Today 6.1 & 6.2

$\boxed{L18}$

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

$\left.\right\}$ Work & kinetic energy

$\boxed{L18}$

ASU

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

Work & kinetic energy

L18

We will look at this subject in 2-ways

Today 6.1 & 6.2
Wednesday 6.1 & 6.2 } Work & kinetic energy

L18

We will look at this subject in 2-ways

* $\vec{F} = m\vec{a}$ + math

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

Work & kinetic energy

L18

We will look at this subject in 2-ways

* $\vec{F} = m\vec{a}$ + math $\Rightarrow$ Work = Δ kinetic energy

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

Work & kinetic energy

L18

We will look at this subject in 2-ways

* $\vec{F} = m\vec{a}$ + math $\Rightarrow$ Work = Δkinetic energy
* As book does

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

Work & kinetic energy

L18

We will look at this subject in 2-ways

* $\vec{F}=m\vec{a}$ + math $\Rightarrow$ Work = Δkinetic energy
* As book does with W defined

<u>Today</u> 6.1 & 6.2

<u>Wednesday</u> 6.1 & 6.2 } Work & kinetic energy

$\boxed{L18}$

We will look at this subject in 2-ways

* $\vec{F} = m\vec{a}$ + math $\Rightarrow$ Work = Δkinetic energy
* As book does with W defined (in 6.1)

Today 6.1 & 6.2

Wednesday 6.1 & 6.2

Work & kinetic energy

L18

We will look at this subject in 2-ways

* $\vec{F} = m\vec{a}$ + math $\Rightarrow$ Work = Δ kinetic energy
* As book does with W defined (in 6.1) & then connected to Kinetic energy (in 6.2)

I want to show you that

I want to show you that

$$\Sigma \vec{F} = m\vec{a} \quad \oplus$$

I want to show you that

$$\left[\sum \vec{F} = m\vec{a} \oplus \text{Calculus}\right]$$

$$\Rightarrow$$

I want to show you that

$$\left[\Sigma \vec{F} = m\vec{a} \oplus \text{Calculus}\right]$$

$$\Rightarrow$$

$$\text{Work} = \left\{\begin{array}{l}\text{Change in} \\ \text{Kinetic energy}\end{array}\right\}$$

$\boxed{\text{1-d case}}$

$$\Sigma F = ma$$

$\boxed{\text{1-D case}}$ $\quad \Sigma F = ma \quad$ But $\quad a = V\frac{\partial V}{\partial x}$

$\boxed{\text{1-D case}}$ $\sum F = ma$ But $a = v\frac{\partial v}{\partial x}$

So $\sum F = m\, v\frac{\partial v}{\partial x}$

$\boxed{\text{1-D case}}$ $\Sigma F = ma$ But $a = v\frac{dv}{dx}$

so $\Sigma\int F\,dx = m\int v\frac{dv}{dx}\,dx$

$\boxed{\text{1-d case}}$ $\sum F = ma$ But $a = v\frac{dv}{dx}$

so $\sum\int F\,dx = m\int v\frac{dv}{dx}\,dx \Rightarrow \sum\int F\,dx = m\int v\,dv$

$\boxed{\text{1-d case}}$ $\quad \Sigma F = ma \quad$ But $\quad a = v\dfrac{dv}{dx}$

So $\quad \Sigma\int F\,dx = m\int v\dfrac{dv}{dx}\,dx \Rightarrow \Sigma\int_{x_1}^{x_2} F\,dx = m\int_{v_1}^{v_2} v\,dv$

$$\Rightarrow \quad \Sigma\int_{x_1}^{x_2} F\,dx = \frac{1}{2}mv^2\Big|_{v_1}^{v_2}$$

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<u>Define</u>: $W_{1\to 2} \equiv$ Work from point 1 to point 2

$\boxed{\text{1-d case}}$ $\quad \sum F = ma \quad$ But $\quad a = v\dfrac{dv}{dx}$

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& $W_{1\to 2} \equiv \Sigma\int_{x_1}^{x_2} F\,dx$

& $K \equiv$ Kinetic energy

$\boxed{\text{1-D case}}$ $\quad \Sigma F = ma \quad$ But $a = v\dfrac{dv}{dx}$

So $\displaystyle \Sigma \int F\,dx = m\int v \frac{dv}{dx}\,dx \Rightarrow \Sigma \int_{x_1}^{x_2} F\,dx = m\int_{v_1}^{v_2} v\,dv$

$$\Rightarrow \Sigma \int_{x_1}^{x_2} F\,dx = \frac{1}{2}mv^2\Big|_{v_1}^{v_2}$$

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So $\sum \int F dx = m \int v \frac{dv}{dx} dx \Rightarrow \sum \int_{x_1}^{x_2} F dx = m \int_{v_1}^{v_2} v\, dv$

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& $K \equiv \frac{1}{2} m v^2$

Now $W_{1\to 2} = K_2 - K_1$

$\boxed{\text{1-d case}}$ $\sum F = ma$ But $a = v\frac{dv}{dx}$

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$\Rightarrow \sum \int_{x_1}^{x_2} F dx = \frac{1}{2} m v^2 \Big|_{v_1}^{v_2}$

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Define: $W_{1\to 2} \equiv$ Work from point 1 to point 2

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so $\sum \int F dx = m \int v \frac{dv}{dx} dx \Rightarrow \sum \int_{x_1}^{x_2} F dx = m \int_{v_1}^{v_2} v\, dv$

$\Rightarrow \sum \int_{x_1}^{x_2} F dx = \frac{1}{2} m v^2 \Big|_{v_1}^{v_2}$

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Define: $W_{1\to 2} \equiv$ Work from point 1 to point 2

& $W_{1\to 2} \equiv \sum \int_{x_1}^{x_2} F dx$

& $K \equiv$ Kinetic energy

& $K \equiv \frac{1}{2} m v^2$

Now $W_{1\to 2} = K_2 - K_1$ or $W_{1\to 2} = \Delta K$ or $K_1 + W_{1\to 2} = K_2$

For 3-d case $U_{1\to 2}$ generalizes as

$$U_{1\to 2} = \sum \int \vec{F} \cdot d\vec{r}$$

For 3-d case $U_{1\to 2}$ generalizes as

$U_{1\to 2} = \sum \int \vec{F} \cdot d\vec{r}$, where $\vec{F} \cdot d\vec{r} = F_x dx + F_y dy + F_z dz$

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$$U_{1\to 2} = \sum \int \vec{F}\cdot d\vec{r}, \text{ where } \vec{F}\cdot d\vec{r} = F_x dx + F_y dy + F_z dz$$

* Proof for 3-d case is slightly more difficult & put at end of these notes.

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We will now follow the treatment provided in the book

Work

In physics we sometimes have very particular definitions of words used in everyday language. A good example is "work"

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In physics we sometimes have very particular definitions of words used in everyday language. A good example is "work"

work = [force in direction of motion]

*

[distance travelled]

These people are doing work as they push on the car because they exert a force on the car as it moves.

Work

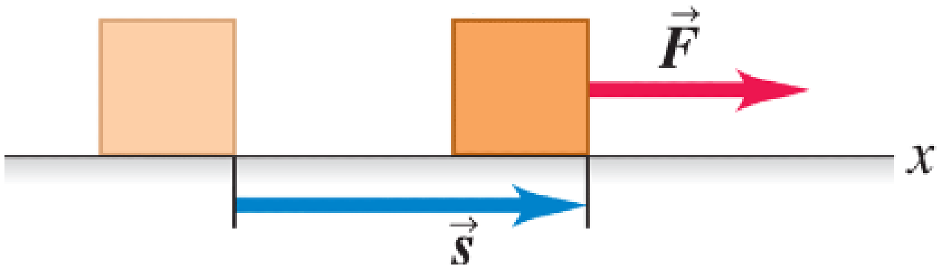
$$W = Fs$$

Work

$W = Fs$, where F is in direction of straight-line displacement s

Work

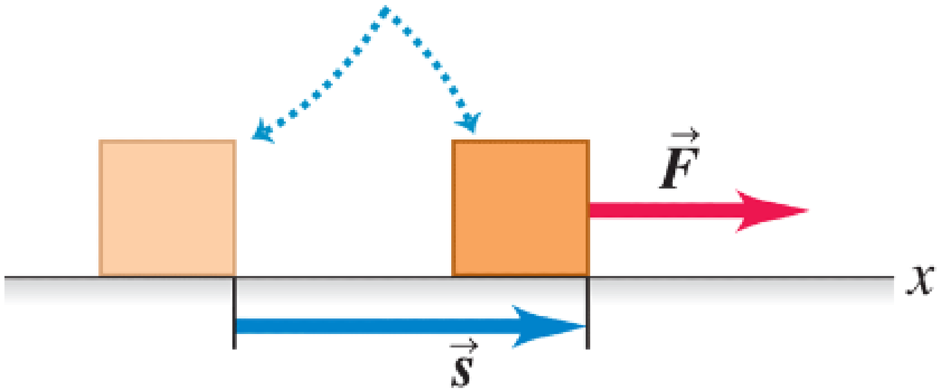
$W = Fs$, where F is in direction of straight-line displacement s



Work

$W = Fs$, where F is in direction of straight-line displacement s

If a particle moves through a displacement $\vec{s}$ while a constant force $\vec{F}$ acts on it in the same direction ...



Work

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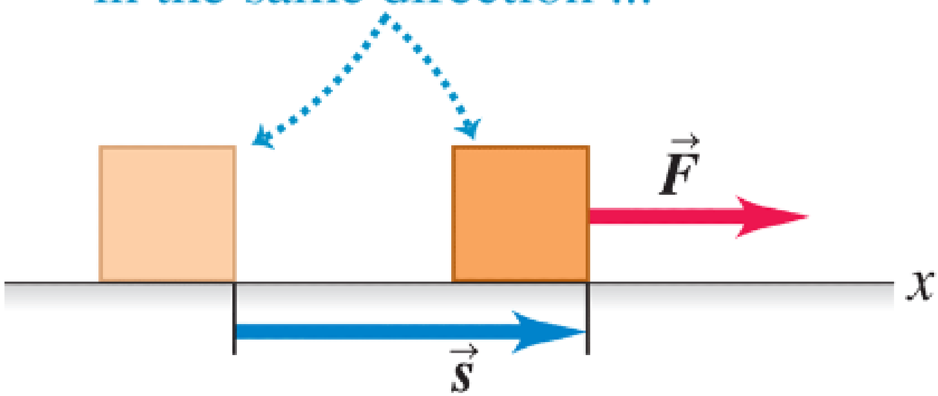
If a particle moves through a displacement $\vec{s}$ while a constant force $\vec{F}$ acts on it in the same direction ...



... the work done by the force on the particle is $W = Fs$.

Work

Work

* Don't confuse W [work] with w [weight]

Work

* Don't confuse W [work] with w [weight]

* Units

  Joule = (Newton)(meter)

Work

* Don't confuse W [work] with w [weight]

* Units

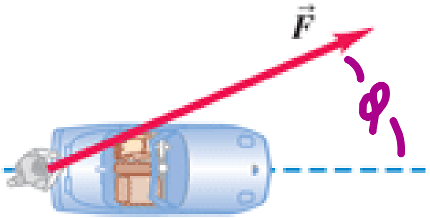
Joule = (Newton)(meter) <u>or</u> $J = N \cdot m$

Work

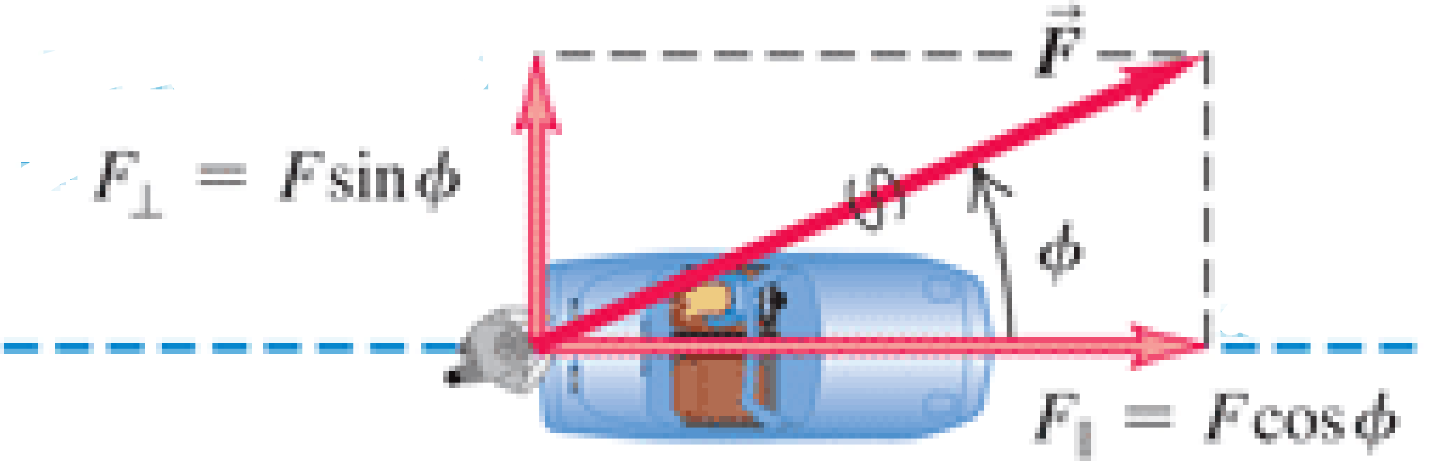
* Don't confuse W [work] with w [weight]

