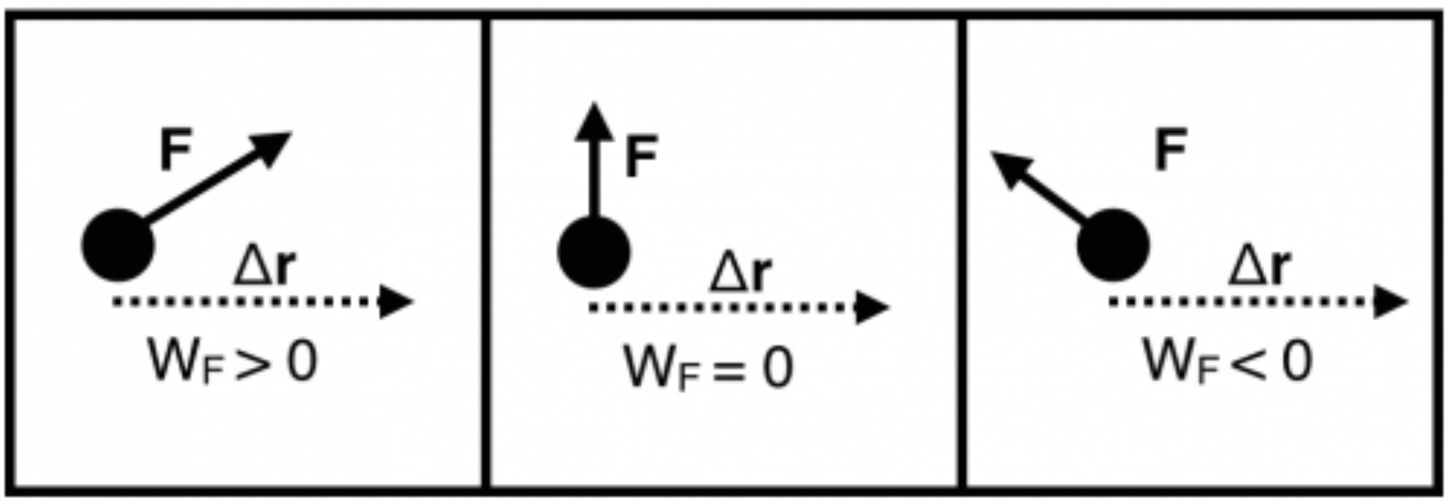
Definition: Work

- For a 1-d constant force:
  - $W = F_x * \Delta x$
- In more dimensions:
  - $W = |F||\Delta r| \cos\theta_{Fr}$
- Units = [Newton][meters] = [Joules]

