Chapter 5 of MHR (Page 152)

Isaac Newton

(1642-1727)

Inertia and Newton's First Law

NEWTON'S FIRST LAW — THE LAW OF INERTIA

An object at rest or in uniform motion will remain at rest or in uniform motion unless acted on by an external force.

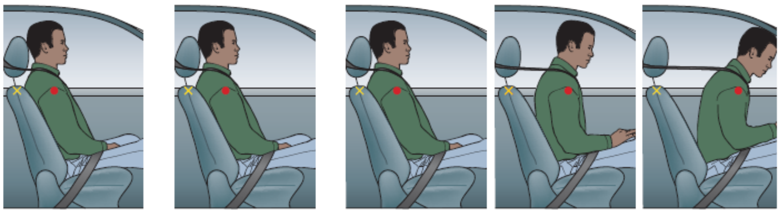
A few demos:

MHR: Pg 154 - 155

INERTIAL AND NON-INERTIAL FRAMES OF REFERENCE

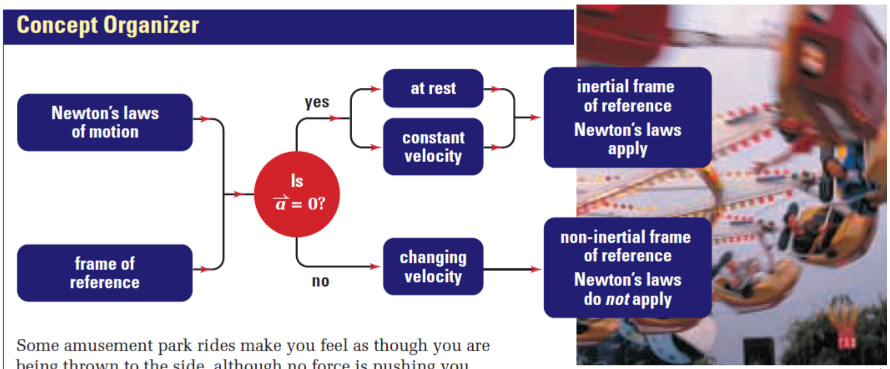
An inertial frame of reference is one in which Newton's laws of motion are valid. Inertial frames of reference are at rest or in uniform motion, but they are not accelerating.

A non-inertial frame of reference is one in which Newton's laws of motion are not valid. Accelerating frames of reference are always non-inertial. (rotating frames of reference are accelerating)



Relative to inside the car, what force caused the passenger to accelerate forward?

Concept Organizer



Some amusement park rides make you feel as though you are being thrown to the side, although no force is pushing you outward from the centre. Your frame of reference is moving rapidly along a curved path and therefore it is accelerating. You are in a non-inertial frame of reference, so it seems as though your motion is not following Newton's laws of motion.

Close read MHR Pg. 156 - 157, conceptual problems on page 158.

* Newton's Laws of motion do not apply at the atomic level.

5.3 Reaction Forces and Newton's Third Law

NEWTON'S THIRD LAW

For every action force on object B due to object A, there is a reaction force, equal in magnitude but opposite in direction, due to object B acting back on object A.

$$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$$

A few qualitative examples.

Close read MHR Pg. 177 - 179.

Newton's 1st & 3rd Law

Grade: 11

Subject: Physics 112

Date: 2014

1 Which of the following objects could ***not*** be analyzed with Newtonian mechanics?

A protons

B model rocket

C space shuttle

D Sun's motion

2 Newtonian mechanics fail when objects approach the speed of ______.

A ants.

B the Earth.

C sound.

D light.

3 If an object is in equilibrium then the net force is zero.

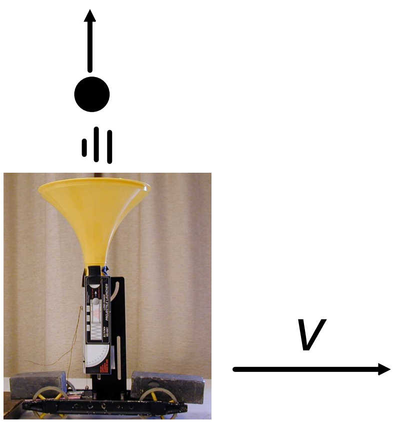
True

False

4 Suppose the object below is moving with a constant velocity. A ball is launched straight up in the air. Is the ball likely to land back in the funnel?

