1. Newton's Second Law: An object experiencing a net external force, accelerates according to the equation:

$$\boxed{\vec{F} = m.\vec{a}}$$

- Force on an object [push / pull]
- Unit: $1N = 1(Kg.m/s^2)$

2. Newton's First Law: An object in motion stays in motion unless acted upon by a net external force...

$$\boxed{\vec{a} = 0 \Rightarrow \vec{F} = 0}$$

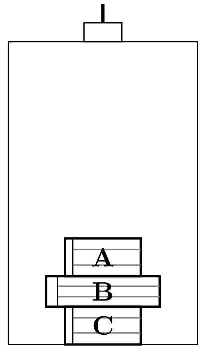
3. Newton's third Law: Every action has an equal & opposite reaction...

4. Types of Forces:
   - Gravitational Force $= -m.g =$ (gravitational mass) $\times -9.8$
   - Normal Force $= m.g \Rightarrow$ only when $a_y = 0$
     - Object Stationary
     - Object inside a system that is stationary
     - Object inside a system that is moving at a constant velocity...
   - Always ((prependicular)) to the surface
     means normal in physics
   - Large as needed to prevent movement of an object into the surface
   - Arise from electrostatic interactions between molecules in matter

1.6 Newton's Laws

1.6.1 A Stationary Elevator

For the questions in this activity, consider a stack of three books in an elevator, as shown in the picture below.



Book A has a mass of 1.5 kg, book B has a mass of 0.9 kg, and book C has a mass of 1.2 kg. The elevator itself has a mass of 1200 kg. In this activity, the elevator is stationary - that is to say, the elevator is neither moving nor accelerating.

1. What does the elevator being stationary imply about the acceleration of the elevator? What does it imply about the acceleration of all of the books in the elevator? By Newton's second law, what does this imply about the next force on the elevator and each of the books? Record your answers below.

   a) Elevator $\vec{a} =$ ________ b) Elevator $\vec{F}_{net} =$ ________ c) Book A $\vec{a} =$ ________ d) Book A $\vec{F}_{net} =$ ________

   e) Book B $\vec{a} =$ ________ f) Book B $\vec{F}_{net} =$ ________ g) Book C $\vec{a} =$ ________ h) Book C $\vec{F}_{net} =$ ________

2. Let us begin by considering book A. Draw and label a free body diagram for book A. How many forces are acting on book A? What are the magnitudes of these forces? In what directions are these forces pointing in? Be sure your free body diagram illustrates the answers to all of these questions!

3. Next, let us consider book B. Draw and label a free body diagram for book B. How many forces are acting on book B? What are the magnitudes of these forces? In what directions are these forces pointing in? Are any of these forces Newton's third law pairs with the forces on your previous diagram for book A? Be sure your free body diagram illustrates the answers to all of these questions!

4. Now consider book C. In the space below, draw and label a free body diagram for book C. How many forces are acting on book C? What are the magnitudes of these forces? In what directions are these forces pointing in? Are any of these forces Newton's third law pairs with the forces on your previous two diagrams for books A and B? Be sure your free body diagram illustrates the answers to all of these questions!

5. Finally, consider the elevator itself. Assume that the elevator is being held up by a tension force, T, in the cable. How large is this tension force? What other forces act on the elevator? Again, be sure to label all the forces and their magnitudes on the free body diagram you draw for the elevator!

1.6.2 An Elevator Moving at Constant Speed

Now consider the situation where the same elevator from Activity #1 is traveling downwards at a constant velocity $v = 2$ m/s.

1. What is the net force on the elevator? What about book A, book B, and book C?

2. Does the elevator in this case represent an inertial frame? Explain.

3. Now draw free body diagrams for each of the three books and the elevator in the case where the elevator is traveling upwards at constant velocity. How do your free body diagrams compare to the ones you drew in Activity #1?