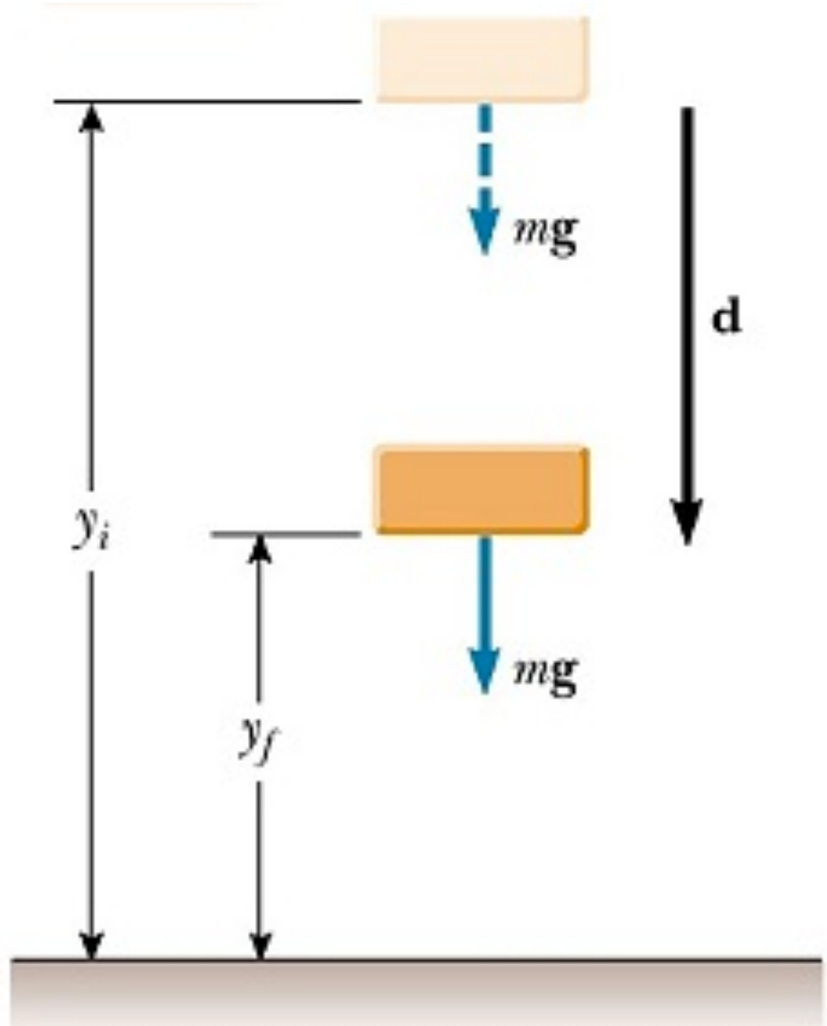
Work: Direction Matters

$$W = Fd\cos\theta$$



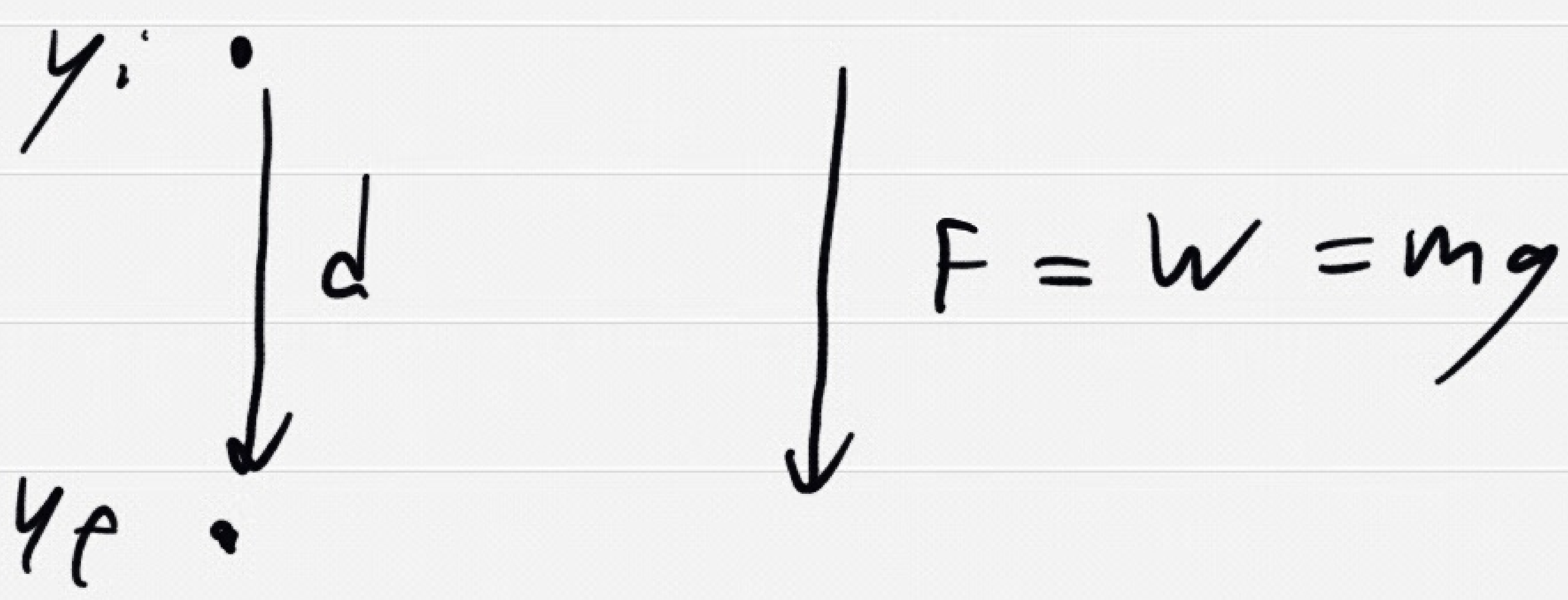


Work Done By Gravity (Free-Fall)



$\boxed{\text{Work of Gravity}}$

Free - fall



$$W = F \cdot d \cdot \cos 0$$

$$= F \cdot d$$

$$= \boxed{mgd}$$

Concept Check

- I lift an object with mass m at a constant speed v to a height d. How much work did <u>I</u> do?

