Energy, Work, Power, and Mechanical Advantage

Work

- Work is done when a force acts on an object and moves it a certain distance.
- Work = net force x distance
- **W=Fd**
- The unit for work is the **<u>Joule</u>** which is a N·m

500 N of force applied

Ex A. How much work is being done by a weightlifter below that applies 500 Newtons of force lifting a mass 2.5 meters?

F= 500 N

d = 2.5 m

W=Fd

W= (500)(2.5) = 1250 J

500 N of force applied

Ex B. How much work is being done by a weightlifter below that applies 1000 Newtons of force but does not move the mass?

F= 1000 N

d = 0 m

W=Fd

W= (1000)(0) = 0 J

Work

- **W=Fd**

- No work is done if the object does not travel a distance

Power

- **Power** is the rate at which work is done. Work divided by time

$$P = \frac{W}{t}$$

or

$$P = \frac{Fd}{t}$$

Unit of Power

- The unit of power would be joules per second or the **watt**
- **A watt equals one joule of energy in one second**

Ex C. A weightlifter who does 1250 Joules of work in 0.5 s applies how much power?

W= 1250J

t= 0.5s

P= W/t

P= 1250/0.5 = 2500 watts

500 N of force applied

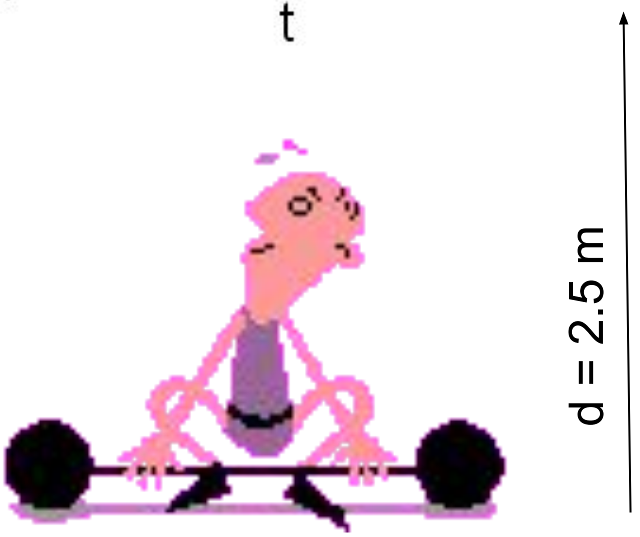
Ex D. A weightlifter pulls with 500N of force lifting an object 2.5m in 1.5s. How much power did he apply?

$$P = \frac{W}{t} \quad \text{or} \quad P = \frac{Fd}{t}$$

F= 500 N

d = 2.5 m

t= 1.5 s



500 N of force applied

P= (Fd)/t = ((500)(2.5))/1.5 = 833 watts

Ex. E: A girl weighing 500 Newtons takes 50 seconds to climb a flight of stairs 18 meters high. What is her power output vertically?

Ex. E: A girl weighing 500 Newtons takes 50 seconds to climb a flight of stairs 18 meters high. What is her power output vertically?

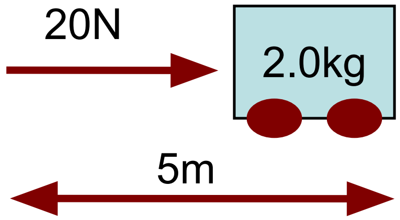
$F = 500 N$

$t = 50 s$

$d = 18 m$

$$P = \frac{Fd}{t} = \frac{(500)(18)}{50} = \underline{180 \text{ watts}}$$

Problem Set #1

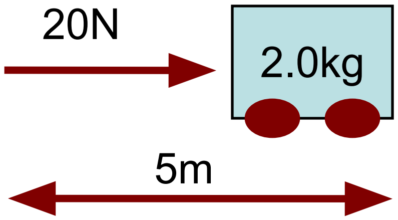


1. A 20 N force is used to push a 2.00 kg cart a distance of 5 meters. What is the work done on the cart?

2. How much power is needed to do push the cart in the example above in 7 seconds?

3. A girl weighing 300 Newtons takes 45 seconds to climb a flight of stairs 24 meters high. What is her power output vertically?

Problem Set #1



1. A 20 N force is used to push a 2.00 kg cart a distance of 5 meters. What is the work done on the cart?

$F = 20N$

$m = 2.00kg$

$d = 5m$

$w = ?$

$w = Fd$

$w = (20)(5) = 100J$

Problem Set #1

2. How much power is needed to do push the cart in the example above in 7 seconds?

$P = \frac{W}{t} = \frac{100}{7} = 14$ watts

Problem Set #1

3. A girl weighing 300 Newtons takes 45 seconds to climb a flight of stairs 24 meters high. What is her power output vertically?

$F_w = 300N$

$t = 45s$

$d = 24m$

$P = ?$

$$P = \frac{W}{t} = \frac{Fd}{t}$$

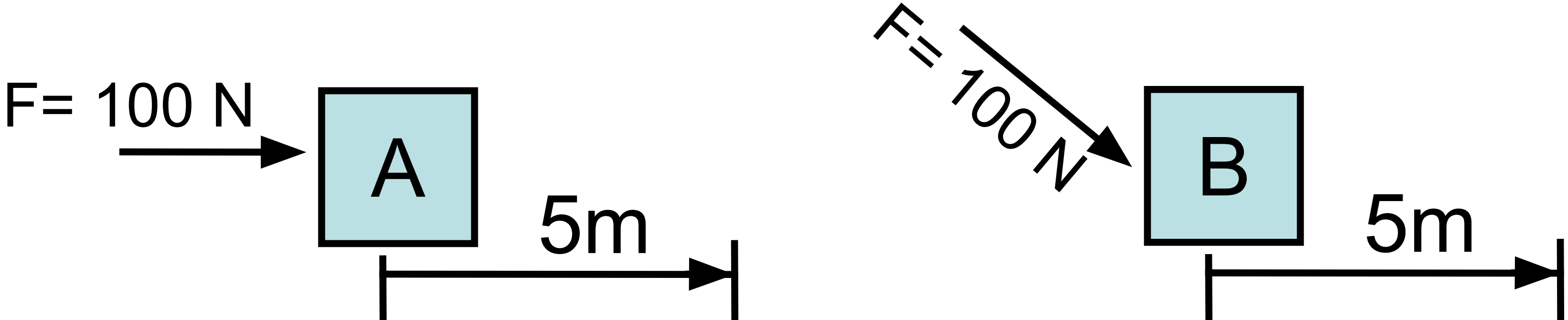
$$P = \frac{(300)(24)}{45} = \underline{160 \text{ watts}}$$

Intro

1. Jill lifts an object with a weight of 100 N one meter high. How much work did she do.

2. Jill lifts an object with a mass of 5 kg one meter high. How much work did she do?

3. Which of the following boxes have more work done on them to move them 5m?

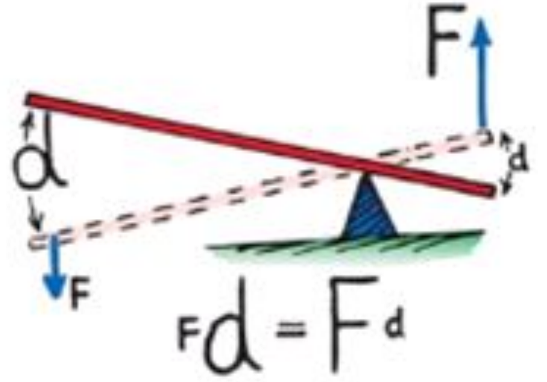


Machines

- **Simple Machine-** a device used to magnify forces or simply change the direction of forces.

Conservation of energy:

- *Energy is not created nor destroyed*
- *Work input = work output*



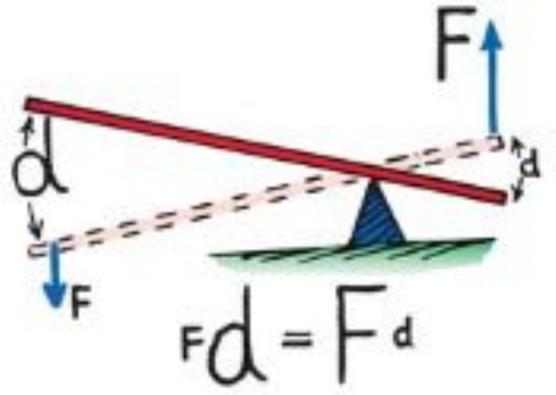
$$Work_{input} = Work_{output}$$

$$Fd_{in} = Fd_{out}$$

Example Simple Machines

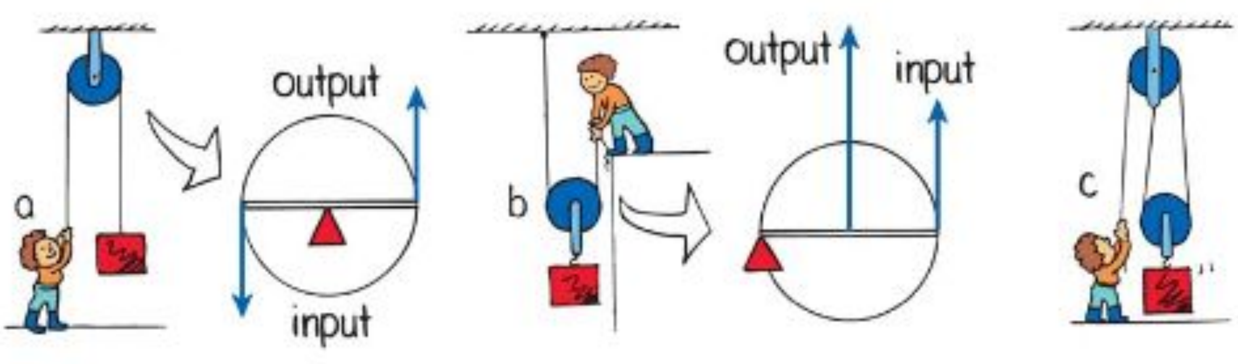
- **Lever-** a simple machine made of a bar that turns around a fixed point

FIGURE 9.10 ▼
In the lever, the work (force × distance) done at one end is equal to the work done on the load at the other end.



Example Simple Machines

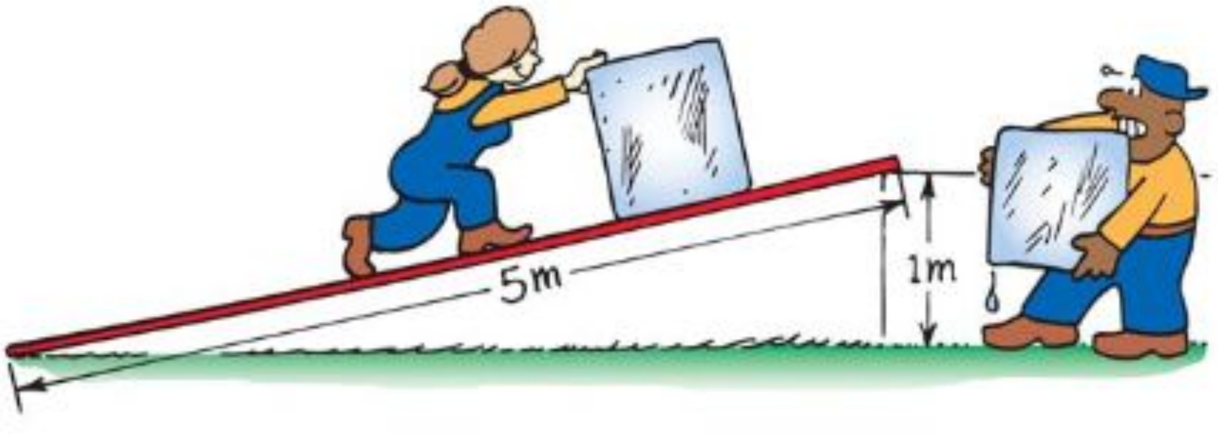
- **<u>Pulley-</u>** a basic lever that can change the direction of force.
- If properly used a pulley system can multiply force



Pulley System

Example Simple Machines

- **<u>Incline Plane-</u>** A surface at a slope
- Sliding a load up an incline requires less force than lifting it up but you have to apply the force over a longer distance.

