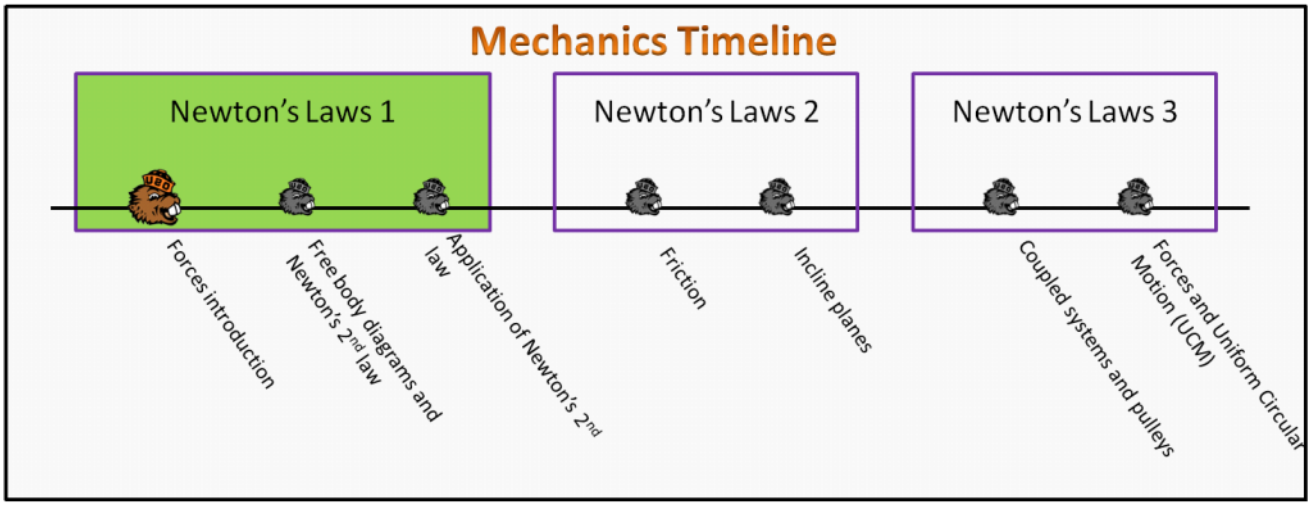
(N1) Forces Introduction

Monday, January 22, 2018 5:44 PM

Newton's Laws 1

Foundation Stage (N1.2)

lecture 1
Forces Introduction



Textbook Chapters

- **BoxSand** :: KC videos (Newton's First Law ; Newton's Second Law ; Newton's Third Law)
- **Giancoli** (Physics Principles with Applications 7th) :: 4-1 ; 4-2 ; 4-3 ; 4-4 ; 4-5 ; 4-6 ; 5-10
- **Knight** (College Physics : A strategic approach 3rd) :: 4.1 ; 4.2 ; 4.3 ; 4.4 ; 4.5 ; 4.7
- **Knight** (Physics for Scientists and Engineers 4th) :: 5.1 ; 5.2 ; 5.3 ; 5.4 ; 5.5 ; 5.6 ; 7.1

Warm up

N1.2-1:

Description: Relate direction of net force to the direction of acceleration.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: Consider Newton's second law: $\sum \vec{\mathbf{F}}_{\text{ext,on sys}} = \mathrm{m}_{sys}\, \vec{\mathbf{a}}_{cm}$, where **m**$_{\text{sys}}$ is the mass of the system, $\vec{\mathbf{a}}_{cm}$ is the accelration of the center of mass of the system, and $\sum \vec{\mathbf{F}}_{\text{ext}}$ is called the "net external force acting on the system". If the net external force points horizontally to the right on a car, what direction is the acceleration of the car?

[✓ (1)] Horizontally to the right.
(2) Horizontally to the left.
(3) Vertically upwards.
(4) Vertically downwards.
(5) Unknown: Depends on the speed of the car.
(6) Unknown: Depends on whether the car is speeding up or slowing down.

