Simple Machines

Lever, Wheel and Axle, and Pulley

Simple Machines

The Six Simple Machines

Mechanisms that manipulate force and distance.

Lever

Wheel and Axle

Pulley

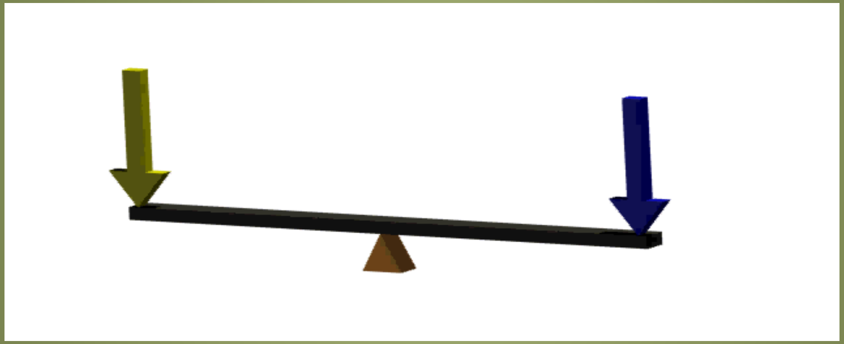
Inclined Plane

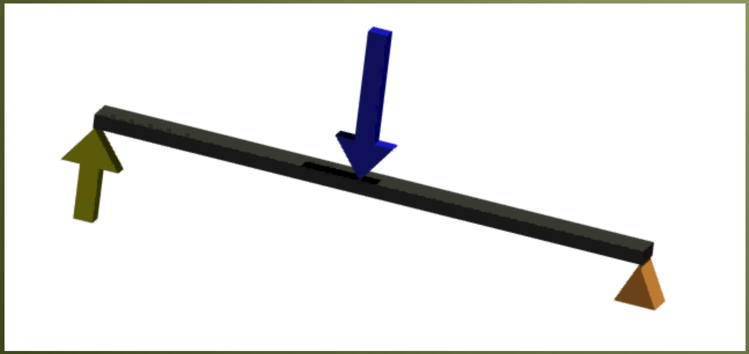
Wedge

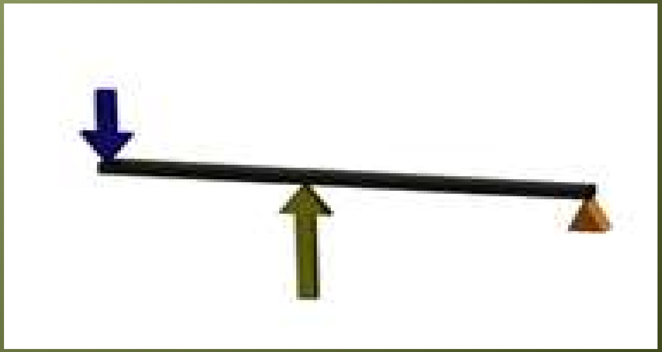
Screw

Lever

A rigid bar used to exert a pressure or sustain a weight at one point, via an applied force at a second point and turning on a fulcrum at a third point.