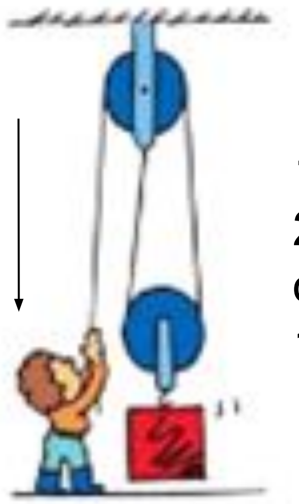


All simple machines follow the conservation of energy. (in the absence of friction)

$$F_{in}d_{in} = F_{out}d_{out}$$

In:

10 N
over
2 m

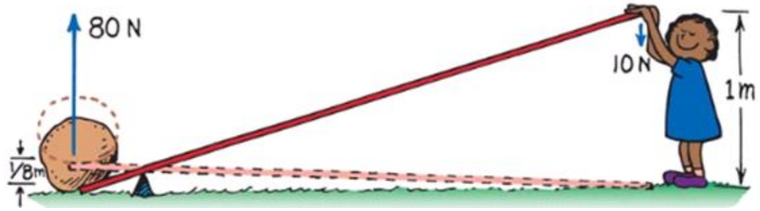


Out:

20 N
over
1 m

Out:

80 N
over
1/8 m



In:

10 N
over
1 m

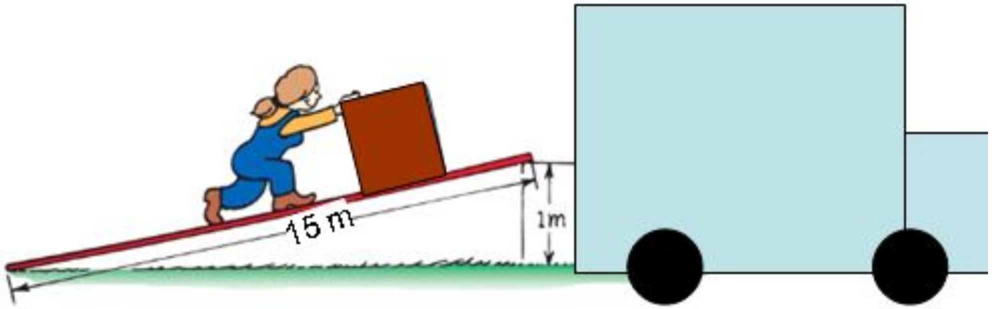
In:

10 N
over
5 m

Out:

50 N
over
1 m

Ex. E: Sally pushes a box up a ramp using a 15m plank. The box moves a vertical distance of 1m and weighs 500 N, ideally with how much force must she push?



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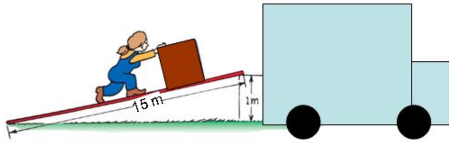

$$F_{in} d_{in} = F_{out} d_{out}$$

$F_{in} = ?$

$d_{in} = 15 m$

$F_{out} = 500 N$

$d_{out} = 1$

$$F_{in} = \frac{F_{out} \, d_{out}}{d_{in}} = \frac{(500)(1)}{15} = \boxed{33 \text{ N}}$$

Ex. F: Eldred lifts a 110 N box a distance of 1.5 meter using a pulley system. She pulls the rope for 3 meters to accomplish this. With what ideal constant force must she pull?

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$F_{in} d_{in} = F_{out} d_{out}$

$F_{in} = ?$

$d_{in} = 3$ m

$F_{out} = 110$ N

$d_{out} = 1.5$

$$F_{in} = \frac{F_{out} d_{out}}{d_{in}}$$

$$F_{in} = \frac{(110)(1.5)}{3} = 55 \text{ N}$$

Mechanical Advantage

- Mechanical advantage: how many times more force you get out of a simple machine

- A mechanical advantage of 6 means the machine outputs 6 times more force

10 N in → Machine w/ 6 M.A. → 60 N out

No machine is 100% efficient because of friction and loss of energy through heat

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

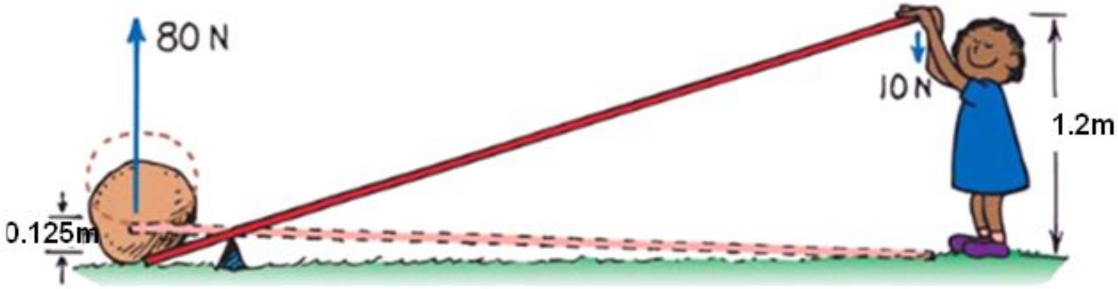
$$\text{Efficiency} = \frac{AMA}{IMA} \times 100\%$$

- Ex. G:
- a. how much work is put into this machine?
- b. how much work does the machine output?
- c. What is the efficiency of this machine?

F_{out}:80N

d_{out}:0.125m

W_{out}=?



F_{in}:10N

d_{in}:1.2m

W_{in}:?

W=Fd

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

Ex. G:

- a. how much work is put into this machine?
- b. how much work does the machine output?
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F_{out}:80N

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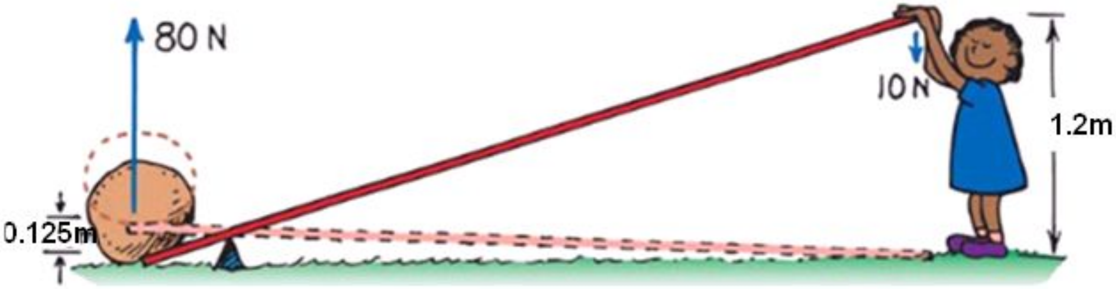


F_{in}:10N

d_{in}:1.2m

W_{in}:?

$w = Fd$

$w = (10)(1.2) = 12J$

W=Fd

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

- Ex. G:
- a. how much work is put into this machine?
- b. how much work does the machine output?
- c. What is the efficiency of this machine?

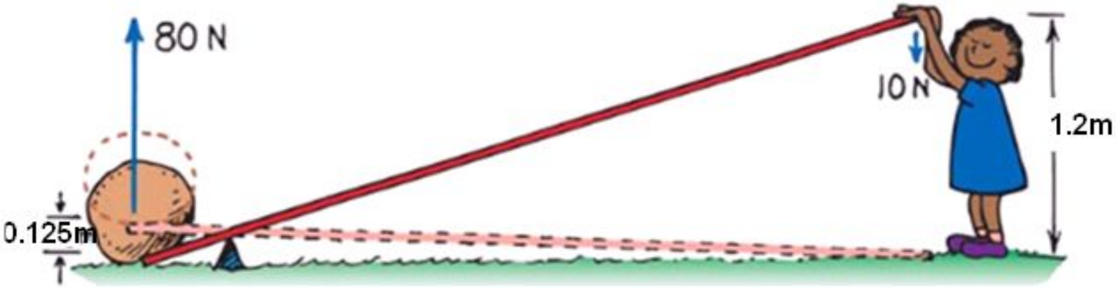
F_{out}:80N

d_{out}:0.125m

W_{out}=?

w=Fd

w=(80)(0.125)= 10J



F_{in}:10N

d_{in}:1.2m

W_{in}:?

W=Fd

w=(10)(1.2) =12J

W=Fd

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

- Ex. G:
- a. how much work is put into this machine?
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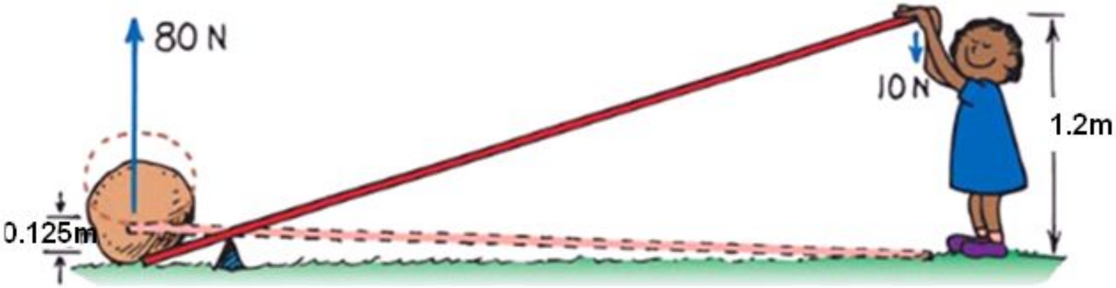
F_{out}:80N

d_{out}:0.125m

W_{out}=?



F_{in}:10N

d_{in}:1.2m

W_{in}:?

$w = Fd$

$w = (80)(0.125) = \overset{W_{out}}{10J}$

$W = Fd$

$w = (10)(1.2) = \overset{W_{in}}{12J}$

W=Fd

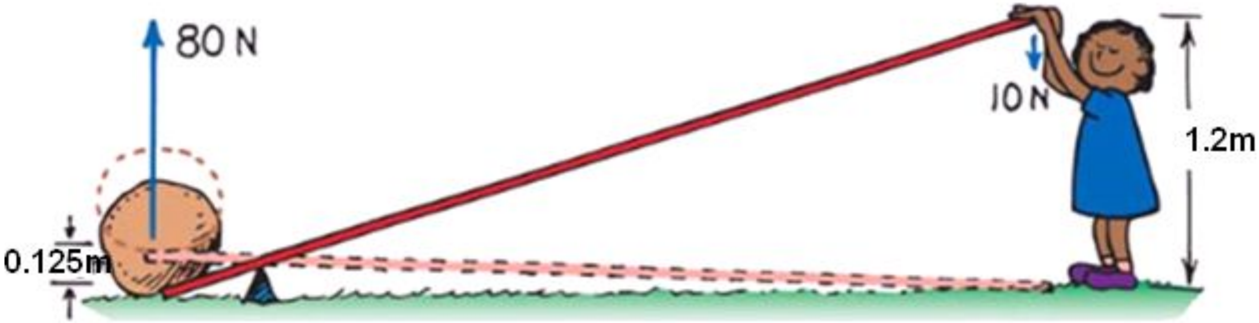
$$\text{Efficiency} = \frac{10}{12} \times 100 = \boxed{83\%}$$

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

Ideal Mechanical Advantage

- **<u>Ideal Mechanical Advantage-</u>** The mechanical advantage you should get out of a simple machine ignoring friction. What you <u>should get</u> based on distance.

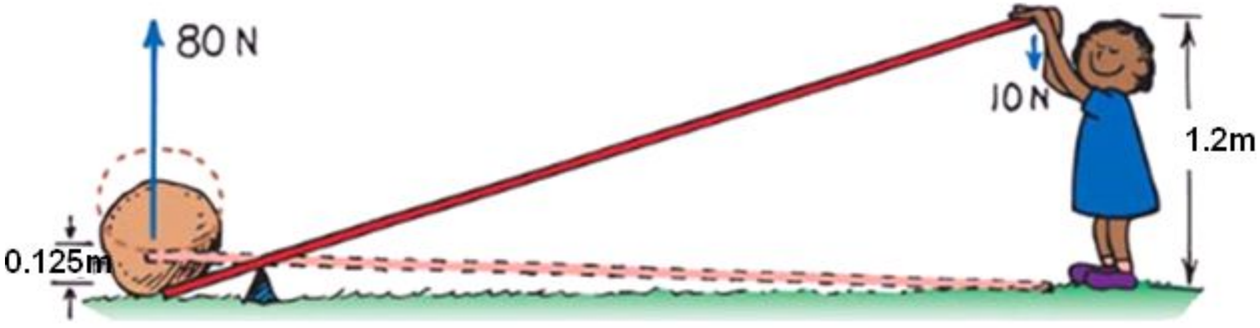
$$IMA = \frac{d_{in}}{d_{out}}$$



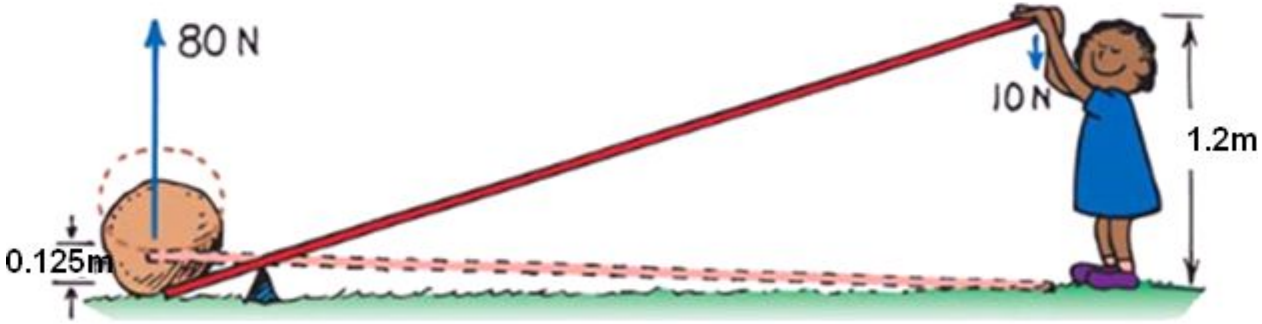
Actual Mechanical Advantage

- **Actual Mechanical Advantage**- ratio of input to output force. How much your force is actually multiplied

$$AMA = \frac{F_{out}}{F_{in}}$$

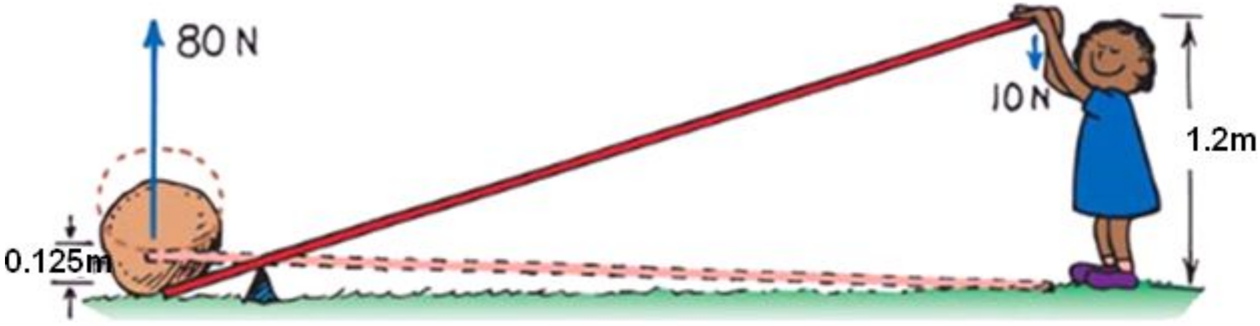


- Ex. H: What is the ideal mechanical advantage below?
- Ex. I: What is the actual mechanical advantage below?