Yes

No



5 Refer to question 4, which of the following are correct statements?

A The frame of reference from outside the cart is interial.

B The frame of referece from outside the cart is non-interial.

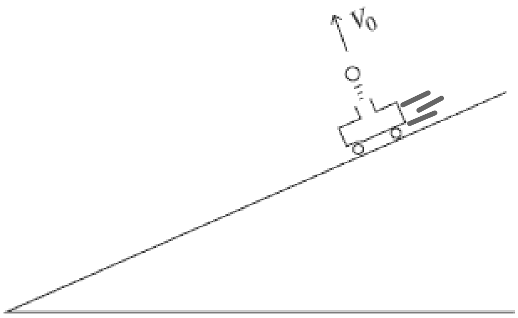
C The frame of reference from within the cart is interial.

D The frame of reference from within the cart is non-interial.

6 In the diagram below, is the ball likely to land back in the cart?

Yes

No



7 Refer to question 6, which statement(s) below are correct?

A The frame of reference from outside the cart is inertial.

B The frame of reference from outside the cart is non-inertial.

C The frame of reference from inside the cart is inertial.

D The frame of reference inside the cart is non-interial.

8 Is being aboard the ISS an inertial frame of reference?

Yes ?

No

9 Is using the surface of the Earth as a reference inertial?

Yes

No, technically, but we assume it is.

10 Relative to a person watching, when running around the track do you push the track or does the track push you?

A Track pushes you forward.

B You push the track backward.

11 Given the situation in the image, the person in the chair will not move (the chair is on wheels).

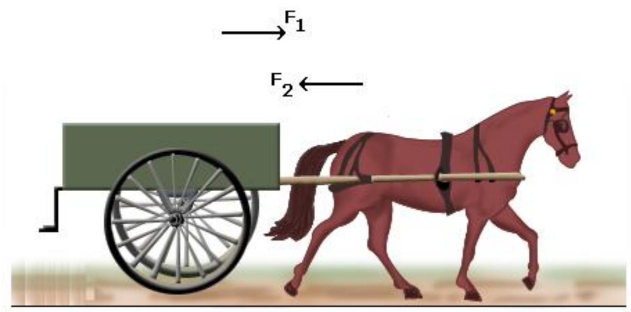
True

False

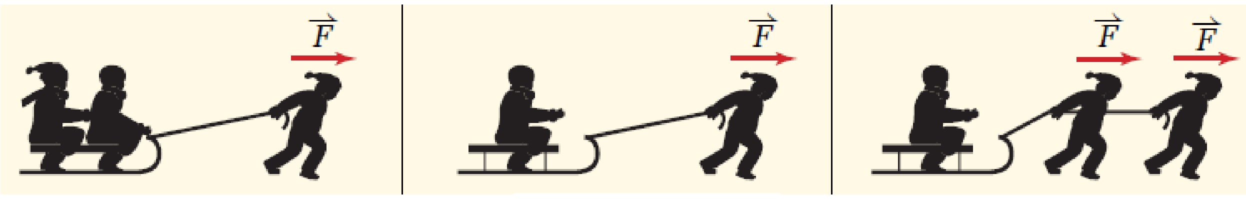
12 The diagram depicts a horse pulling a cart with a certain force. Considering Newton's 3rd Law, will the horse make the cart move?

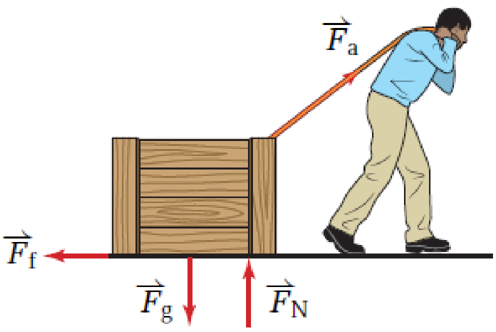
Yes

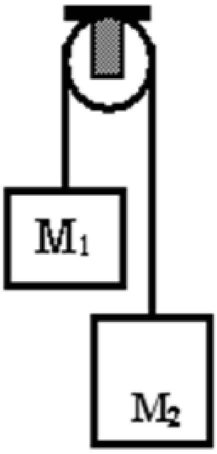
No

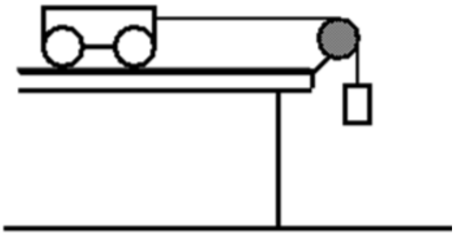


5.2 Motion and Newton's Second Law









5.2 Motion and Newton's Second Law

NEWTON'S SECOND LAW

Force is the product of mass and acceleration, or, acceleration is the quotient of the force and the mass.