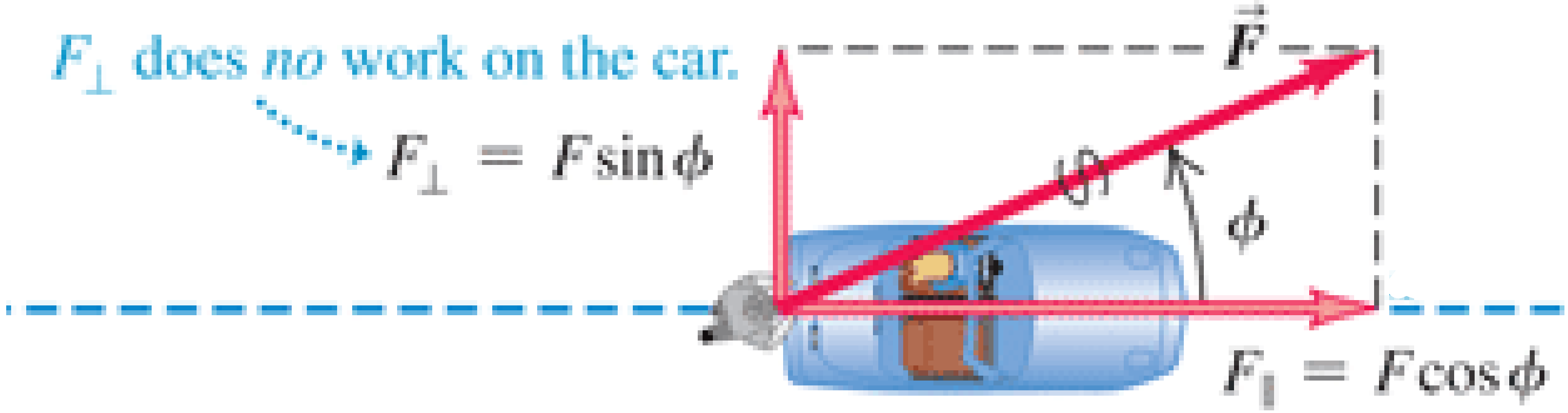
* Units

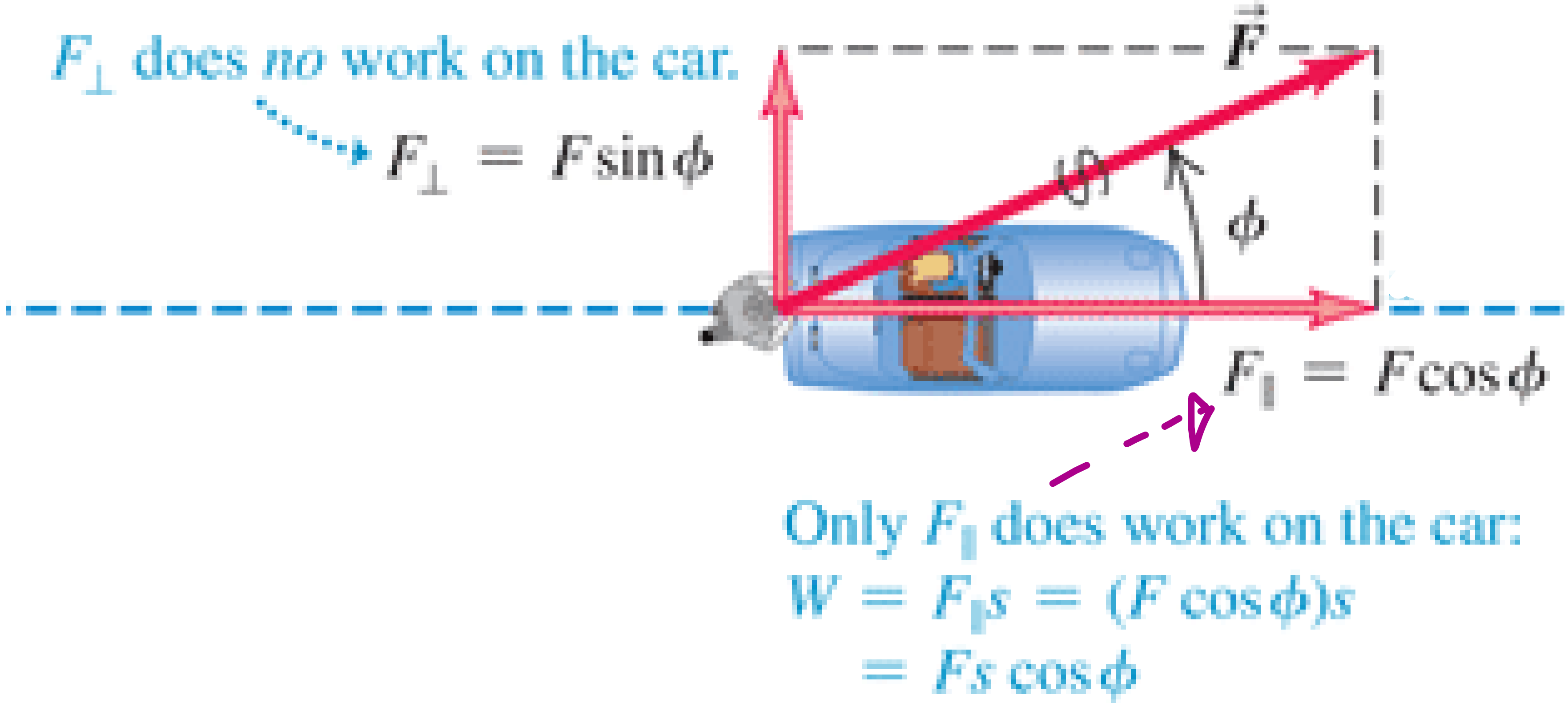
  Joule = (Newton)(meter) or $J = N \cdot m$

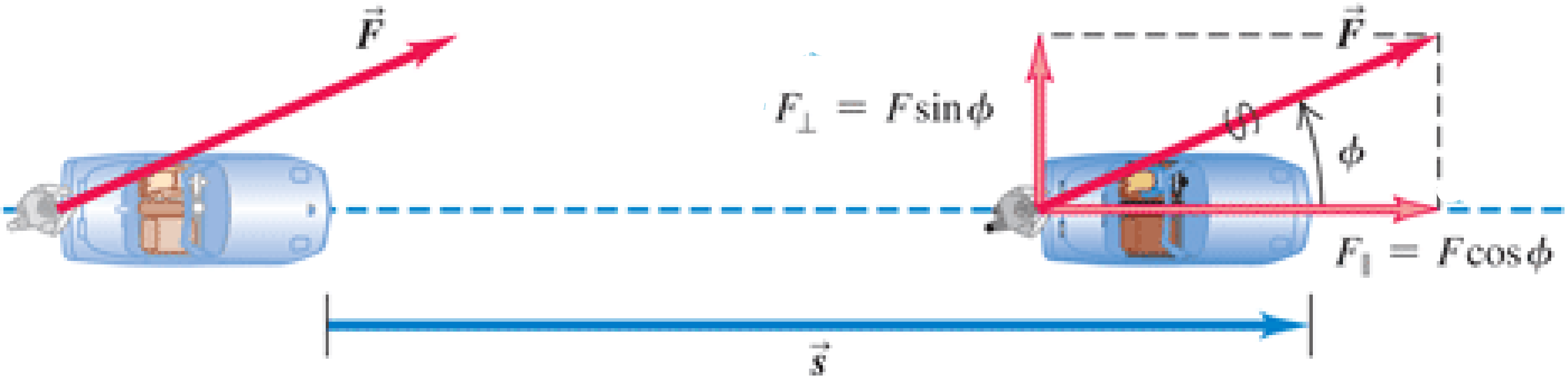


The car moves through displacement $\vec{s}$ while a constant force $\vec{F}$ acts on it at an angle ϕ to the displacement.

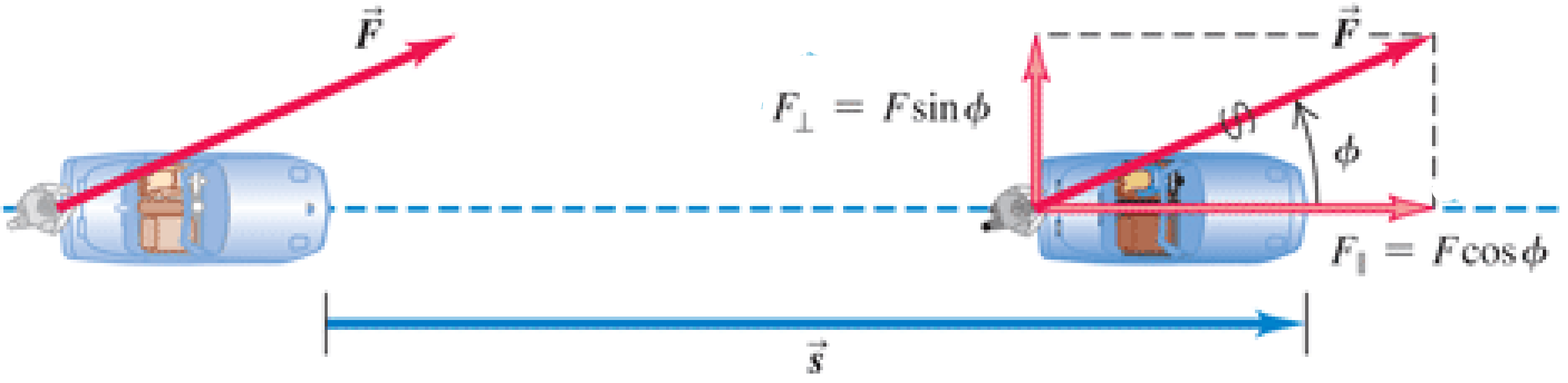

$\vec{F}$
$F_\perp = F\sin\phi$
ϕ
$F_\parallel = F\cos\phi$


$F_\perp$ does *no* work on the car.
$F_\perp = F \sin\phi$
$\vec{F}$
ϕ
$F_\parallel = F\cos\phi$


$F_\perp$ does *no* work on the car.
$F_\perp = F \sin\phi$
$\vec{F}$
ϕ
ϕ
$F_\parallel = F \cos\phi$
Only $F_\parallel$ does work on the car:
$W = F_\parallel s = (F \cos\phi)s$
$= Fs\cos\phi$

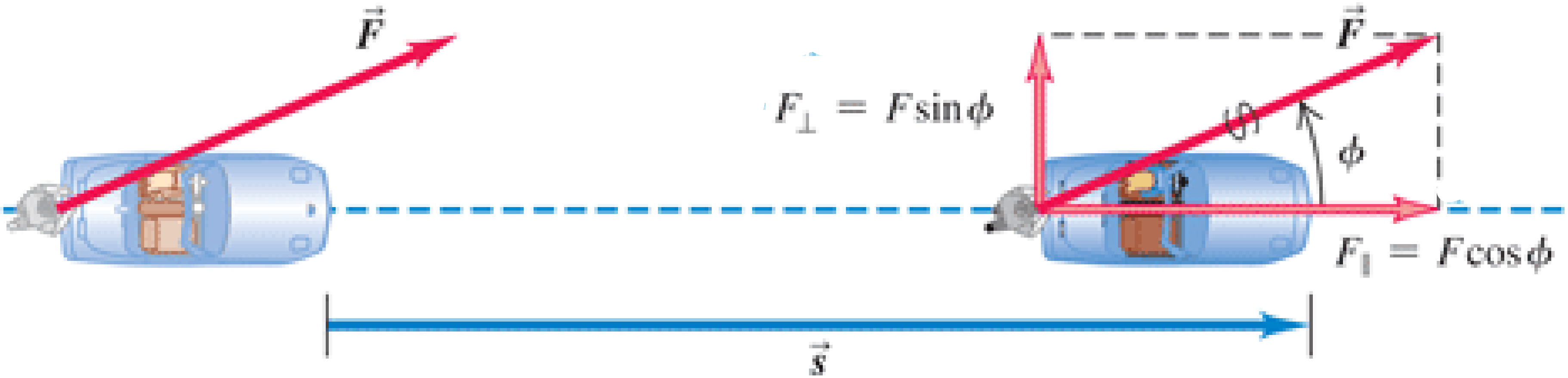


$$W = Fs\cos\phi$$



Work done on a particle by **constant force $\vec{F}$** during **straight-line displacement $\vec{s}$**