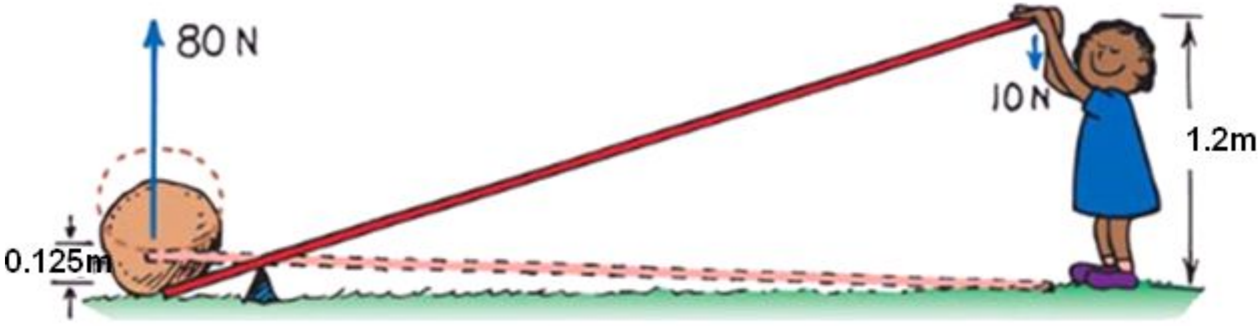
- Ex. H: What is the ideal mechanical advantage below?

$$IMA = \frac{d_{in}}{d_{out}} = \frac{1.2}{0.125} = 9.6$$



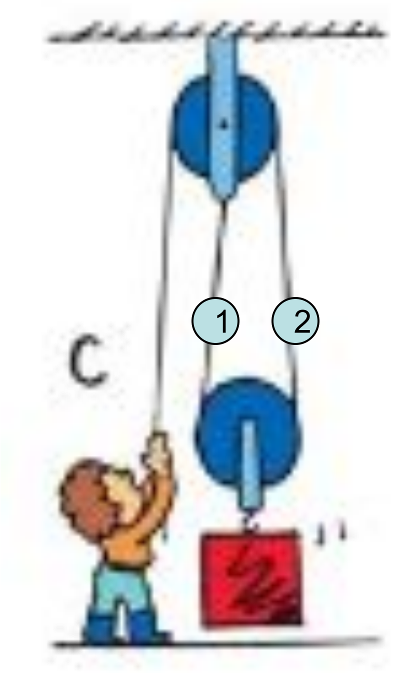
- Ex. I: What is the actual mechanical advantage below?

$$AMA = \frac{F_{out}}{F_{in}} = \frac{80}{10} = 8$$

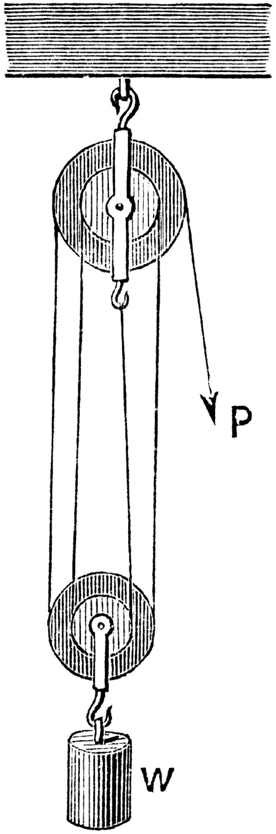


(MA) Mechanical Advantage of a Simple Pulley System

- MA = same as the number of strands of rope that actually support the load.
- Only two strands support the load here- one is only used to change direction
- MA here is 2 – The individual only has to pull with <u>half the force</u> but twice the distance.



J. What would be the ideal mechanical advantage of the pulley system below?



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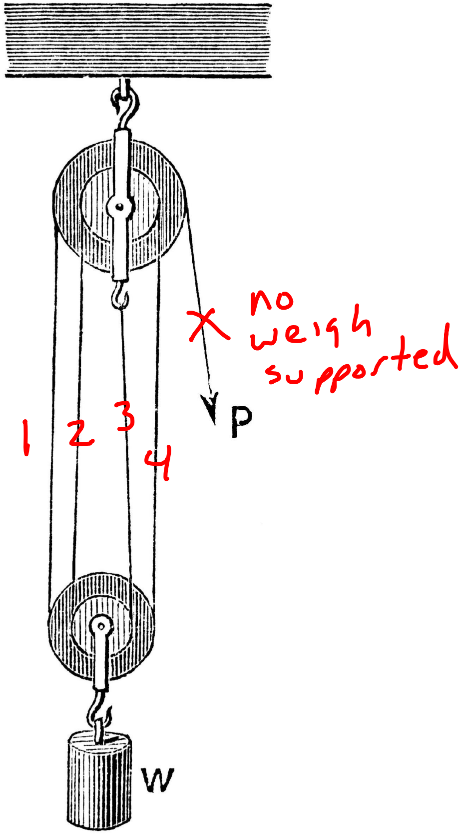
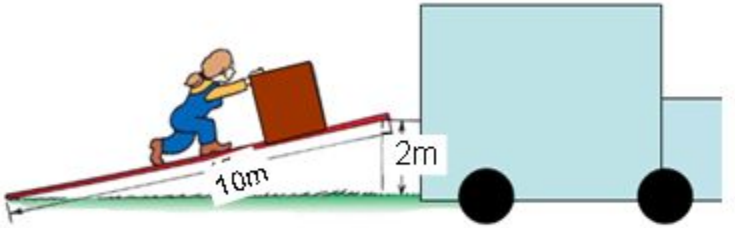


MA = 4 times

4 supporting strands



Problem Set 2

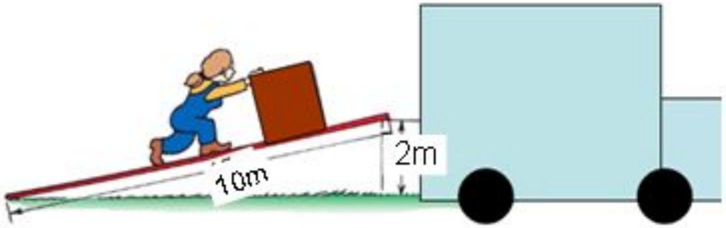
1. John pushes a box up a ramp using a 10m plank. The box moves a vertical distance of 2m and weighs 500 N, ideally with how much force must he push?

2. What is the actual mechanical advantage when you apply a force of 3N to lift a 15 N object?

3. What is the ideal mechanical advantage when you use a 8m long slab as an incline plane to lift an object 2?

4. Sam uses an inclined plane to move a 65 N box onto a loading dock. The ramp is five meters long and the loading dock is 1.5 meters high. If the loading dock height was 2.5 meters, how would the mechanical advantage of the inclined plane change?

a. MA would decrease
b. MA would increase
c. MA would become zero
d. MA would not change



Problem Set 2

#1 John pushes a box up a ramp using a 10m plank. The box moves a vertical distance of 2m and weighs 500 N, ideally with how much force must he push?

$F_{in} d_{in} = F_{out} d_{out}$

$F_{in} = \frac{F_{out} d_{out}}{d_{in}}$

$F_{in} = \frac{(500)(2)}{10} = \boxed{100 N}$

$F_{in} = ?$

$d_{in} = 10m$

$F_{out} = 500N$

$d_{out} = 2m$

Problem Set 2

#2 What is the actual mechanical advantage when you apply a force of 3N to lift a 15 N object?

$F_{out} = 15 N$

$F_{in} = 3 N$

$$AMA = \frac{F_{out}}{F_{in}} = \frac{15}{3} = 5 \text{ times}$$

Problem Set 2

#3 What is the ideal mechanical advantage when you use a 8m long slab as an incline plane to lift an object 2 m?

$d_{in}=8m$

$d_{out}=2m$

$$IMA = \frac{d_{in}}{d_{out}} = \frac{8}{2} = 4 \text{ times}$$

Problem Set 2

#4 Sam uses an inclined plane to move a 65 N box onto a loading dock. The ramp is five meters long and the loading dock is 1.5 meters high. If the loading dock height was 2.5 meters. How would the mechanical advantage of the inclined plane change?

[✓ a. MA would decrease]
b. MA would increase
c. MA would become zero
d. MA would not change

before

$d_{in} = 5 m$

d_{out} 1.5 m

after

$d_{in} = 5 m$

$d_{out} = 2.5$

change $\frac{2.5}{1.5} = 1.67$ times

Law of ones

$$IMA = \frac{1}{1.67} = 0.6 \text{ times}$$

simply

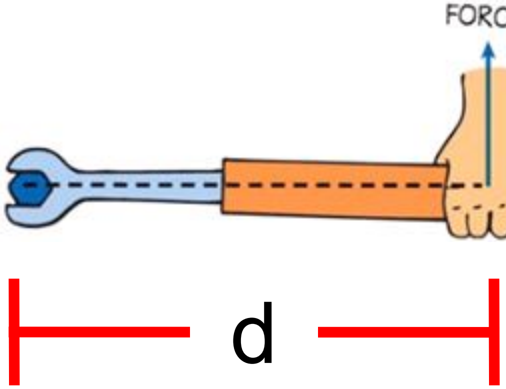
$$\downarrow IMA = \frac{d_{in}}{d_{out}\uparrow}$$

If dout goes up

IMA goes down

Torque (τ)

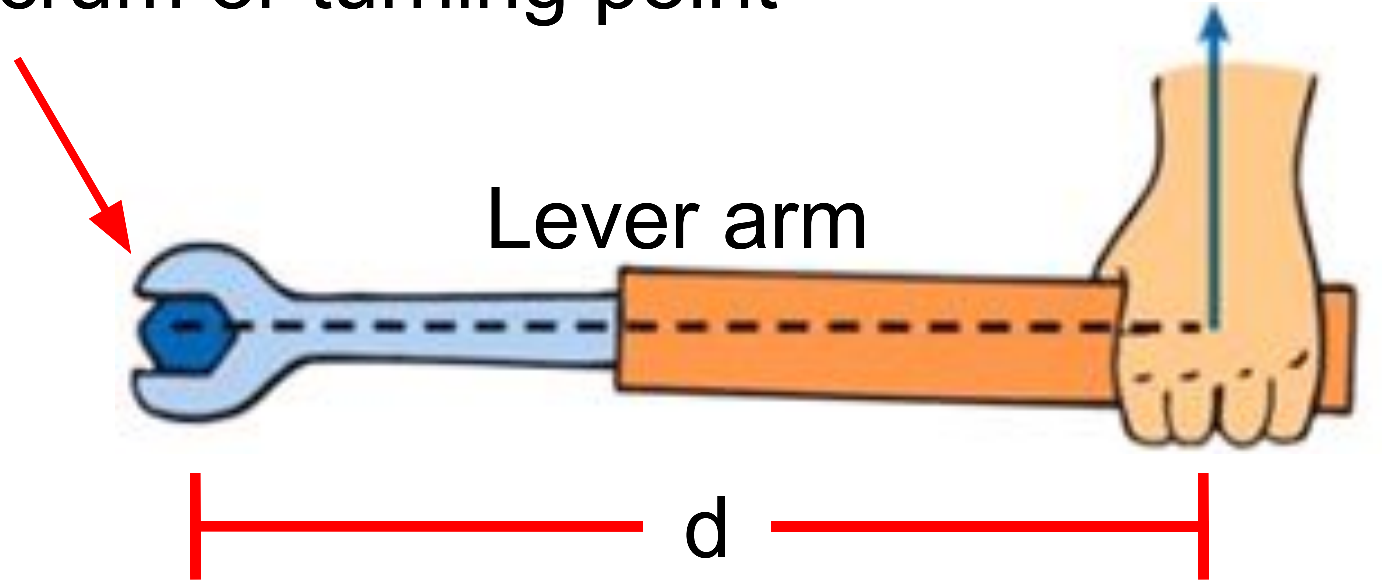
- Torque (τ) : A rotational analog of force
- Produces a rotational acceleration
- Occurs when a force is applied to a lever with a perpendicular component.
- Unit: Newton meter (N·m)



$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

Torque (τ)



