**Forces – Formula Sheet:**

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| **Newton’s 1st Law:** | An object at rest will remain at rest and an object in motion will continue in motion unless acted on by a net external force. |
| **Newton’s 2nd Law:** | $$F\_{net}=ma$$ |
| **Newton’s 3rd Law:** | For every action force, there’s an equal and opposite reaction force.$$F\_{AB}=-F\_{BA}$$ |
|  | **Weight Force:**$$W=mg$$**Normal Force:**$$F\_{N}=mg$$**Net Force:**$$F\_{net}=\sum\_{}^{}F\_{x}=F\_{A}-f$$$$F\_{net}=\sum\_{}^{}F\_{y}=F\_{N}-W$$**Kinetic Friction:**$$f\_{k}=u\_{k}F\_{N}$$**Static Friction:**$$f\_{s}\leq u\_{s}F\_{N}$$ |
|  | **Net Force:**$$F\_{net}=\sum\_{}^{}F\_{x}=T\_{x}-f\_{k}$$$$F\_{net}=\sum\_{}^{}F\_{y}=F\_{N}+T\_{Y}-W$$**Normal Force:**$$F\_{N}=mg-T\_{y}$$**Tension Force:**$$T=\sqrt{T\_{x}^{2}+T\_{y}^{2}}$$$$T\_{x}=T\cos(θ) T\_{y}=T\sin(θ)$$ |

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|  | **The Elevator Problem:**$$\sum\_{}^{}F\_{y}=F\_{N}-W$$$$ma\_{y}=F\_{N}-mg$$**Normal Force:**$$F\_{N}=m\left(a\_{y}+g\right)$$$$g=+9.8 m/s^{2} $$ |
|  | **Contact Force:** (Without Friction)$$F\_{1, 2}=\frac{m\_{2}}{m\_{T}}F$$$$a=\frac{F}{m\_{T}} m\_{T}=m\_{1}+m\_{2}$$ |
|  | **Contact Force:** (Without Friction)$$a=\frac{F}{m\_{T}} m\_{T}=m\_{1}+m\_{2}+m\_{3}$$$$F\_{1,2}=\frac{m\_{2}+m\_{3}}{m\_{T}}F F\_{2,3}=\frac{m\_{3}}{m\_{T}}F$$ |
|  | **Tension Force:**$$T=\frac{m\_{1}}{m\_{T}}F a=\frac{F}{m\_{T}} m\_{T}=m\_{1}+m\_{2}$$ |
|  | **Tension Force:**$$T\_{1}=\frac{m\_{1}}{m\_{T}}F T\_{2}=\frac{m\_{1}+m\_{2}}{m\_{T}}F$$ |
|  | **Tension Force:**$$T\_{1}=m\_{1}g T\_{2}=\left(m\_{1}+m\_{2}\right)g$$ |
| Note: For examples with friction, see my physics video playlist at ***www.Video-Tutor.net*** |

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|  | **Acceleration:**$$a= \frac{m\_{2}}{m\_{T}}g m\_{T}=m\_{1}+m\_{2}$$**Tension Force:**$$T=m\_{1}a\_{x} T=m\_{2}(a\_{y}+g)$$$$a=\left|a\_{x}\right|=\left|a\_{y}\right| g=+9.8 m/s^{2}$$**Note:** $a\_{y}=- since m\_{2} is falling and a\_{x}=+for m\_{1}. $ |
|  | **Acceleration:**$$a=\frac{m\_{2}-u\_{k}m\_{1}}{m\_{T}}g m\_{T}=m\_{1}+m\_{2}$$**Tension Force:**$$T=m\_{1}\left(a\_{x}+u\_{k}g\right) T=m\_{2}\left(a\_{y}+g\right) $$$$a=\left|a\_{x}\right|=\left|a\_{y}\right| g=+9.8 m/s^{2} a\_{y}=- a\_{x}=+$$ |
| $$a\_{y}=+for m\_{1} since it^{'}s going up. $$$$a\_{y}=- for m\_{2} since it^{'}s going down.$$ | **Acceleration:** (If **m2** > **m1**)$$a=\frac{m\_{2}-m\_{1}}{m\_{T}}g m\_{T}=m\_{1}+m\_{2}$$**Tension Force:**$$T=m\_{1}\left(a\_{y}+g\right) T=m\_{2}(a\_{y}+g)$$$$a=\left|a\_{y}\right| g=+9.8 m/s^{2}$$ |
|  | **Minimum Angle Needed for the Box to Begin Sliding:**$$θ=tan^{-1}(u\_{s})$$$$f\_{s}\leq u\_{s}F\_{N}$$$$F\_{g}=mg\sin(θ) F\_{N}=mg\cos(θ)$$ |