$$\vec{F} = m\vec{a} \quad \text{or} \quad \vec{a} = \frac{\vec{F}}{m}$$

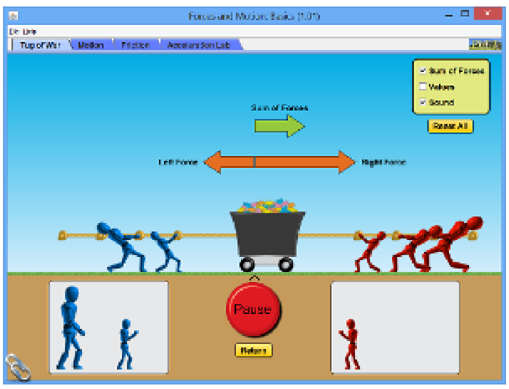
Quantity	Symbol	SI unit
acceleration	$\vec{a}$	$\frac{\text{m}}{\text{s}^2}$ (metre per second squared)
force	$\vec{F}$	N (newton)
mass	m	kg (kilogram)

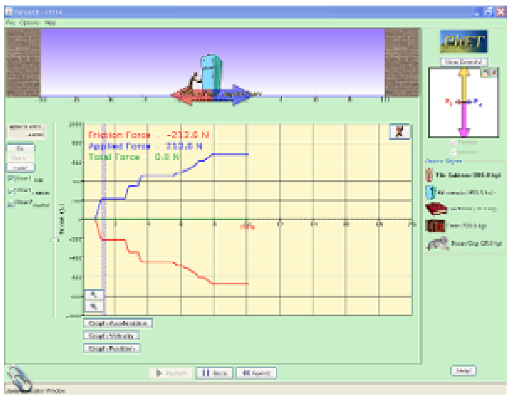
Unit Analysis

(mass) (acceleration) = $\text{kg}\,\frac{\text{m}}{\text{s}^2} = \text{N}$

Note: The $\vec{F}$ in Newton's second law always represents the vector sum of all the forces, or the net force, acting on the mass. (or average force)

PhET Demos





Mathematical Practice

1. What is the acceleration of a 12 kg cart under a constant force of 88 N?

$a = ?$
$m = 12\,kg$
$F_{net} = 88\,N$

$\vec{F}_{net} = m\vec{a}$
$88 = 12a$
$\boxed{7.3\,m/s^2 = a}$

2. An average force of 1200 N accelerates an object at 21 m/s^2. What is the mass of the object?

$\vec{F}_{avg} = \vec{F}_{net}$
$= 1200\,N$
$a = 21\,m/s^2$
$m = ?$

$\vec{F}_{net} = m\vec{a}$
$1200 = m(21)$
$\boxed{57\,kg = m}$

3. What average (net) force is required to accelerate a 33 kg mass at 4.6 m/s^2?

$F_{net} = ?$
$m = 33\,kg$
$a = 4.6\,m/s^2$

$F_{net} = ma$
$= (33)(4.6)$
$\boxed{F_{net} = 152\,N}$

Newton's 2nd Law Basics Review

Grade: 11

Subject: Physics 112

Date: 2014

1 A massive box sits on a frictionless surface. Will a force of 0.0001 N cause an acceleration?

Yes

No

2 A car is acted upon by a net force of 1000 N. Suddenly that force is tripled, by what factor did the acceleration change?

A x 3

B x 1/3

C no change

3 Calculate the resulting acceleration of an 25 kg mass under a net force of 142 N.

A 0.18 m/s^2

B 5.7 m/s^2

C 3550 m/s^2

Rocket Launches

Take 3-5 minutes and write a few detailed sentences about how all of Newton's 3 Laws applies to rockets from launch to orbit.

Combining Dynamics and Kinematics

We will now be mathematically solving problems that could require one or more of a large selection of equations (review handbook).

$$\vec{F}_{net} = m\vec{a}$$

Involve problems we've done previously with common forces like applied force, gravity and friction.

Involve concepts from kinematics incorporating displacement, velocity, and acceleration.