Fulcrum or turning point

Lever arm

Applying the force perpendicular gets the most torque

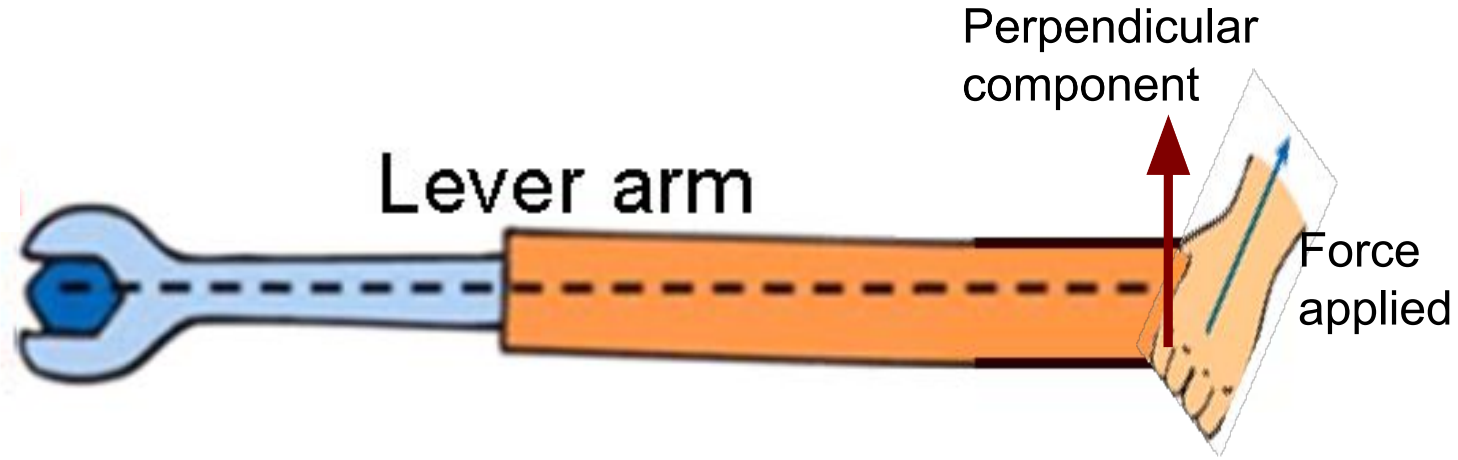
d

$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

Torque (τ)

- Only the perpendicular component of force goes into torque
- This is not as efficient

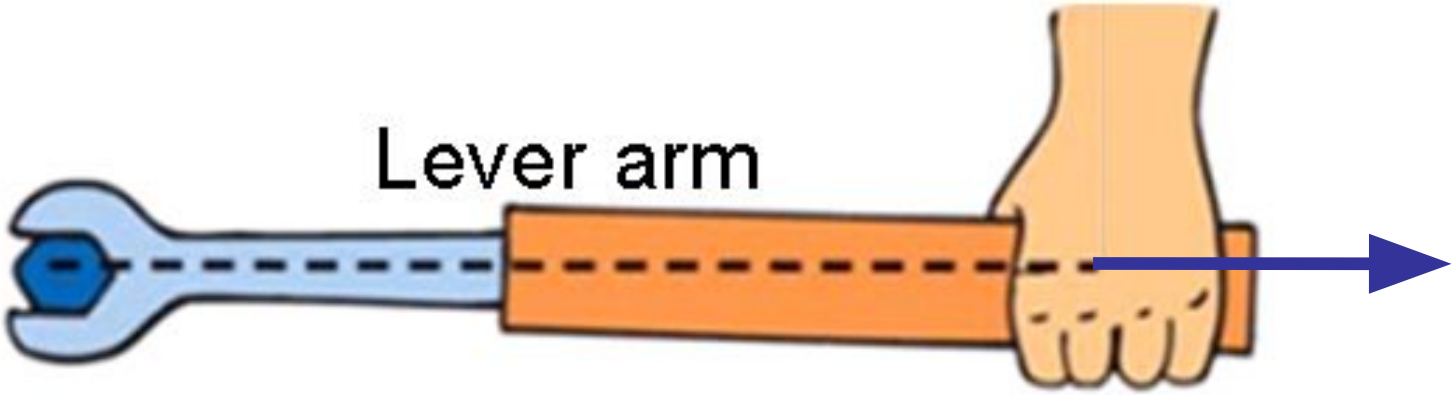


$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

Torque (τ)

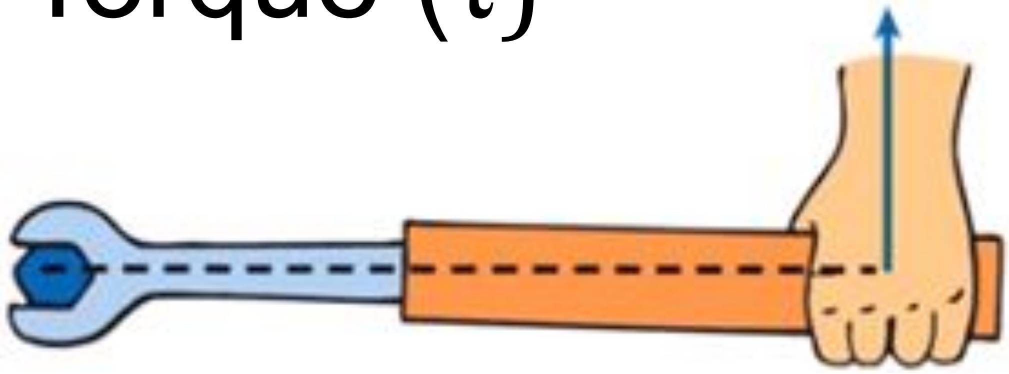
- Applying the force parallel gives no torque
- The perpendicular component of force equals 0



$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

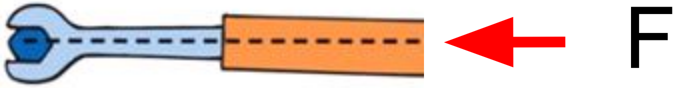
Torque (τ)



Ex. K: Increasing the lever arm does what to torque?

Ex. L: Applying more force perpendicular does what to torque?

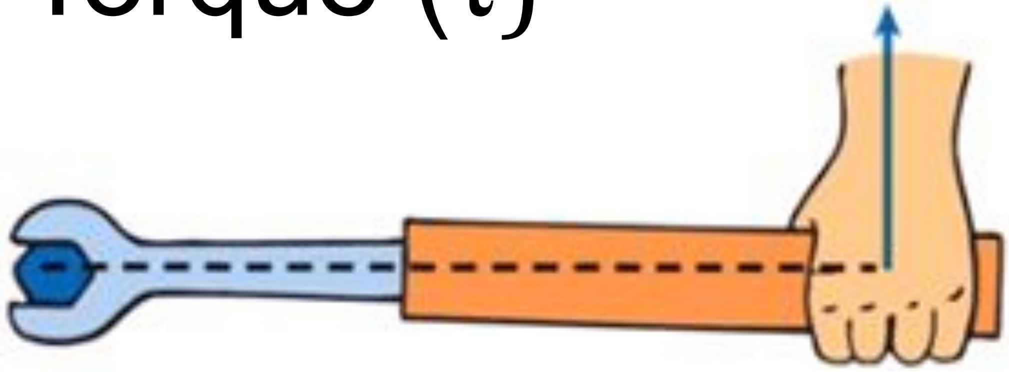
Ex. M: How much torque would you have if you apply a parallel force at a distance seen below?



$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

Torque (τ)



Ex. K: Increasing the lever arm does what to torque?

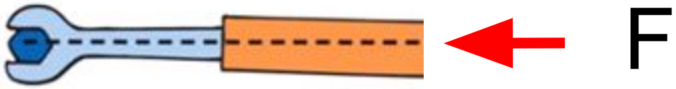
↑ d increases τ

Ex. L: Applying more force perpendicular does what to torque?

↑ $F_{\perp}$ increases τ

Ex. M: How much torque would you have if you apply a parallel force at a distance seen below? $F_{\perp} = 0$

$\boxed{\tau = 0}$



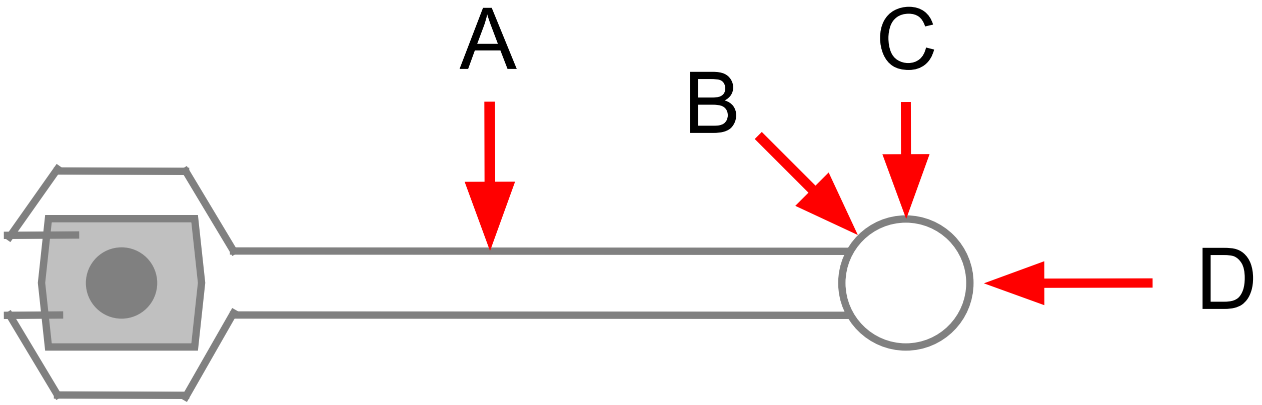
$$\tau = F_{\perp} d$$

Torque = (force perpendicular) x (distance of the lever arm)

N. The drawing below represents a wrench. The left end of the wrench is attached to a bolt. Four equal forces of 100N are applied as indicated in the drawing.

(a) Which of the four forces exerts the greatest torque on the bolt? (and why)

(b) Which of the four forces exerts the least torque on the bolt? (and why)



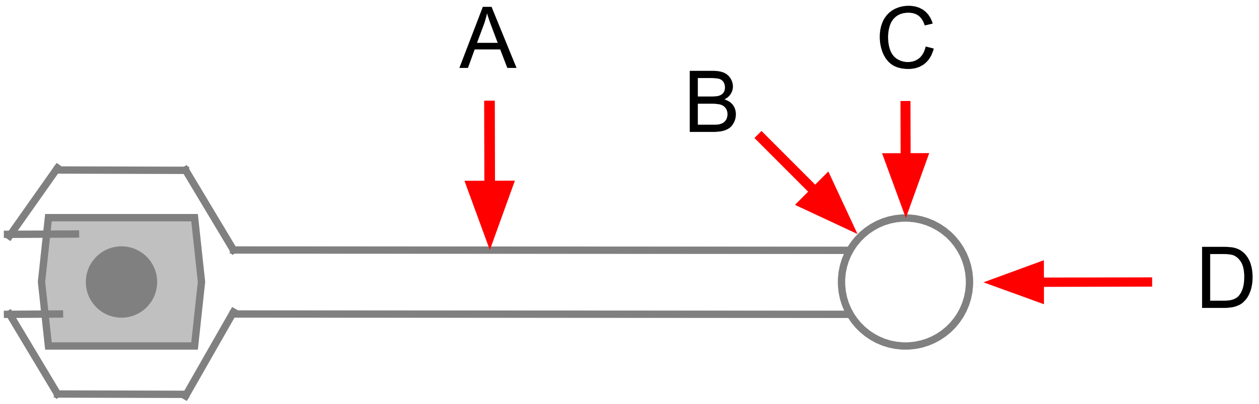
N. The drawing below represents a wrench. The left end of the wrench is attached to a bolt. Four equal forces of 100N are applied as indicated in the drawing.