VECTORS

$$\sum \vec{F}_{EXT} = m_{sys}\vec{a}_{cm}$$

+ SCALAR ALWAYS

Selected Learning Objectives

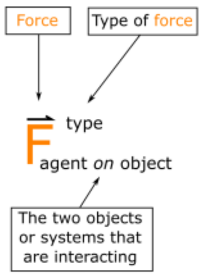
1. Demonstrate the fact that a force is inherently an interaction between two objects or two systems.
2. Explain Newton's 1st law as it relates to inertia.
3. Explain Newton's 1st law and how it relates to the 2nd law.
4. Define static and dynamic equilibrium.
5. Explain Newton's 2nd Law.
6. Explain Newton's 3rd Law force pairs.
7. Define the point particle model.
8. Define a system(s) boundary and adhere their analysis to that boundary(s).
9. Identify the type of forces interacting with your system and the direction they are applied.
10. Differentiate between contact and non-contact forces.
11. Demonstrate that the normal force is always perpendicular to the surface.
12. Draw a free-body-diagram (FBD) for the system(s).
13. Demonstrate the ability to draw a *properly scaled* FBD.
14. (UPMF) Draw the coordinate system that reduces the complexity of the vector analysis next to the FBD.
15. Apply geometry to determine appropriate angles for the given coordinate system.
16. Find the components of a force in the chosen coordinate system.
17. Differentiate between *A* force and a *NET* force.
18. Apply Newton's 2nd law in the mathematical representation.
19. Differentiate between static and dynamic equilibrium.
20. Differentiate between weight and apparent weight.
21. Synthesize a force and kinematics analysis via the acceleration.
22. Demonstrate that the net force points in the same direction as the acceleration.
23. Demonstrate the fact that the net force can be in the opposite direction of the motion.

Key Terms

- Point particle model
- Interaction
- Newton's 1st law
- Newton's 2nd law
- Newton's 3rd law
- Newton's 3d law force pairs
- System
- Boundary
- Environment
- Equilibrium
- Static Equilibrium
- Dynamic Equilibrium
- Force
- Net external force
- Contact force.
- Non-contact force.
- Force of gravity (Weight)
- Normal force
- Apparent weight
- Free Body Diagram (FBD)

Key Equations

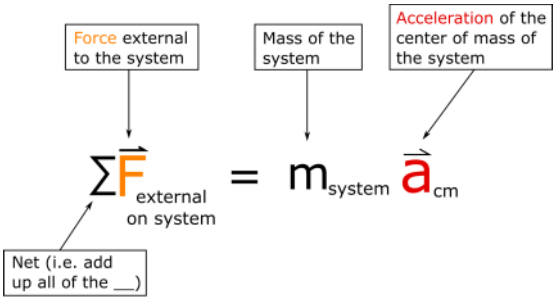
Forces notation



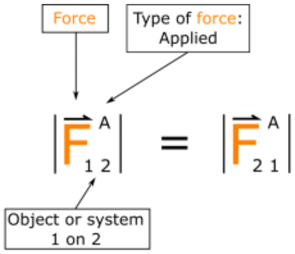
In words: For example: $\vec{F}^{N}_{12}$, which is read as "the Normal force from object 1 acting on object 2.
* See force inventory for list of all forces.

Newton's 1st law **Newton's 2nd law** **Newton's 3rd law**

An object or system moving with a constant velocity will continue to move with the same speed and direction unless an there is an unbalanced interaction with its environment.



In words: The net force external to the system is equal to the mass of the system multiplied by the acceleration of the center of mass of the system.



In words: The magnitude of the applied force from 1 on 2 is equal to the magnitude of the applied force from 2 on 1.

Key Concepts

- Draw a dashed line around your chosen system to help identify external forces.
- A net external force causes a system's center of mass to accelerate.
- A force is an interaction between objects.
- The force of gravity (often called weight) is a non-contact interaction between two objects that have mass (e.g. the earth and a book).
- The normal force is a contact interaction between any objects that are touching each other (e.g. a book resting on a table) and points perpendicular to the two surfaces in contact.
- A scale reads the apparent weight of an object, which is the normal force between the object and scale.
- Net force points in the same direction as acceleration.

Act I: Forces introduction

Questions

N1.2-2:

Description: Choosing a system conceptual question. (3 minutes)

Learning Objectives: [8]

Problem Statement: Which of following statements are necessarily true?