1.6.1

1

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

b) Elevator $\vec{F}_{net} = 0$

c) Book A $\vec{a} = 0$

d) Book A $\vec{F}_{net} = 0$

e) Book B $\vec{a} = 0$

f) Book B $\vec{F}_{net} = 0$

g) Book C $\vec{a} = 0$

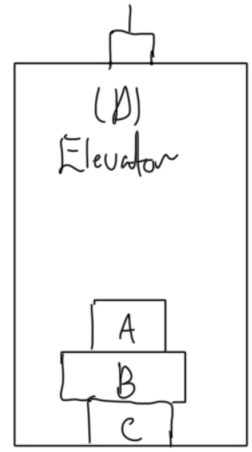
h) Book C $\vec{F}_{net} = 0$

$A = 1.5\,kg$

$B = 0.9\,kg$

$C = 1.2\,kg$

$E = 1200\,kg$



Book (A)

2

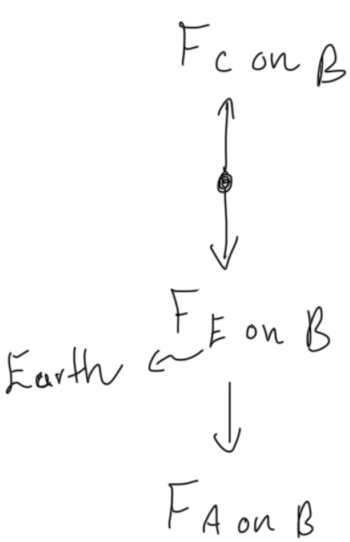
$\underbrace{F_{E\ on\ A}}_{gravity}$

$F_{E\ on\ A} = -mg = 1.5 \times -9.8 = \boxed{-14.7\,N}$

$F_{A\ on\ E} = -F_{E\ on\ A} = \boxed{+14.7\,N}$

3

Book (B)



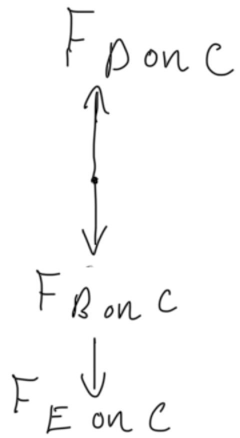
$F_{E\ on\ B} = 0.9 \times 9.8 = \boxed{-8.82\,N}$

$F_{A\ on\ B} = 1.5 \times 9.8 = \boxed{-14.7\,N}$

$F_{C\ on\ B} = +8.82\,N + 14.7\,N$

$= \boxed{23.52\,N}$

$\boxed{4}$ Book (c)



$F_{B \text{ on } C} = \boxed{-23.52\,N}$

$F_{E \text{ on } C} = 1.2 \times 9.8 = \boxed{-11.76\,N}$

$F_{D \text{ on } C} = +23.52 + 11.76$

$= \boxed{35.28\,N}$

$\boxed{5}$ Elevator

$F_{E \text{ on } D} = 1200 \times -9.8 = \boxed{-11{,}760\,N}$

$F_{C \text{ on } D} = \boxed{-35.28\,N}$

$F_{T \text{ on } E} = 35.28 + 11{,}760$

$= \boxed{11{,}795.28\,N}$

$\boxed{1.6.2}$

since velocity is constant, $a = 0\,m/s^2$ ... that means these questions has the same answer as $\boxed{1.6.1}$ ... the Elevator represents an inertial frame...

1.6.3 An Accelerating Elevator

Now consider the situation that our same elevator is traveling upwards at a speed of 2 m/s, but accelerating downwards with an acceleration $a = 1$ m/s^2.

1. In this case, does the elevator represent an inertial frame? Explain your answer.
2. What is the net force on book A? What about the net forces on book B and book C?
3. What is the net force on the elevator?
4. Now draw and label free body diagrams for the three books as well as the elevator in this scenario. Once again, be sure to label the magnitudes of all the forces.

1.6.4 A Dropped Book

Now let's imagine a completely different scenario, in which a book is dropped and free falls straight to the ground.

1. Draw a qualitative free body diagram illustrating the forces acting on the book the instant before it strikes the ground. Be sure to name all forces! What is the direction of the acceleration of the book in this instant?
2. Now draw and label a qualitative free body diagram illustrating the forces acting on the book as it hits the ground. What is the the direction of the acceleration of the book at this point in time?
3. Now draw and label a qualitative free body diagram illustrating the forces acting on the book after it has come to rest on the ground. What is the the direction of the acceleration of the book at this point in time?
4. Would any of your free body diagrams change if, instead of being dropped, the book were thrown forward? If so, which ones? (Hint: what is the direction of the acceleration now required to being this book to a stop on the floor?)
5. Would any of your free body diagrams change if, instead of being dropped, the book were thrown straight upward? If so, which ones?