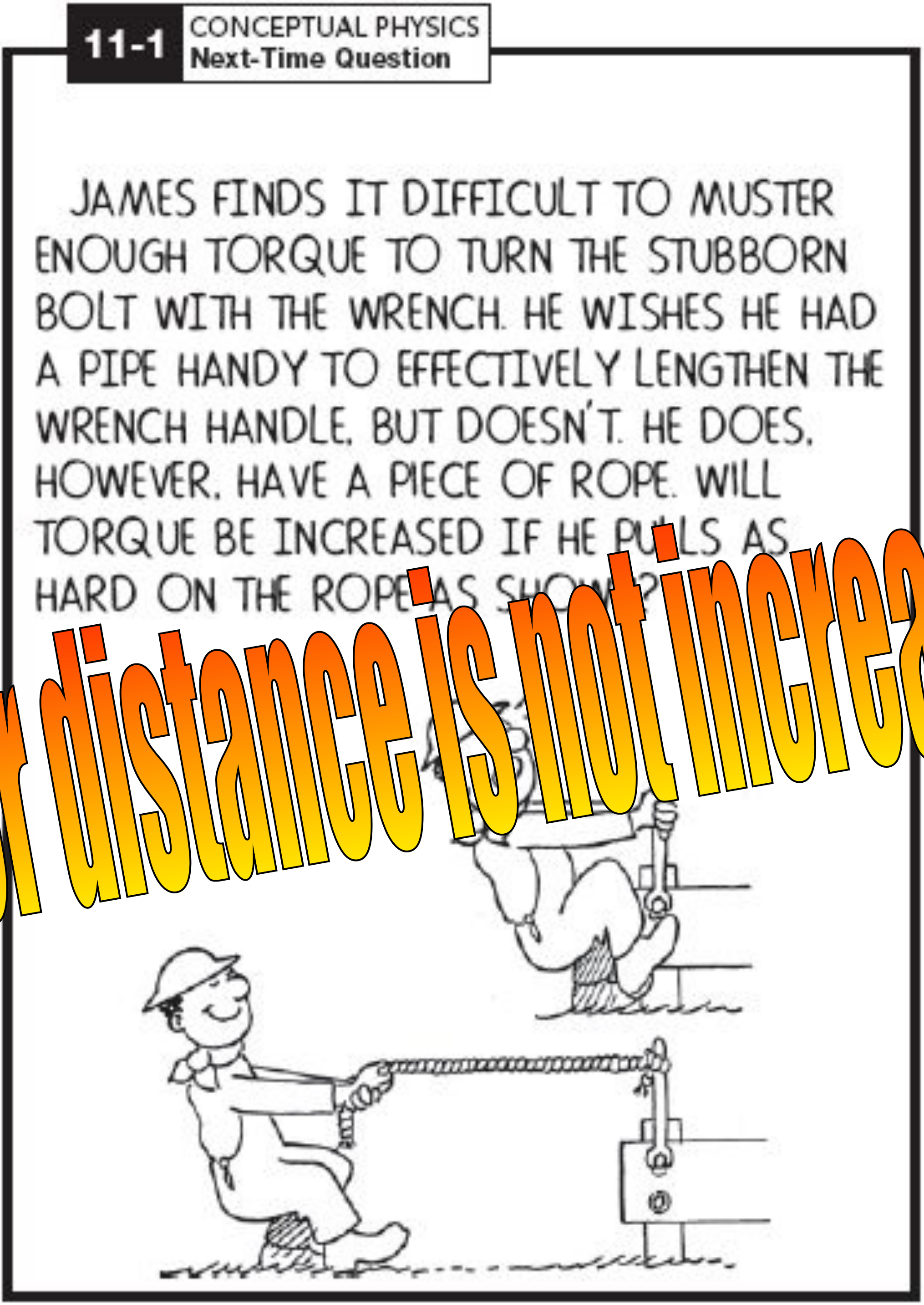
(a) Which of the four forces exerts the greatest torque on the bolt? (and why)

C greatest perpendicular force

(b) Which of the four forces exerts the least torque on the bolt? (and why)

D no perpendicular force





11-1 CONCEPTUAL PHYSICS
Next-Time Question

JAMES FINDS IT DIFFICULT TO MUSTER ENOUGH TORQUE TO TURN THE STUBBORN BOLT WITH THE WRENCH. HE WISHES HE HAD A PIPE HANDY TO EFFECTIVELY LENGTHEN THE WRENCH HANDLE, BUT DOESN'T. HE DOES, HOWEVER, HAVE A PIECE OF ROPE. WILL TORQUE BE INCREASED IF HE PULLS AS HARD ON THE ROPE AS SHOWN?

No.... lever distance is not increased

Ex. O: Ned tightens a bolt in his car engine by exerting a 12 N force on his wrench at a distance of 0.40 m from the fulcrum. How much torque must Ned produce to turn the bolt?

Ex. O: Ned tightens a bolt in his car engine by exerting a 12 N force on his wrench at a distance of 0.40 m from the fulcrum. How much torque must Ned produce to turn the bolt?

$F_1 = 12\ N$

$d = 0.40\ m$

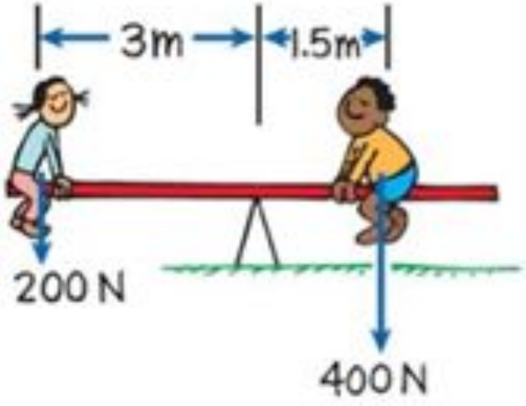
$\tau = ?$

$\tau = Fd = (12)(0.40)$

$\boxed{\tau = 4.8\ \mathbf{N \cdot m}}$

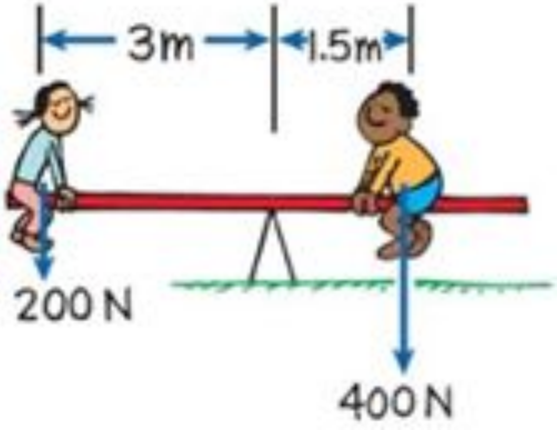
Balanced Torques ($\Sigma\ \tau = 0$)

- When balanced torques act on an object, there is no change in rotation
- The heavier boy must be closer the fulcrum to balance out.



Simple Balanced Torques Problem

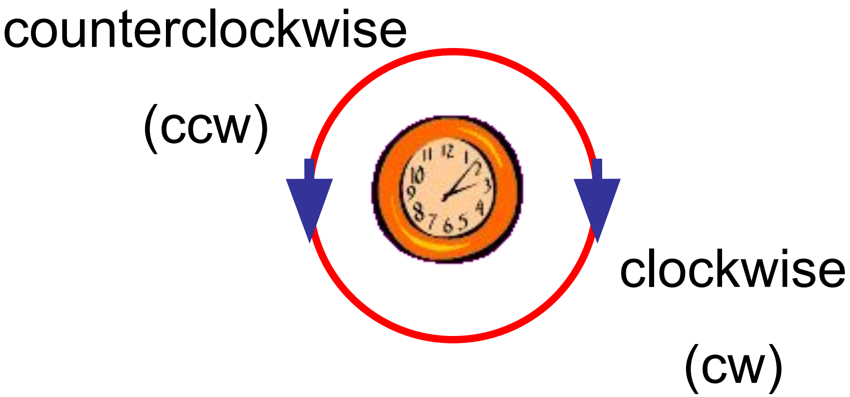
- Sum of torques = 0



- All clockwise torques = all counterclockwise torques

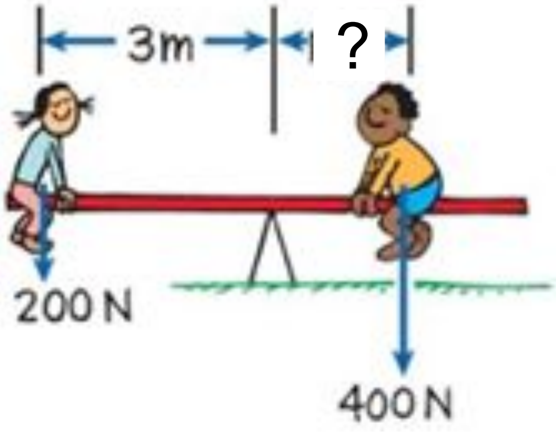
- $\tau_{cw} = \tau_{ccw}$

- $F_{cw} d_{cw} = F_{ccw} d_{ccw}$



Ex. P: How far from the fulcrum must the boy sit to balance out the teeter totter?

- $F_{cw} d_{cw} = F_{ccw} d_{ccw}$
- $(200)(3) = (400)(d_{ccw})$
- $d_{ccw} = (200)(3) / (400)$
- $d_{ccw} = 1.5$ m



Complex Balanced Torques Problem

- Sum of torques = 0
- All clockwise torques = all counterclockwise torques

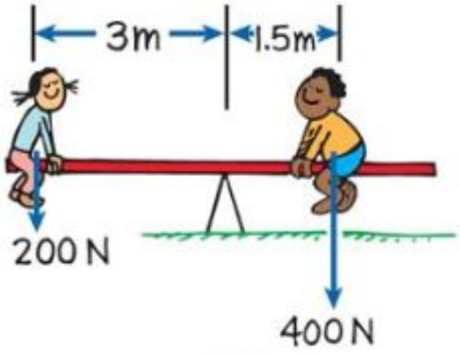


FIGURE 11.4 ▲
A pair of torques can balance each other.

- $\tau_{1cw} + \tau_{2cw} + \ldots = \tau_{1ccw} + \tau_{2ccw} + \ldots$
- $F_{1cw}d_{1cw} + F_{2cw}d_{2cw} + \ldots = F_{1ccw}d_{1ccw} + F_{2ccw}d_{2ccw} + \ldots$

Center of gravity (CG)

- The center of gravity of a uniform object is the geometric center.

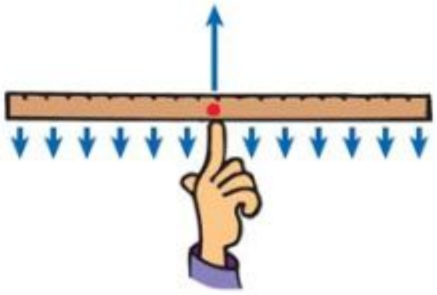
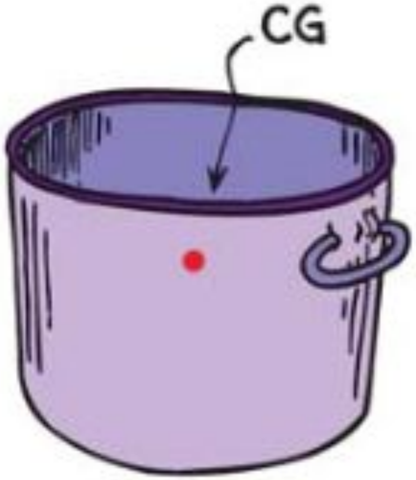
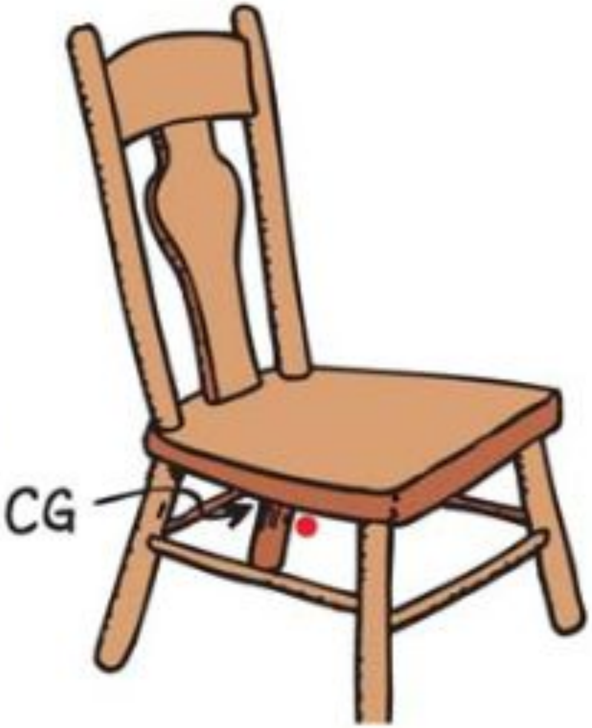
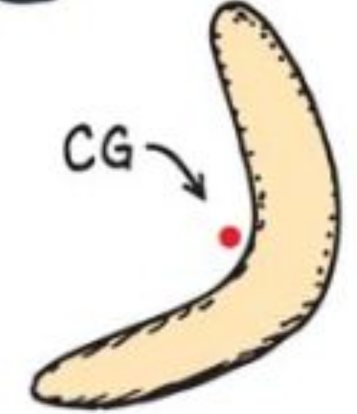


FIGURE 11.13 ▲
The weight of the entire stick behaves as if it were concentrated at its center.

Non-uniform Objects CGs



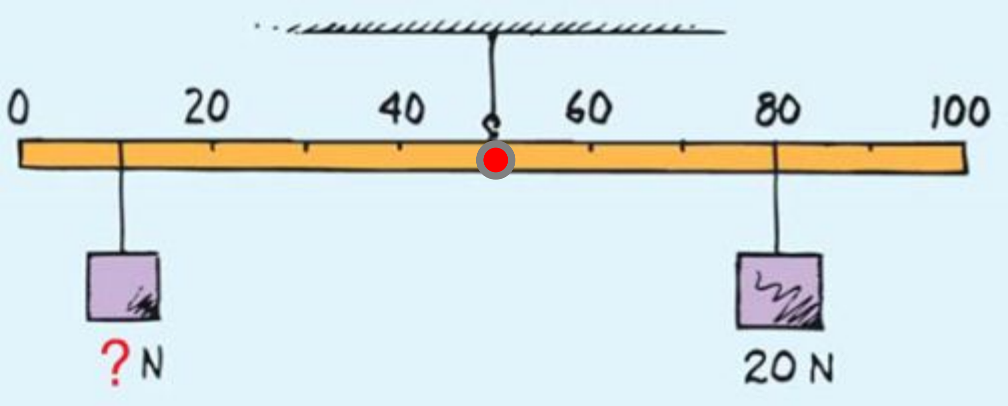




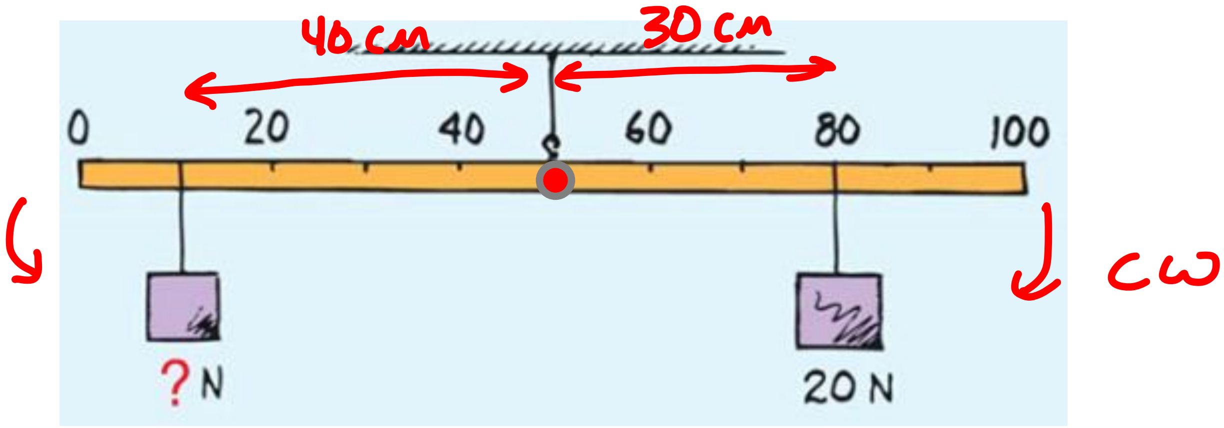
- When an object is thrown it will rotate around its center of gravity

Ex. Q: What would be the weight of the block below be to balance out the torques below?

