MECHANICAL ENERGY

1

NEW MEANINGS

2

2 Volunteers

- Place a chair on the table
- Hold a chair at the same height
- the big question:
  - who did more work?

3

Work

W = F d

Work = **F**orce **x** **d**istance

- Joules (J) = N m
- Force and Distance must be collinear

col·lin·ear *adj* \kə-ˈli-nē-ər, kä-\

Definition of COLLINEAR

1 : lying on or passing through the same straight line

2 : having axes lying end to end in a straight line <*collinear* antenna elements>

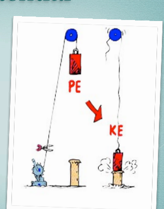
— **col·lin·ear·i·ty** *noun*

4

Kinetic & Potential

Kinetic - Energy of a mass in motion

Potential - Energy stored for later



5

Potential Energy

PE = mgh

- mass (kg)
- gravity (9.8 m/s^2)
  - height (m)
- the height must be relative to some “ground” level

6

Kinetic Energy

KE = ½mv²

- mass (kg)
- velocity (m/s)
- KE is often relative to an original velocity of 0 m/s (0 Joules)

7

Conservation of Energy

- Find the total Energy at any one point
- The total can not change in a closed system
- KE is often used to find final velocities

8

Another Volunteer

- A race to put the chair on the desktop
- Who was stronger?
- Who did more Work?
- So what's the difference?

9

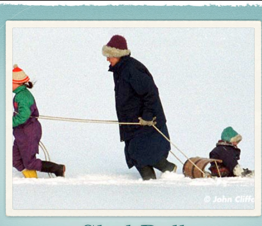
Power

How Fast Work is Done

P = Work / time

- Watts (W) = J/s
- 1 hp = 550 ft lb / s = 746 W

10



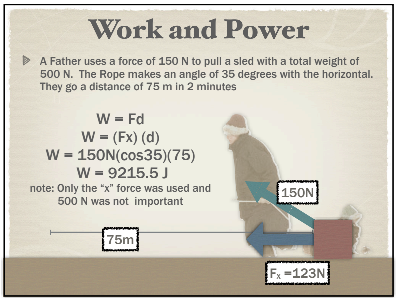
Sled Pull

11

Work and Power

- A Father uses a force of 150N to pull a sled with a total weight of 500 N. The Rope makes an angle of 35º with the horizontal. They go a distance of 75 m in 2 minutes

12



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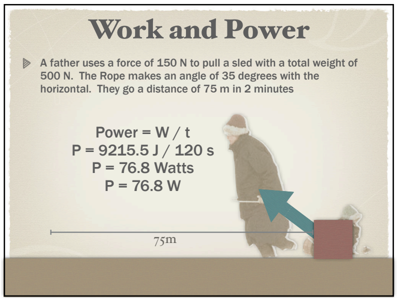

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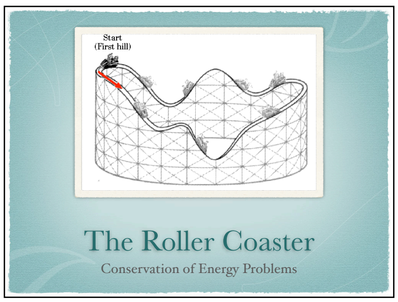

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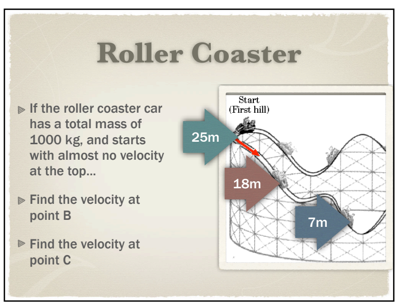
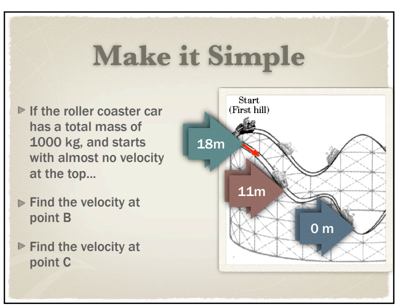
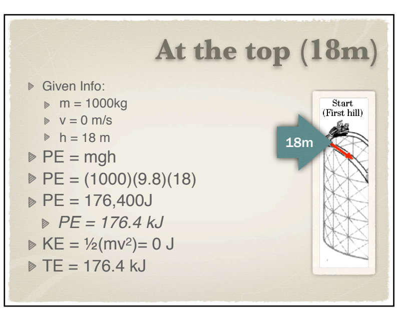