This section takes practice. Review problem solving strategies. You will have many mathematical problems to solve, but unlike your math class, you will need to determine what equations apply to the problem first.

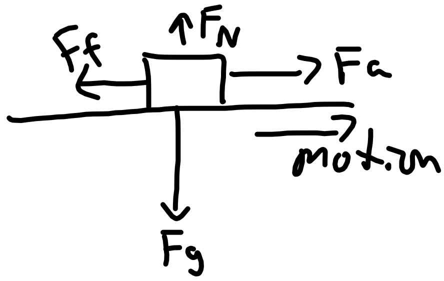
*very important difference

Let's do some examples ⇒

Combining Dynamics and Kinematics

An applied force of 50 N is used to accelerate an object to the right across a frictional surface. The object encounters 10 N of friction. The mass of the object is 8.0 kg.

1. Calculate the net force. (40 N)
2. Calculate the acceleration. (~~4.0~~ 5.0 m/s^2)
3. From the initial push, calculate how far the object will travel if the constant force was applied for 12 seconds. (353 m)



$F_a = 50N$ $m = 8.0kg$

$F_f = -10N$

1.) $\vec{F}_{net} = \sum Forces$

$F_{net} = F_a + F_f$

$= 50 + (-10)$

$= \underline{40N}$

2) $\vec{a} = ?$ $\vec{F}_{net} = m\vec{a}$

$40 = 8a$

$\boxed{5.0 m/s^2 = \vec{a}}$

Combining Dynamics and Kinematics

Undergoing an acceleration a 750 kg car's velocity goes from 21 m/s [E] to 15 m/s [W] in 7.5 s.

1. Calculate the average (net) force acting on the car. (-3600 N)
2. Calculate the final position of the car assuming the initial position is zero. (22.5 m)

1.)

$\vec{F}_{net} = m\vec{a}$ $a = ?$

$t = 7.5 s$

$v_0 = 21 m/s [E]$

$v_f = -15 m/s [E]$

$\vec{a} = \frac{v_f - v_0}{t}$

$a = \frac{-15 - 21}{7.5}$

$= \frac{-36}{7.5} \rightarrow a = -4.8 m/s^2$

$F_{net} = ma$

$= (750)(-4.8)$

$F_{net} = -3600 N$

(- ← west)

#5) $m_c = 20\,kg$ $a_c = 0.5\,m/s^2$

$m_{SB} = 3\,kg$ $a_{SB} = ?$

$$|F_{net,child}| = |F_{net,SB}|$$

$$m_c a_c = m_{SB} a_{SB}$$

$$(20)(0.5) = (3)a_{SB}$$

$$10 = 3a_{SB}$$

$$\boxed{3.33\,m/s^2 = a_{SB}}$$

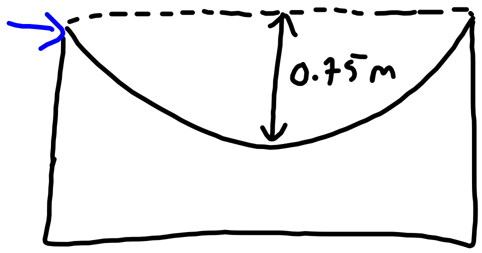
Combining Dynamics and Kinematics

A 2.5 kg ball falls on an air mattress. Just as it hit the ball had a speed of 19 m/s. The air mattress depressed 0.75 m to stop the ball. Calculate the average stopping force acting on the ball. (602 N)

$v_0 = -19$ m/s (down)

$m = 2.5$ kg $F_{Avg} = ?$

↑ + ↓ −



← position zero

$d_0 = 0$ m $a = ?$ ↖ calculate first

$d_f = -0.75$ m

$V_f = 0$ m/s (stops)

$$V_f^2 = V_0^2 + 2\vec{a}(\vec{d_f} - \vec{d_0})$$

$$0^2 = (-19)^2 + 2a(-0.75 - 0)$$

$$0 = 361 - 1.5a$$

$$-361 = -1.5a$$

$$241 \text{ m/s}^2 = a$$

$$F_{avg} = ma$$

$$= (2.5)(241)$$

$$\boxed{= 603 \text{ N}}$$

Your Turn:

Combining Dynamics and Kinematics

A a 45 kg diver enters the water with a speed of 14 m/s (assume no jumping and initial velocity was zero).

1. Calculate the average stopping force of the water if she comes to rest at a depth of 2.5 m.
2. Calculate how high the diving platform is above the surface of the water.