$\boxed{1.6.3}$

$\boxed{1}$ the elevator isn't an inertial frame anymore because $a \neq 0\ m/s^2$

$\boxed{2}$ Since $a = -1\ m/s^2$, then all bodies has a net force equal to $\boxed{ma}$

Book A $\vec{F}_{net} = 1.5 \times -1 = \boxed{-1.5\ m/s^2}$

Book B $\vec{F}_{net} = 0.9 \times -1 = \boxed{-0.9\ m/s^2}$

Book c $\vec{F}_{net} = 1.2 \times -1 = \boxed{-1.2\ m/s^2}$

$\boxed{3}$ Elevator $\vec{F}_{net} = 1200 \times -1 = \boxed{-1200\ m/s^2}$

$\boxed{4}$

(A)

$F_n = 14.7 - 1.5$

$\boxed{= 13.2\ N}$

$F_{gA} = -14.7 N$

(B)

$F_n = 22.02 - 0.9$

$= \boxed{21.12 N}$

$F_{gB} = -8.82 N$

$F_{A\ on\ B} = -13.2 N$

(C)

$F_n = 32.88 - 1.2$

$= \boxed{31.68 N}$

$F_{gC} = -11.76 N$

$F_{B\ on\ C} = -21.12 N$

(D)

$F_T = 11.791.68 - 1200$

$= \boxed{10.591.68 N}$

$F_g = -11,760 N$

$F_{C\ on\ E} = -31.68 N$

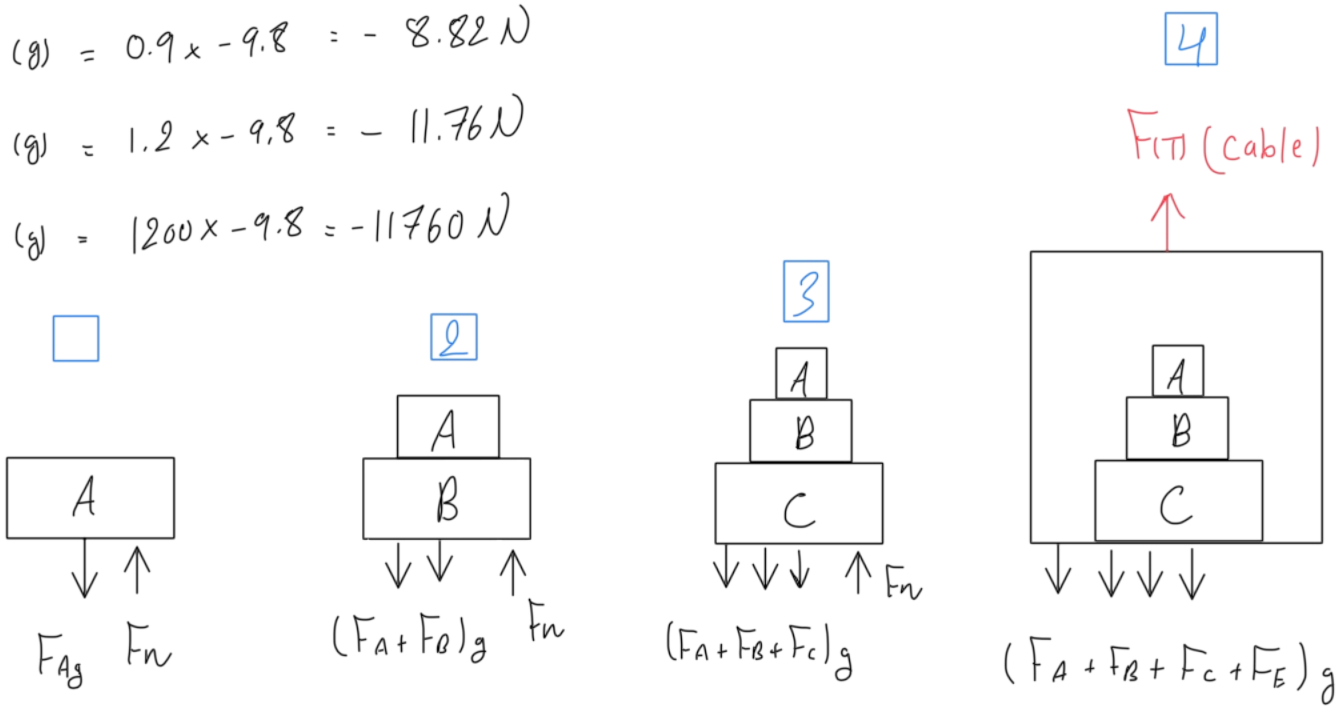
$\boxed{1.6.1}$ & $\boxed{1.6.3}$

$F_{A(g)} = 1.5 \times -9.8 = -14.7N$

$F_{B(g)} = 0.9 \times -9.8 = -8.82N$