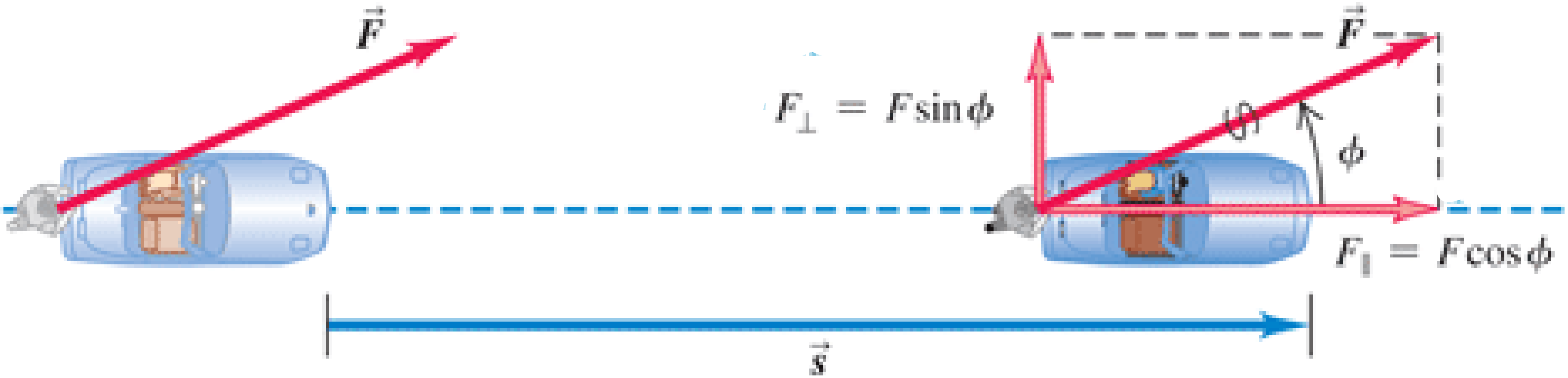
$$W = Fs\cos\phi$$



Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$

Magnitude of $\vec{F}$

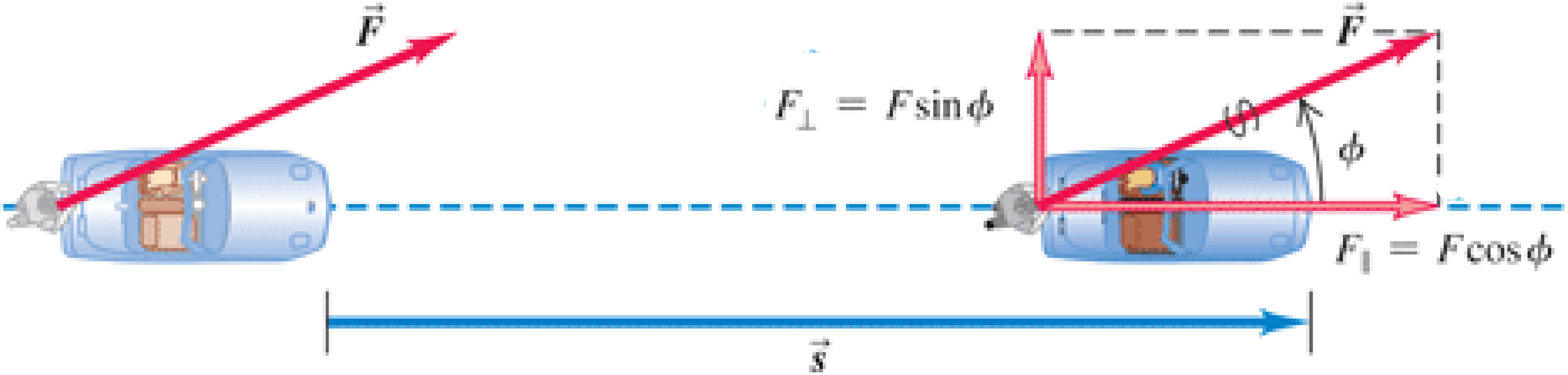
$$W = Fs\cos\phi$$



Work done on a particle by **constant force $\vec{F}$** during **straight-line displacement $\vec{s}$**

$$W = Fs\cos\phi$$

Magnitude of $\vec{F}$ (F); Magnitude of $\vec{s}$ (s)



Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$

$$W = Fs\cos\phi$$

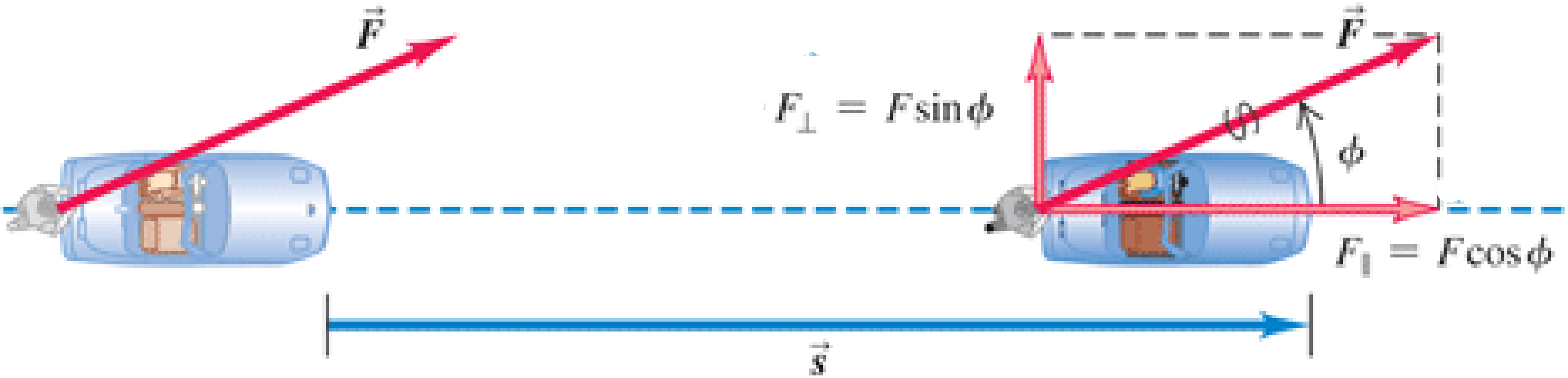
Magnitude of $\vec{F}$

Angle between $\vec{F}$ and $\vec{s}$

Magnitude of $\vec{s}$

Same as

$$W = \vec{F} \cdot \vec{s}$$

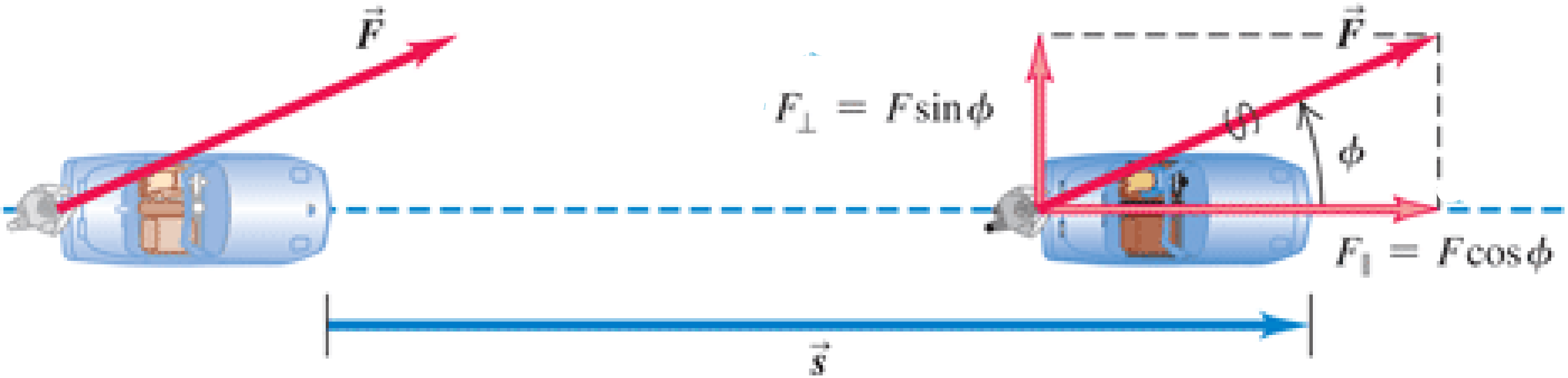


Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$ $\rightarrow$ $W = Fs\cos\phi$

- F: Magnitude of $\vec{F}$
- s: Magnitude of $\vec{s}$
- ϕ: Angle between $\vec{F}$ and $\vec{s}$

Same as

Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$ $\rightarrow$ $W = \vec{F} \cdot \vec{s}$



Magnitude of $\vec{F}$

Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$

$$W = Fs\cos\phi$$

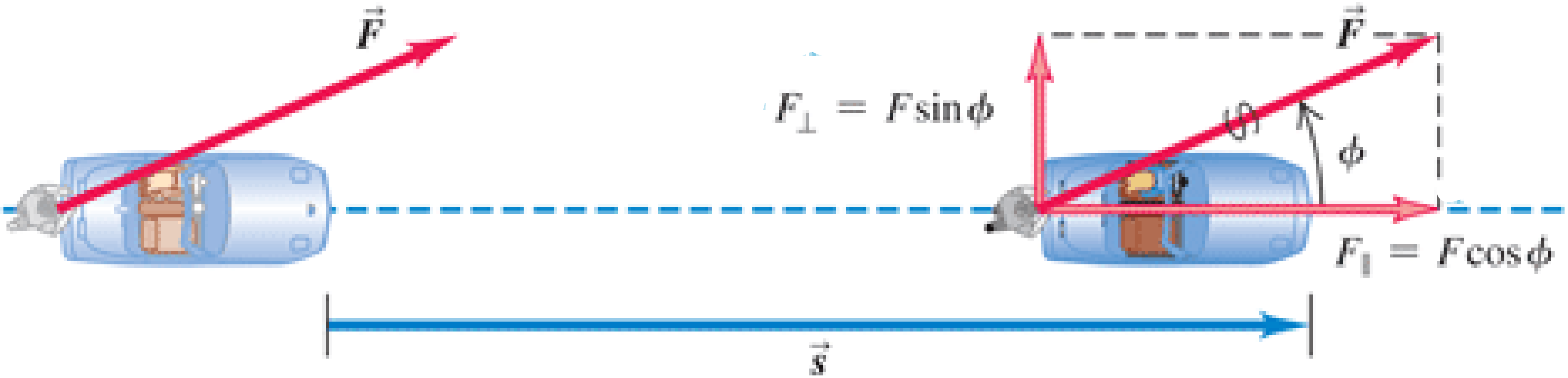
Angle between $\vec{F}$ and $\vec{s}$

Magnitude of $\vec{s}$

Same as

Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$

$$W = \underbrace{\vec{F} \cdot \vec{s}}_{\text{Scalar product (dot product) of vectors } \vec{F} \text{ and } \vec{s}}$$



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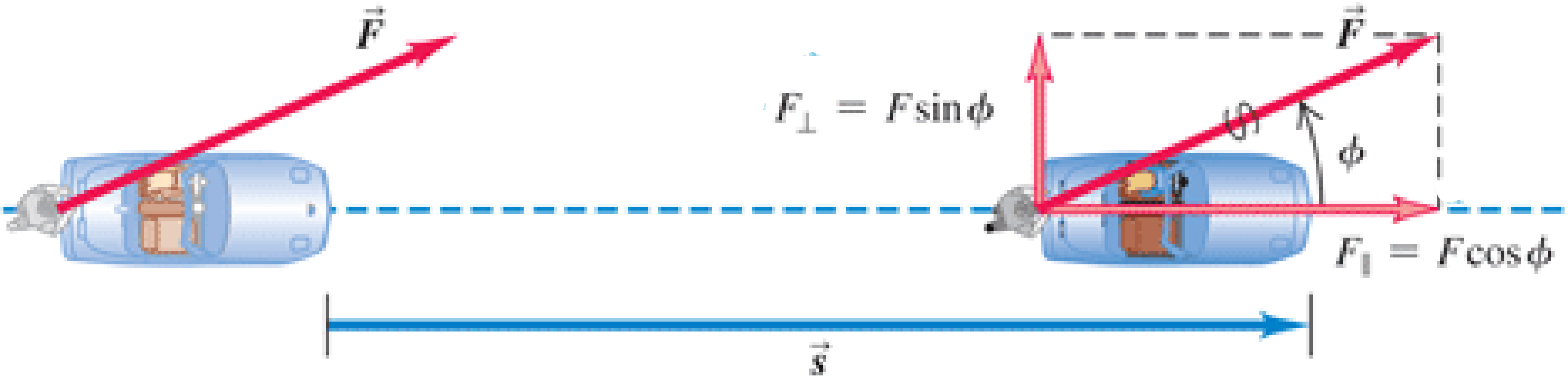
Scalar product (dot product) of vectors $\vec{F}$ and $\vec{s}$

NOTE: Work is a scalar!!



Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$ → $W = Fs\cos\phi$

- F: Magnitude of $\vec{F}$
- ϕ: Angle between $\vec{F}$ and $\vec{s}$
- s: Magnitude of $\vec{s}$

Same as

Work done on a particle by **constant force** $\vec{F}$ during **straight-line displacement** $\vec{s}$ → $W = \underbrace{\vec{F} \cdot \vec{s}}$

Scalar product (dot product) of vectors $\vec{F}$ and $\vec{s}$

NOTE: Work is a scalar !! <u>NOT</u> vector !!

(a) Steve exerts a steady force of magnitude 210 N (about 47 lb) on the stalled car in Fig. 6.3 as he pushes it a distance of 18 m. The car also has a flat tire, so to make the car track straight Steve must push at an angle of 30° to the direction of motion. How much work does Steve do?

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$F = 210N$

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$F = 210\,N$ at $30°$ to displacement

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ASU

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So $W = Fs\cos\phi \Rightarrow W = (210N)(18m)\cos 30°$

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$F = 210 N$ at $30°$ to displacement

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So $W = Fs\cos\phi \Rightarrow W = (210 N)(18 m)\cos 30°$

$\Rightarrow \boxed{W = 3300 J}$

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$\vec{F} = [160\hat{i} - 40\hat{j}]\ N$

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$\vec{F} = [160\hat{i} - 40\hat{j}]\ N$ &

$\vec{s} = [14\hat{i} + 11\hat{j}]\ m$

(a) Steve exerts a steady force of magnitude 210 N (about 47 lb) on the stalled car in Fig. 6.3 as he pushes it a distance of 18 m. The car also has a flat tire, so to make the car track straight Steve must push at an angle of 30 ° to the direction of motion. How much work does Steve do? (b) In a helpful mood, Steve pushes a second stalled car with a steady force $\vec{F} = (160\text{ N})\hat{\imath} - (40\text{ N})\hat{\jmath}$. The displacement of the car is $\vec{s} = (14\text{ m})\hat{\imath} + (11\text{ m})\hat{\jmath}$. How much work does Steve do in this case?