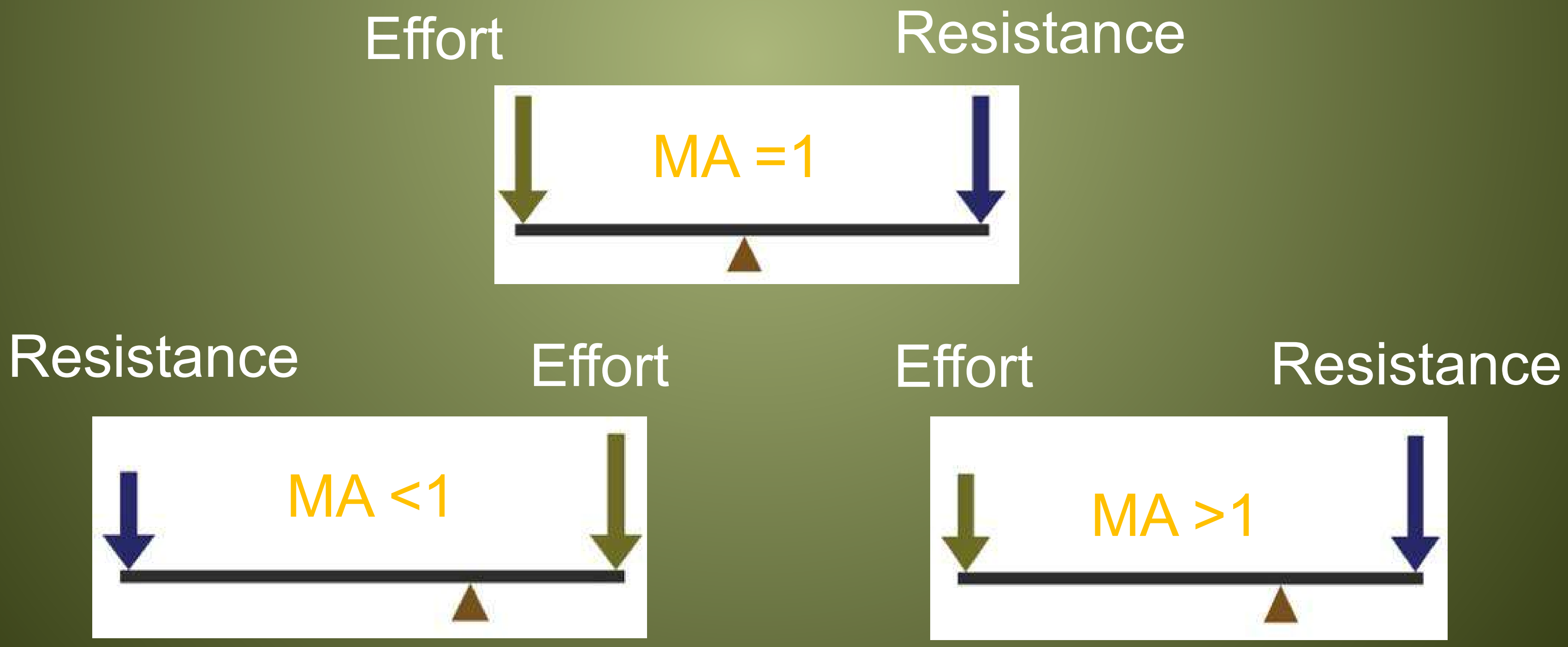


1st Class Lever

Fulcrum located between the effort and the resistance

Effort and resistance are applied in the same direction

May have a MA > 1 OR MA < 1



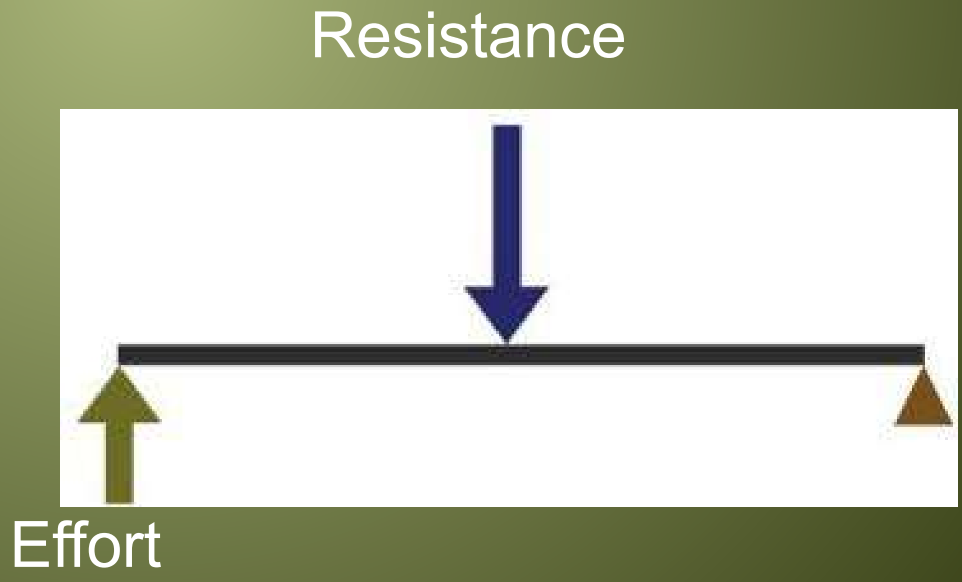
2nd Class Lever

Fulcrum located at one end

Resistance located between fulcrum and effort

Resistance and effort are in opposing directions

Always has MA > 1



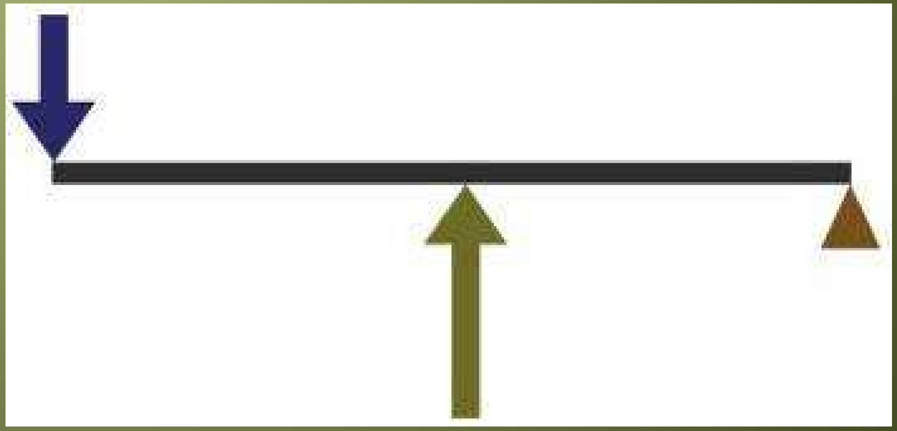
3rd Class Lever

Fulcrum located at one end

Effort located between fulcrum and resistance

Resistance and effort are in opposing directions

Always has MA < 1



Moment

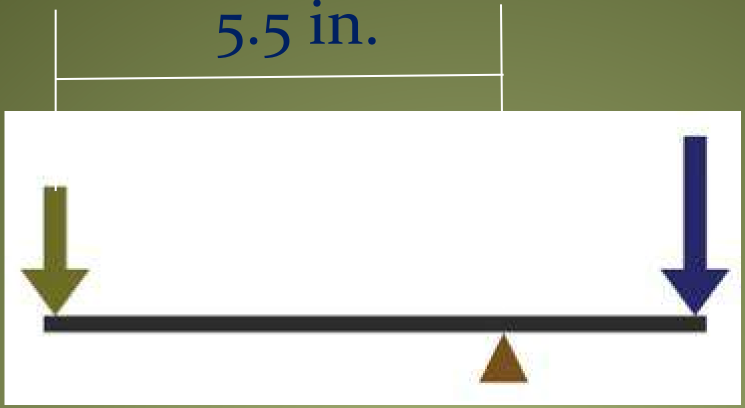