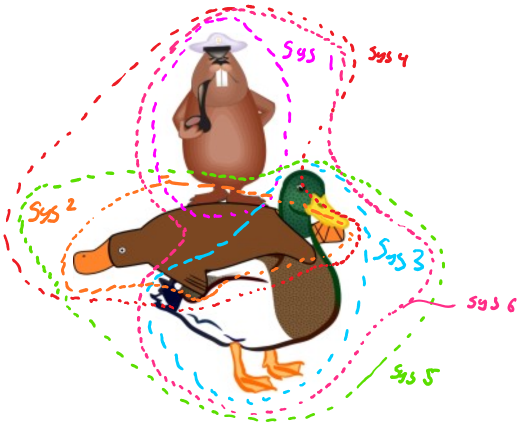
T [✓ (1)] A system is defined by a boundary you choose.
? (2) A system is defined by a boundary already predestined by nature.
F (3) A system is defined by a boundary the author (teacher) of a problem has chosen.
F (4) A system only includes one object.
T [✓ (5)] A system can include more than one object.

N1.2-3:

Description: Choosing a system conceptual question. (3 minutes)

Learning Objectives: [8]

Problem Statement: Consider the image below of a beaver on top of a platypus on top of a duck. How many systems can you define?



MORE ....

N1.2-4:

Description: Conceptual question about Newton's first law. (3 minutes)

Learning Objectives: [2, 4]

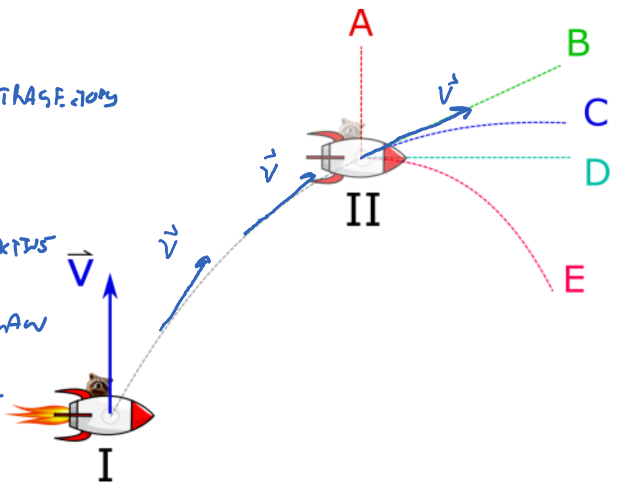
Problem Statement: A raccoon on a rocket with horizontal thrusters is shown below. The initial velocity is vertically upwards at location **I** as seen in the image. The dashed gray line represents the trajectory of the rocket raccoon while the horizontal thrusters are on. The thrusters are suddenly shut off at location **II**. Which dashed line represents the trajectory after the thrusters are turned off?

(1) A
[✓ (2)] B
(3) C
(4) D
(5) E

$\vec{V}$ IS ALWAYS TANGENT TO TRAJECTORY

@ II $\vec{V}$ POINTS ALONG B

AND ROCKET NO LONGER INTERACTING WITH ANY THING. SO FIRST LAW TELLS US ROCKET WILL CONTINUE WITH CONSTANT VELOCITY.



ALSO. FROM 2nd LAW. $\cancelto{\vec{0}}{\sum \vec{F}_{EXT}} = m\vec{a}$

$\vec{0} = m\vec{a}$

$\vec{a} = \vec{0}$ SO $\vec{V}$ IS CONSTANT

N1.2-5:

Description: Relate position vs time graph to net force. (5 minutes)

Learning Objectives: [21]

Problem Statement: The graph below shows the position as a function of time for Fillion the firefly while flying along a straight line. During which time intervals is there no net force on Fillion?