16



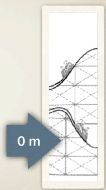
17



18

At the bottom (0 m)

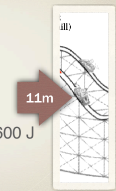
- Given Info:
  - m = 1000 kg
  - h = 0 m
  - TE = 176.4 kJ
- PE = mgh = 0 J
- KE = 176,400 J
  - 176,400 J = ½(1000)v^2
  - v^2 = 352.8
  - v = 18.78 m/s



19

At point B(11m)

- Given Info:
  - m = 1000 kg
  - h = 11 m
  - TE = 176.4 kJ
- PE = mgh
- PE = (1000)(9.8)(11)
  - PE = 107,800 J
- KE = 176,400-107,800 J = 68,600 J
- KE = 68,600 J = ½(mv^2)
  - 68,600 J = ½(1000)v^2
  - v = 11.71 m/s



20

Pendulum Swing

Conservation of Energy Problems

21

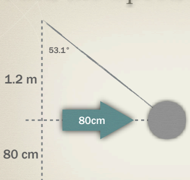
Find the Speed

- A pendulum bob on a 2m string is released from a height of 80cm.
- What is the maximum velocity of the pendulum?
- What is the speed at half the height?

22

Find the Speed

A 100g pendulum bob on a 2m string is released from a height of 80cm. What is the maximum velocity of the pendulum? What is the speed at half the height?

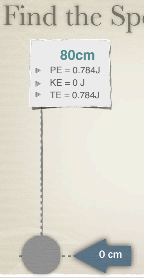


- Mass = 0.1 kg
- h = 0.8 m
- PE = mgh = 0.784J
- Velocity = 0 m/s
- KE = 0 J
- TE = 0.784J

23

Find the Speed

A 100g pendulum bob on a 2m string is released from a height of 80cm. What is the maximum velocity of the pendulum? What is the speed at half the height?



- Given Info:
  - Mass = 0.1 kg
  - TE = 0.784J
  - h = 0.0 m
- PE = mgh = 0 J
- KE = 0.784 J = ½(mv^2)
- 0.784 J = ½(0.1)(v^2)
- v = 3.96 m/s

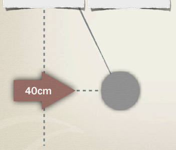
24

Find the Speed

A 100g pendulum bob on a 2m string is released from a height of 80cm.
What is the maximum velocity of the pendulum?
What is the speed at half the height?

80cm
- PE = 0.784J
- KE = 0 J
- TE = 0.784J
- v = 0.0 m/s

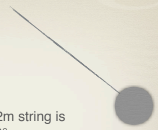
0cm
- PE = 0 J
- KE = 0.784J
- TE = 0.784J
- v = 3.96 m/s



- Given Info:
  - m = 0.1 kg
  - TE = 0.784J
  - h = 0.4 m
- PE = mgh = 0.392 J
- KE = 0.392 J = ½(mv^2)
- 0.392 J = ½(0.1)(v^2)
- v^2 = 7.84
- v = 2.8 m/s
  - *(not half the maximum speed)*

25

Find the Speed
honors style



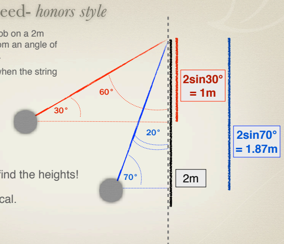
- A 250g pendulum bob on a 2m string is released from an angle of 60°.
- What is the speed when the string forms a 20°angle with the vertical

26

Find the Speed- *honors style*

A 250g pendulum bob on a 2m string is released from an angle of 60° with the vertical.

What is the speed when the string forms a 20°angle?



So, you need to find the heights!

60° with the vertical.

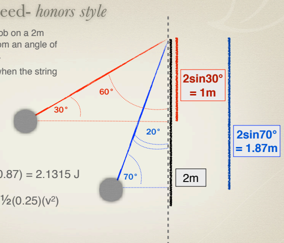
20°angle?

27

Find the Speed- *honors style*

A 250g pendulum bob on a 2m string is released from an angle of 60° with the vertical.

What is the speed when the string forms a 20°angle?