A. $-mg\,d$
B. $mg\,d$
C. $mv\,d$
D. mv^2/d

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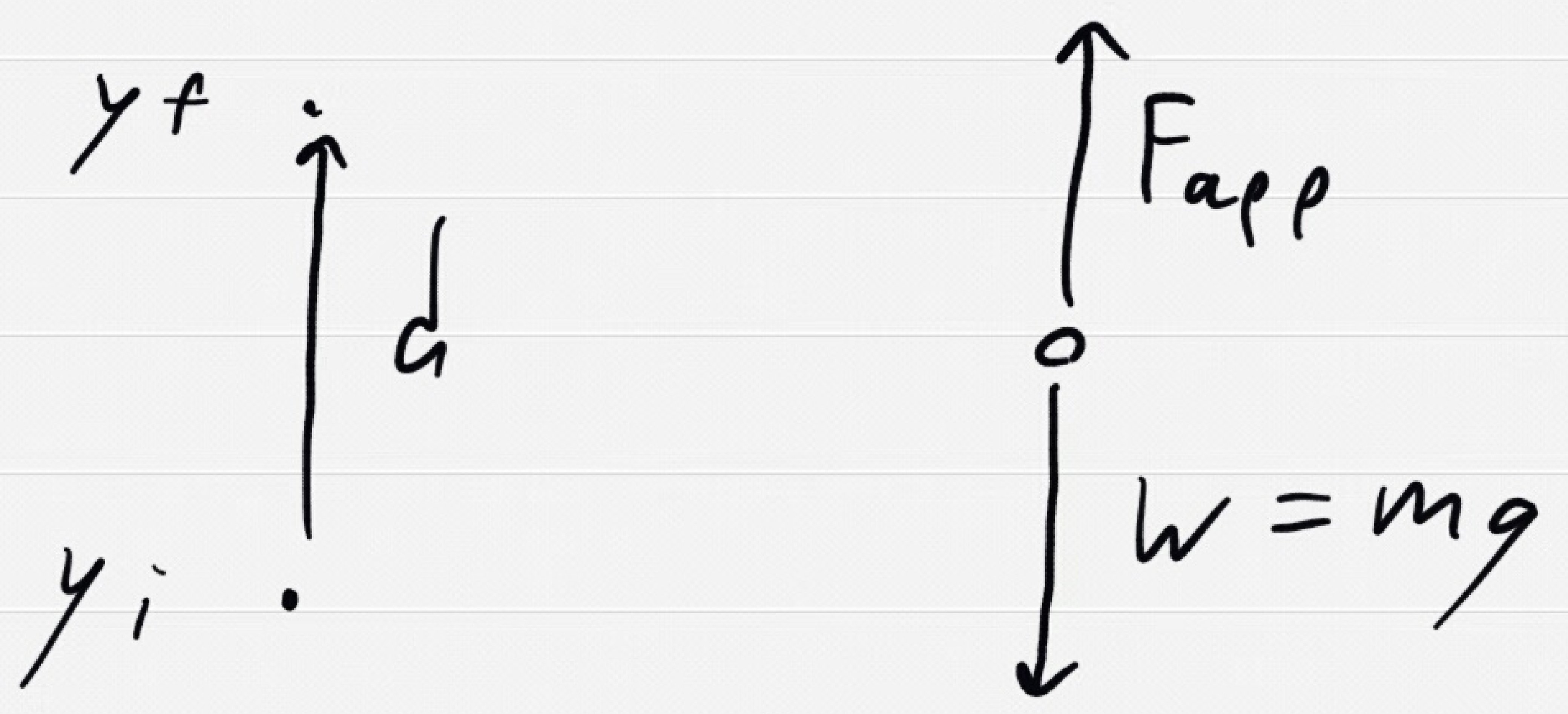
Lifting an object



$$W_{me} = F_{app} \cdot d \cdot \cos\theta$$
$$= mgd$$

$$W_{gravity} = mgd \cos(180^\circ)$$
$$= -mgd$$

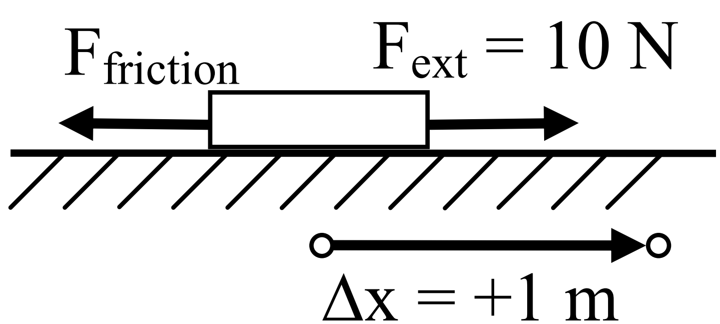
Work done by me and by gravity are equal and opposite since the forces are equal and opposite