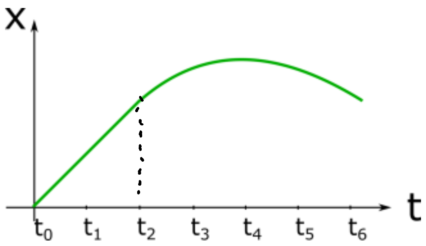
(1) t_4
(2) t_0 - t_6
[✓ (3)] t_0 - t_2
(4) t_2 - t_6

$$\cancelto{\vec{0}}{\sum \vec{F}_{EXT}} = m\vec{a}$$

$$\vec{0} = m\vec{a}$$

So $\vec{a} = \vec{0}$

↳ $\boxed{\text{LINEAR } X(t)}$



$$\begin{tikzcd} X(t) \arrow[d, "\text{SLOPE}"] \\ V_x(t) \arrow[d, "\text{SLOPE}"] \\ a_x(t) \end{tikzcd}$$

N1.2-6:

Description: Definition of a force. (2 minutes)

Learning Objectives: [1, 17]

Problem Statement: A force is:

F (1) equal to mass time acceleration.
T [✓ (2)] an interaction between objects.
F (3) dependent on the mass of an object.
F (4) dependent on the acceleration of an object.
F? (5) dependent on the velocity of an object.
F (6) only involving one object.
F (7) always making objects accelerate.

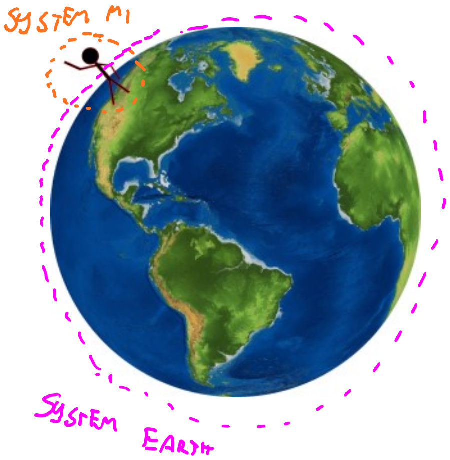
N1.2-7:

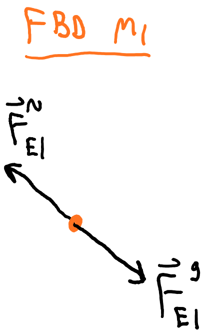
Description: Definition of Newton's third law. (2 minutes)

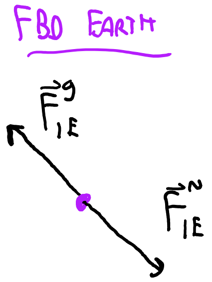
Learning Objectives: [1, 4, 6]

Problem Statement: Which is bigger: the gravitational force of the earth on you or the gravitational force of you on the earth?

(1) Gravitational force of earth on me.
(2) Gravitational force of me on earth.
[✓ (3) They are equal.]







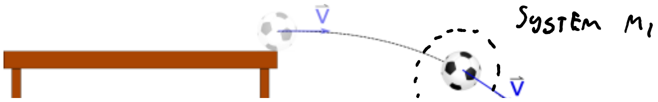
N1.2-8:

Description: Identify forces acting on an object. (2 minutes)

Learning Objectives: [1, 2, 9]

Problem Statement: A balls rolls off a table at a pretty good speed. The ball is flying through the air and has not yet hit the ground. What forces act on the ball. Ignore air resistance.

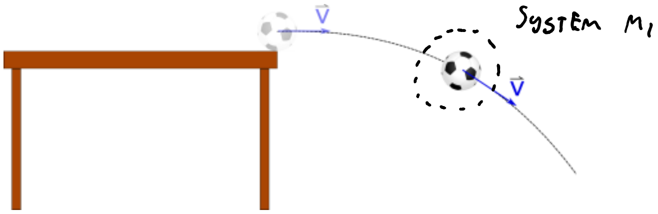
A normal force	$\vec{F}N$
A tension force	$\vec{F}T$



[✓ (1) Only $\vec{F}g$]

(2) Only $\vec{F}N$

A normal force	$\vec{F}^N$
A tension force	$\vec{F}^T$
A friction force	$\vec{F}^f$
A weight	$\vec{F}^g$



[✓ (1) Only $\vec{F}^g$]