- In this problem the meter sticks weight does not effect force since its center of gravity is at the fulcrum (d=0)
- Do not just read the meter stick, determine how far the mass is from the fulcrum.



Ex. Q: What would be the weight of the block below be to balance out the torques below?



Clockwise = Counter clockwise

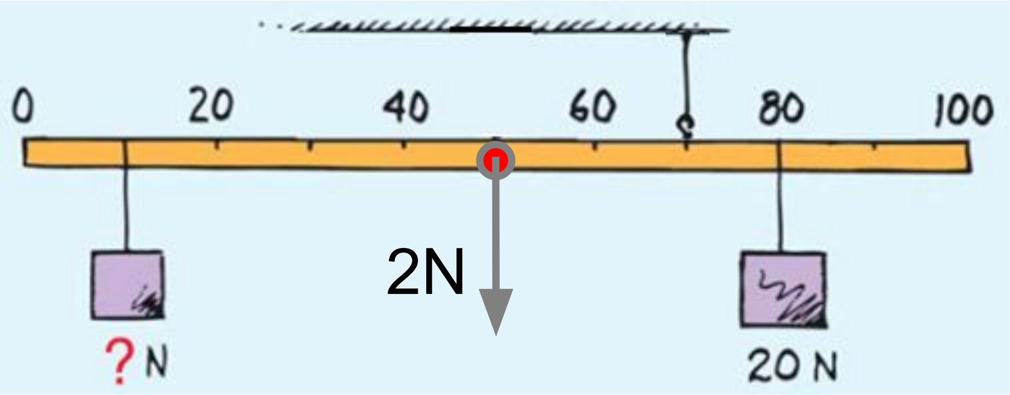
$$Fd = Fd$$

$$(20)(0.30) = F(0.40)$$

$$F = \frac{(20)(0.30)}{.40} = 15\ N$$

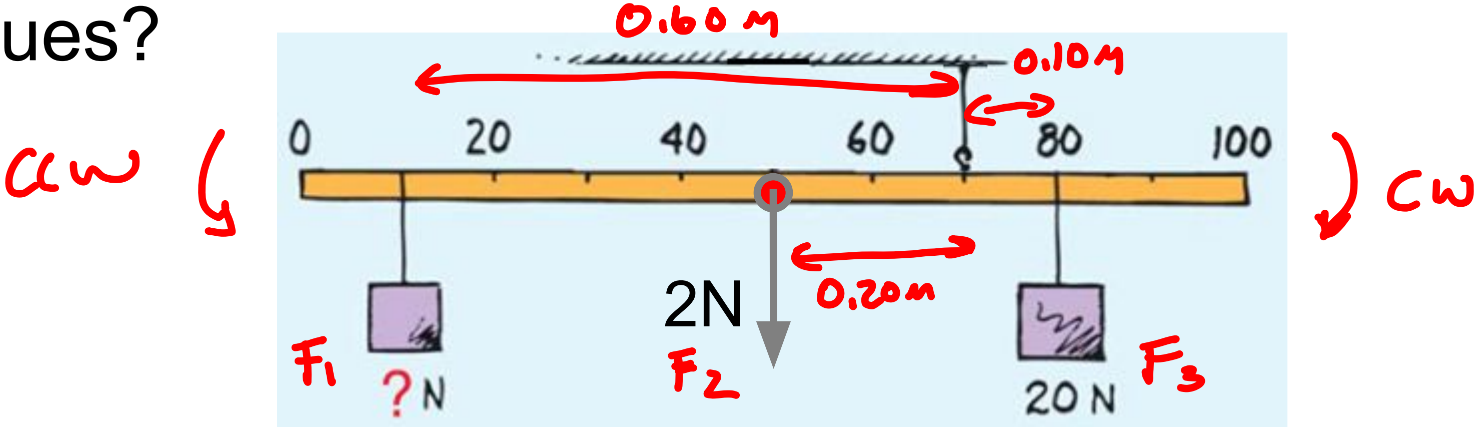
An objects mass is applied from its center of gravity.

Ex. R: If the meter stick weighed 2N with a center of gravity at the 50cm mark, what would be the weight of the block below be to balance out the torques?



An objects mass is applied from its center of gravity.

Ex. R: If the meter stick weighed 2N with a center of gravity at the 50cm mark, what would be the weight of the block below be to balance out the torques?



$$F_1 d_1 + F_2 d_2 = F_3 d_3$$

$$F_1 (0.60) + (2)(0.20) = (20)(0.10)$$

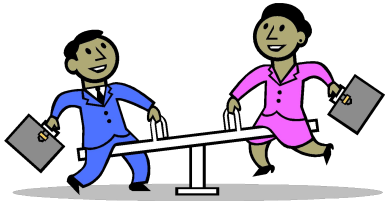
$$F_1 = \frac{(20)(0.10) - (2)(0.20)}{0.60} = \boxed{2.7 \text{ N}}$$

Rules for toppling

- If the center of gravity lies outside the area of support an object will topple over.

FIGURE 11.18 ▲
The Leaning Tower of Pisa does not topple over because its CG lies above its base.

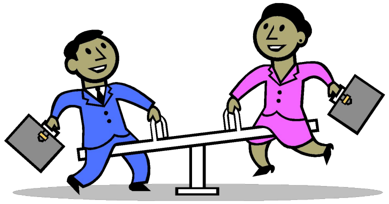
Problem Set 3



1. Sam tightens a bolt in his bicycle by exerting a 15 N force on his wrench at a distance of 0.10 m from the fulcrum. How much torque must Sam produce to turn the bolt?

2. John weighs 600N and is sitting 1.5 m from the fulcrum. Where must a 450N Mary move to balance Johns weight?

Problem Set 3



1. Sam tightens a bolt in his bicycle by exerting a 15 N force on his wrench at a distance of 0.10 m from the fulcrum. How much torque must Sam produce to turn the bolt?

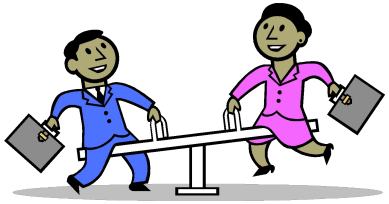
$F_\perp = 15 N$

$d = 0.10 m$

$\tau = ?$

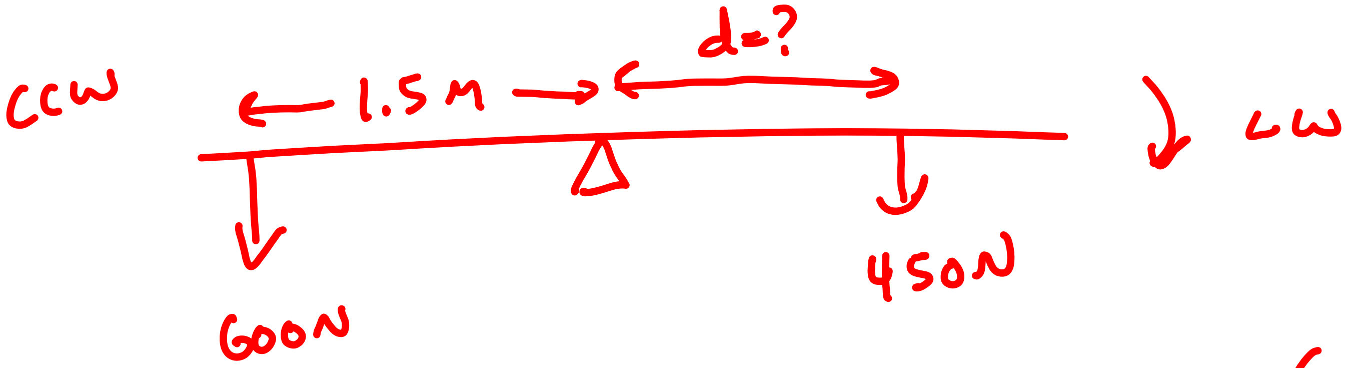
$\tau = F_\perp d$

$\tau = (15)(0.10) = 1.5 N \cdot m$



Problem Set 3

2. John weighs 600N and is sitting 1.5 m from the fulcrum. Where must a 450N Mary move to balance Johns weight?



$Fd_{ccw} = Fd_{cw}$

$(600)(1.5) = (450)(d)$

$d = \frac{(600)(1.5)}{450} = \boxed{2\text{ m}}$

Mechanical Energy

- Mechanical energy- the energy due to the position of something or the movement of something.

- Two types of Mechanical energy
  - Kinetic Energy
  - Potential Energy

- The unit for all energy and work is the **Joule**

Potential Energy (PE)

- **Potential Energy-** Energy that is stored
  - **Elastic Potential Energy-** caused by a stretched or compressed spring
  - **Chemical Energy-** energy in a substance (energy of position at a subatomic level released when electric charges within and between molecules are altered)
  - **Gravitational Potential Energy-** energy due to an elevated position

Elastic Potential Energy

- Elastic potential energy = (F)(d)
- Elastic potential energy equals the work done to store it

- PE = (F)(d)

Ex S: How much potential energy is in a bow pulled back 0.40m with a force of 50N?

Elastic Potential Energy

Ex S: How much potential energy is in a bow pulled back 0.40m with a force of 50N?

$F = 50N$ $d = 0.40\ m$

$$PE = Fd$$

$$PE = (50)(0.40) = 20J$$

Gravitational Potential Energy

- Gravitational potential energy is also equal to the work done to store it
- Gravitational potential energy = weight x height
- PE= F_wh or PE= mgh

The more height or more mass the more PE

Ex T: How much potential energy is in a 50kg boulder 3.5m off the ground?

Gravitational Potential Energy

Ex T: How much potential energy is in a 50kg boulder 3.5m off the ground?