The turning effect of a force about a point. Equal to magnitude of the force times the perpendicular distance from the point to the location of the force.

Moment = Force *x* Distance

Torque

A force that produces or tries to produce rotation (aka turning) or torsion (aka twisting).

Lever Moment Calculation



Calculate the effort moment acting on the lever above.

Moment = Force x Distance

Effort Moment = 15 lb x 5.5 in.

Effort Moment = 82.5 in.-lb

Lever Moment Calculation

When the effort and resistance moments are equal, the lever is in static equilibrium.

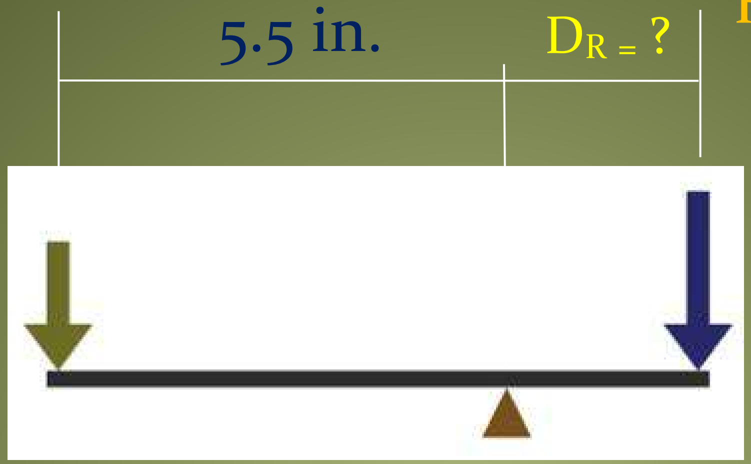
Static equilibrium:
A condition where there are no net external forces acting upon a particle or rigid body. As a result the body remains at rest or continues at a constant velocity.