3. A 5.2 kg bowling ball is accelerated from rest to a velocity of 12 m/s as the bowler covers 5.0 m of approach before releasing the ball. What force is exerted on the ball during this time? (F = 75 N)

$F = ma$

$a = ?$

$m = 5.2\ kg$

$V_0 = 0\ m/s$

$V_f = 12\ m/s$

$d_0 = 0\ m$

$d_f = 5\ m$

$$V_f^2 = V_0^2 + 2a(d_f - d_0)$$

$$(12)^2 = 0^2 + 2a(5 - 0)$$

$$144 = 10a$$

$$14.4\ m/s^2 = a$$

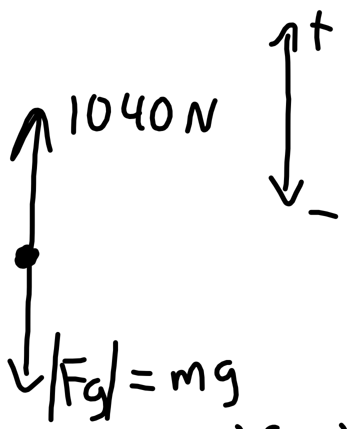
$$F_{net} = (5.2)(14.4)$$

$$= 75N$$

9. In bench pressing 100 kg, a weight lifter applies a force of 1040 N. How large is the upward acceleration of the weights during the lift? (a = 0.59 m/s²)

$F_{net} = \sum Forces$

$F_{net} = ma$



$|F_g| = mg$

$= (100)(9.81)$

$= 981\ N$

$F_{net} = F_a + F_g$

$= 1040 + (-981)$ ← down

$F_{net} = 59\ N$

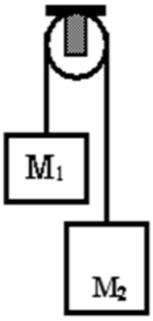
$F_{net} = ma$

$59 = 100a$

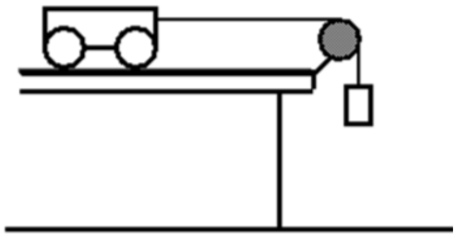
$\boxed{0.59\ m/s^2 = a}$

Force Problems Involving Twoor More Connected Objects

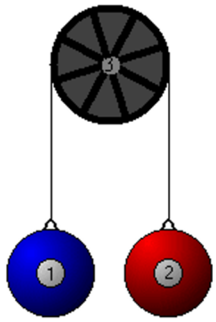
Atwood's Machine



Fletcher's Trolley



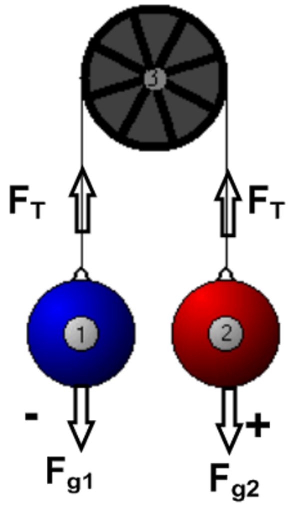
Atwood Machine Problems



This is an example of a system where there are multiple masses.

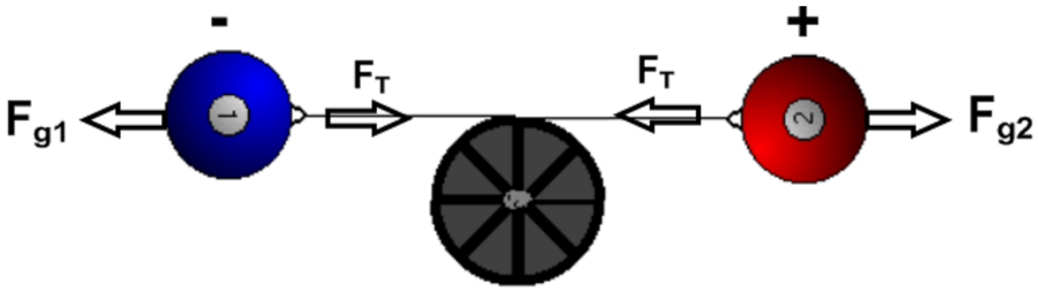
We will apply the concept of forces to determine the resulting acceleration.