PE= (0.25)(9.8)(0.87) = 2.1315 J

KE = 2.1315 J = ½(0.25)(v^2)

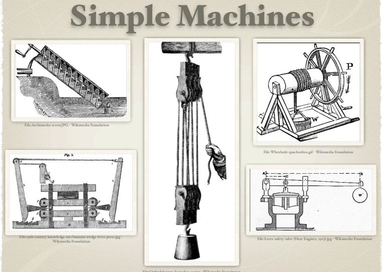
v = 4.13 m/s

28

SIMPLE MACHINES

29

Simple Machines



30

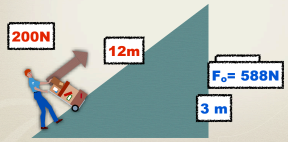
Simple Machines

- IMA - the Ideal Mechanical Advantage
  - based on the geometry of the system
- AMA - the Actual Mechanical Advantage
  - based on the real forces used
- Efficiency = Work Output / Work Input
  - Efficiency = Wo / Wi = AMA / IMA

31

Laura lifts some boxes up 3m by pushing the 60 kg cart up a 12 m ramp. She uses a force of 200 N and takes 30 seconds to travel.

Find; the work input, the work output, the IMA and AMA, the efficiency of the ramp, energy wasted by friction, her power



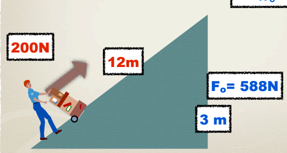
32

Laura lifts some boxes up 3m by pushing the 60 kg cart up a 12 m ramp. She uses a force of 200 N and takes 30 seconds to travel.

Find; the work input, the work output, the IMA and AMA, the efficiency of the ramp, energy wasted by friction, her power

$W_i = F\ d$
$W_i = (200\ N)\ (12m)$
$W_i = 2400\ J$

$W_o = F\ d$
$W_o = (588\ N)\ (3m)$
$W_o = 1764\ J$



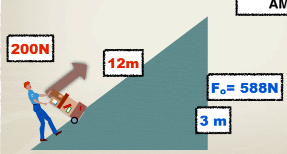
33

Laura lifts some boxes up 3m by pushing the 60 kg cart up a 12 m ramp. She uses a force of 200 N and takes 30 seconds to travel.

Find; the work input, the work output, the IMA and AMA, the efficiency of the ramp, energy wasted by friction, her power

$IMA = D_i / D_o$
$IMA = 12 / 3 = 4$

$AMA = F_o / F_i$
$AMA = 588/200$
$AMA = 2.94$



34

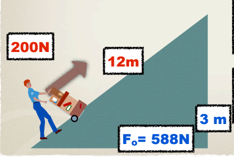
Laura lifts some boxes up 3m by pushing the 60 kg cart up a 12 m ramp. She uses a force of 200 N and takes 30 seconds to travel.

Find; the work input, the work output, the IMA and AMA, the efficiency of the ramp, energy wasted by friction, her power

Efficiency
$= W_o / W_i$
= AMA / IMA
Eff = 73.5%

Lost Energy to Friction
2400J - 1764J
636J

Power = W / t
P = 2400J / 30s
P = 80 W



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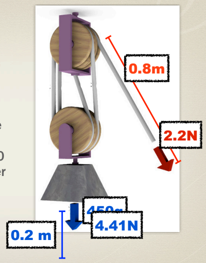
Pulley Arrangements

36

In the Pulley arrangement shown, A force of 2.2 N is used to lift a 450 g Mass. While the mass goes up 20 cm, a student pulls in 80 cm of string. It takes her 5 seconds to lift.



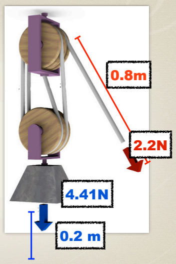
37

A force of 2.2 N is used to lift a 450 g mass. While the mass goes up 20 cm, a student pulls in 80 cm of string. It takes her 5 seconds to lift

Find the work input,
the work output,
the IMA,
the AMA,
the efficiency of the pulley,
the energy wasted by friction,
her power

$W_i = FD$
$W_i = (2.2N)(0.8m)$
$W_i = 1.76$ J

$W_o = FD$
$W_o = 4.41N(0.2m)$
$W_o = 0.882$ J



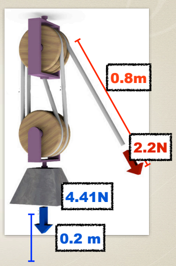
38

A force of 2.2 N is used to lift a 450 g mass. While the mass goes up 20 cm, a student pulls in 80 cm of string. It takes her 5 seconds to lift