$F_{C(g)} = 1.2 \times -9.8 = -11.76N$

$F_{E(g)} = 1200 \times -9.8 = -11760N$



$a = 0 \Rightarrow F_{net} = 0$

$\boxed{1}$

$F_{net} = m_{total} \times a$

$F_n - F_{Ag} = m_A \times 0$

$F_n - 14.7 = 0$

$F_n = 14.7N$

$\boxed{2}$

$F_{net} = m_{total} \times a$

$F_n - F_{Ag} - F_{Bg} = (m_A + m_B) \times 0$

$F_n - 14.7 - 8.82 = 0$

$F_n = 23.52N$

$\boxed{3}$

$F_{net} = m_{total} \times a$

$F_n - F_{Ag} - F_{Bg} - F_{cg} = (m_A + m_B + m_C) \times 0$

$F_n - 14.7 - 8.82 - 11.76 = 0$

$F_n = 35.28N$

$a = -1 \Rightarrow F_{net} \neq 0 \quad F_{net} = \text{negative}$

$\boxed{1}$

$F_{net} = m_{total} \times a$

$F_n - F_{Ag} = m_A \times -1$

$F_n - 14.7 = 1.5 \times -1$

$F_n = 13.2N$

$\boxed{2}$

$F_{net} = m_{total} \times a$

$F_n - F_{Ag} - F_{Bg} = (m_A + m_B) \times -1$

$F_n - 14.7 - 8.82 = (1.5 + 0.9) \times -1$

$F_n = 21.12 N$

$\boxed{3}$

$F_{net} = m_{total} \times a$

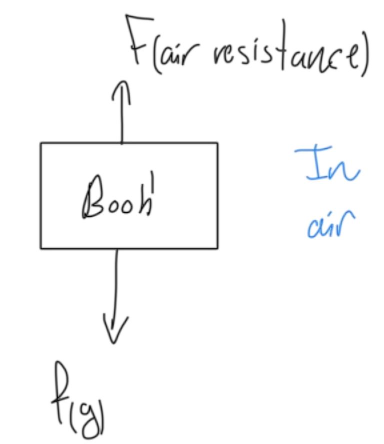
$F_n - F_{Ag} - F_{Bg} - F_{cg} = (m_A + m_B + m_C) \times -1$

