Lesson 3.1: Energy, Work, and Power

Unit 3: Momentum and Energy

Work:

Work is done when a force is applied over a distance (in the same direction as that force)

Work = (Force component in direction of motion) × distance

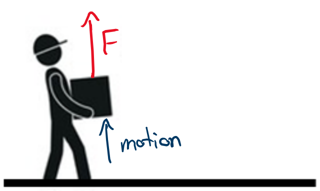
$$\boxed{W = F_d \cdot d = F\cos\theta \cdot d}$$

W = Work – Joules (J)
F = Force (N)
d = distance (m)

$1 J = 1 N{\cdot}m = 1\, kg{\cdot}m^2/s^2$

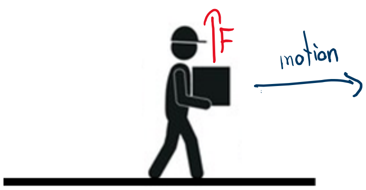
* Work is a scalar, not vector.

Example 1: A box is lifted off the ground



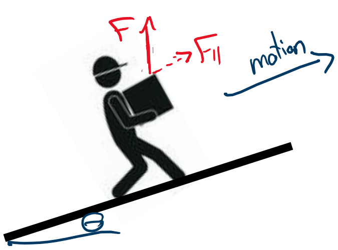
Work is done on the box.
$F \parallel d$

Now move forward with the box:



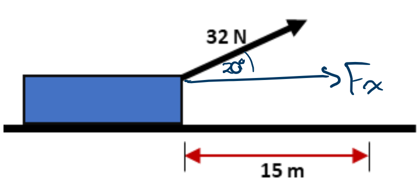
No work done on the box
$F \perp d$

Now walk up a ramp:



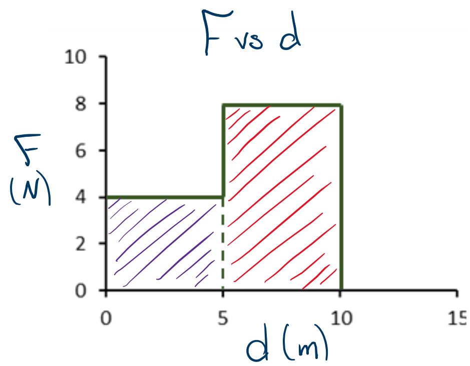
Work is done on the component of $F \parallel d$
$(F\cos\theta)$

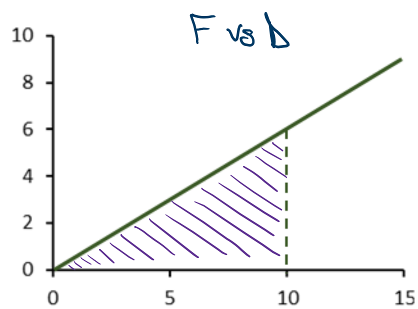
Example 2: Calculate the work done in the following if the force is at a 20°incline.

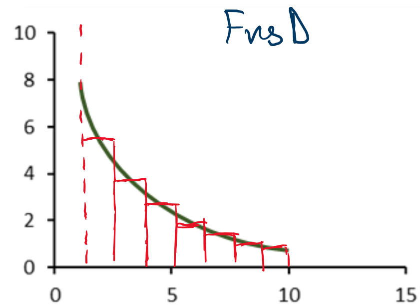


$W = F \cdot d$
$W = (32\cos 20)(15)$
$\boxed{W = 451 J}$

Work = Area under a curve.