$\vec{F} = [160\hat{\imath} - 40\hat{\jmath}]\text{ N}$ &

$\vec{s} = [14\hat{\imath} + 11\hat{\jmath}]\text{ m}$ Do

$W = \vec{F} \cdot \vec{s}$

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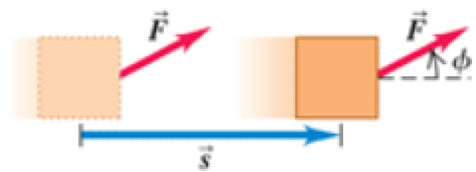
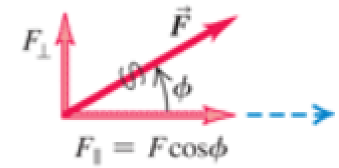
$\Rightarrow \boxed{W = [160 * 14 - 40 * 11]\ J = 1800\ J}$

Work: Positive, Negative, or Zero

Direction of Force (or Force Component)	Situation	Force Diagram
(a) **Force $\vec{F}$ has a component in direction of displacement:** $W = F_{\parallel} s = (F\cos\phi)s$ Work is *positive*.		

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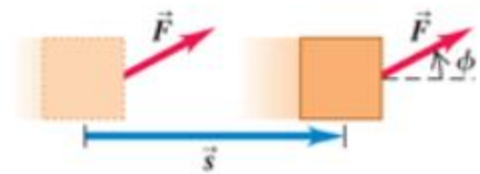
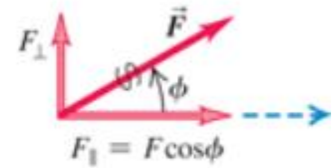
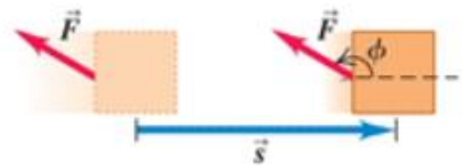
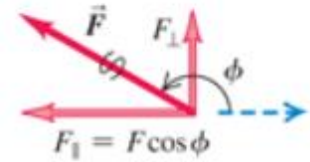




(b) **Force $\vec{F}$ has a component opposite to direction of displacement:**
$W = F_{\parallel}s = (F\cos\phi)s$
Work is *negative* (because $F\cos\phi$ is negative for $90° < \phi < 180°$).





ASU

Work: Positive, Negative, or Zero

Direction of Force (or Force Component) | **Situation** | **Force Diagram**

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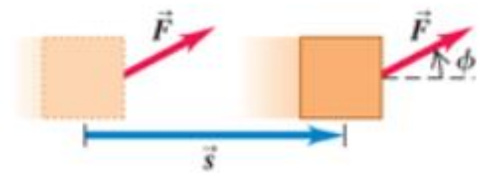

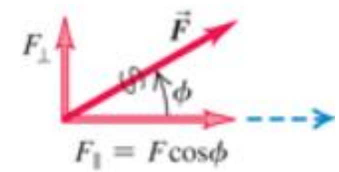

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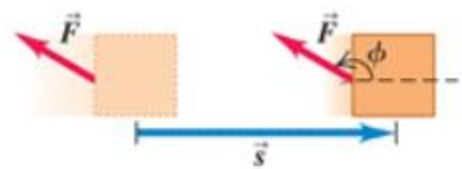
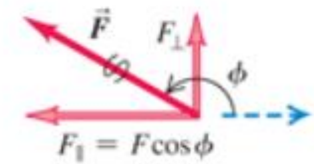
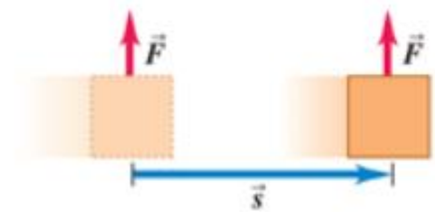
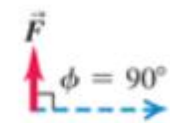


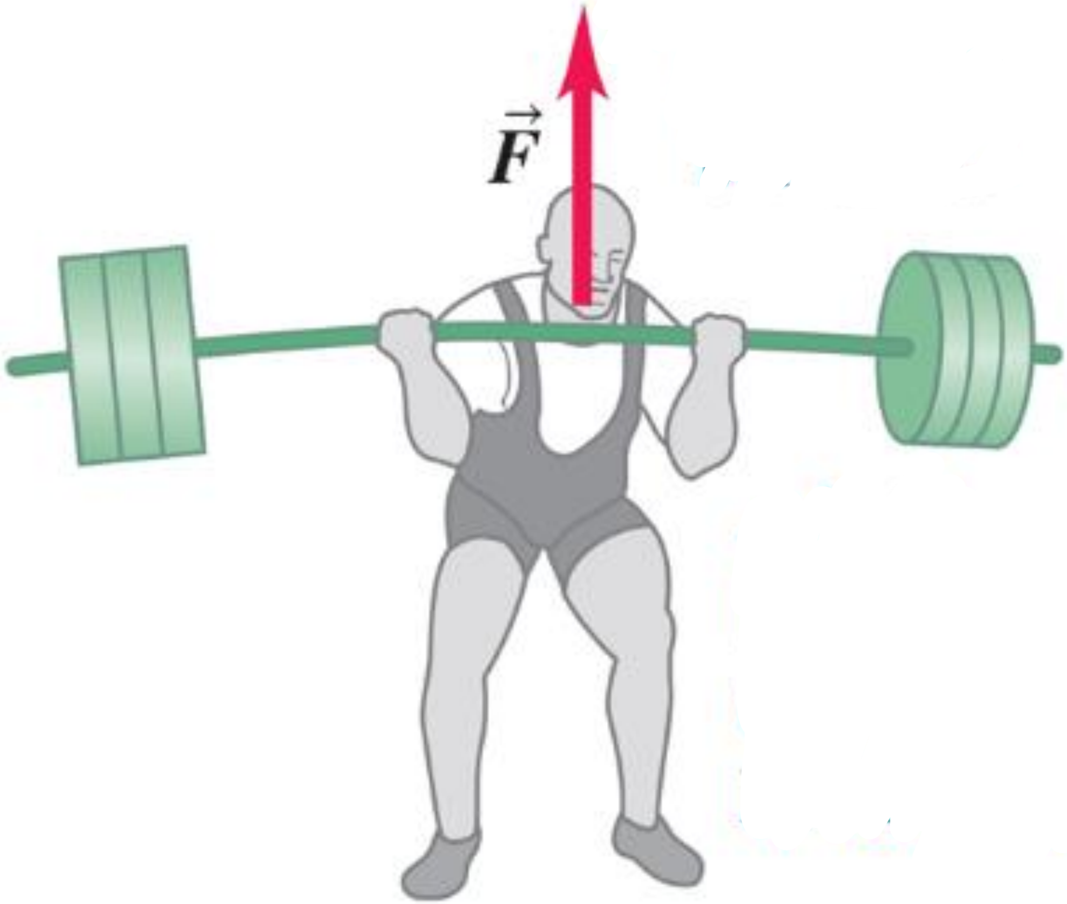


(c) **Force $\vec{F}$ (or force component $F_{\perp}$) is perpendicular to direction of displacement:** The force (or force component) does *no* work on the object.

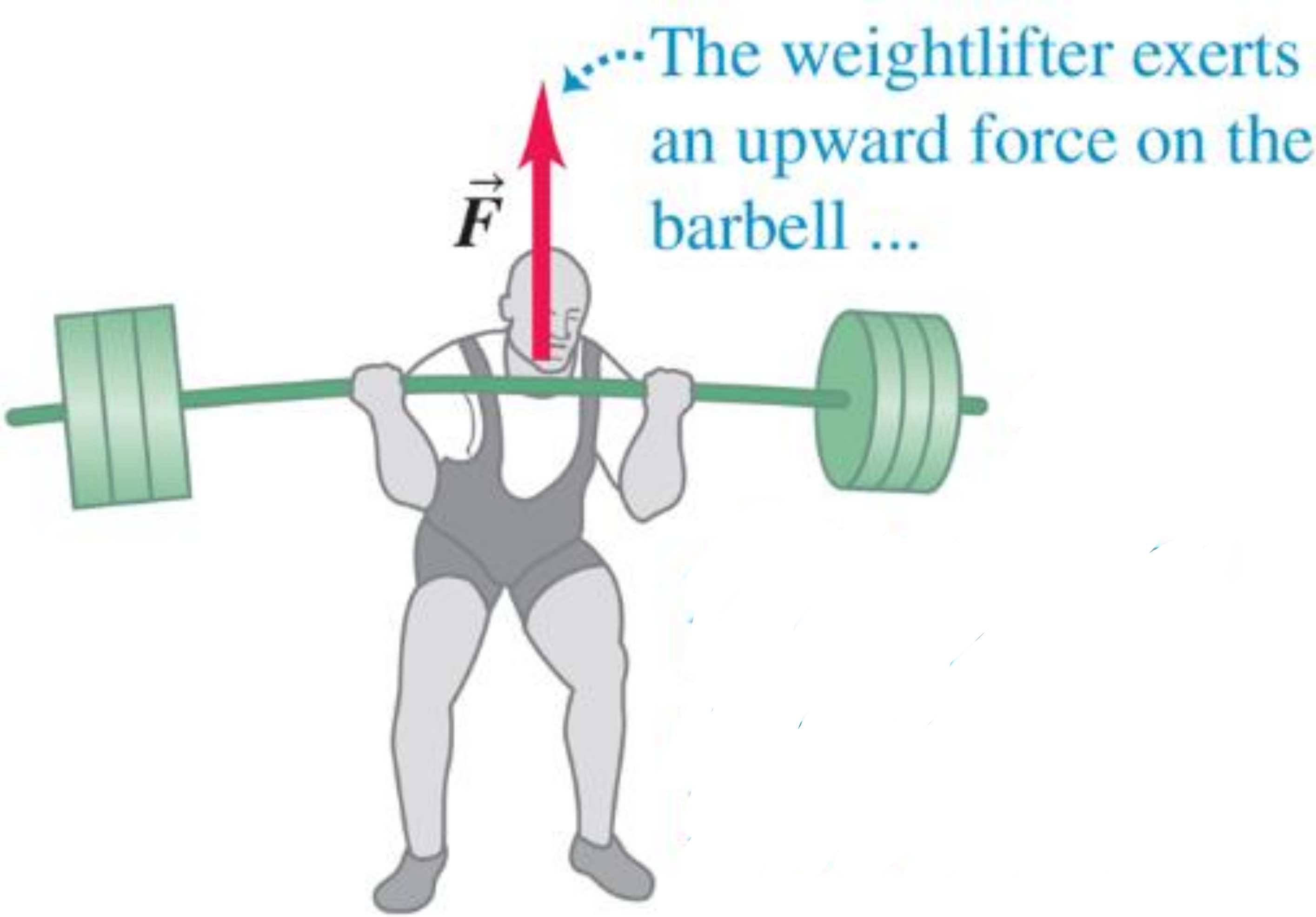




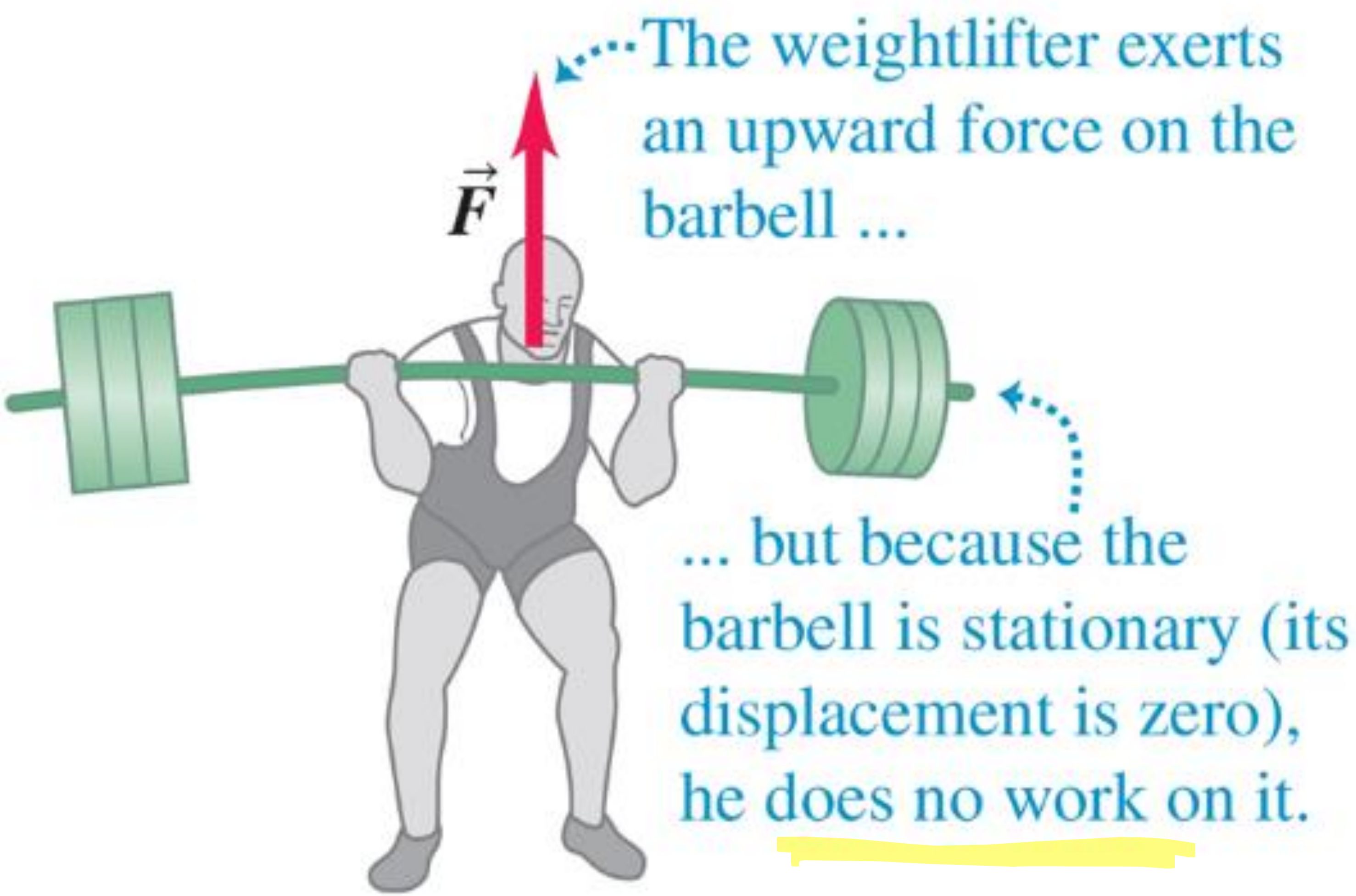
Weights held stationary



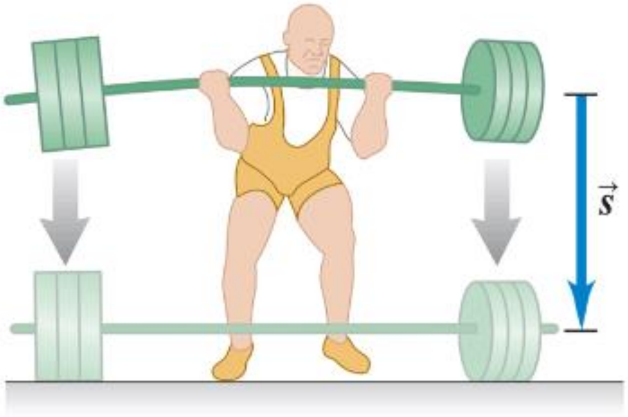
Weights held stationary



Weights held stationary



(a) A weightlifter lowers a barbell to the floor.