$F_n - 14.7 - 8.82 - 11.76 = (1.5 + 0.9 + 1.2) \times -1$

$F_n = 31.68N$

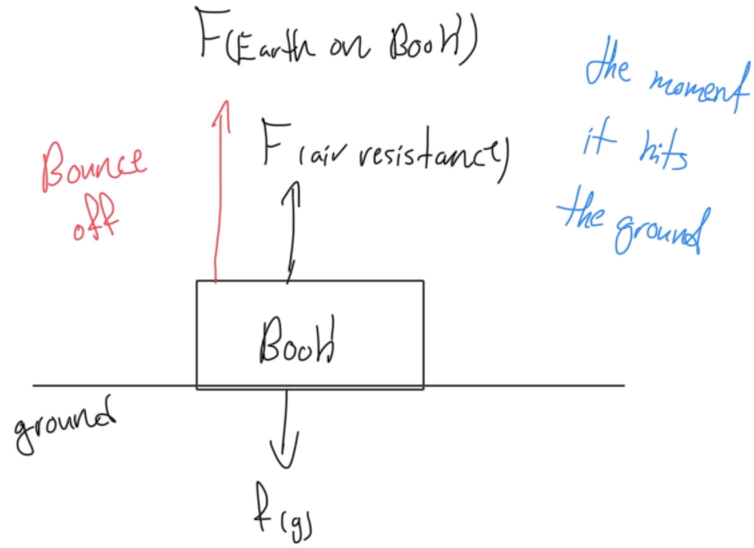
1.6.4

1



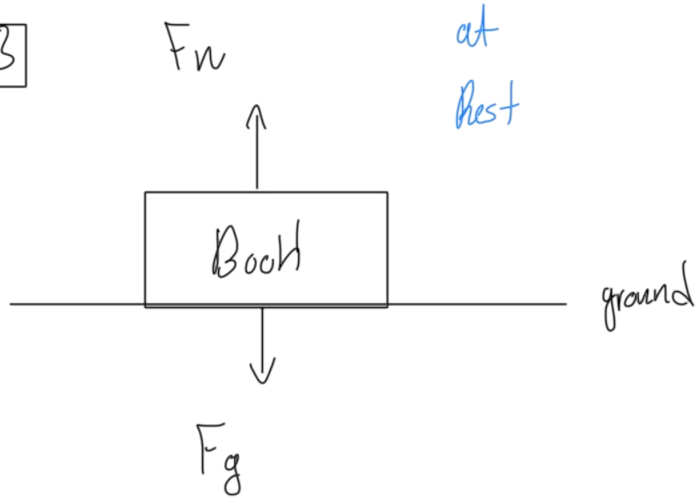
(acceleration downward)

2



(acceleration upward)

3



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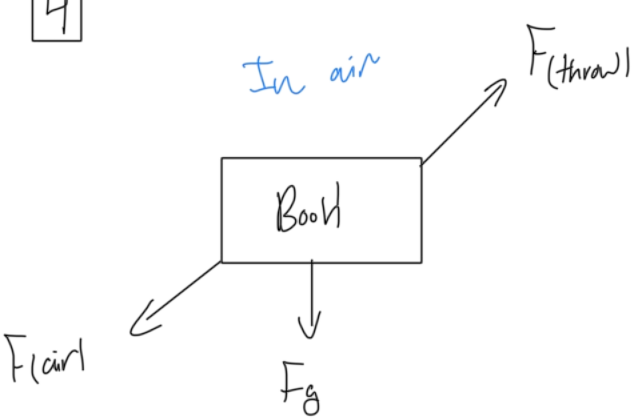
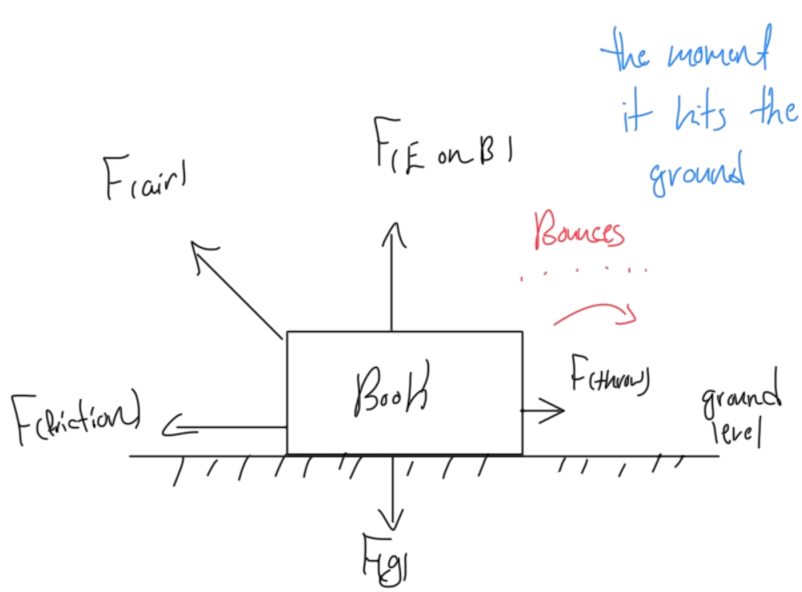
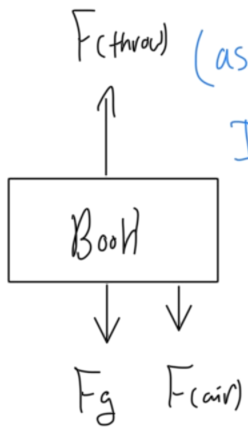
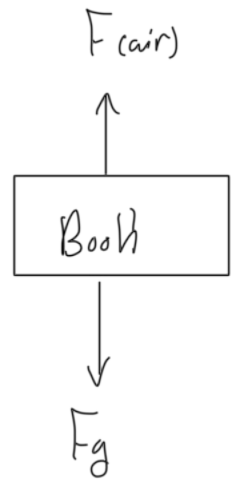




$\boxed{5}$



(ascending)
In air



descending
In air