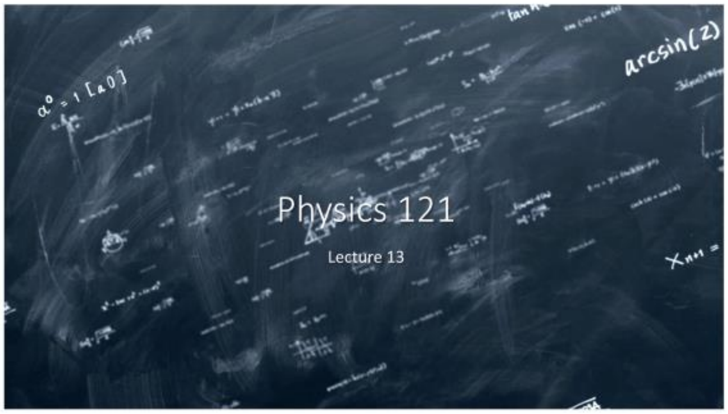
Lecture 13 - 2.23

Thursday, February 23, 2023 9:00 AM



Devotional (breakational?) Thought

Mormon 9:20 And the reason why [God] ceaseth to do [a]miracles among the children of men is because that they dwindle in unbelief…

Matthew 7 ¶ [a]Ask, and it shall be [b]given you; [c]seek, and ye shall find; [d]knock, and it shall be opened unto you:

- Expect Miracles
  - Pray for Eric!

Review

Const acc:

$a(t) = a = \text{const}$

$v(t) = v_0 + a \cdot t$

$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$

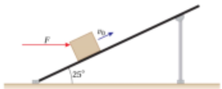
Newton's first

A body at rest remains at rest or, if in motion, remains in motion at constant velocity unless acted on by a net external force.

Newton's second

The acceleration of a system is directly proportional to and in the same direction as the net external force acting on the system and is inversely proportional to its mass.

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



Pedantic Bookkeeping Required!

$$f_s \leq \mu_s N,$$

Static Friction

$$f_k = \mu_k N$$

Kinematic Friction

Experiment – Can Crusher

Discussion:

1. What do we observe?

   2 different heights, 2 different can crush amounts

2. What was different?

   the greater the height, the greater the crush amount

3. What might be the reason?

   More height results in a greater speed in the bottle when it hits the can, which crushes the can more.

Principle: We call the ability of an object to do something energy!

But why does one item have more energy than another?

The force acts along a longer distance, accelerating the item more!

This ability to do something useful is described as "energy"
Energy, the ability of an object to do 'something'

The weight acts on this object the whole time its falling, so the longer it has to fall, the more energy the weight can add.

Quiz

Where does the item receive the energy from to crash the can?

A) Me putting it in the tube at a certain height
B) Earth pulling on the item
C) The item accelerating by itself
D) A mystical force moving the aether

Discussion

Let's explore how Energy is adjusted. What is the difference between the free-falling object and a mass lowered on a string?

Observation: Force acting over a distance changes the energy.

What shall we call this "Energy Transformer"; Force x Displacement?

Force · displacement = Work (Joules / J)

Principle: Work is defined as the energy transferred to or from an object.

Earth pulling the item over a distance adds energy!

Tension in a string during the fall can suck out energy!

→In general: The force applied along the direction of displacement is called work. Or, casually: Work = Force x Distance

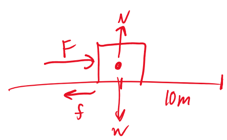
$$\text{Work} = |F| \cdot |d| \cdot \cos(\theta)$$

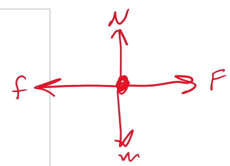
Discussion

Given Newton's third law,
did the item also do work on earth?

Yes, but it's so small that it's negligible.

Also frame of reference of bottle/ball, earth is moving to it.





$\Sigma F_y = 0 \Rightarrow N = w = m \cdot g$

$\Sigma F_x = 0 \Rightarrow f = F$

Q1: Pushing

$f_k = \mu \cdot N = 0.7 \cdot 100 = \underline{70\ N}$

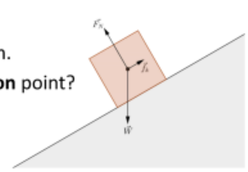
$N = m \cdot g = 10 \cdot 10 = 100$

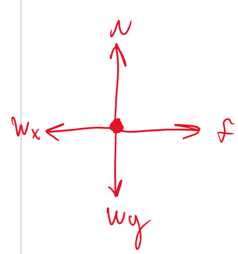
$W = F \cdot d = 70 \cdot 10 = \underline{700\ J}$

You push horizontally on a 10 kg box and it moves 10 meters across the floor (μ=0.70) at constant speed. How much work do you do? Choose the best answer. The right answer is

A. Between 10 and 100 J
B. Between 100 and 500 J
C. Between 500 and 1000 J
D. Between 1000 and 5000 J
E. More than 5000 J

Quiz



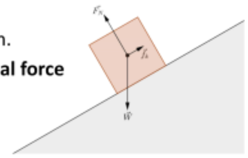


Consider a box sliding down a ramp with friction.
In which direction does the work done by **friction** point?