(2) Only $\vec{F}^N$

(3) Only $\vec{F}^T$

(4) Only $\vec{F}^f$

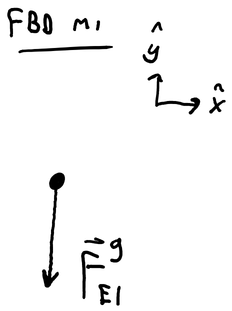
(5) No forces

(6) $\vec{F}^N$ and $\vec{F}^g$

(7) $\vec{F}^N$, $\vec{F}^g$, and $\vec{F}^f$

(8) $\vec{F}^w$ and $\vec{F}^f$

(9) $\vec{F}^N$ and $\vec{F}^f$

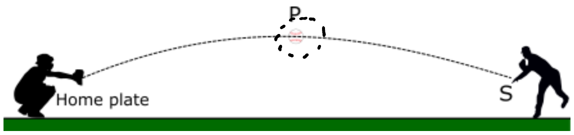


N1.2-9:

Description: Identify forces acting on an object. (3 minutes)

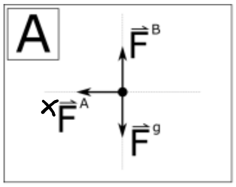
Learning Objectives: [1, 2, 9, 12, 22]

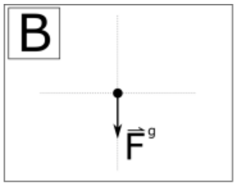
Problem Statement: A baseball is thrown from right field to home plate, traveling from right to left in the diagram.

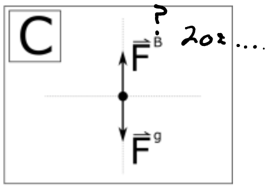


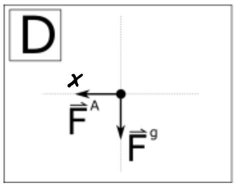
A group of physics students watching the game create the following free-body diagrams for the baseball at the top of its path (point **P**). Note, that the forces are not drawn to scale. If they decided to ignore air resistance, which is the correct free-body diagram for the baseball at point **P**.

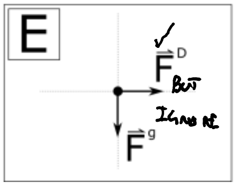
(1) A
[✓ (2) B]
(3) C
(4) D
(5) E
(6) F
(7) None of these
(8) Depends on the coordinate system

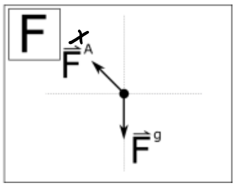












N1.2-10:

Description: Identify forces acting on an object and match the proper FBD. (2 minutes + 3 minutes)

Learning Objectives: [1, 2,4, 9, 12, 22]

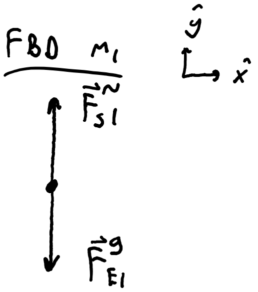
Problem Statement: You are standing on a bathroom scale in your uncle Benny's broken down motorhome.

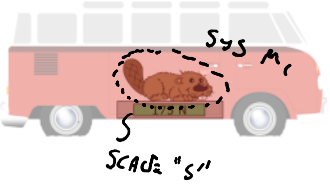
(a) Which of the following forces are acting on you?

[✓ (1)] Gravity
[✓ (2)] Normal
(3) Abnormal
(4) Tension
(5) Electromagnetic
(6) Friction

$\vec{a}=\vec{0}$

$\therefore \sum \vec{F}_{ext}=\vec{0}$

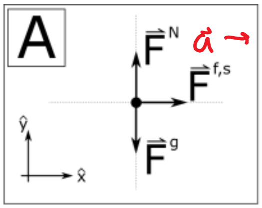


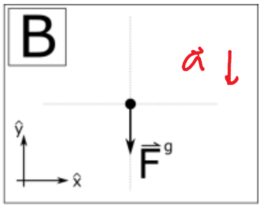


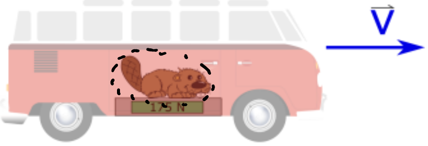
(b) After aunt Bernice fixes their motorhome, you again find yourself standing on the scale. This time though, the coach is puttering steadily down the highway at 55 mph. Which of the following FBD represents the forces acting on you?