Note: "no net external forces" doesn't mean "no forces"… it just means if forces exist they are cancelling each other out. So, the "net result" is that nothing is happening. It's kind of like two even teams have a tie in tug-o-war. People are pulling but nobody is moving.

Lever Moment Calculation

Effort
15 lbs

Resistance
36 2/3 lb



Using what you know regarding static equilibrium:

Calculate the unknown distance D_R needed to balance the lever.

If static equilibrium, then Effort Moment = Resistance Moment

If they equal each other then "no net forces" is true

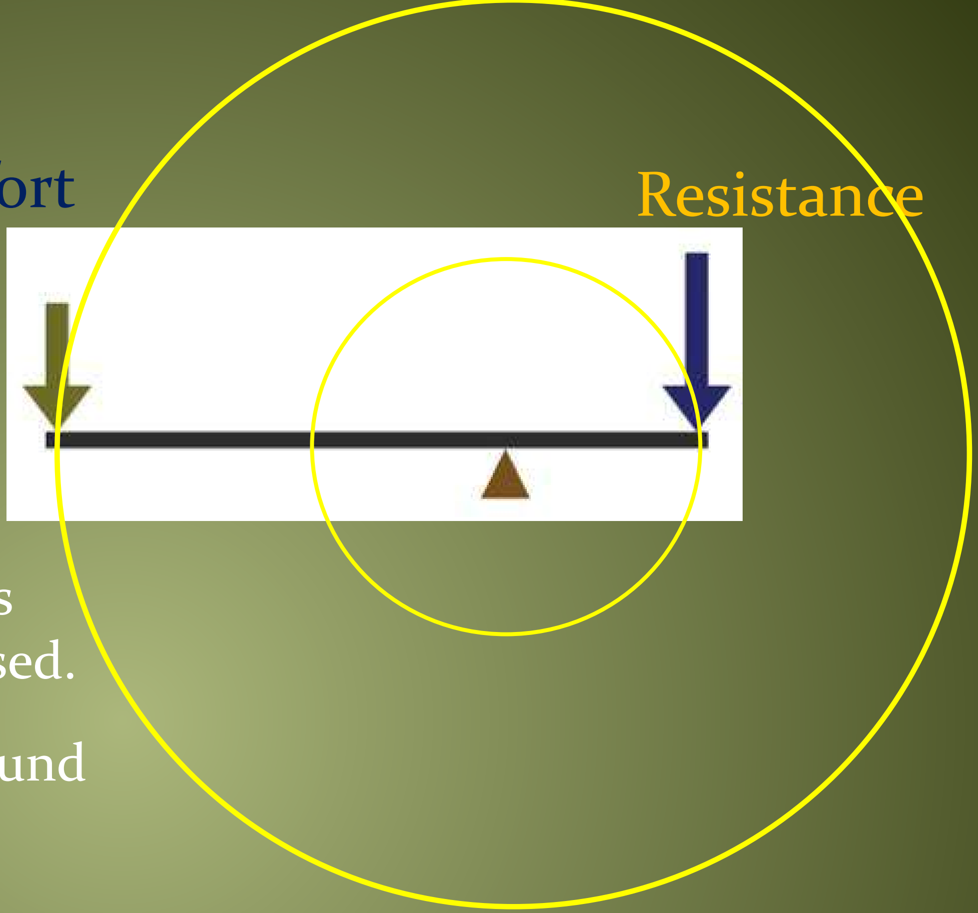
82.5 in.-lb = 36 2/3 lb x D_R in.

82.5 in.-lb / 36 2/3 lb = D_R in.

D_R = 2.25 in.

Lever IMA

$$IMA = \frac{D_E}{D_R}$$



Both **effort** and **resistance** forces would travel in a circle if unopposed.

Circumference is the distance around the perimeter of a circle.