A) Left along the ramp.
B) Nowhere, this force does no work.
C) Right along the ramp.
D) I refuse to do any further ramp problems, sorry.

Quiz

Consider a box sliding down a ramp with friction.
In which direction does the work done by **normal force** point?

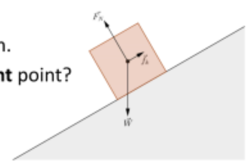


A) Left along the ramp.
B) Nowhere, this force does no work.
C) Right along the ramp.
D) I refuse to do any further ramp problems, sorry.

Since N is perpendicular, it does no work. (bc Cos 90° = 0)

Quiz

Consider a box sliding down a ramp with friction.
In which direction does the work done by **weight** point?



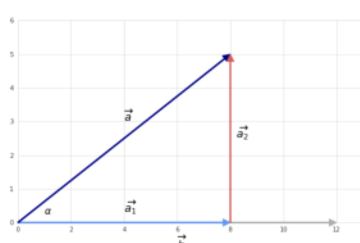
A) Left along the ramp.
B) Nowhere, this force does no work.
C) Right along the ramp.
D) I refuse to do any further ramp problems, sorry.

W_y does nothing

W_x points left, which is what is adding energy and moving the box.

Principle: Work can be positive, negative, or 0!

Review:
Vector Projections



Small confession, when
I did finally understand this...

Now what exactly is the energy in that falling item?

Definition of work: $Work = F \cdot d$

Our favorite Kinematic Equation: $V_f^2 = \cancel{V_i^2} = 2a(x_f - x_i)$

Newton's 2nd law: $\sum F = m \cdot a$ $\qquad a = \frac{V_f^2}{2 \cdot d}$

Some algebra:

$$Work = m \cdot a \cdot d = \frac{m \cdot V_f^2 \cdot \cancel{d}}{2 \cdot \cancel{d}} = \underline{\frac{1}{2} m v^2}$$

$$\boxed{E_{kinetic} = \frac{1}{2} m v^2}$$

$x_i = 0$
$V_i = 0$

$d = x_f - x_i$

$x_f = \_\_$
$V_f = \_\_$

Elevate the derivation to a principle: Work/Energy Theorem

THE WORK-ENERGY THEOREM

The net work on a system equals the change in the quantity $\frac{1}{2}mv^2$.

$$W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

$$W_{net} = K_a - K_B$$

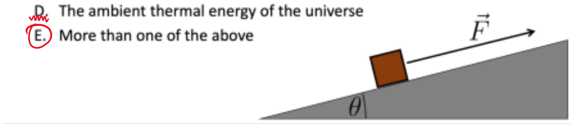
Quiz: A bucket of iron is lowered with a string. It accelerates downwards with a = g/2. Is the work done by the string:

A) Positive
B) Negative
C) Not existing

What if there is no change in the kinetic energy?

You push a block up a frictionless ramp at constant speed. Where does all that work go? Choose the best answer.

A. The gravitational potential energy of the block
B. The thermal energy of the block and the ramp
C. The thermal energy inside your body
D. The ambient thermal energy of the universe
E. More than one of the above



Important: Work Energy Theorem requires bookkeeping of all forces, directions, and distances!

Only the Net-Work matters for changes in kinetic Energy!

Energy is a scalar, not a vector.

Why is this useful? Alternative approach to solve long-known problems:

You throw an object upwards with initial velocity of 10m/s. How high will it go? (assume g = 10m/s**2)

A) 5 m
B) 10 m
C) 15 m
D) 20 m

$\text{Work} = F \cdot d = \Delta K = K_f - K_i$

$K_f = 0$

$K_i = \frac{1}{2} \cdot m \cdot v_i^2$

$d = \frac{-\frac{1}{2} \cancel{m} v_i^2}{-\cancel{m} \cdot g} = \frac{\frac{1}{2} v^2}{g} \Rightarrow \frac{\frac{1}{2}\, 100}{10} = \frac{50}{10} = \boxed{5m}$

Some Ruminations: Energy is conserved

Exit Poll

- Please provide a letter grade for todays lecture:

A. A
B. B
C. C
D. D
E. Fail