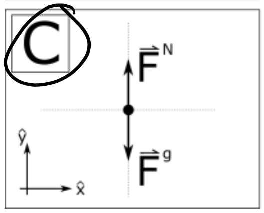
$\vec{a}=\vec{0}$

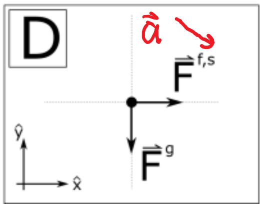
$\therefore \sum \vec{F}_{ext}=\vec{0}$











N1.2-11:

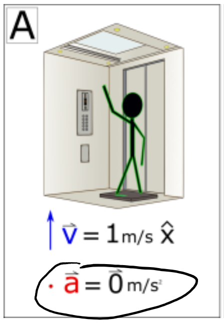
Description: Given velocity and acceleration information, rank force from scale on person inside an elevator. (6 minutes + 2 minutes + 3 minutes + 6 minutes)

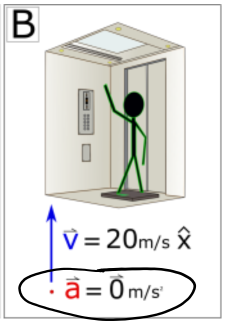
Learning Objectives: [5, 17, 19, 20, 22, 23]

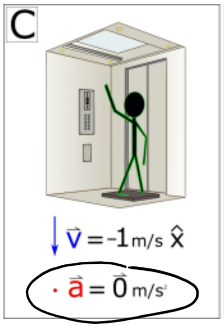
Problem Statement: A person who weighs 700 N is standing on a scale in an elevator. The elevator is identical in all cases. The velocity and acceleration of the elevator at the instant shown are given.

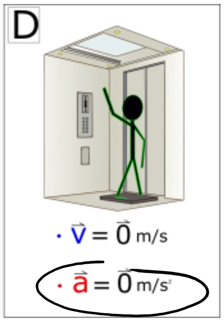
(a) Rank the reading on the scales.

SCALES READ
NORMAL FORCE









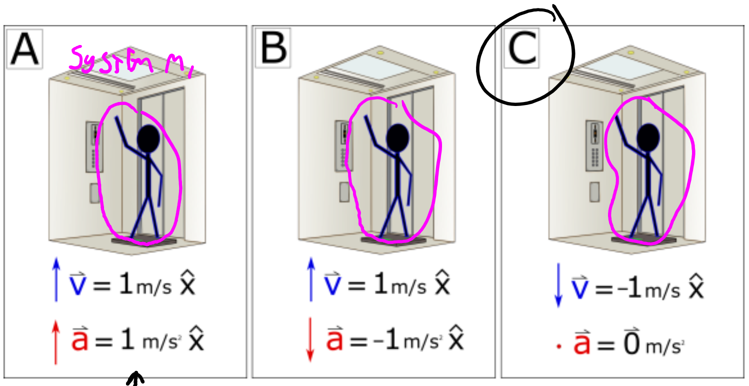
$$\boxed{|\vec{F}^N_A| = |\vec{F}^N_B| = |\vec{F}^N_C| = |\vec{F}^N_D|}$$

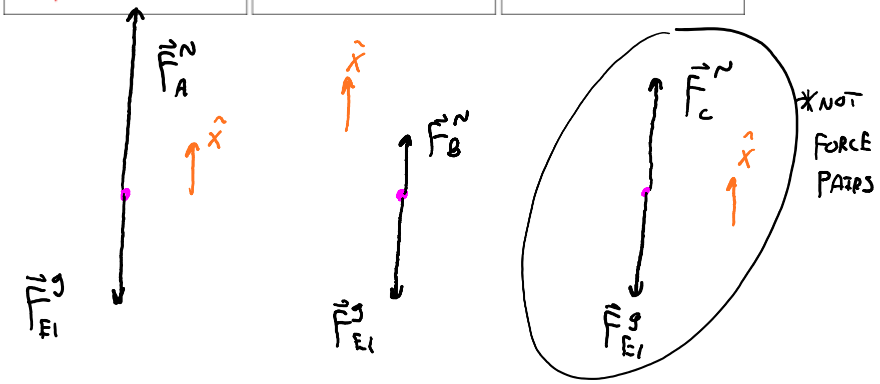
(b) In which case is the person's magnitude of their apparent weight equal to their magnitude of weight?