Define the Direction of Forces



Our problems will not include friction and the pulley will always be massless.

You may find it easier to picture, or draw, the system horizontally.



To solve we use the formula:

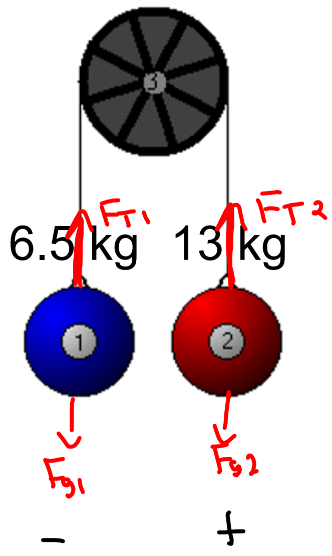
$$\sum \vec{F} = \sum m \times \vec{a}$$

Sum of the forces = sum of the masses x acceleration

*only forces acting in the direction of motion are to be incorporated.

Reading Review MHR: 476, 478 - 479.

Calculate the acceleration of the masses in the diagram below.



$|F_{T1}| = |F_{T2}|$

equal and opposite

$\sum \vec{F} = \sum m \times \vec{a}$

$F_{g1} + F_{T1} + F_{g2} + F_{T2} = (m_1+m_2)a$

$|F_{g1}| = m_1 g = (6.5)(9.81) = 64\,N$

$|F_{g2}| = m_2 g = (13)(9.81) = 128\,N$

$-(64) + (128) = (6.5+13)a$

$64 = 19.5a$

$3.27\,m/s^2 = a$

Calculate the magnitude of tension in the string.

* Apply Newton's 2nd law to only one mass.

Analyzing m_1

$\sum \vec{F} = m_1 a$ ← on m_1

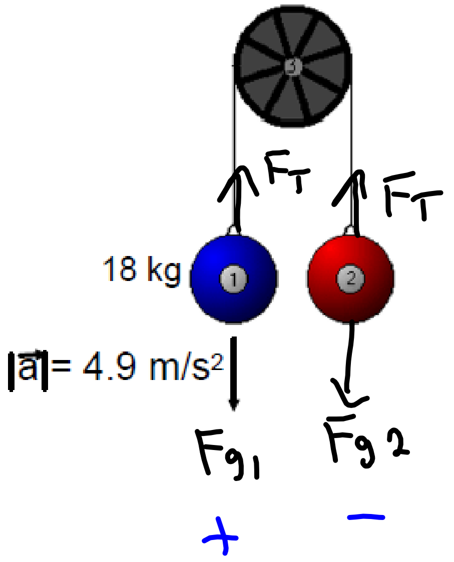
$F_{g1} + F_T = m_1 a$

$(-64) + F_T = (6.5)(3.27)$

$F_T = 21 + 64$

$F_T = 85\,N$

Given the information in the diagram, calculate M_2 and the magnitude of tension in the string.



$|F_T| = 91\ N$

$M_2 = 6.0\ kg$

$$\sum F = \sum m \times a$$

$$F_{g1} + F_{g2} = (m_1 + m_2)a$$

$$|F_{g1}| = (18)(9.81) = 179\ N$$

$$|F_{g2}| = 9.81 M_2$$

$$(179) + (-9.81 M_2) = (18 + M_2)(4.9)$$

$$179 - 9.81 m_2 = 88.2 + 4.9 m_2$$

$+9.81 m_2$ $\quad$ $+9.81 m_2$

$$179 = 88.2 + 14.71 m_2$$

-88.2 $\quad$ -88.2

$$90.8 = 14.71 m_2$$

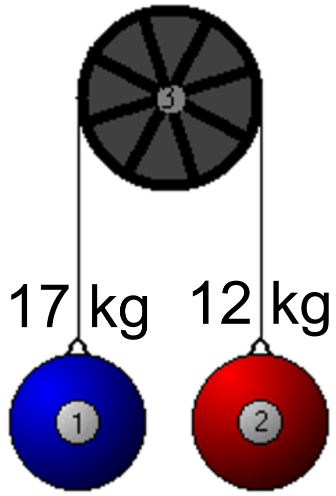
$$\boxed{6.17\ kg = m_2}$$

Your Turn:

Calculate the acceleration of the masses in the diagram below.