Work Done on/by an Object

- In this part of the course we mostly talk about work done on or to objects
- Later in the course we will talk about work done by objects (e.g. ideal gases)
- Since Newton's 3rd law tells us that $\mathbf{F}_{ab} = -\mathbf{F}_{ba}$:
  - The work done by an object is equal and opposite to the work done on an object

Work by Individual Forces

- Work can be decomposed into that done by individual forces
  - The total should be the net work done by the net force



V = Constant

$\boxed{\text{Sliding Block}}$

$$\Delta x = 1\,m$$

$$W_{ext} = F_{ext} \cdot \Delta x \cdot \cos(0)$$
$$= 10N \cdot 1m$$
$$= 10\,J$$

$$W_f = F_f \cdot \Delta x \cdot \cos(180)$$
$$= -F_f \cdot 1m$$

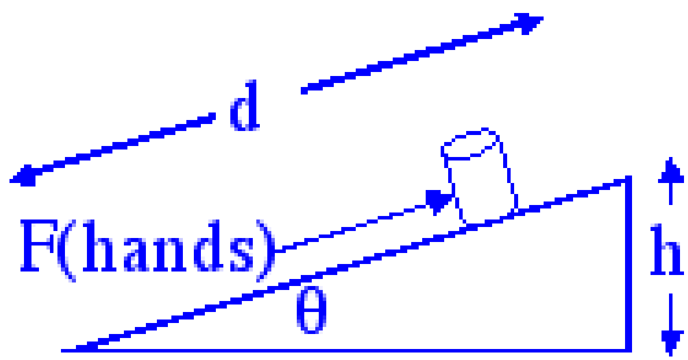
but $|F_f| = |F_{ext}|$ since v const.

$$W_f = -10\,J$$

Concept Check Part-I

You push a beer keg up a (frictionless) ramp with *constant* speed. Suppose you push parallel to the ramp, with force "F".

The ramp travels a distance d along the ramp, ending at height h as shown.



How much work did YOU do on the keg?

A) F d **B)** F d cosθ **C)** zero

D) F h (which is equal to F d sinθ) **E)** None of these

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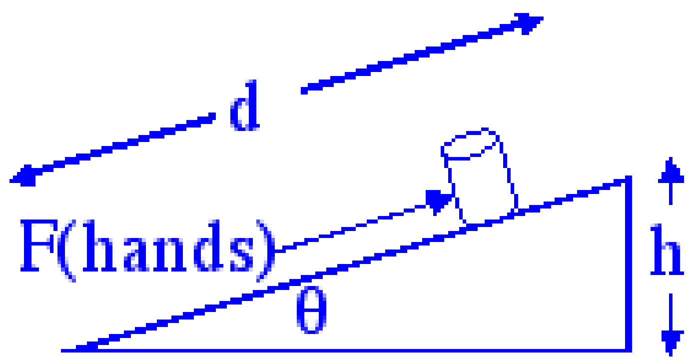

How much work did YOU do on the keg?

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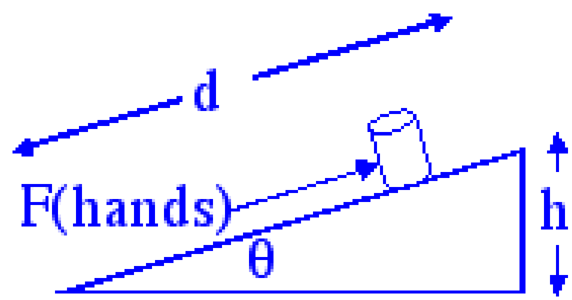
Concept Check Part-II

- How much work did GRAVITY do on the keg?