SCALES READ NORMAL FORCE ALSO REFERRED TO AS APPARENT WEIGHT WHEN "WEIGHING" SOMETHING.

SCALES DO NOT READ WEIGHT

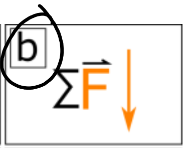
WEIGHT $\equiv \vec{F}^g$

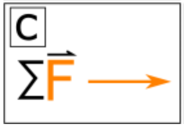


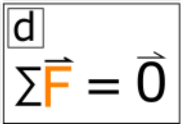


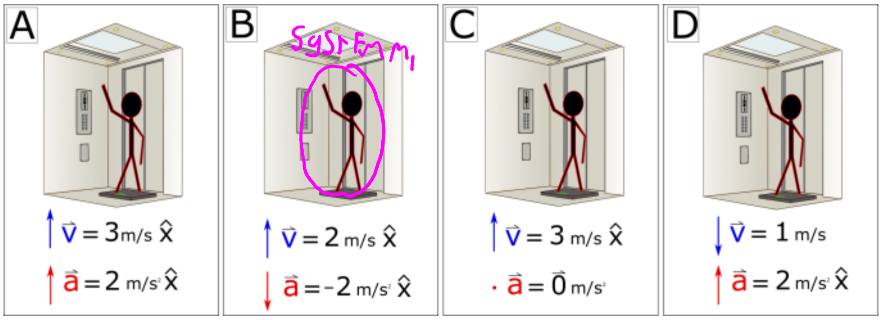
(c) Which net force vector could represent the net force for case **B**?

(1) a
[✓ (2) b]
(3) c
(4) d

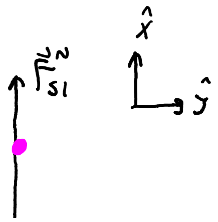








$\vec{a} \downarrow$ so $\Sigma\vec{F} \downarrow$

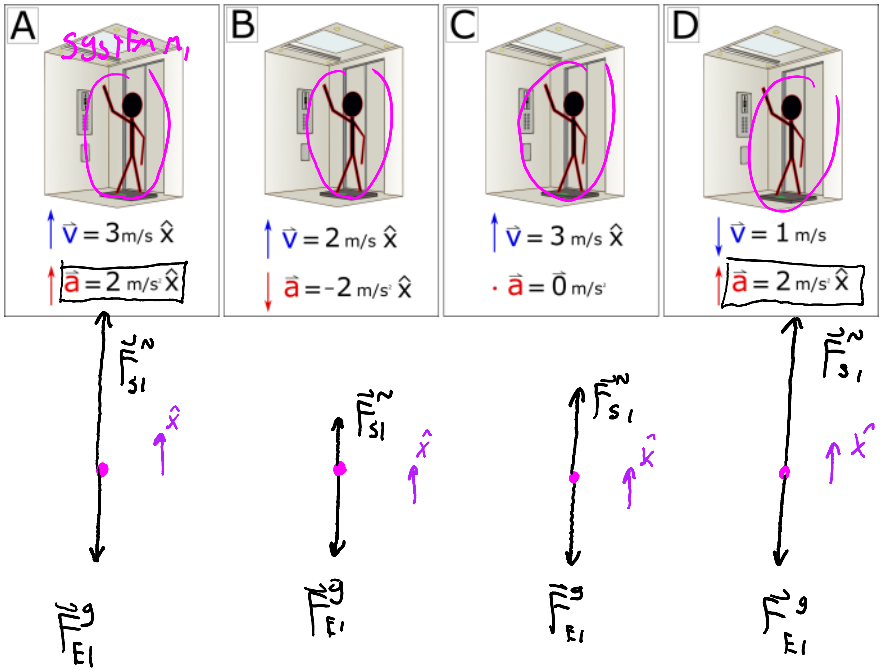


(d) Rank the reading on the scales.