$|\vec{a}| = 1.7\,m/s^2$

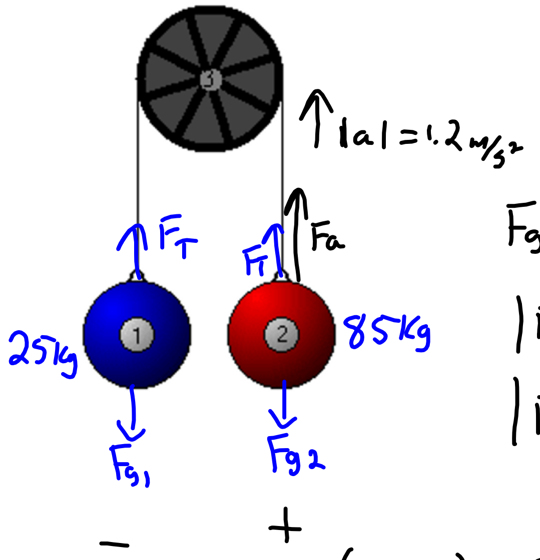
$|\vec{F}_T| = 138\,N$



Calculate the magnitude of tension in the string.

A counter weight of 25 kg is used to help a person of mass 85 kg do chin ups.

1. Calculate the force applied by the person if he accelerates at 1.2 m/s^2. → magnitude
2. Calculate the magnitude of tension in the wire.



$$\sum F = \sum m \times a$$

$$F_{g1} + F_{g2} + F_a = (m_1 + m_2)a$$

$$|F_{g1}| = 245\,N \leftarrow m_1 g$$

$$|F_{g2}| = 834\,N \leftarrow m_2 g$$

$$(-245) + 834 + F_a = (25+85)(-1.2) \quad *$$

$$589 + F_a = -132$$

$$\boxed{F_a = -721\,N}$$

$$F_T = ? \qquad \sum F = m_1 a$$

↑ on m_1

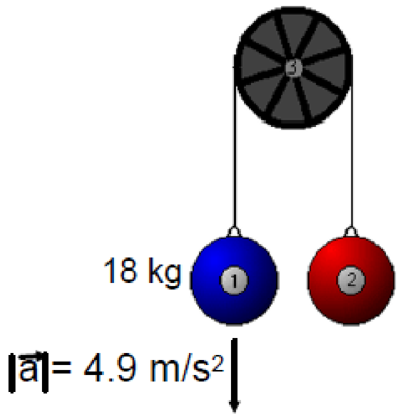
$$F_{g1} + F_T = m_1 a$$

$$(-245) + F_T = (25)(-1.2)$$

$$-245 + F_T = -30$$

$$\boxed{F_T = 215\,N}$$

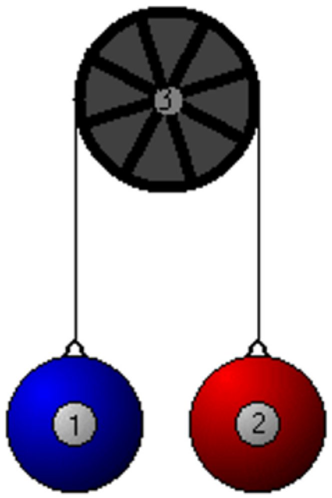
Given the information in the diagram, calculate M_2 and the magnitude of tension in the string.



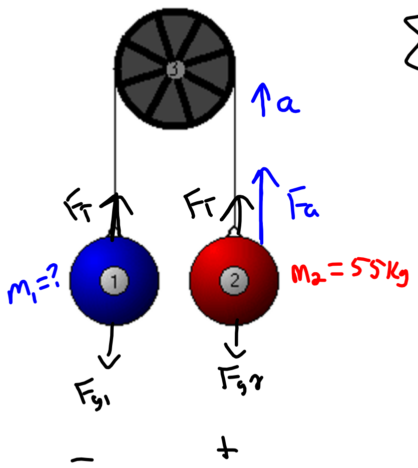
Your Turn:

A counter weight of 37 kg is used to help a person of mass 71 kg do chin ups.

1. Calculate the force applied by the person if he accelerates at 0.25 m/s^2.
2. Calculate the magnitude of tension in the wire.