$m = 50\,kg$

$h = 3.5\,m$

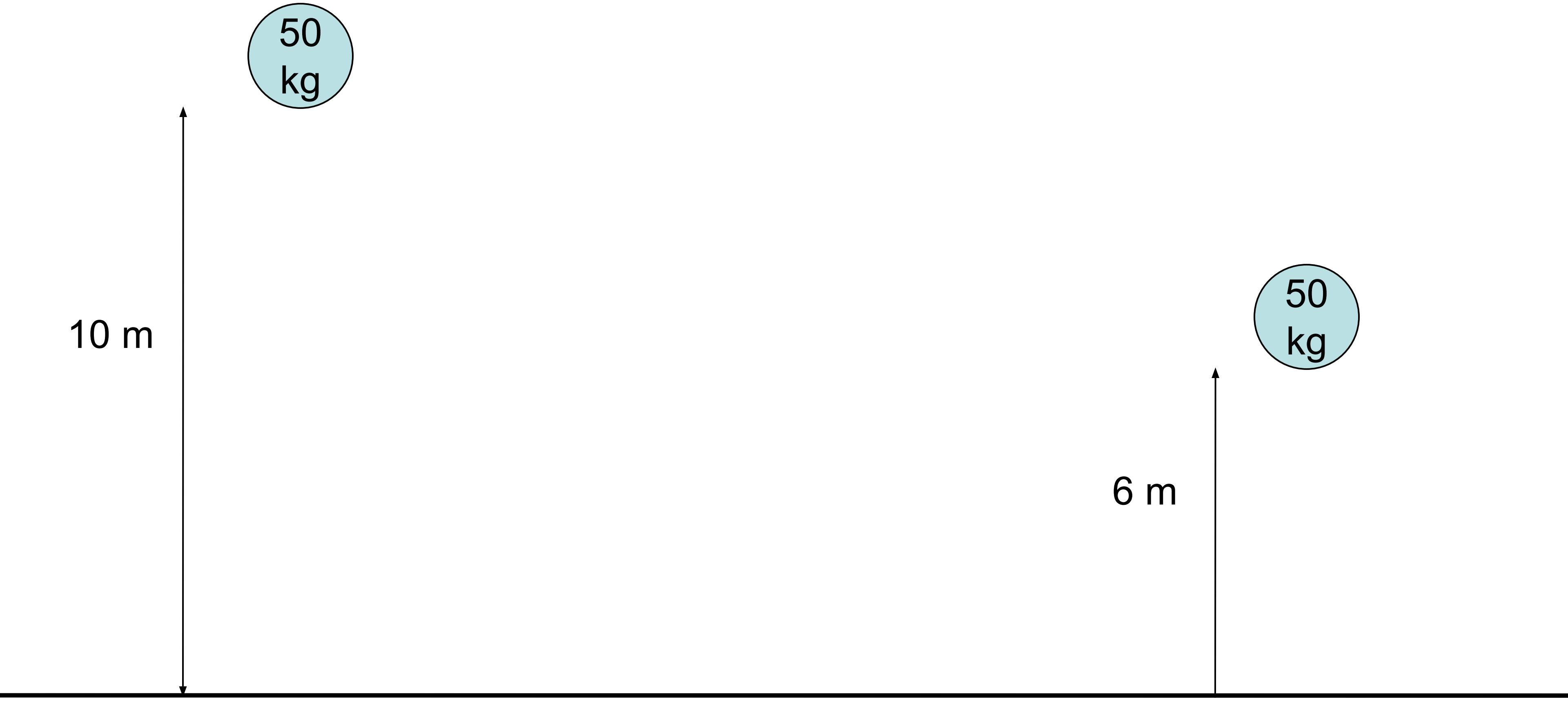
$g = 10\,m/s^2$

$PE = mgh$

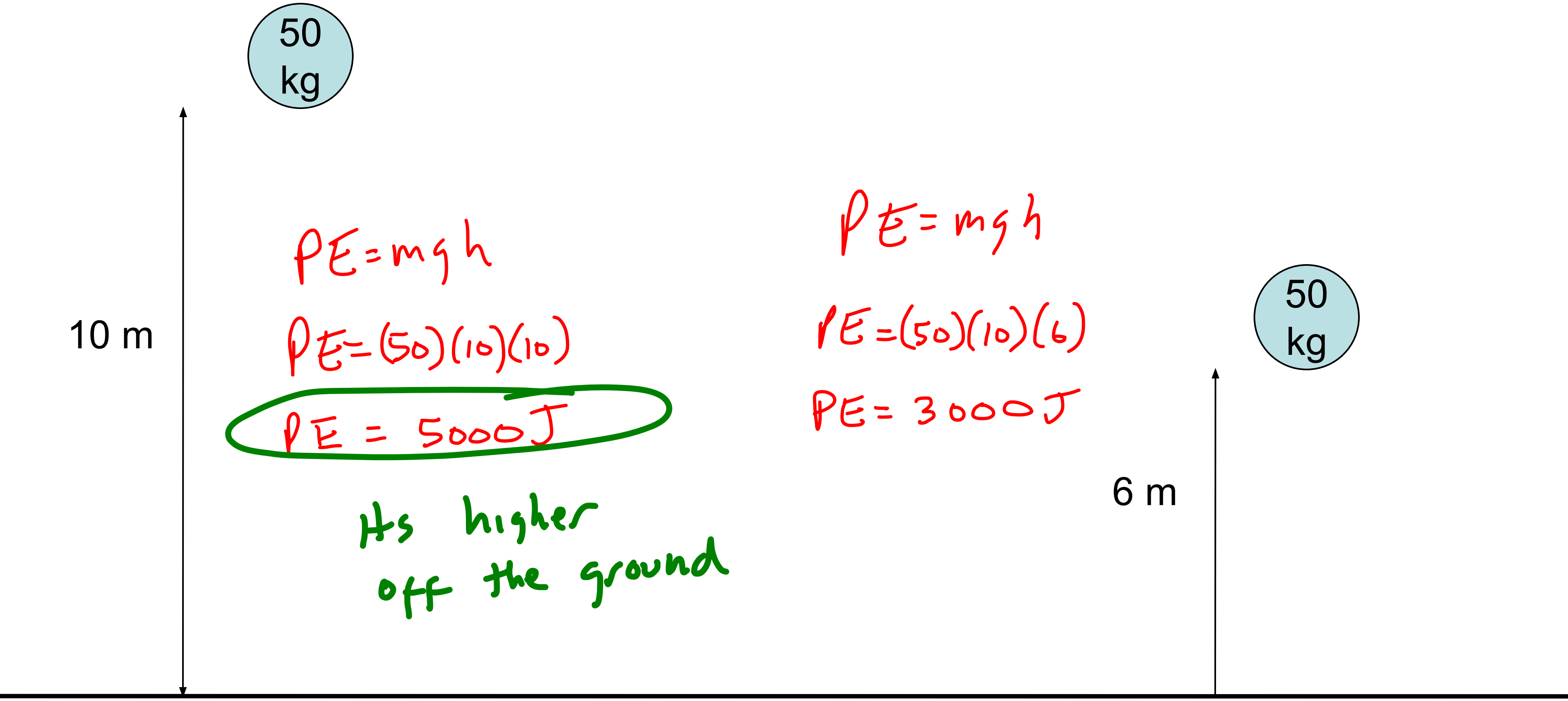
$PE = (50)(10)(3.5)$

$PE = 1750\,J$

Ex U: Which ball has more potential energy?



Ex U: Which ball has more potential energy?



$PE = mgh$

$PE = (50)(10)(10)$

$PE = 5000 J$

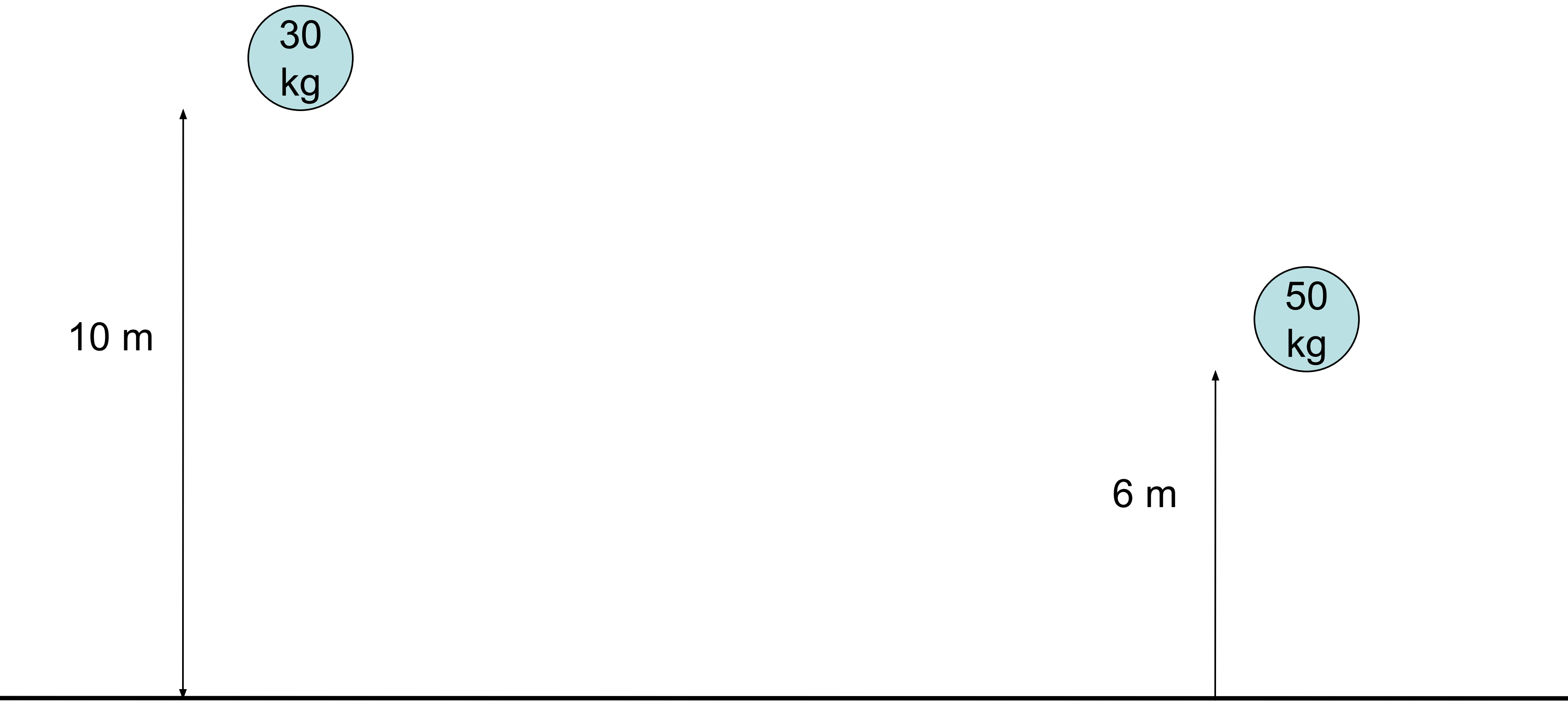
Its higher off the ground

$PE = mgh$

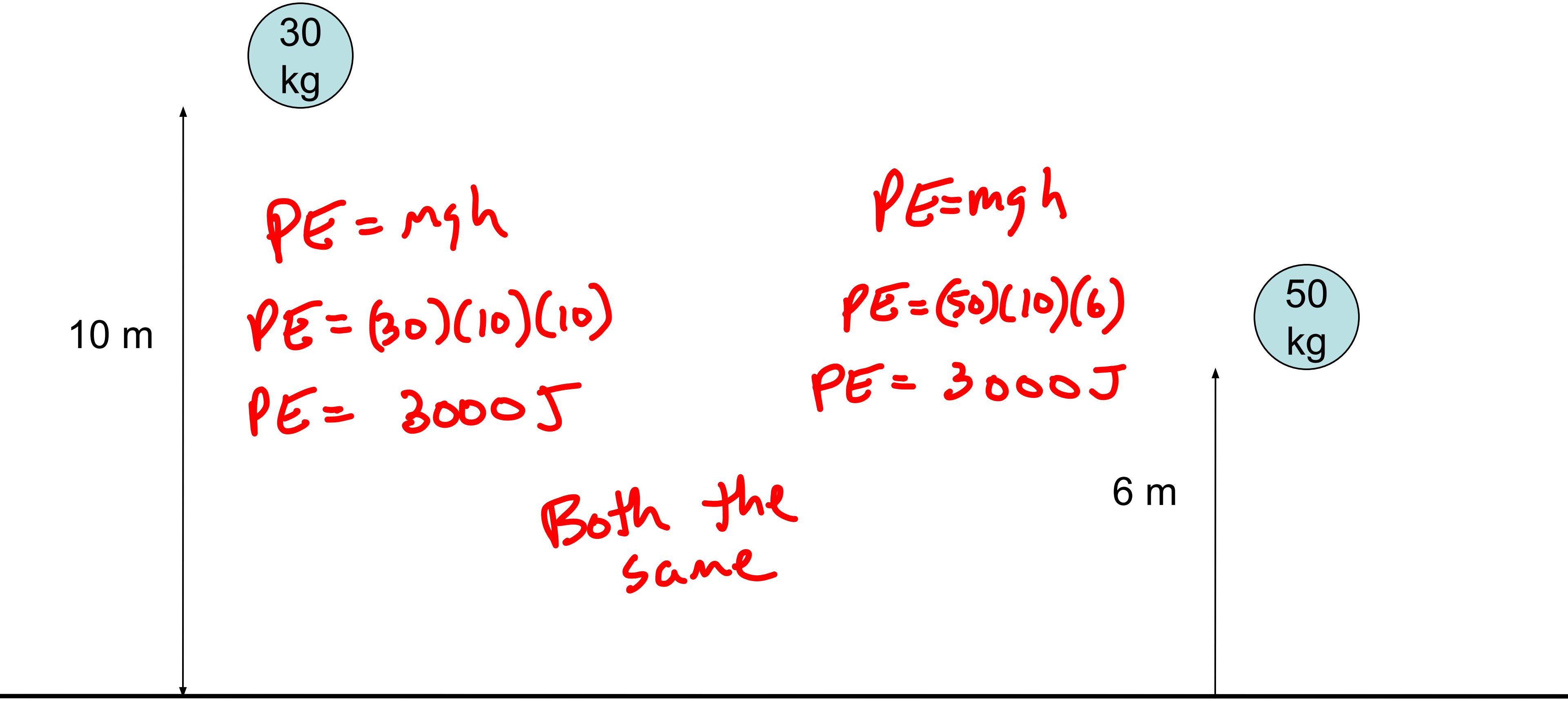
$PE = (50)(10)(6)$

$PE = 3000 J$

Ex V: Which ball has more potential energy?



Ex V: Which ball has more potential energy?



$PE = mgh$

$PE = (30)(10)(10)$

$PE = 3000 J$

$PE = mgh$

$PE = (50)(10)(6)$

$PE = 3000 J$

Both the same

Kinetic Energy (KE)

- Kinetic Energy- Energy of an object in motion
- KE = ½ mass x speed^2
- KE = ½ mv^2

KE = ½ mv2

Ex. W: How much kinetic energy does a 500 kg car have when moving at 20 m/s?

KE = ½ mv2

Ex. W: How much kinetic energy does a 500 kg car have when moving at 20 m/s?