$W = 4(5) + 10(5)$

$W = 20 + 50 = 70J$

$W = \frac{10(6)}{2} = \frac{60}{2} = 30J$

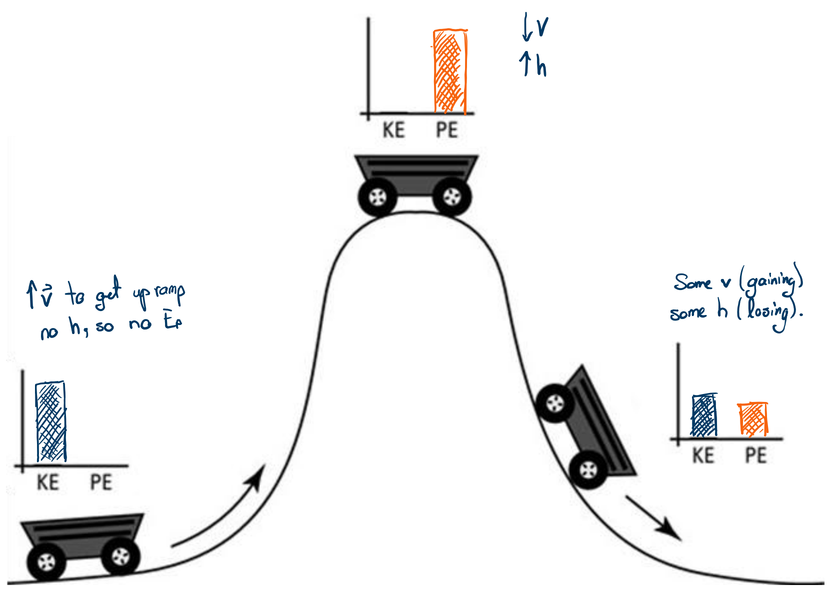
$W = \int_b^a F(x)dx$

Energy: The ability to do work:

	Gravitational Potential Energy	Kinetic Energy
Definition	Stored energy caused by work being done to an object against a gravitational field.	The energy of motion with the ability to do work.
Equation	$E_p = mgh$	$E_k = ½ mv^2$
Variables and Units	m = mass (kg) g = gravity (m/s^2) h = height (m)	m = mass (kg) v = velocity (m/s)
Proportionality in Kinetic Energy:		
Double the mass, velocity is the same:		
Same mass, double the velocity:		
Triple the mass, triple the velocity		

* E_p is only valid near the surface of the gravitational body.

* Work done to an object to move it to height h is converted E_p.



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The Work-Energy Theorem:

The <u>total work</u> done on an object is equal to the total change in <u>kinetic</u> energy.

$$W = \Delta E_K \qquad W = E_K - E_{Ko} \qquad W = \frac{m\vec{v}^2}{2} - \frac{m\vec{v}_o^2}{2}$$

When Total Work done is positive: E_K is increased

When Total Work done is negative: E_K is decreased

When Total Work done is zero: E_K stays the same

Conceptual 1 (no work) *Discuss tossing a ball back and forth between your hands or playing pass with someone back and forth. Someone throws a ball to you with velocity v. They create this initial velocity by applying a forward force with their hand. As you catch it, your hand does negative work on the ball brining its final velocity to zero meaning your hand has done negative work and taken E_K out of the system. The amount of work done on that ball is therefore zero.*

Conceptual 2 (no work): *You are moving your couch from one spot in the living room to another. The floor is quite rough. You apply a horizontal force causing horizontal displacement across the room. The couch starts at rest but gains kinetic energy as you continue to apply force. Once the couch reaches the intended location, you release force and the couch immediately stops. Friction has done negative work to your applied work resulting in a net zero work being done to that couch. You may be tired, but you didn't do any work.*

Conceptual 3 (added E_k): *You push a shopping cart harder than friction. The cart speeds up. Kinetic energy is added and the work done is positive.*

Conceptual 4 (E_K removed): *You're pushing the shopping cart out of the store into the parking lot. As you arrive outside, the deep slush slows you down considerably. Total work is negative.*

Example 3: A 5.0 kg box is pushed from <u>rest</u> with 20 N of force for 2.0 m on a frictionless surface. Find the velocity when it is released.

$E_{Ko} = 0$

$$W = \Delta E_K$$
$$Fd = E_K - \cancel{E_{Ko}} \rightarrow 0$$
$$Fd = \frac{mv^2}{2}$$

$$V = \sqrt{\frac{2F \cdot d}{m}}$$
$$V = \sqrt{\frac{2(20)(2)}{5}}$$
$$\boxed{V = 4.0\,m/s}$$

Power:

Who is more powerful—someone who carries 20 kg up the stairs, or someone who carries the same 20 kg up the stairs in half the time?

Power Definition: The rate at which work is being done or transferred.

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

P = power ($J/s = W \leftarrow$ Watt)

W = work (J)

t = time (s)

1 W is very small so kW often used

$1\,kW = 1000\,W$

Imperial Conversion: $1\,hp = 746\,W$

Example 4: How much work can a 1000 hp engine in a Formula 1 car do in 5.0 minutes?

$$1000\,hp \times \frac{746\,W}{1\,hp} = 746000\,W \qquad 5\,min \times \frac{60\,s}{1\,min} = 300\,s$$

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

$$= 746000\,W(300\,s)$$

$$= 2.24 \times 10^8\,J$$

or 224 MJ of work.

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