Circumference = 2 π r

$D_E = 2\pi$ (effort arm length)

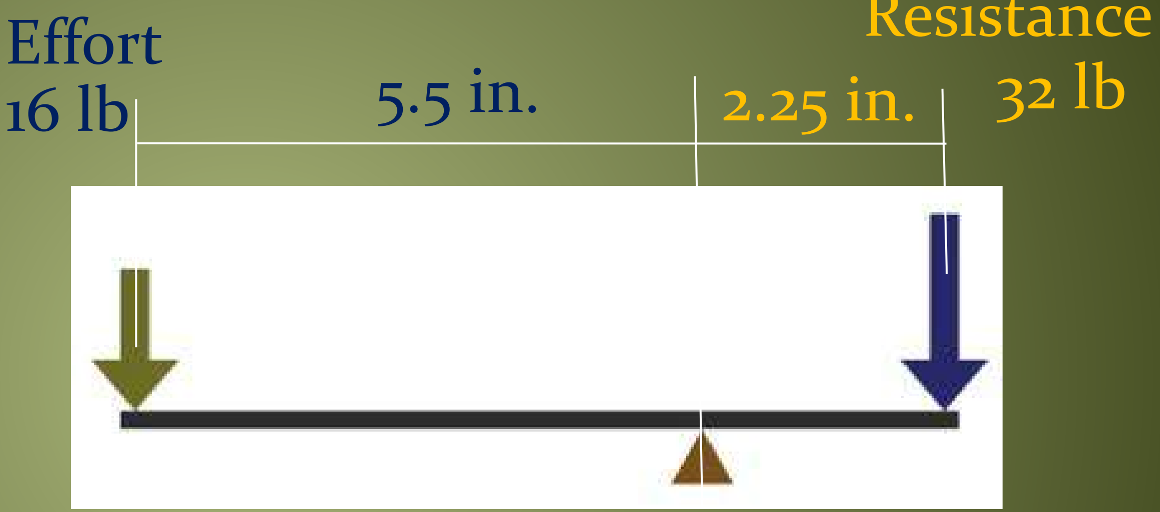
$D_R = 2\pi$ (resistance arm length)

$$IMA = \frac{\cancel{2\pi}\text{ (effort arm length)}}{\cancel{2\pi}\text{ (resistance arm length)}}$$

Lever AMA

Ratio of applied resistance to applied effort

$$AMA = \frac{F_R}{F_E}$$



What is the AMA of the lever?

AMA = 2:1

What is the IMA of the lever?

$$IMA = \frac{\text{effort arm length}}{\text{resistance arm length}}$$

IMA = 2.44:1

Q: Why is the IMA larger than the AMA?

Efficiency

In a machine, the ratio of useful energy output to total energy input. Also, the percentage of work input converted to work output.

The efficiency is simply the ratio of AMA to IMA

$$\text{Efficiency} = \frac{AMA}{IMA}$$

What is the efficiency of the lever on the previous slide?

AMA = 2:1

IMA = 2.44:1

Efficiency = 0.82 or 82%

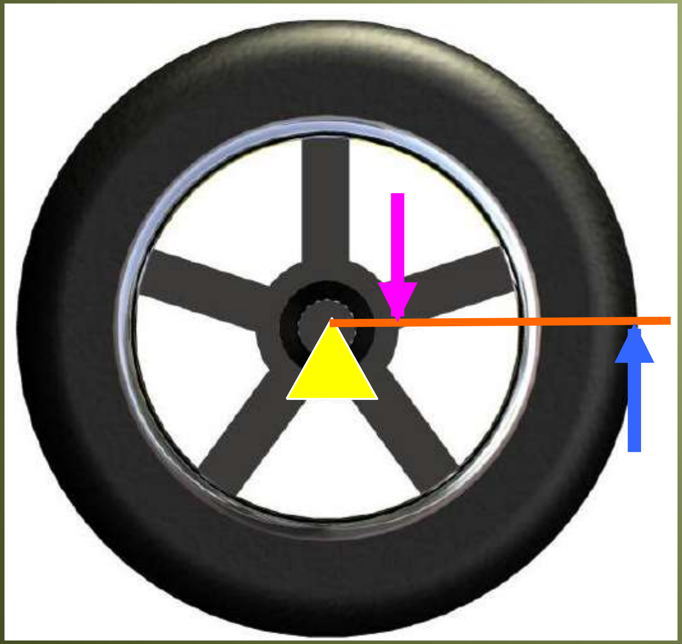
A: No machine is 100% efficient.