$KE = \frac{1}{2} mv^2$

m = 500 kg

v = 20 m/s

$KE = \frac{1}{2}(500)(20)^2 = 100000 J$

$1.0 \times 10^5 J$

Problem Set 4

1. A 0.20kg apple falls 7.0m and hits you on the head. What was the apples change in PE during the fall?

2. A greyhound can run at a speed of 16.0m/s. What is the KE of a 20.0kg greyhound running at this speed?

Problem Set 4

1. A 0.20kg apple falls 7.0m and hits you on the head. What was the apples change in PE during the fall?

$m = 0.20\,kg$ $g = 10\, m/s^2$

$h = 7.0\,m$

$PE = ?$

$PE = mgh = (0.20)(10)(7)$

$PE = 14\,J$

Problem Set 4

2. A greyhound can run at a speed of 16.0m/s. What is the KE of a 20.0kg greyhound running at this speed?

$KE = \frac{1}{2} mv^2$

$v = 16.0 m/s$

$m = 20.0 kg$

$KE = \frac{1}{2}(20)(16^2) = 2560 J$

Work Energy Theorem

- Whenever work is done, energy changes.

- Work = ΔKE

- Work equals a change in kinetic energy

- Net force x distance = kinetic energy
- $Fd = ½ mv^2$

Ex. X: If a car has a mass of 750 kg, how much force is required to stop the car if it was traveling 12.5 m/s and took 10m to stop?

$Fd = ½ mv^2$

Ex. X: If a car has a mass of 750 kg, how much force is required to stop the car if it was traveling 12.5 m/s and took 10m to stop?

$Fd = \frac{1}{2} mv^2$

m = 750 kg

F = ?

v = 12.5 m/s

d = 10 m

$$F = \frac{\frac{1}{2} m v^2}{d}$$

$$F = \frac{\frac{1}{2}(750)(12.5^2)}{10}$$

$$\boxed{F = 5859\ N}$$

Conservation of Energy

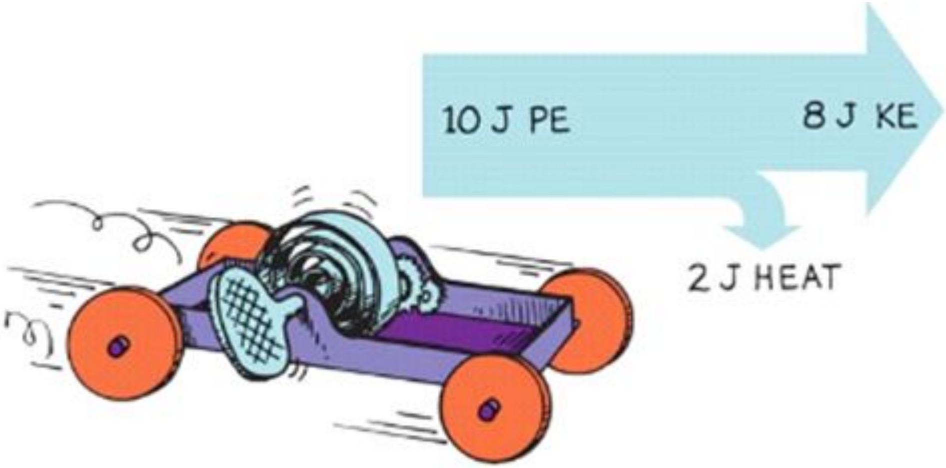
- **Law of conservation of energy-** energy cannot be created or destroyed. It can be transformed from one form into another, but the total energy never changes.

FIGURE 9.6 ▲ ©

When released, potential energy will become the kinetic energy of the arrow.

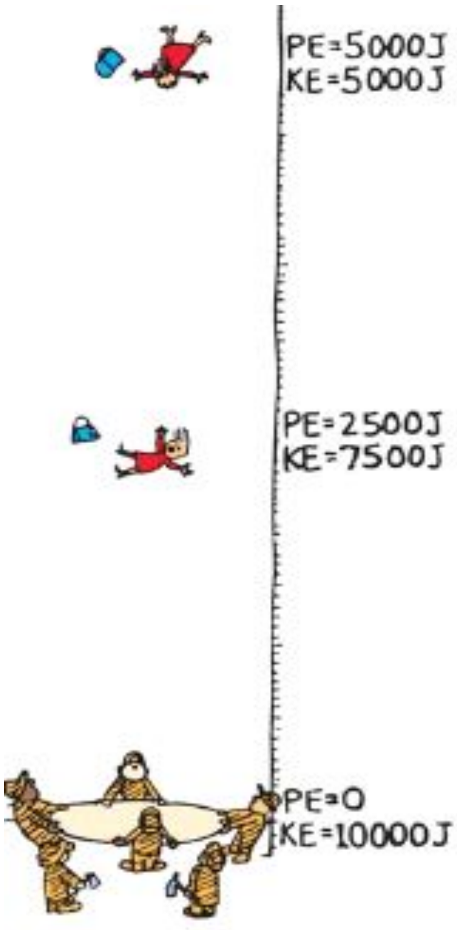
Conservation of Energy

- All potential energy stored in a spring will be transformed into other forms.
- Part becomes KE and the rest is lost to the surrounding as heat.



Conservation of energy formula

$PE_{before} + KE_{before} = PE_{after} + KE_{after} + \text{Heat lost}$



Formula in an ideal situation heat lost:

$PE_{before} + KE_{before} = PE_{after} + KE_{after}$

or

$mgh_{before} + ½\ mv^2_{before} = mgh_{after} + ½\ mv^2_{after}$

Mass is not needed in the conservation of energy formula

$$\frac{mgh_{before}}{m} + \frac{½\, mv^2_{before}}{m} = \frac{mgh_{after}}{m} + \frac{½\, mv^2_{after}}{m}$$

$$gh_{before} + ½\, v^2_{before} = gh_{after} + ½\, v^2_{after}$$

Ex. Y: A pool ball is flung off of a 0.68m high table and the ball hits the floor with a speed of 6.0 m/s. How fast was the ball moving when it left the pool table?

Ex. Y: A pool ball is flung off of a 0.68m high table and the ball hits the floor with a speed of 6.0 m/s. How fast was the ball moving when it left the pool table?

Before

after

$$PE + KE = \overset{0}{\cancel{PE}} + KE$$

$$\cancel{m}gh + \frac{1}{2}\cancel{m}v^2 = 0 + \frac{1}{2}\cancel{m}v^2$$

Before

$h = 0.68m$

After

$v = 6.0 m/s$

$$gh + \frac{1}{2}v^2 = \frac{1}{2}v^2$$

$$(10)(0.68) + \frac{1}{2}v^2 = \frac{1}{2}(6)^2$$

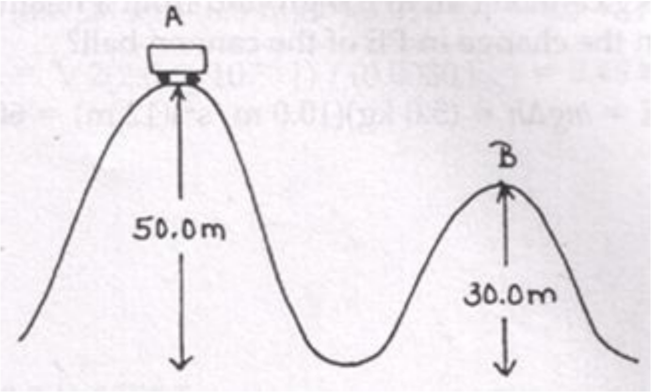
$$6.8 + \frac{1}{2}v^2 = 18$$

$$\frac{1}{2}v^2 = 18 - 6.8$$

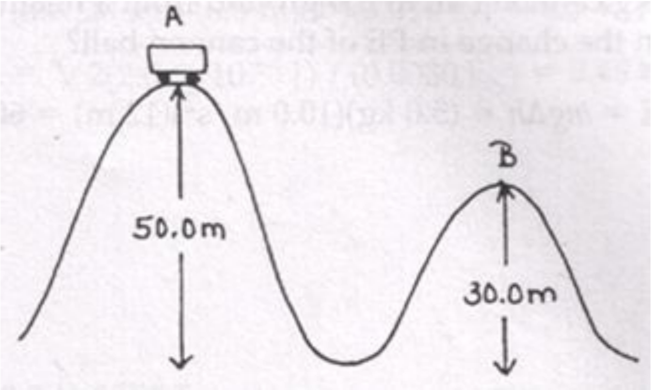
$$v^2 = 2(11.2)$$

$$v = \sqrt{22.4} = \boxed{4.7 m/s}$$

Ex. Z: A 300kg cart is going 8.0m/s when is at the top of hill A. How fast is it going at the top of hill B?



Ex. Z: A 300kg cart is going 8.0m/s when is at the top of hill A. How fast is it going at the top of hill B?



Before

$v = 8$ m/s

$d = 50$ m

after

$v = ?$

$d = 30$ m

KE PE KE PE

$$\frac{1}{2}v^2 + gh = \frac{1}{2}v^2 + gh$$

$$\frac{1}{2}(8)^2 + (10)(50) = \frac{1}{2}v^2 + (10)(30)$$

$$32 + 500 = \frac{1}{2}v^2 + 300$$

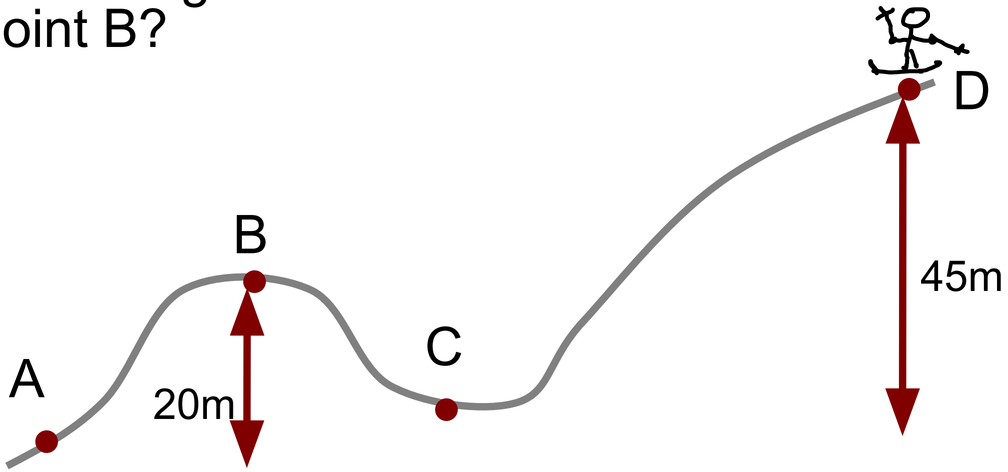
$$\frac{1}{2}v^2 = 232$$

$$v = \sqrt{2(232)}$$

$$\boxed{v = 21.5 \text{ m/s}}$$

Problem Set 5

1. A one kilogram rock is dropped from a cliff. After 20 meters, the kinetic energy of the rock is approximately what?
2. A 100 kg cart accelerates from 5 m/s to 10 m/s. How does the carts final kinetic energy compare to it initial kinetic energy?
3. At which point below does the skier have the most potential energy?
4. At which point below does the skier have the most kinetic energy?
5. At which point would the skier have the most energy (ideally)?
6. Assuming that a 50kg skier started at rest. What was the velocity of the skier at point B?



Problem Set 5

1. A one kilogram rock is dropped from a cliff. After 20 meters, the kinetic energy of the rock is approximately what?

Before

$m = 1 kg$

$h = 20 m$

After

$v = ?$

Before · · · · · · · · · · After

$$\underbrace{PE + \overset{\text{none}}{\cancel{KE}}}_{} = \overset{\text{none}}{\cancel{PE}} + KE$$

$$mgh = KE$$

$$KE = (1)(10)(20) = \boxed{200 J}$$

Problem Set 5

2. A 100 kg cart accelerates from 5 m/s to 10 m/s. How does the carts final kinetic energy compare to it initial kinetic energy?

$KE = \frac{1}{2} m v^2$

Law of ones $\frac{10}{5} = 2 \text{ times } v$

$KE = \frac{1}{2}(1)(1^2)$ $KE = \frac{1}{2}(1)(2^2)$ $\frac{\text{new}}{\text{ones}} = \frac{2}{\frac{1}{2}} = \boxed{4 \text{ times}}$

$KE = \frac{1}{2}$ when all ones

$KE = 2$ with change

Problem Set 5

2. A 100 kg cart accelerates from 5 m/s to 10 m/s. How does the carts final kinetic energy compare to it initial kinetic energy?

or

Before

$KE = \frac{1}{2} m v^2$

$KE = \frac{1}{2}(100)(5^2)$

$KE = 1250 J$

After

$KE = \frac{1}{2} m v^2$

$KE = \frac{1}{2}(100)(10^2)$

$KE = 5000 J$

change $\frac{5000}{1250} =$ 4 times

Problem Set 5

3. At which point below does the skier have the most potential energy?

D the highest point

4. At which point below does the skier have the most kinetic energy?

A the lowest point

5. At which point would the skier have the most energy (ideally)?

SAME EVERYWHERE IF NONE WAS LOST AS HEAT

6. Assuming that a 50kg skier started at rest. What was the velocity of the skier at point B?

Before $\qquad\qquad\qquad\qquad$ After

$$PE + \overset{\text{none}}{\cancel{KE}} = PE + KE$$

$$\cancel{m}gh = \cancel{m}gh + \frac{1}{2}\cancel{m}v^2$$

$$(10)(45) = (10)(20) + \frac{1}{2}v^2$$

$$v = \sqrt{2(250)}$$

$$\boxed{v = 22.4\ M/s}$$