- **A)** -mg d
- **B)** -mg d cosθ
- **C)** +mg d cosθ
- **D)** -mg h (-mg d sinθ)
- **E)** +mg h (+mg d sinθ)



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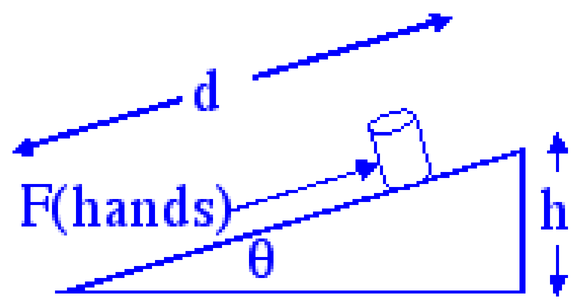
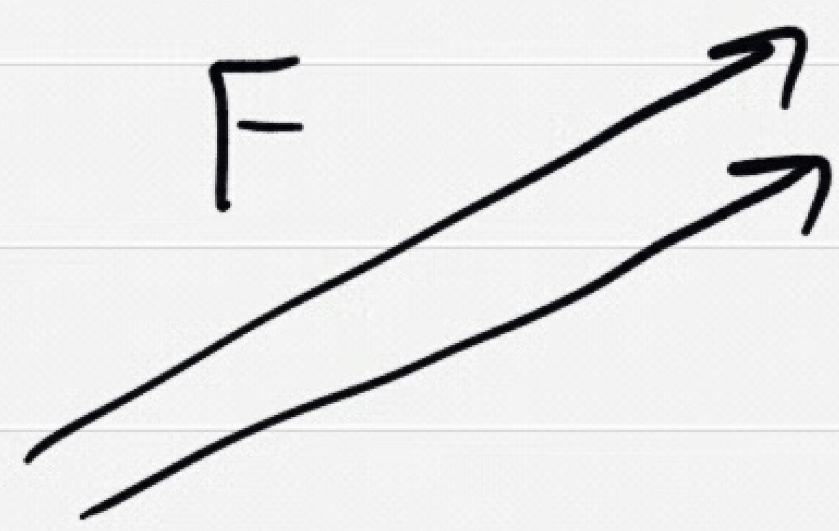


