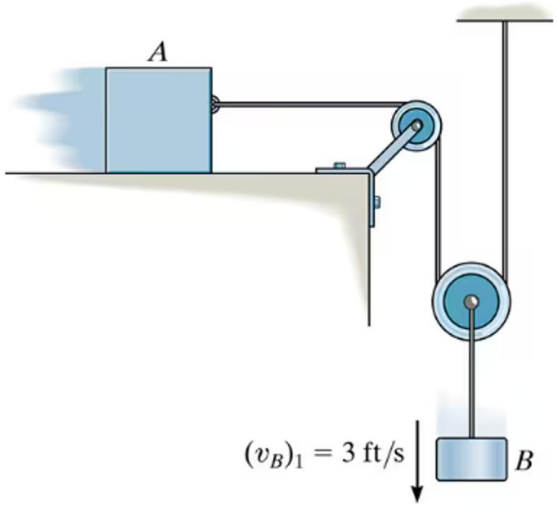
Harold's Physics
Blocks and Pulleys
(Comparing Force FBDs with Impulse-Momentum)
Cheat Sheet

13 October 2026

<table>
<tr><th colspan="3">Blocks + Movable Pulley</th></tr>
<tr><td>Question</td><td colspan="2">Block A weighs 10 lbf.
Block B weighs 3 lbf.
Block B is moving downward with an initial velocity $v_{B1} = 3\ \frac{ft}{s}$ at $t = 0$.
The coefficient of kinetic friction between the horizontal plane and block A is $\mu_{kA} = 0.15$.

Determine the velocity of block A at $t = 1\ s$.

Assume:
The fixed pulley has negligible rotational inertia, so torque balance makes the rope tension uniform (T).
The moving pulley is supported by two rope segments (2T).
The mass of the rope is negligible.</td></tr>
<tr><td>Diagram</td><td colspan="2">
</td></tr>
<tr><td>Givens</td><td>$\boldsymbol{W_A} = 10\ lb$
$\boldsymbol{W_B} = 3\ lb$
$\boldsymbol{v_{B1}} = 3\ \frac{ft}{s}$ at $t = 0$</td><td>$t_1 = 0\ s$
$t_2 = 1\ s$
$\mu_{kA} = 0.15$</td></tr>
<tr><td>Observations</td><td>$g = 32.2\ \frac{ft}{s^2}$</td><td>$\boldsymbol{F_\mu} = \boldsymbol{F_{\mu_k}} = \mu_k\ \boldsymbol{F_N}$
$\Delta t = t_2 - t_1 = 1\ s$</td></tr>
<tr><td>Solution Methods</td><td>Method 1: Force FBDs</td><td>Method 2: Linear Impulse-Momentum</td></tr>
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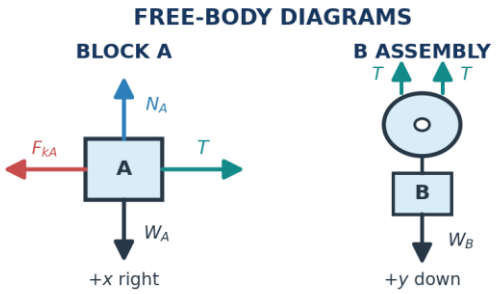
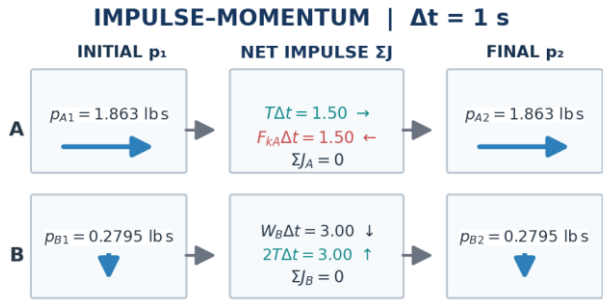
FBD Procedures	Identify the object, draw only external forces, choose axes, resolve components, and apply equations.	Identify each object's initial momentum, net impulse, and final momentum, then show them as an L→ R box flow diagram with the vector magnitude and direction indicated per box.
FBDs		
Equations	Newton's 2nd Law: $\sum \boldsymbol{F_x} = m\boldsymbol{a_x}$ $\sum \boldsymbol{F_y} = m\boldsymbol{a_y}$	Momentum: $p = mv$ $\Delta p = mv_2 - mv_1$ Impulse: $J = \int_{t_1}^{t_2} F(t)\, dt$ If a constant force, $J = F\ \Delta t = F\ (t_2 - t_1)$ Combined: $\sum J = \Delta p$ $\sum \int_{t_1}^{t_2} F(t)\, dt = mv_2 - mv_1$
Choose Signs	+x right for *A*	+y down for *B*
Constraints	Due to the pulley rope configuration, $\boldsymbol{a_A} = 2\ \boldsymbol{a_B}$ $\boldsymbol{v_A} = 2\ \boldsymbol{v_B}$	Due to the pulley rope configuration, when *B* moves down, *A* moves right twice as fast. $\boldsymbol{v_A} = 2\ \boldsymbol{v_B}$ $v_{A1} = 2\ v_{B1} = 2\ \left(3\ \frac{ft}{s}\right) = 6\ \frac{ft}{s}$
Friction	$\boldsymbol{N_A} = \boldsymbol{F_{N_A}} = \boldsymbol{W_A} = 10\ lb$ $\boldsymbol{F_{\mu_k}} = \mu_k\ \boldsymbol{F_{N_A}} = (0.15)(10\ lb) = 1.50\ lb$ acting left	
Block *A* (Horizontal Equation)	$\boldsymbol{T} - \boldsymbol{F_{\mu_k}} = m_A\ \boldsymbol{a_A}$ $\boldsymbol{T} - \boldsymbol{F_{\mu_k}} = \left(\frac{W_A}{g}\right)\ \boldsymbol{a_A}$ $\boldsymbol{T} - 1.50\ lb = \left(\frac{10\ lb}{32.2\ \frac{ft}{s^2}}\right)\ \boldsymbol{a_A}$ $\boldsymbol{T} - 1.50\ lb = 0.3106\ \boldsymbol{a_A}$	$p_{A1} + J_T - J_{\mu_k} = p_{A2}$ $m_A\ v_{A1} + T(\Delta t) - F_{\mu_k}(\Delta t) = m_A\ v_{A2}$ $\left(\frac{W_A}{g}\right)(v_{A1}) + T(\Delta t) - F_{\mu_k}(\Delta t) = \left(\frac{W_A}{g}\right) v_{A2}$ $\left(\frac{10}{32.2}\right)\left(6\ \frac{ft}{s}\right) + T\ (1\ s) - 1.5\ (1\ s) = \left(\frac{10}{32.2}\right) v_{A2}$