Find the work input Wi = 1.76 J
the work output, Wo = 0.882 J
the IMA,
the AMA,
the efficiency of the pulley,
the energy wasted by friction,
her power

$IMA = D_i / D_o$
IMA = (0.8m) / (0.2m)
IMA = 4

$AMA = F_o / F_i$
AMA = 4.41N /(2.2N)
AMA = 2



39

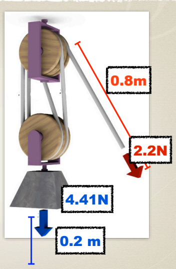
A force of 2.2 N is used to lift a 450 g mass. While the mass goes up 20 cm, a student pulls in 80 cm of string. It takes her 5 seconds to lift

Find the work input Wi = 1.76 J
the work output, Wo = 0.882 J
the IMA, IMA = 4
the AMA, AMA = 2
the efficiency of the pulley,
the energy wasted by friction,
her power

Efficiency = W_o / W_i
Efficiency = (0.882J)/(1.76J)
Efficiency = 0.5 = 50%

Energy Lost
1.76 - 0.882 = 0.878J

Power = W / t
Power = 1.76 / 5s = 0.352W



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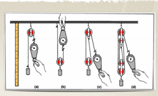
Pulley Lab



Data:		Draw the pulley arrangement	Calculations:	
mass lifted			Number of lifting strings	
Weight Lifted				
Height lifted			Work input **F x D**	
mass needed			Work output **W x H**	
Force applied				
Distance			Efficiency Wo / Wi	

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Academic Assignment

Academic Physics
Set 1 - Chapter 10
1, 2, 3, 5, 6, 7, 25, 26, 27, 28, 52, 53, 56, 57

42

Solving Problems with Energy

instead of old equations

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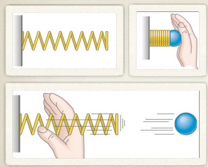
Elastic Potential Energy



- W = F D
- F = k x
- $F_{avg} = ½\ k\ x$
- W = (½ k x) (x)
- $W = ½\ k\ x^2$
- $PE = ½\ k\ x^2$

44

Elastic Potential

- In an earlier lab, you compressed a spring to "two clicks" or a distance of 6cm. The 10g ball went up 1.08m when launched at 90º.
- Find the PE at the top
- Find the Spring Constant k
- Find the KE at the top of the cannon, and the maximum velocity of the ball
- Find the maximum force used to push the spring

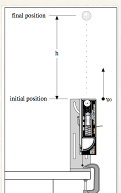


Figure 5.1: Conservation of Energy

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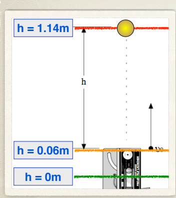
Elastic Potential

- In lab, you compressed a spring a distance of 6cm. The 10g ball went up 1.08m.

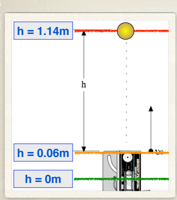


- Find the PE at the top
- Find the Spring Constant k
- Find the KE at the top of the cannon, and the maximum velocity of the ball
- Find the maximum force used to push the spring

46

Elastic Potential

- In lab, you compressed a spring a distance of 6cm. The 10g ball went up 1.08m.

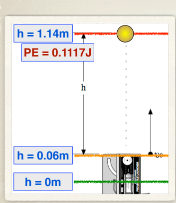


- Find the PE at the top
- PE = mgh
- PE = (0.010kg)(9.8)(1.14)
- PE = 0.1117J
- TE = 0.1117J

47

Elastic Potential

- In lab, you compressed a spring a distance of 6cm. The 10g ball went up 1.08m.

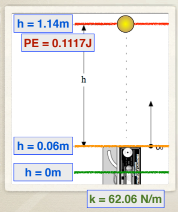


- Find the Spring Constant k
- $\text{Elastic PE} = ½kx^2$
- $0.1117J = ½\ k\ (0.06)^2$
- k = 62.06 N/m

48

Elastic Potential

- In lab, you compressed a spring a distance of 6cm. The 10g ball went up 1.08m.