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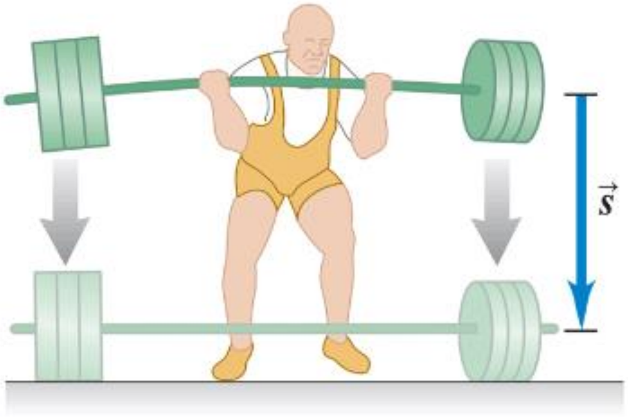
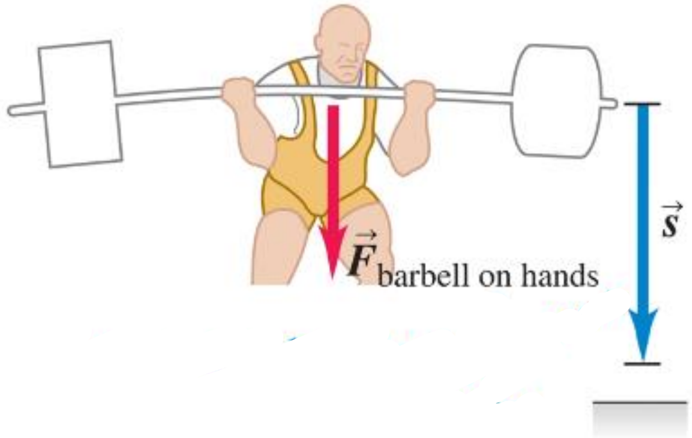


(b) The barbell does *positive* work on the weightlifter's hands.



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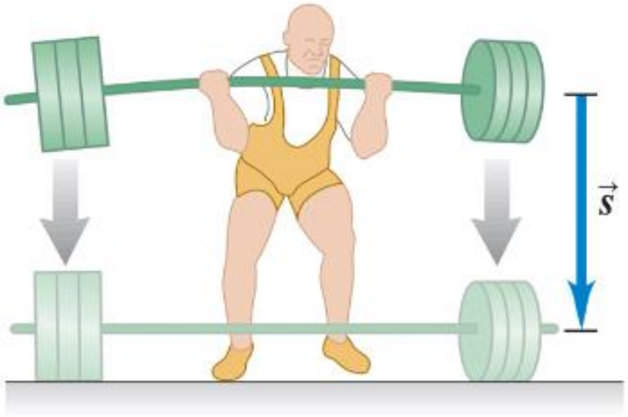

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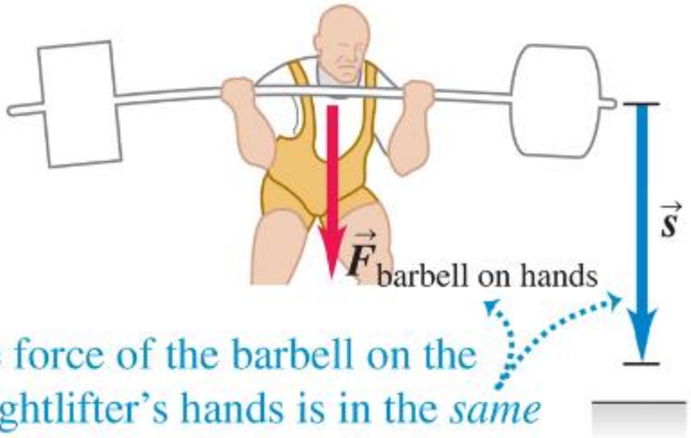
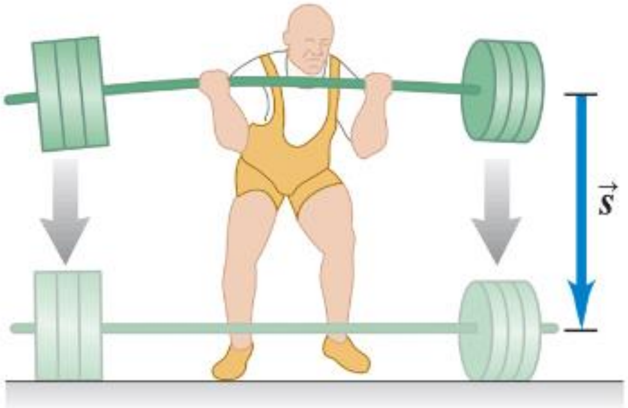


The force of the barbell on the weightlifter's hands is in the *same* direction as the hands' displacement.

(a) A weightlifter lowers a barbell to the floor.



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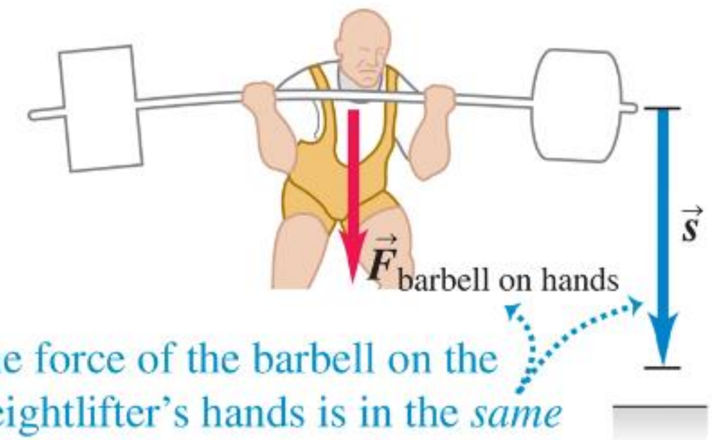
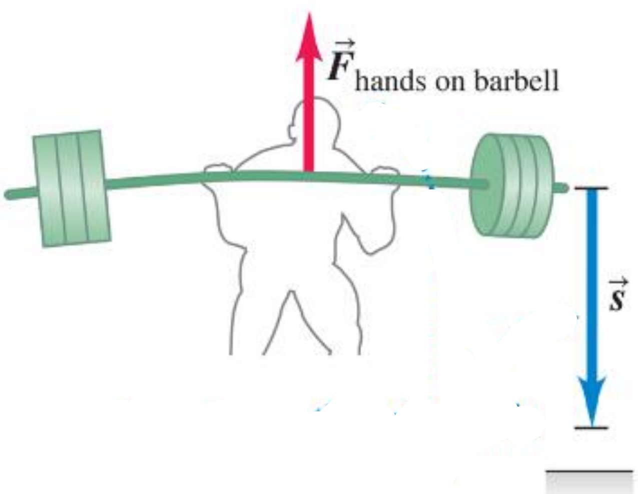
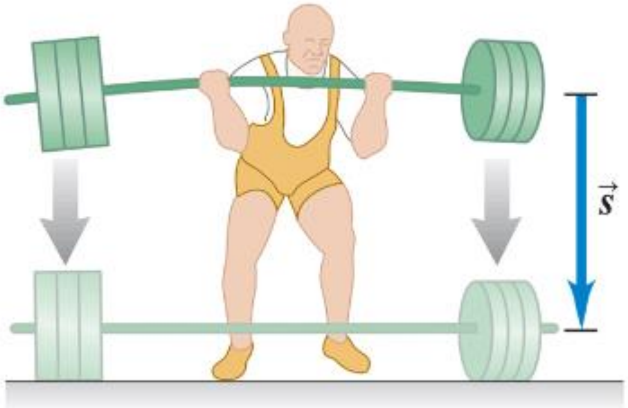


(c) The weightlifter's hands do *negative* work on the barbell.



(a) A weightlifter lowers a barbell to the floor.



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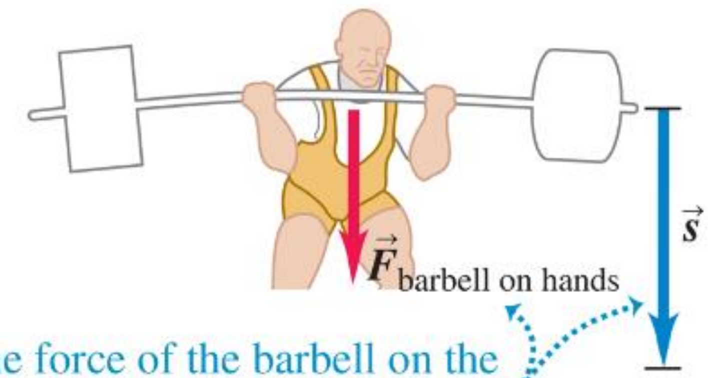
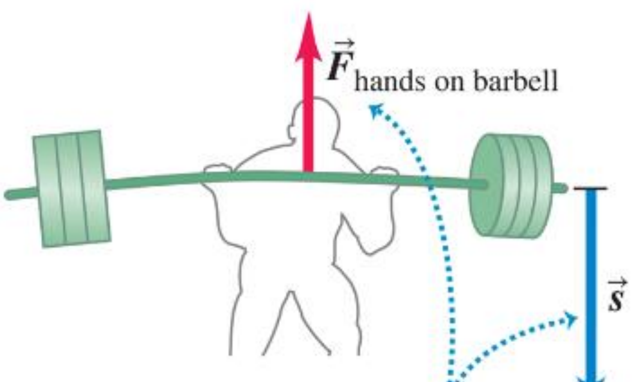


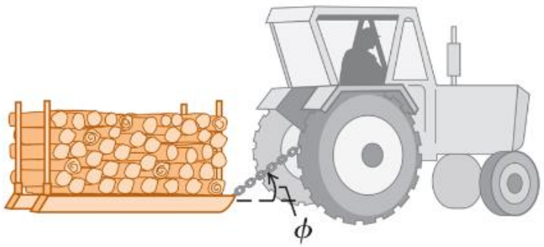
The force of the barbell on the weightlifter's hands is in the *same* direction as the hands' displacement.

(c) The weightlifter's hands do *negative* work on the barbell.



The force of the weightlifter's hands on the barbell is *opposite* to the barbell's displacement.

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.