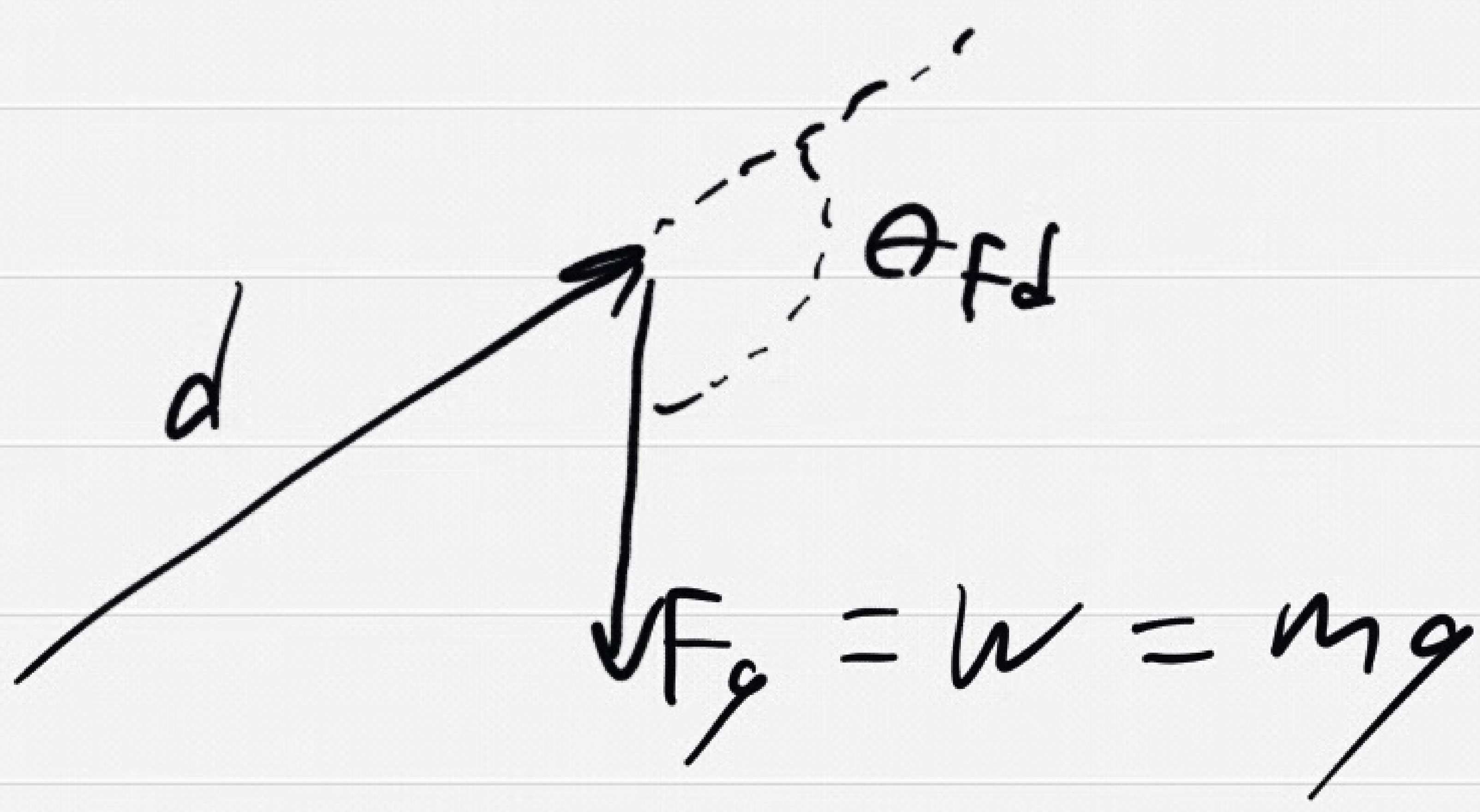
$$\boxed{\text{Beer Keg}}$$

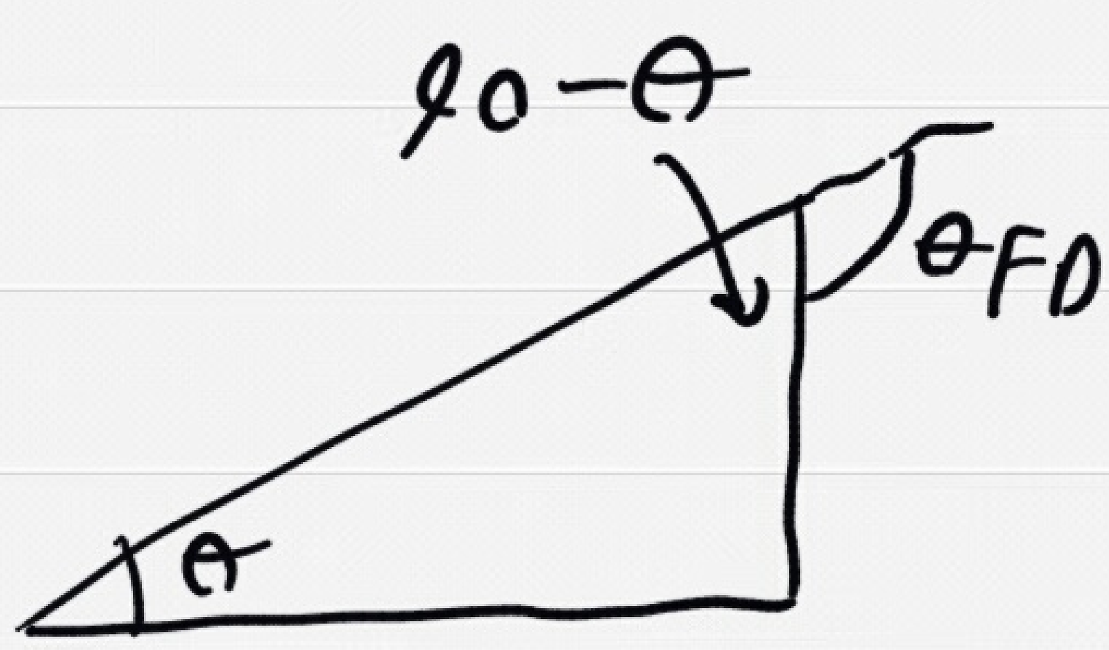
$$W_{ext} = F_{ext} \cdot d \cdot \cos\theta_{Fd}$$