$|\vec{F}^N_{S1}|$

"APPARENT WEIGHT"

$$\boxed{A = D > C > B}$$



N1.2-12:

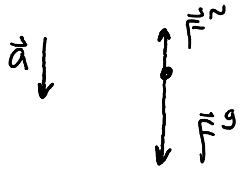
Description: Sketch a normal force as a function of time for tossing a ball in the air. (3 minutes + 5 minutes)

Learning Objectives: [5]

Problem Statement: A person throws a ball up in the air and then catches it again.

(a) The first motion you'll see is the hand goes from being stationary at t0 to moving downward. During this time, the magnitude of the normal force from the hand on the ball is ____________ mg.

(1) greater than
[✓ (2)] less than
(3) equal to



(b) Sketch the magnitude of the normal force of the hand on the ball as a function of time.

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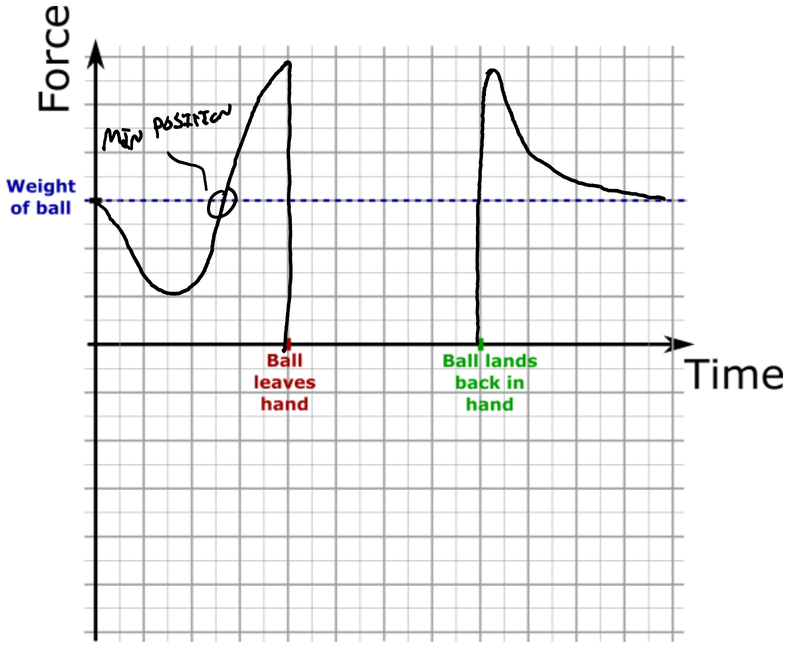

Conceptual questions for discussion

1. You are unsafely riding in a car without a seatbelt on. The driver suddenly applies the brakes and you go flying forward. What force pushed you forward? Also, always wear your seatbelt.
2. Do you agree with the following statement? *The acceleration of an object is zero, thus there are no forces acting on the object.*
3. Have you ever dared to pull a tablecloth out from under plates, glasses, and utensils? Use Newton's laws of motion to explain how it is possible to pull the tablecloth out from under the items without causing a big mess.

Hints

N1.2-1: Mass is always a positive scalar.

N1.2-2: No hints.

N1.2-3: Fact: Bears eat beavers - bears, beavers, Battlestar Galactica.

N1.2-4: What does Newton's first law say?

N1.2-5: Recall graphical analysis techniques. How to get from position to velocity? Velocity to acceleration? How is acceleration related to net force?

N1.2-6: No hints.

N1.2-7: No hints.

N1.2-8: Are there any contact forces? Are there any non-contact forces?

N1.2-9: Are there any contact forces? Are there any non-contact forces?

N1.2-10: No hints.

N1.2-11: Scales read the normal force between the person and the scale.

N1.2-12: Are you touching the ball when it is in the air? Also, what is the direction of acceleration the moment the ball is caught?