Wheel & Axle

A wheel is a lever arm fixed to a shaft called an axle.

The wheel and axle move together as a simple lever to lift or move an item by rolling.

Important: It must be known whether the wheel or the axle is applying the effort, as the other is the resistance.



An axle driving a wheel is common

Examples of a wheel driving an axle

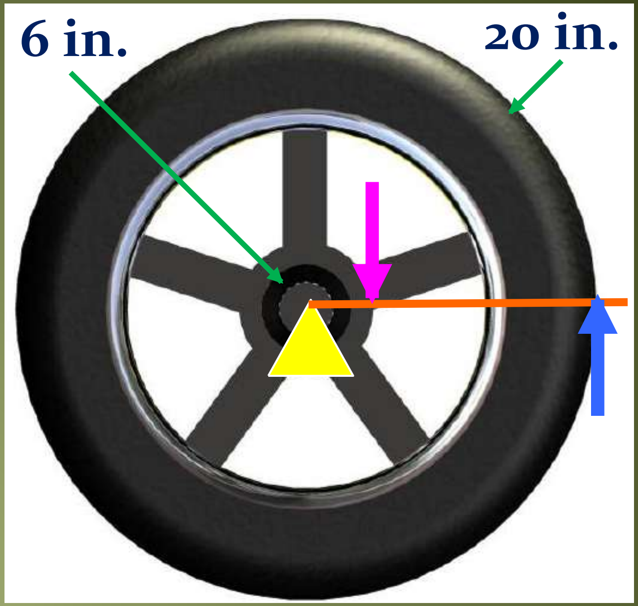
Wheel & Axle IMA

$$IMA = \frac{D_E}{D_R}$$

Both **effort** and **resistance** forces would travel in a circle if unopposed.

Circumference is the distance around the perimeter of a circle.

Circumference = 2 π r



$D_E = 2\pi$ (effort arm length)

$D_R = 2\pi$ (resistance arm length)

$$IMA = \frac{\cancel{2\pi}\text{ (effort arm length)}}{\cancel{2\pi}\text{ (resistance arm length)}}$$

What is the IMA if the axle is driving the wheel?

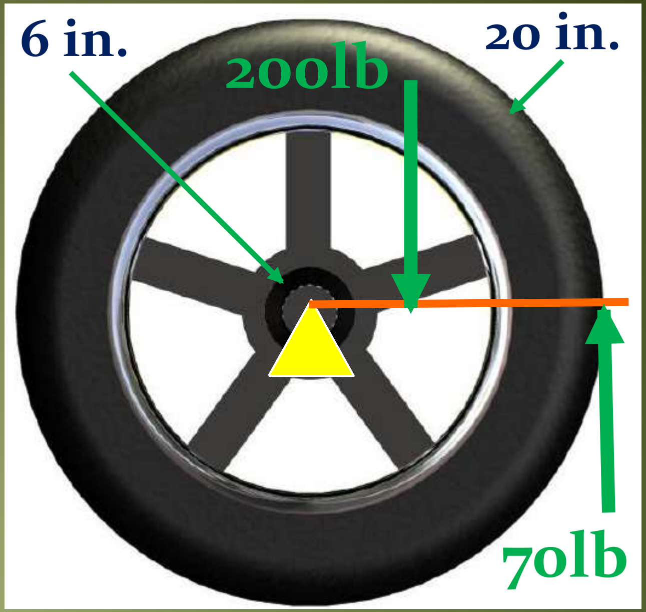
6 in. / 20 in. = 0.3 = 0.3:1 = 3:10

What is the IMA if the wheel is driving the axle?

20 in. / 6 in. = 3.33 = 3.33:1

Wheel & Axle AMA

$$AMA = \frac{F_R}{F_E}$$



What is the AMA if the wheel is driving the axle?