$$= \vec{F} \cdot \vec{d}$$



$W_{gravity}$



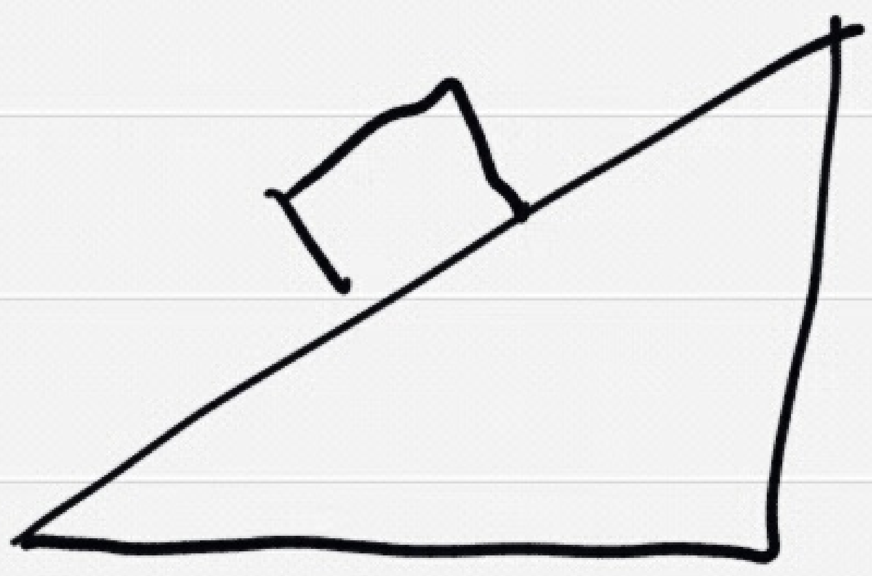


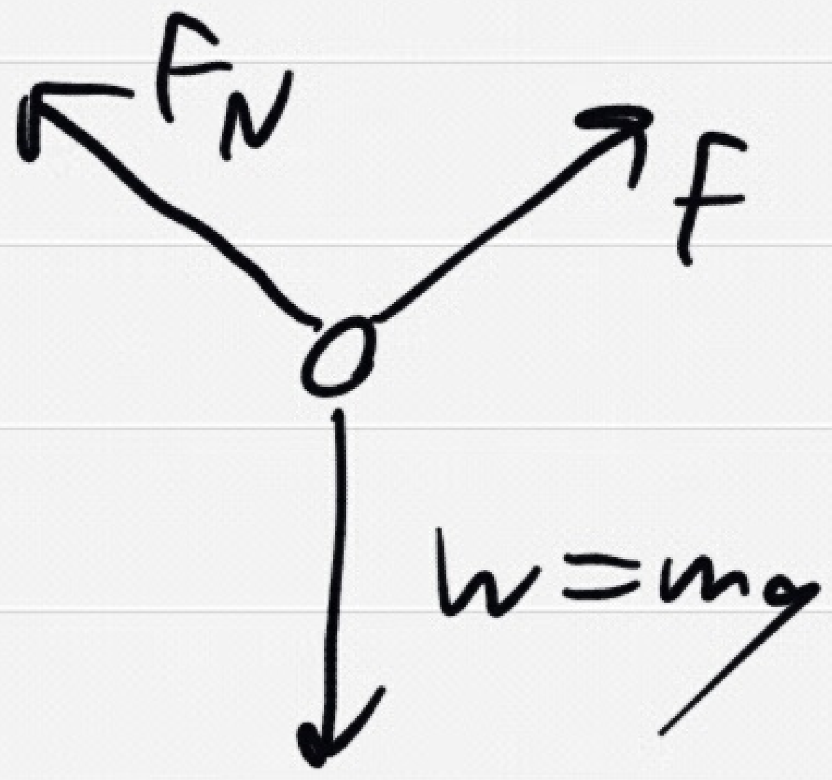
$$\theta_{FD} = 180 - (90 - \theta)$$
$$= \theta + 90^\circ$$