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Block *B* (Vertical Equation)	$$\boldsymbol{W_B} - 2\,\boldsymbol{T} = \left(\frac{W_B}{g}\right)\boldsymbol{a_B}$$ $$3.00\ lb - 2\,\boldsymbol{T} = \left(\frac{3\ lb}{32.2\ \frac{ft}{s^2}}\right)\boldsymbol{a_B}$$ $$3.00\ lb - 2\,\boldsymbol{T} = 0.0932\ \boldsymbol{a_B}$$	$$p_{B1} + J_{W_B} - J_{2T} = p_{B2}$$ $$m_B\ v_{B1} + W_B(\Delta t) - 2T(\Delta t) = m_B\ v_{B2}$$ $$\left(\frac{W_B}{g}\right)(v_{B1}) + W_B(\Delta t) - 2T(\Delta t) = \left(\frac{W_B}{g}\right)v_{B2}$$ $$\left(\frac{3}{32.2}\right)\left(3\ \frac{ft}{s}\right) + 3\ (1\ s) - 2T(1\ s) = \left(\frac{3}{32.2}\right)v_{B2}$$ $$3.2795 - 2T = 0.09317\ v_{B2}$$
Solve	Solve for *T* in the block *A* equation. $$\boldsymbol{T} - 1.50\ lb = 0.3106\ (2\ \boldsymbol{a_B})$$ $$\boldsymbol{T} = 1.50\ lb + 0.6212\ \boldsymbol{a_B}$$ Substitute *T* into the block *B* equation. $$3.00\ lb - 2\boldsymbol{T} = 0.0932\ \boldsymbol{a_B}$$ $$3.00\ lb - 2\ (1.50\ lb + 0.6212\ \boldsymbol{a_B}) = 0.0932\ \boldsymbol{a_B}$$ $$-1.2424\ \boldsymbol{a_B} = 0.0932\ \boldsymbol{a_B}$$ $$\boldsymbol{a_B} = \boldsymbol{0}$$ $$\boldsymbol{T} = 1.50\ lb$$ $$\boldsymbol{a_A} = \boldsymbol{a_B} = 0\ \frac{ft}{s^2}$$	Solve for *T* in the block *A* equation. $$T\ + 0.3634\ = 0.3106\ v_{A2}$$ Substitute ($v_{A2} = 2\ v_{B2}$) into the block A equation. $$T\ + 0.3634\ = 0.3106\ v_{A2}$$ $$T\ + 0.3634\ = 0.3106\ (2\ v_{B2})$$ $$T\ + 0.3634\ = 0.6211\ v_{B2}$$ $$T\ = 0.6211\ v_{B2} - \ 0.3634$$ Solve with the block B equation. $$3.2795 - 2T = 0.09317\ v_{B2}$$ $$3.2795 - 2\ (0.6211\ v_{B2} - \ 0.3634) = 0.09317\ v_{B2}$$ $$v_{B2} = 3\ \frac{ft}{s}\ \text{downward}$$
Velocity	The blocks have zero acceleration, so their velocities remain constant. $$\boldsymbol{v}_{B1} = 3\ \frac{ft}{s}\ \text{at}\ t = 0$$ $$v_{A1} = 2\ (v_{B1}) = 2\left(3\ \frac{ft}{s}\right) = \ 6\ \frac{ft}{s}$$ $$v_{A2} = v_{A1} + a_{A2}t$$ $$= 6\ \frac{ft}{s} + \left(0\ \frac{ft}{s^2}\right)(1\ s)$$ $$v_{A2} = 6\ \frac{ft}{s}\ \text{to the right}$$	• On *A*, the rightward tension impulse $T\Delta t$ balances the leftward friction impulse $F_{\mathrm{k}}\ \Delta t$. • On B, the downward weight impulse $W_B\ \Delta t$ balances the upward rope impulse $2T\Delta t$. • Both net impulses are zero, so both velocities remain constant. $$v_{A2} = 2\ v_{B2} = 6\ \frac{ft}{s}\ \text{to the right}$$
Solution	**The velocity of block *A* at $t = 1\ s$ is $6\ \frac{ft}{s}$ to the right.**	

Sources

- Hibbeler, R. C. (April 1, 2012). Engineering Mechanics: Dynamics, 13th Edition, Prob. 15–32 (problem image supplied).

Acknowledgements

- Proofread with assistance from ChatGPT 6.1 Sol, https://chatgpt.com/

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