200lb/70lb = 2.86 = 2.86:1

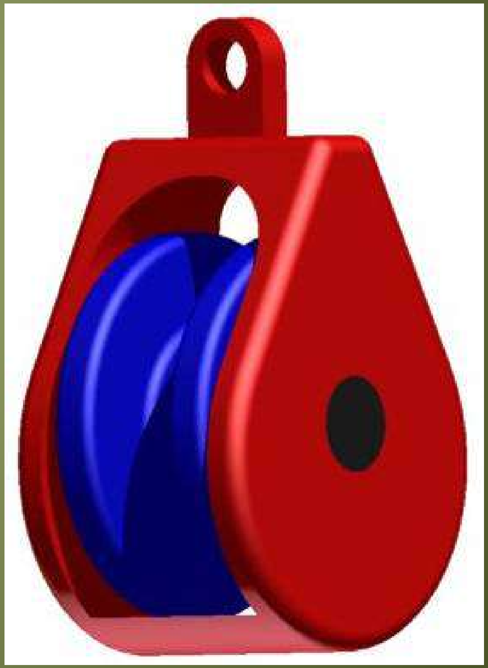
What is the efficiency of the wheel and axle?

$$Efficiency = \frac{AMA}{IMA}$$

2.86/3.33 = .859 or 85.9%

Pulley

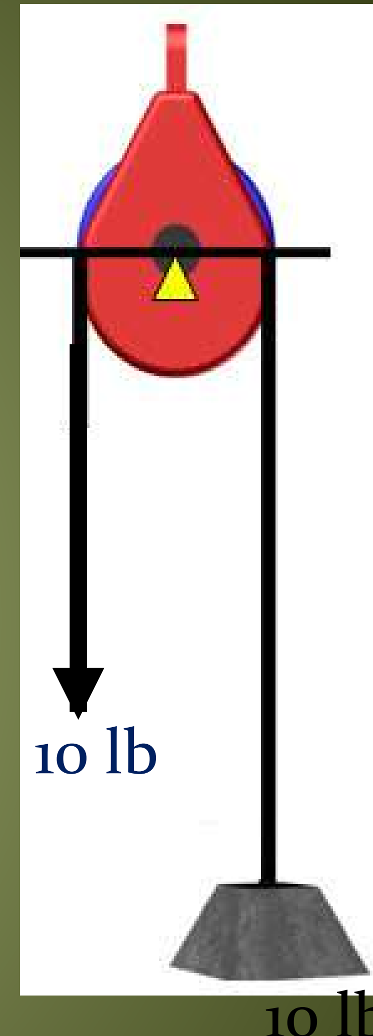
A pulley is a lever consisting of a wheel with a groove in its rim which is used to change the direction and magnitude of a force exerted by a rope or cable.