$$\cos(\theta_{FD}) = \cos(\theta + 90^\circ)$$
$$= -\sin(\theta)$$

$$W_{gravity} = -mgd\sin\theta$$
$$= -mgh$$

– depends only on height





Recall $F = mg\sin\theta$
to balance
tangential component
of weight force

so $W_{app} = mg\sin\theta\, d$

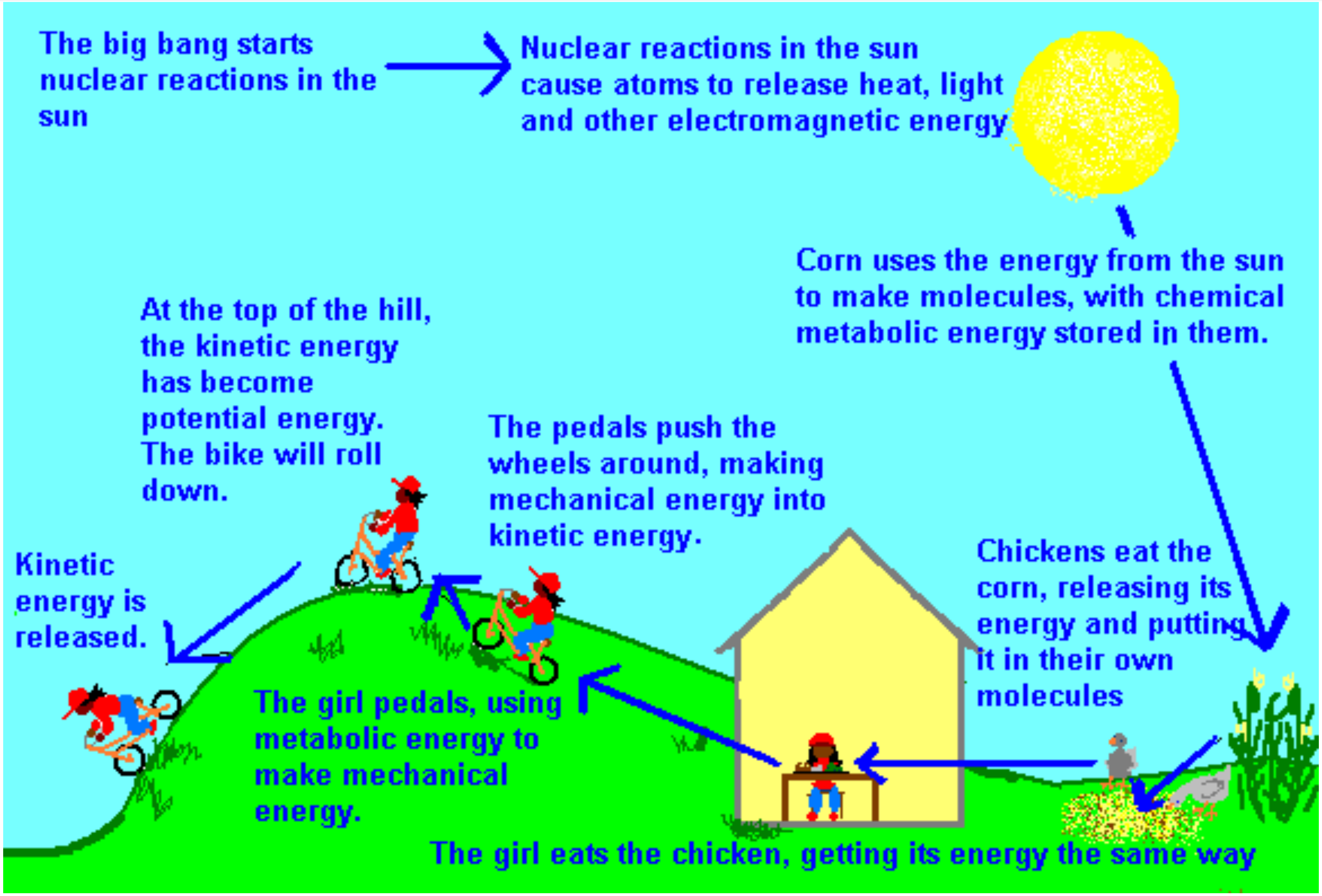
$= -W_{gravity}$

Definition: Energy

- Many Kinds of Energy
  - Kinetic Energy
  - Thermal Energy
  - Electromagnetic Energy
  - Potential Energy (Lots of kinds)
  - Etc.

- All Forms of Energy Have Units of Joules in SI
  - $[J] = [kg][m^2]/[s^2] = [N][m]$

Energy Flow



The big bang starts nuclear reactions in the sun
Nuclear reactions in the sun cause atoms to release heat, light and other electromagnetic energy
Corn uses the energy from the sun to make molecules, with chemical metabolic energy stored in them.
At the top of the hill, the kinetic energy has become potential energy. The bike will roll down.
The pedals push the wheels around, making mechanical energy into kinetic energy.
Kinetic energy is released.
Chickens eat the corn, releasing its energy and putting it in their own molecules
The girl pedals, using metabolic energy to make mechanical energy.
The girl eats the chicken, getting its energy the same way

Energy Conservation

- Energy is **always** (always!!!!) conserved
- Energy can be converted from one form to another, or transferred between bodies
  - This can make it difficult to see that the total energy is conserved
    - But it is an unbreakable law that the (total) energy of a closed system is always conserved

Other Units for Energy

- Calories are also units of energy
  - One calorie = 4.18 J
- One calorie provides enough energy to lift a ~400g mass one meter high, or to give a one kg mass a ~3 m/s velocity
- Our units for food calories are actually kilocalories, or one thousand times as large!