Suppose the maximum mass a person can lift is 324 N. A counterbalance is set up to help that person lift other objects. Calculate the mass of the counter weight for the person to lift 55 kg with an acceleration magnitude of 1.5 m/s^2
(M = 36 kg)



$$\sum F = \sum m \times a$$

$$F_{g1} + F_{g2} + F_a = (m_1 + m_2)a$$

$$|F_{g1}| = 9.81 m_1$$

$$|F_{g2}| = (55)(9.81) = 540 N$$

$$|F_a| = 324 N$$

$$|a| = 1.5 m/s^2$$

$$-9.81 m_1 + 540 + (-324) = (m_1 + 55)(-1.5)$$

$$-9.81 m_1 + 216 = -1.5 m_1 - 82.5$$

$$-9.81 m_1 + 9.81 m_1 + 216 = -1.5 m_1 - 82.5 + 9.81 m_1$$

$$216 + 82.5 = 8.31 m_1 - 82.5 + 82.5$$

$$298.5 = 8.31 m_1$$

$$\boxed{36 kg = m_1}$$

$F_T = ?$

$$\sum F_{\text{on } m_2} = m_2 a$$

$$F_{g2} + F_a + F_T = m_2 a$$

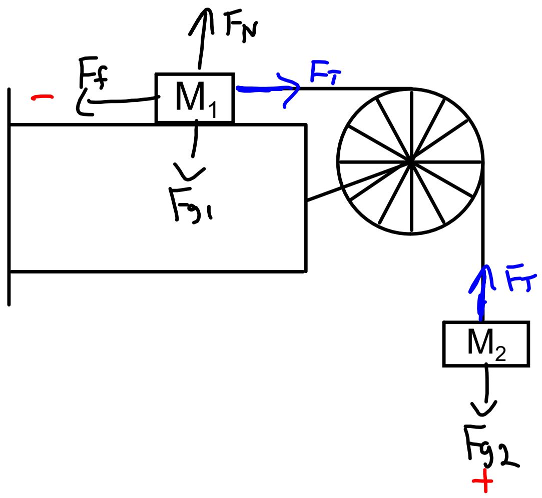
$$540 + (-324) + F_T = 55(-1.5)$$

$$216 + F_T = -82.5$$

$$\boxed{F_T = -298.5 N}$$

Fletcher's Trolley

Calculate the acceleration of the masses if M_1 = 5.2 kg, M_2 = 4.5 kg, and μ_k = 0.22. Then calculate the tension in the wire.



***Pay close attention to the direction of the forces!**

$$\sum \vec{F} = \sum m \times \vec{a}$$

↑ only forces in dimension of motion

$$F_f + F_{g2} = (m_1 + m_2)\,a$$

$$|F_f| = \mu F_N \quad \rightarrow \quad |F_N| = |F_{g1}|$$

$$= \mu F_{g1}$$

$$= (0.22)(5.2)(9.81)$$

$$|F_f| = 11\ N$$

$$|F_{g2}| = m_2 g = (4.5)(9.81)$$

$$= 44.1\ N$$

$$-11 + 44.1 = (5.2 + 4.5)\,a$$

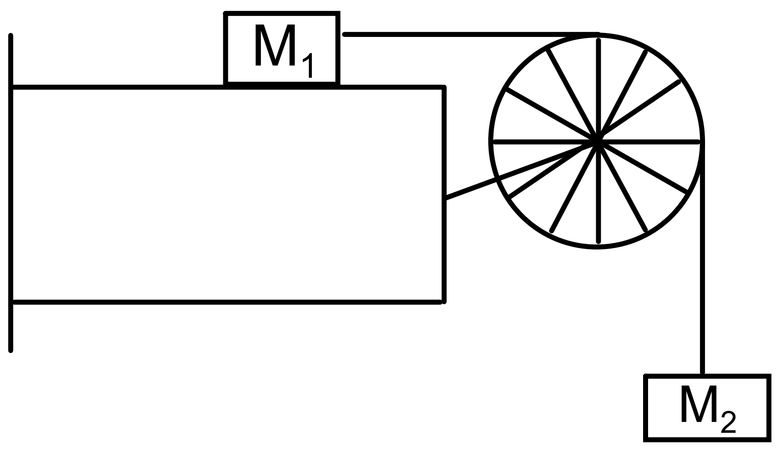
$$33.1 = 9.7a$$

$$\boxed{3.4\ m/s^2 = a}$$

$$F_T = ?$$

Your Turn: Fletcher's Trolley

Calculate the acceleration of the masses if M_1 = 12.6 kg, M_2 = 16.5 kg, and μ_k = 0.42. Then calculate the tension in the wire.



Attachments

forces-and-motion-basics_all.jar

forces-1d_all.jar