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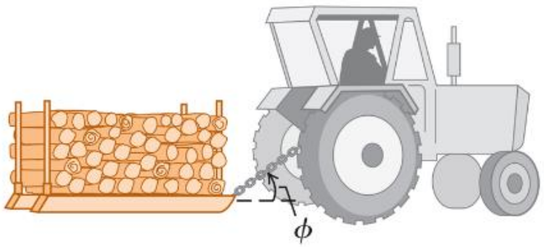
$d = 20\,m$



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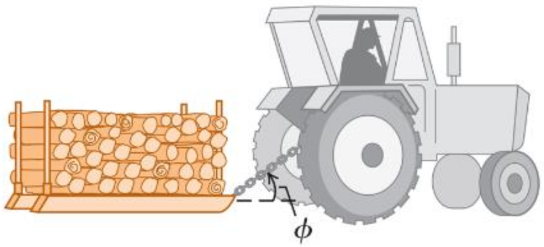
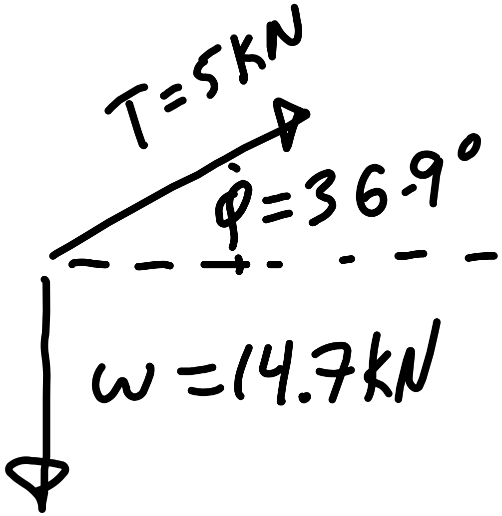
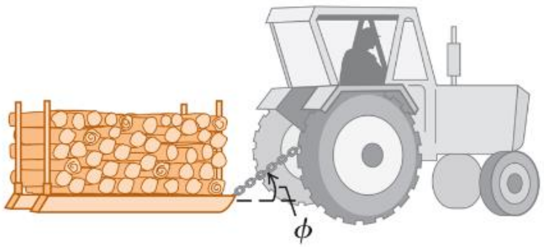


$w = 14.7\,kN$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





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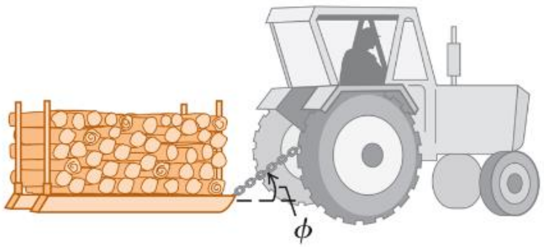
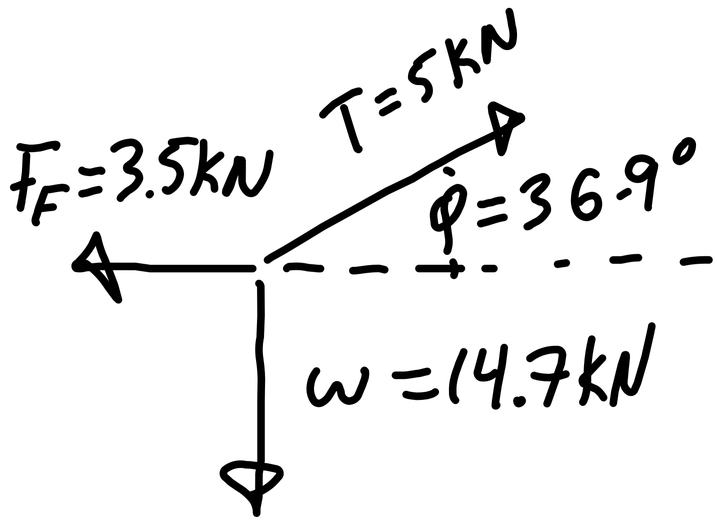
$d = 20\,\text{m}$





A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

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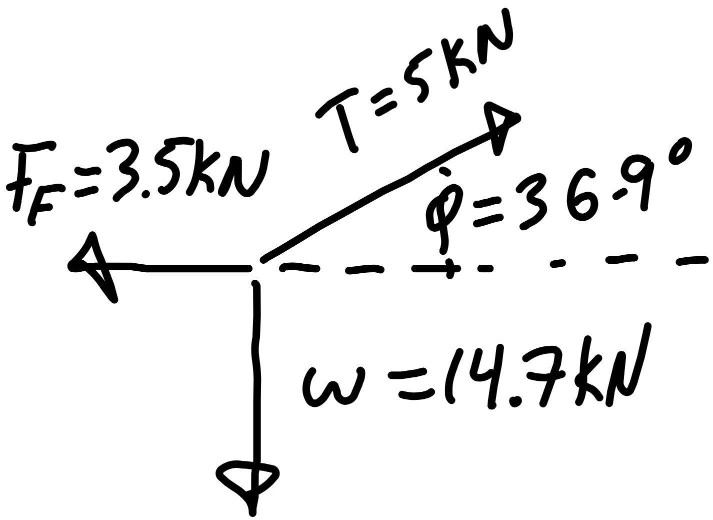
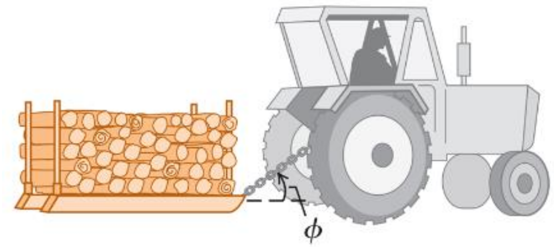
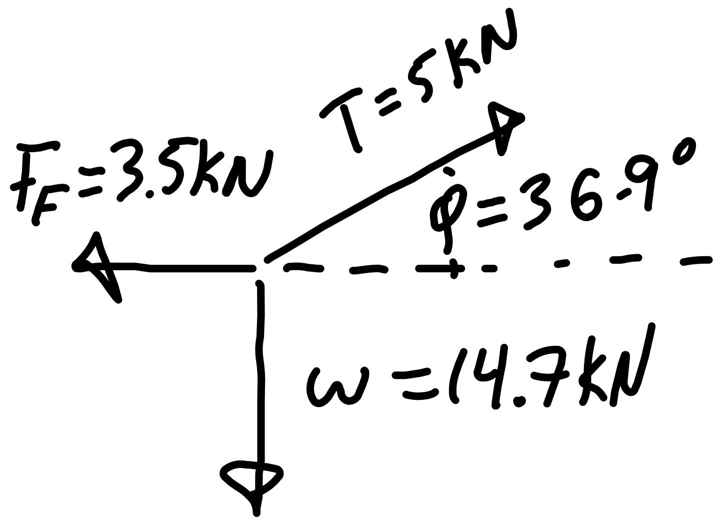


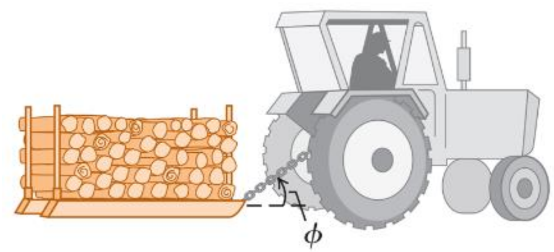


$$W_T = T d \cos\varphi$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





$W_T = T d \cos\phi$

$= (5 * 20 \cos 36.9^{\circ})\,kJ$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

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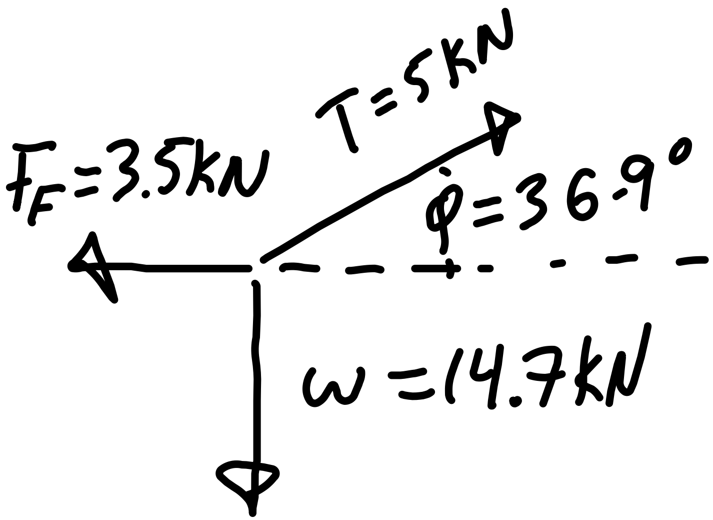
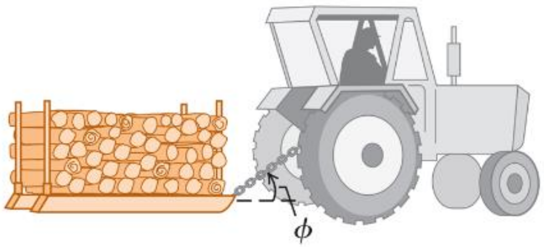
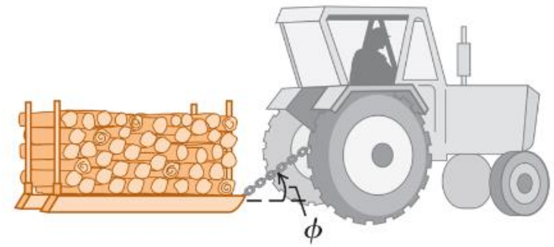


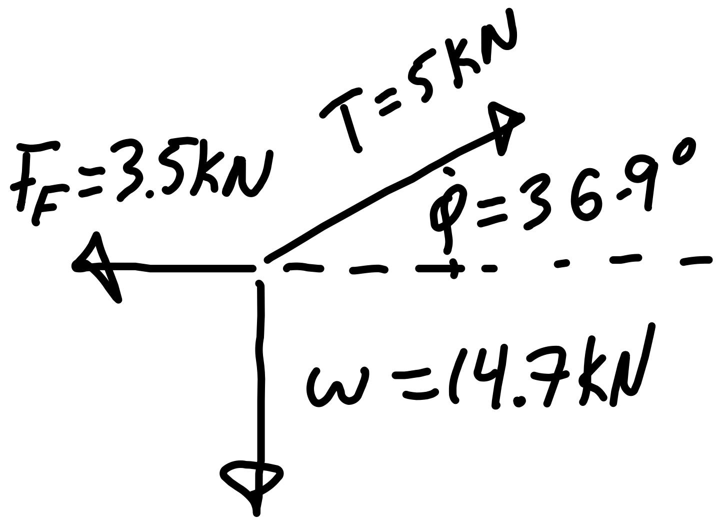


$$W_T = Td\cos\varphi$$
$$= 80\,\text{kN}$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$

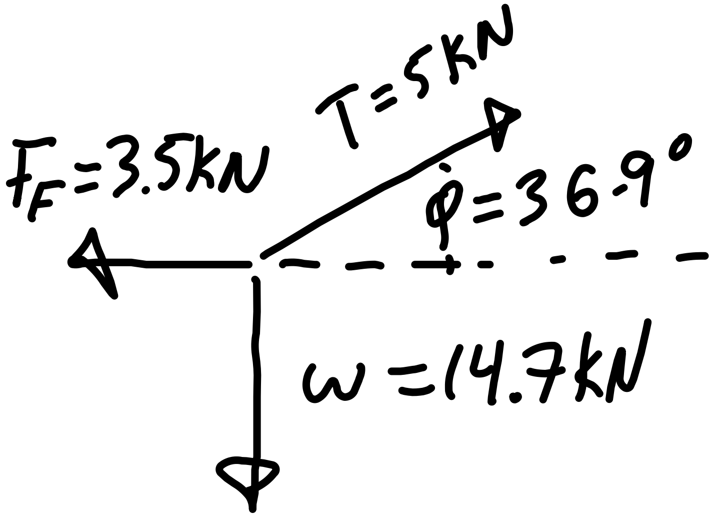


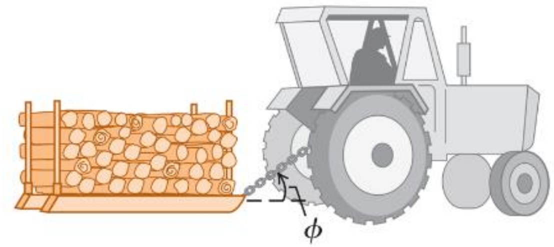


$$W_T = T d \cos\phi$$
$$= 80kN$$
$$W_F = F_F d \cos(180^\circ)$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20 m$





$W_T = T d \cos\varphi$

$= 80 kN$

$W_F = F_F d \cos(180°)$

$= -3.5 * 20 kJ$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

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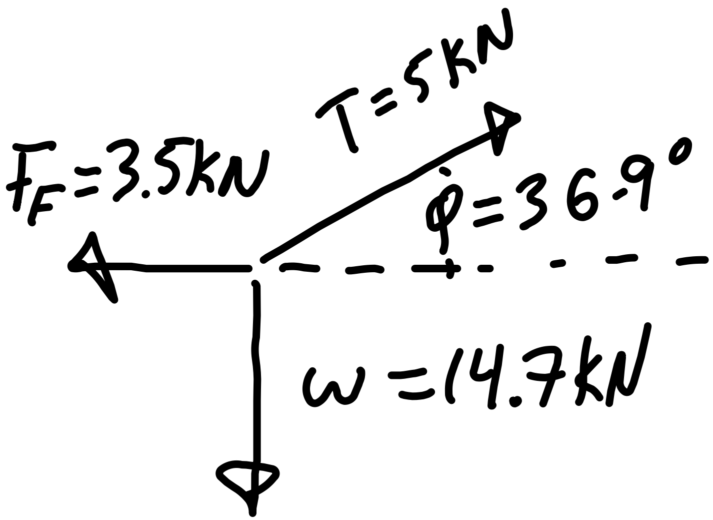
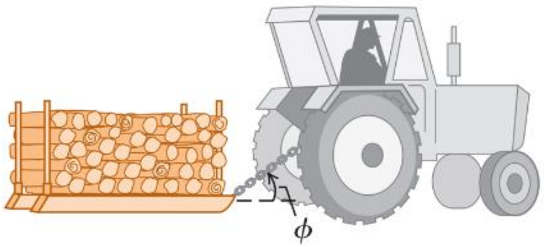