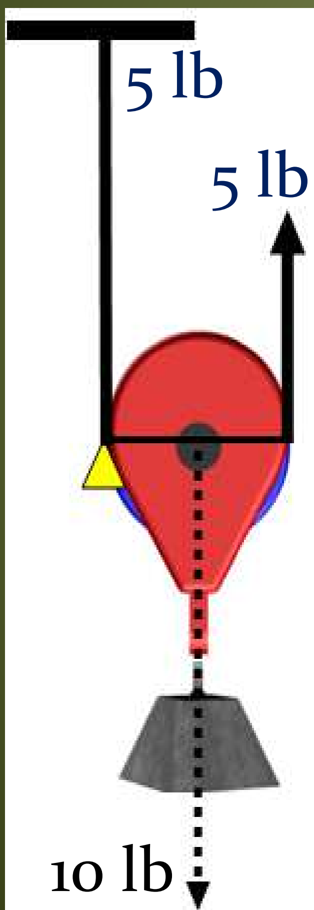


Pulley IMA

Fixed Pulley

- 1st class lever with an **IMA of 1**
- Changes the direction of force



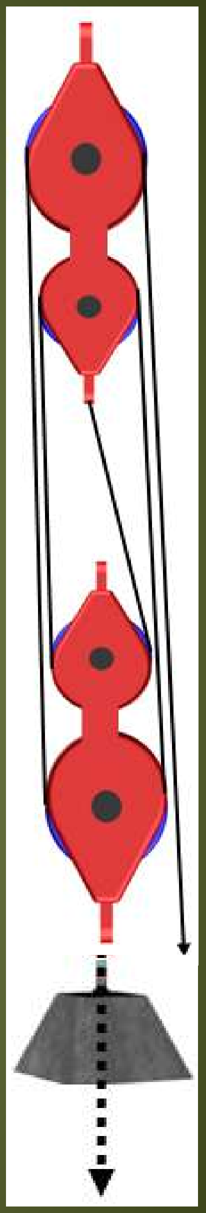


Movable Pulley

- 2nd class lever with an **IMA of 2**
- Force directions stay constant

Pulleys In Combination

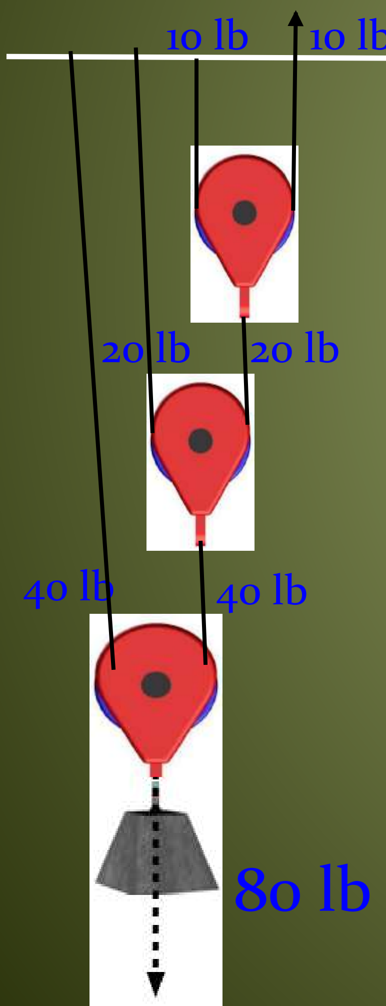
Combinations of fixed and movable pulleys can provide mechanical advantage and/or a change of direction for effort force.



800 lb

Q: What is the IMA of the pulley system on the right?

A: 4



Movable pulleys in combination provide mechanical advantage without change in effort force direction.

Q: What is the IMA of the pulley system on the left?

A: 8

Pulley AMA

$$AMA = \frac{F_R}{F_E}$$

What is the AMA of the pulley system?

$$AMA = \frac{800\text{lb}}{230\text{lb}}$$

AMA = 3.48 = 3.48:1

What is the efficiency of the pulley system?

$$\text{Efficiency} = \frac{AMA}{IMA} = \frac{3.48}{4}$$ = 0.87 or 87%

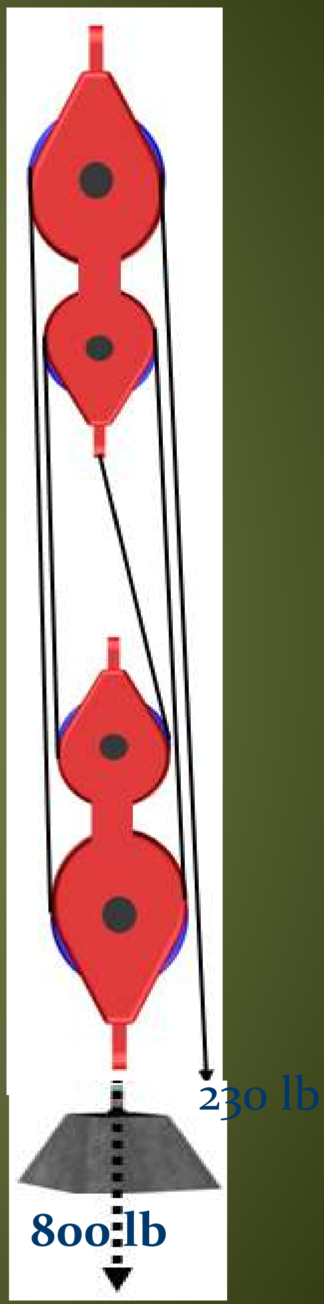


Image Resources

Microsoft, Inc. (2008). Clip Art. Retrieved January 10, 2008, from http://office.microsoft.com/en-us/clipart/default.aspx