- Find the KE and the velocity
- PE = (0.010kg)(9.8)(0.06)
- PE = 0.00588 J = 5.88 mJ
- **KE** = 0.1117- 0.00588 = 0.1058 J
- 0.1058 J = ½(mv²)
- 0.1058 J = ½ (0.010) v²
- **v = 4.6 m/s**

and that is about what you calculated using old equations before

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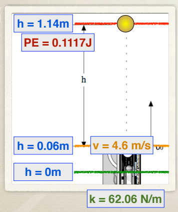
Elastic Potential

- In lab, you compressed a spring a distance of 6cm. The 10g ball went up 1.08m.



- Find the maximum force used to push the spring
- **F = k x**
- **F = (62.06 N/m) (0.06m)**
- **F = 3.7236 N**

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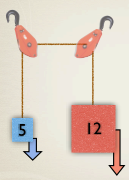
The Atwood Machine



- Find the velocity of the red block as it hits the ground 3 m below.

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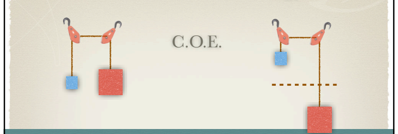
Conservation Of Energy



- Initial: Not moving, both have a height of 3m.
- Final: Both moving, Blue is at 6m, Red is at 0m.

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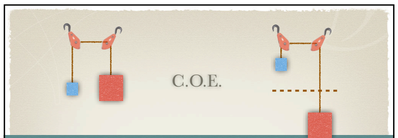

PE + PE = PE + KE + KE

mgh + mgh = mgh + ½(mv²) + ½(mv²)

5(9.8)(3) + 12(9.8)(3) = 5(9.8)(6) + ½(5v²) + ½(12v²)

147 + 352.8 = 294 + 2.5v² + 6v²

205.8 = 8.5v²

4.92 = v

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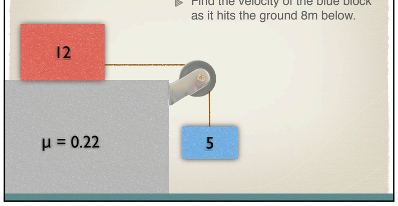
Energy Lost to Friction

- Find the velocity of the blue block as it hits the ground 8m below.



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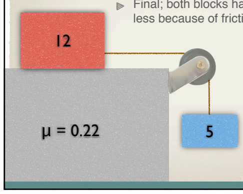
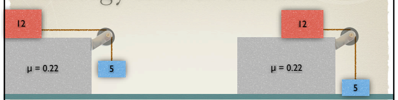
Energy Lost to Friction

- Initial; the blue block has potential energy.
- Final; both blocks have kinetic, and TE is less because of friction.



55

Energy Lost to Friction



$$PE = W_f + KE + KE$$
$$mgh = (\mu N)d + \tfrac{1}{2}(mv^2) + \tfrac{1}{2}(mv^2)$$
$$5(9.8)(8) = (0.22)(12(9.8))(8) + \tfrac{1}{2}(5v^2) + \tfrac{1}{2}(12v^2)$$
$$392 = 206.98 + 2.5v^2 + 6v^2$$
$$185 = 8.5v^2$$
$$4.67\ m/s = v$$

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Academic Assignment

Academic Physics
Set 1 - Chapter 10
1, 2, 3, 5, 6, 7, 25, 26, 27, 28, 52, 53, 56, 57

Academic Physics
Set 2 - Chapter 10
60, 63, 67, 70, 71, 76, 79, 81, 83, 84, 85, 90, 93

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Hooke's Law

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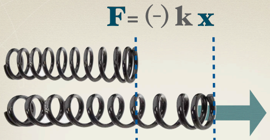
$F = (-)\,k\,x$



- Force - required to stretch the spring, or restoring force. Often the weight (N)
- k - Spring Constant - How "tight" the spring is. (N/m)
- x - Stretch - a change in length (m)

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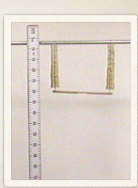
Springs in Parallel

- The same force is supported by two springs so neither has to stretch as far...
- ...or, it is harder to stretch two springs so the constant is increased
- $k = k_1 + k_2$



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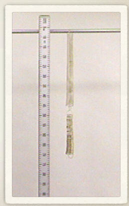
Springs in Series

- Both springs support the same amount of weight (not split in two like before)...
- or... it is easier to stretch
- $1/k = 1/k_1 + 1/k_2$



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