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|  | **Acceleration:** (Without Friction)$$a=g\sin(θ)$$**Acceleration:** (With Friction)$$a\_{x}=g\sin(θ)-u\_{k}g\cos(θ)$$$$\sum\_{}^{}F\_{x}=F\_{g}-f\_{k}$$$$F\_{g}=mg\sin(θ) F\_{N}=mg\cos(θ) f\_{k}=u\_{k}F\_{N}$$ |
|  | **Net Force:**$$\sum\_{}^{}F\_{x}= T-f\_{k}-F\_{g}$$$$ma\_{x}=T-u\_{k}mg\cos(θ)-mg\sin(θ)$$**Note:** $f\_{k}$ will always point opposite to the direction of motion. |
| $$m\_{2}g>m\_{1}g\sin(θ)$$ | $$If m\_{2}g>m\_{1}g\sin(θ), the system will move to the right. $$**Acceleration:** (Without Friction) $a=\left|a\_{x}\right|=|a\_{y}|$$$a=\frac{\sum\_{}^{}F\_{x}}{m\_{T}}=\frac{m\_{2}-m\_{1}\sin(θ)}{m\_{T}}g a=+$$**Tension:** (Without Friction) $a\_{x}=+ and a\_{y}=-$$$T=m\_{1}\left(a\_{x}+g\sin(θ)\right) T= m\_{2}\left(a\_{y}+g\right) $$ |
| $$m\_{2}g>m\_{1}g\sin(θ)$$ | **Acceleration:** (With Friction) $a=\left|a\_{x}\right|=|a\_{y}|$$$a=\frac{\sum\_{}^{}F\_{x}}{m\_{T}}=\frac{m\_{2}-m\_{1}\sin(θ)- u\_{k}m\_{1}\cos(θ)}{m\_{T}}g$$**Tension:** (With Friction) $a\_{x}=+ and a\_{y}=-$$$T=m\_{1}\left(a\_{x}+g\sin(θ)+u\_{k} g\cos(θ)\right) T= m\_{2}(a\_{y}+g)$$ |

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| $$m\_{2}g<m\_{1}g\sin(θ)$$ | $If m\_{2}g<m\_{1}g\sin(θ), the system will move to the left.$ (a = **-**)**Acceleration:** (Without Friction) $a=\left|a\_{x}\right|=|a\_{y}|$$$a=\frac{\sum\_{}^{}F\_{x}}{m\_{T}}=\frac{m\_{2}-m\_{1}\sin(θ)}{m\_{T}}g a=-$$**Tension:** (Without Friction) $a\_{x}=- and a\_{y}=+$$$T=m\_{1}\left(a\_{x}+g\sin(θ)\right) T= m\_{2}\left(a\_{y}+g\right)$$ |
| $$m\_{2}g<m\_{1}g\sin(θ)$$ | **Acceleration:** (With Friction) $a=\left|a\_{x}\right|=|a\_{y}|$$$a=\frac{\sum\_{}^{}F\_{x}}{m\_{T}}=\frac{m\_{2}-m\_{1}\sin(θ)+ u\_{k}m\_{1}\cos(θ)}{m\_{T}}g a=-$$**Tension:** (With Friction) $a\_{x}=- and a\_{y}=+$$$T=m\_{1}\left(a\_{x}+g\sin(θ)-u\_{k} g\cos(θ)\right) T= m\_{2}\left(a\_{y}+g\right) $$ |