$W_T = T d \cos\phi$

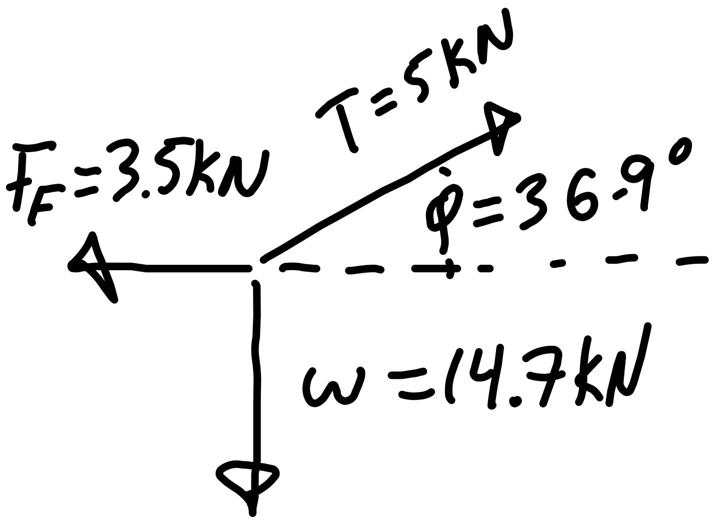
$= 80\,kN$

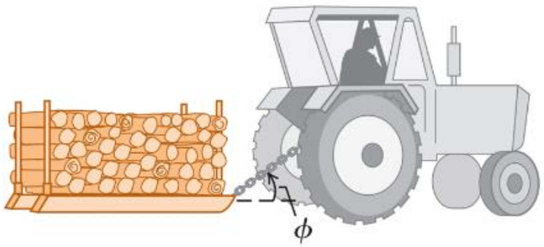
$W_F = F_F d \cos(180^\circ)$

$= -70\,kN$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$

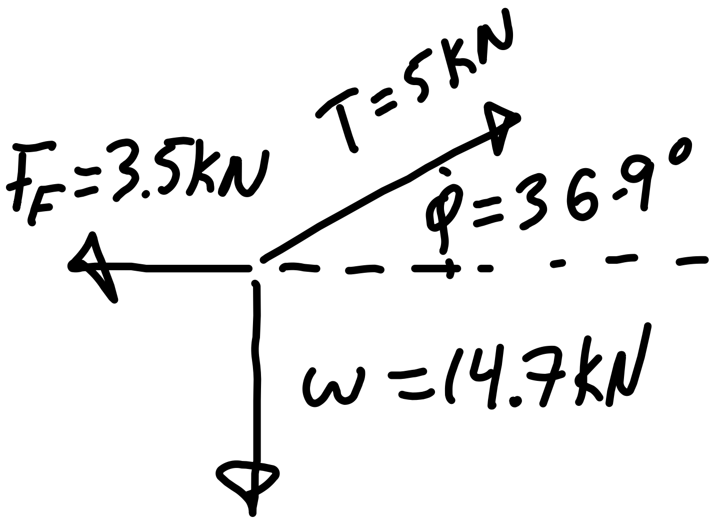


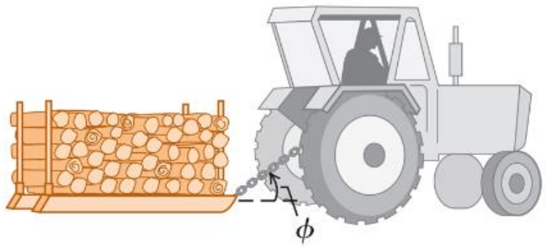


$$W_T = T d \cos\phi$$
$$= 80\,kN$$
$$W_F = F_F d \cos(180^\circ)$$
$$= -70\,kN$$
$$W_w = w d \cos(90^\circ)$$
$$= 0$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\text{m}$





$$W_T = T d \cos\phi$$
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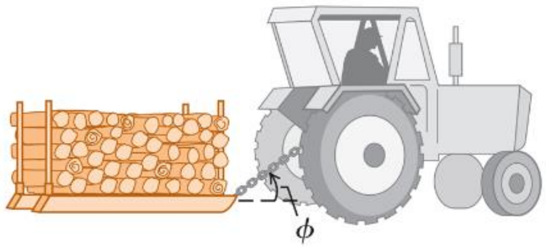
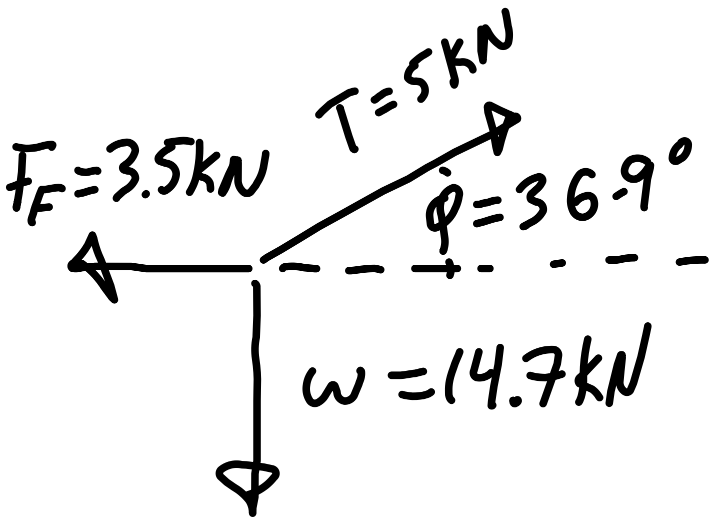
$$W_F = F_F d \cos(180^\circ)$$
$$= -70\,\text{kN}$$
$$W_w = w d \cos(90^\circ)$$
$$= 0$$

0

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





$W_T = T d \cos\phi$
$= 80\,kN$

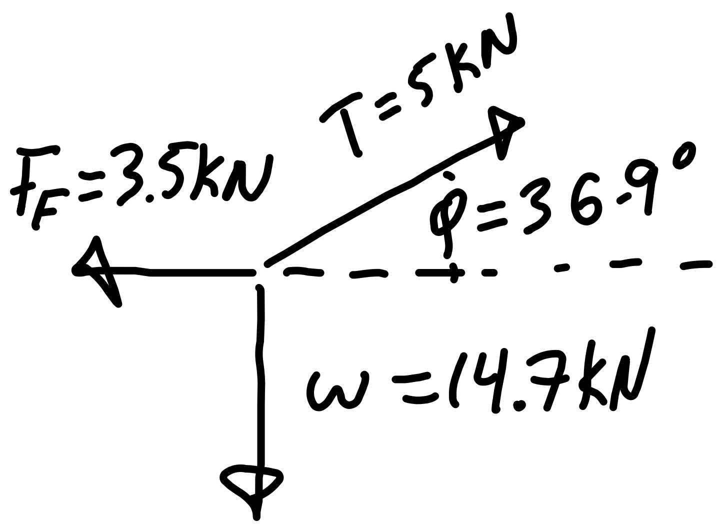
$W_F = F_F\, d \cos(180°)$
$= -70\,kN$

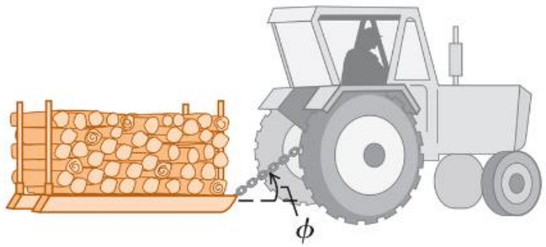
$W_w = w\, d \cos(90°)$
$= 0$

$W_{TOT} = W_T + W_F + W_w$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\text{m}$





$$W_T = T d \cos\varphi = 80\,\text{kN}$$

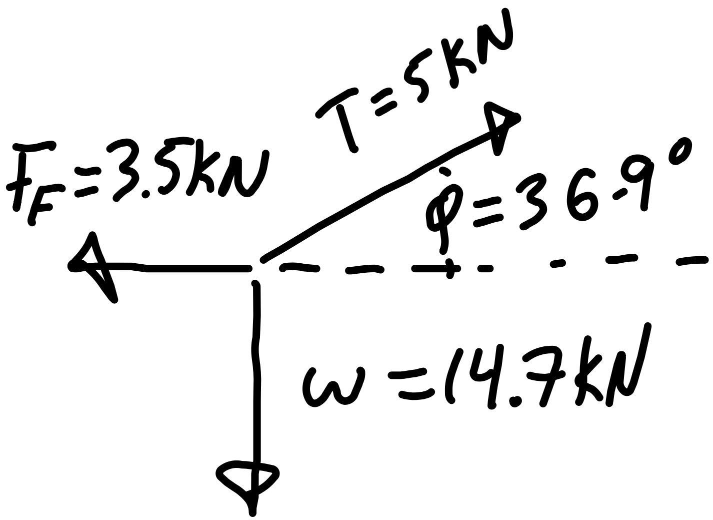
$$W_F = F_F d \cos(180^\circ) = -70\,\text{kN}$$

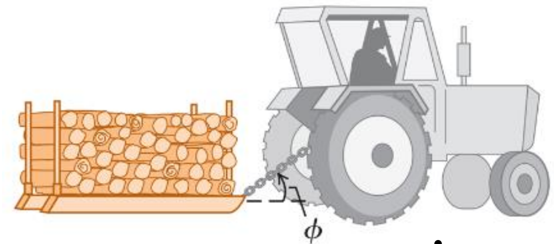
$$W_w = w d \cos(90^\circ) = 0$$

$$\boxed{W_{TOT} = W_T + W_F + W_w = (80-70)\,\text{kN} = 10\,\text{kN}}$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\text{m}$

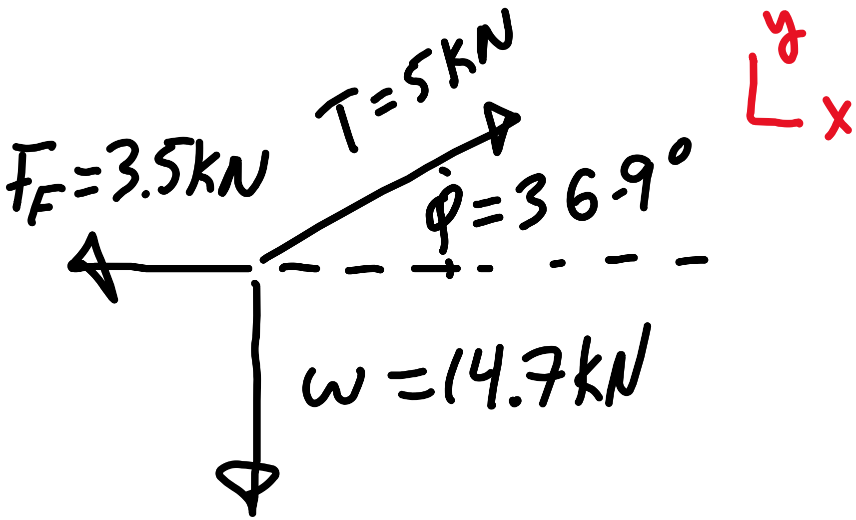


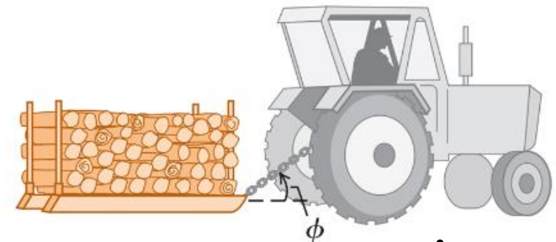


Another way to find W_{TOT} :

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





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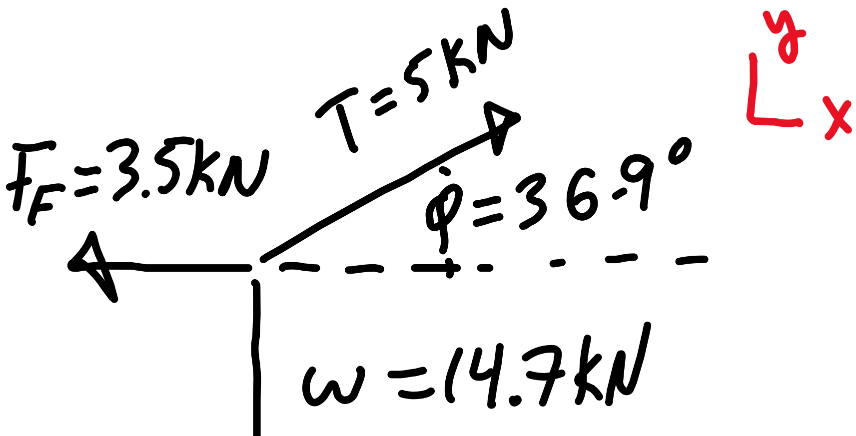
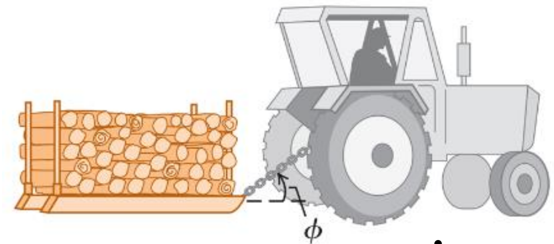
A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\mathrm{m}$



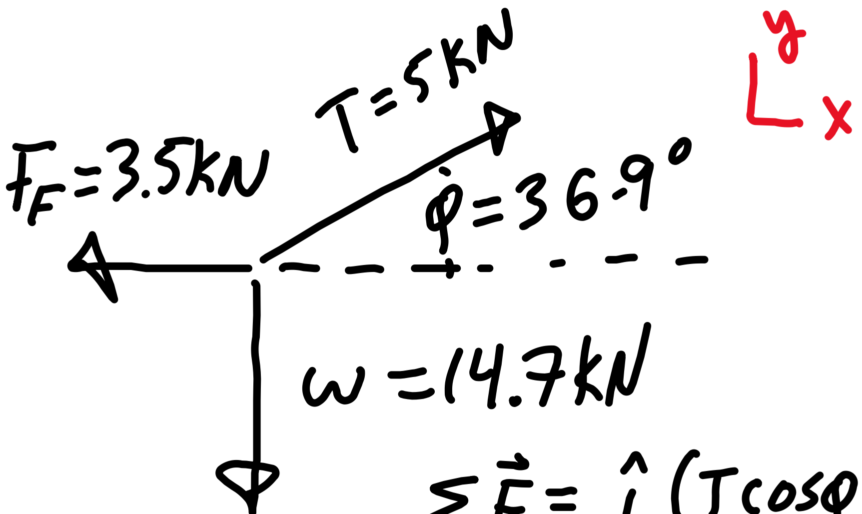


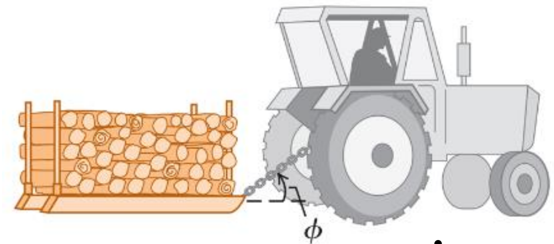
Another way to find W_{TOT}:

$$\sum \vec{F} = \hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





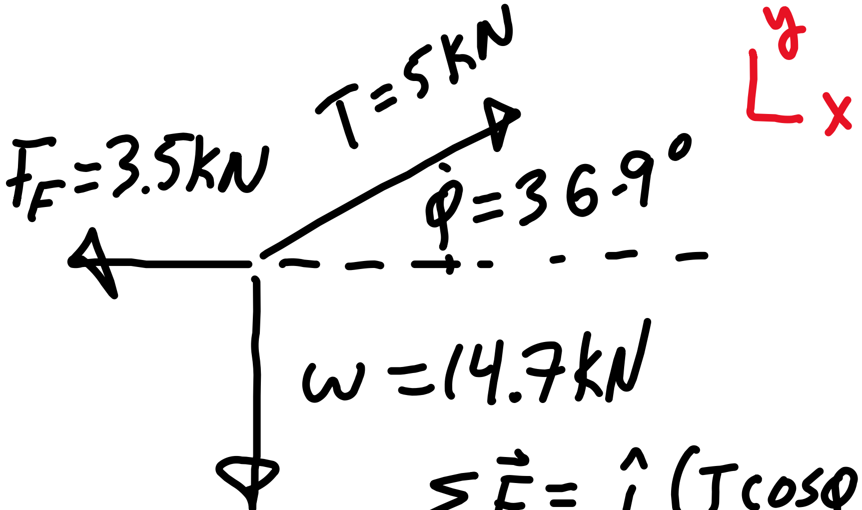
Another way to find W_{TOT}:

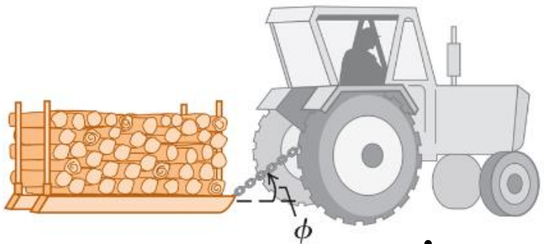
$$\Sigma \vec{F} = \hat{i}\,(T\cos\phi - F_F) - w\hat{j}$$

$$W = (\Sigma \vec{F}) \cdot \vec{d}$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





Another way to find W_{TOT}:

$$\Sigma\vec{F} = \hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}$$

$$W = (\Sigma\vec{F})\cdot\vec{d} = \left[\hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}\right]\cdot 20m\,\hat{i}$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

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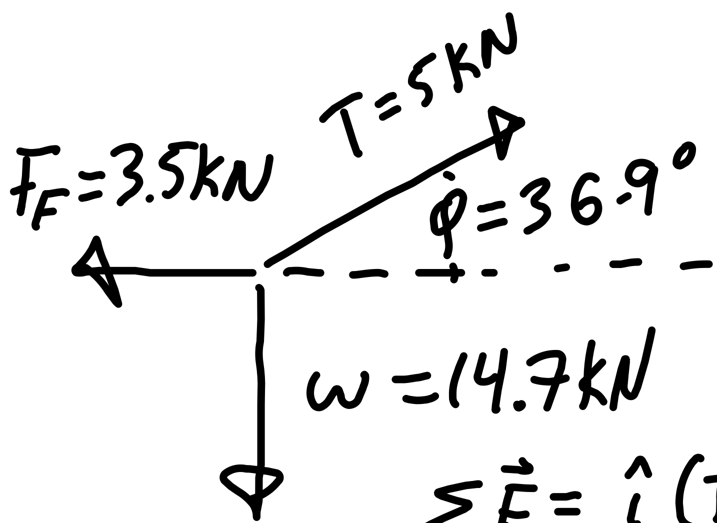
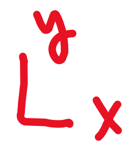
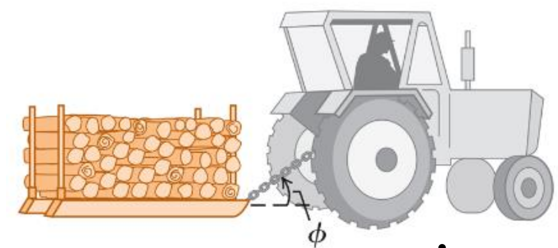






Another way to find W_{TOT}:

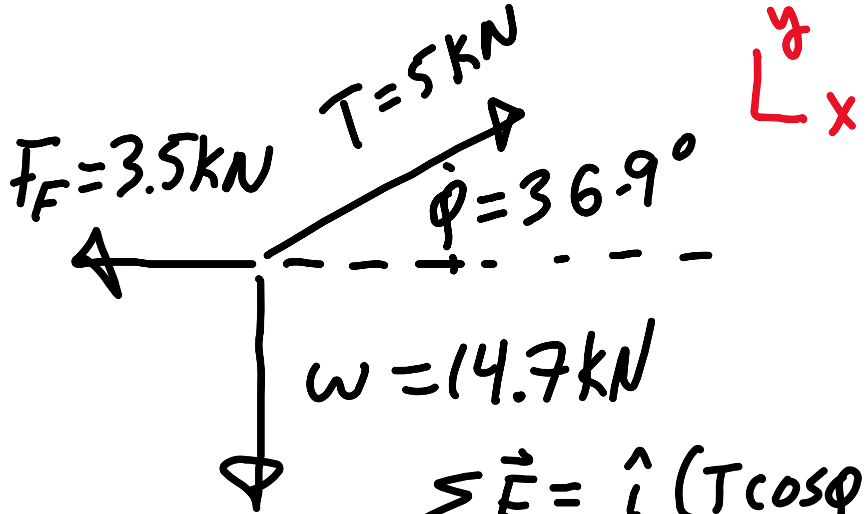
$$\Sigma\vec{F} = \hat{i}\,(T\cos\varphi - F_F) - w\hat{j}$$

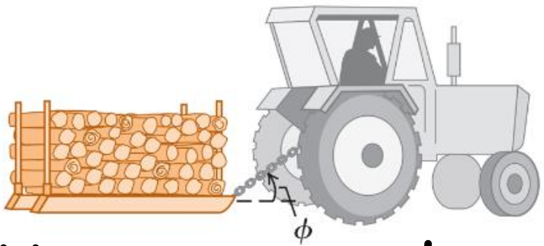
$$W = (\Sigma\vec{F})\cdot\vec{d} = \left[\hat{i}\,(T\cos\varphi - F_F) - w\hat{j}\right]\cdot 20m\,\hat{i}$$

$$= (T\cos\varphi - F_F)\,20m$$

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,m$





Another way to find W_{TOT}:

$$\sum \vec{F} = \hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}$$

$$W = (\sum \vec{F})\cdot \vec{d} = [\hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}]\cdot 20m\,\hat{i}$$

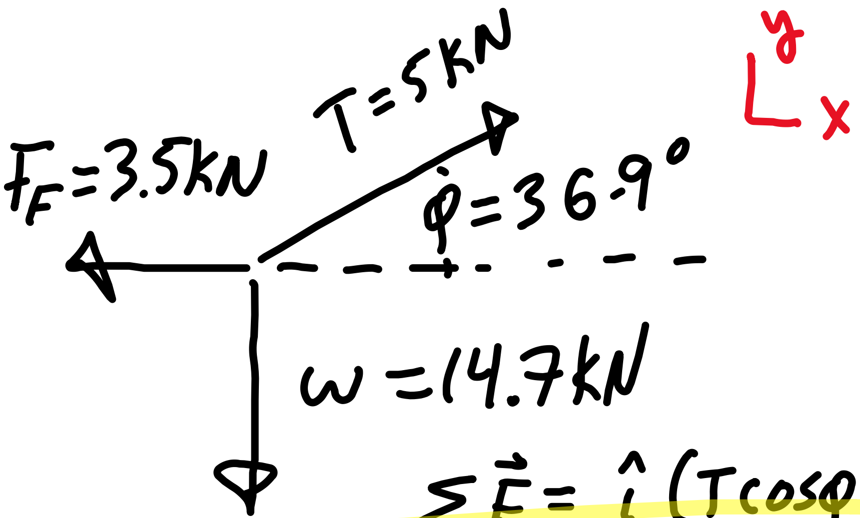
$$= (T\cos\phi - F_F)\,20m$$

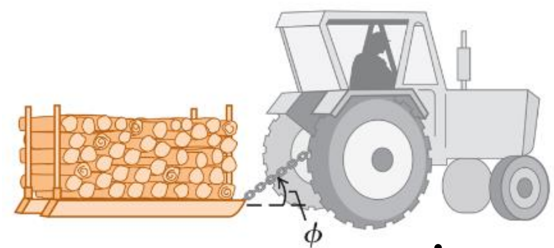
$$= [5\cos(36.9°) - 3.5]\times 20\,kJ$$

ASU

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\text{m}$





Another way to find W_{TOT}:

$$\sum \vec{F} = \hat{\imath}\,(T\cos\phi - F_F) - w\,\hat{\jmath}$$

$$W = \left(\sum \vec{F}\right)\cdot \vec{d} = \left[\hat{\imath}\,(T\cos\phi - F_F) - w\,\hat{\jmath}\right]\cdot 20\,\text{m}\,\hat{\imath}$$

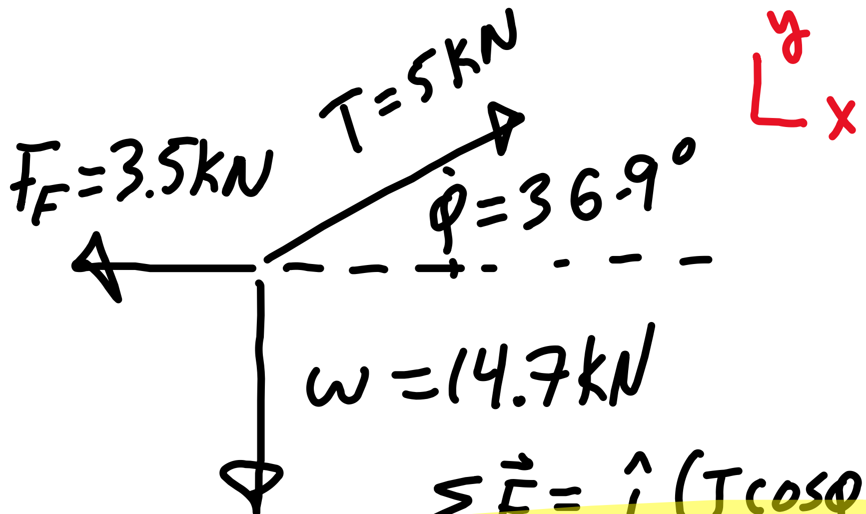
$$= (T\cos\phi - F_F)\,20\,\text{m}$$

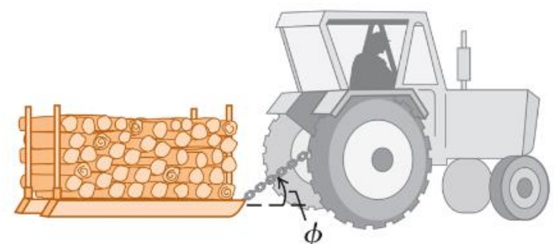
$$= \left[5\cos(36.9°) - 3.5\right] * 20\,\text{kJ} = 10\,\text{kJ}$$

ASU

A farmer hitches her tractor to a sled loaded with firewood and pulls it a distance of 20 m along level ground (Fig. 6.7a). The total weight of sled and load is 14,700 N. The tractor exerts a constant 5000 N force at an angle of 36.9° above the horizontal. A 3500 N friction force opposes the sled's motion. Find the work done by each force acting on the sled and the total work done by all the forces.

$d = 20\,\text{m}$





Another way to find W_{TOT}:

$$\sum \vec{F} = \hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}$$

$$W = \left(\sum \vec{F}\right)\cdot \vec{d} = \left[\hat{i}\,(T\cos\phi - F_F) - w\,\hat{j}\right]\cdot 20\,\text{m}\,\hat{i}$$

$$= (T\cos\phi - F_F)\,20\,\text{m}$$

$$= \left[5\cos(36.9°) - 3.5\right] \times 20\,\text{kJ} = 10\,\text{kJ}$$

Same as before

3d case

$\sum \vec{F} = m\vec{a} \Rightarrow \sum \vec{F}\cdot d\vec{r} = m\vec{a}\cdot d\vec{r}$, But

$d\vec{r} = \frac{d\vec{r}}{dt}dt = \vec{v}\,dt$ & $\vec{a} = \frac{d\vec{v}}{dt}$

so $\sum \vec{F}\cdot d\vec{r} = m\vec{v}\cdot\left(\frac{d\vec{v}}{dt}\right)dt$ & since

$d\vec{v} = \left(\frac{d\vec{v}}{dt}\right)dt$, then $\int \sum \vec{F}\cdot d\vec{r} = \int m\vec{v}\cdot d\vec{v}$

$= m\left\{\int v_x\,dv_x + \int v_y\,dv_y + \int v_z\,dv_z\right\} \Rightarrow \int_{\vec{r}_1}^{\vec{r}_2} \vec{F}\cdot d\vec{r} = \frac{m}{2}\left(v_x^2+v_y^2+v_z^2\right)\Big|_{v_I}^{v_F}$

$= \left(\frac{m}{2}\right)\left\{v_F^2 - v_I^2\right\} \Rightarrow \sum \int_{\vec{r}_1}^{\vec{r}_2} \vec{F}\cdot d\vec{r} = T_2 - T_1$ or

$U_{1\to 2} = \Delta T$ with $U_{1\to 2} \equiv \sum \int_{\vec{r}_1}^{\vec{r}_2} \vec{F}\cdot d\vec{r}$

ASU