Chapter 6 – Dynamics in 1D

- Applying Newton's 2nd Law
  - equilibrium (no acceleration)
  - constant net force (acceleration)
- Mass, weight and gravity
- Friction
  - static friction and kinetic friction
- Drag
- Solving problems with Newton's 2nd Law

1

Newton's 2nd Law

2

PROBLEM-SOLVING APPROACH 5.1 Equilibrium problems

STRATEGIZE If an object is in equilibrium, the net force acting on it must be zero. We will use this fact to find the forces that keep it in equilibrium.

PREPARE First check that the object is in equilibrium: Does $\vec{a} = \vec{0}$?

- An object at rest is in static equilibrium.
- An object moving at a constant velocity is in dynamic equilibrium.

Then identify all forces acting on the object and show them on a free-body diagram. Determine which forces you know and which you need to solve for.

SOLVE An object in equilibrium must satisfy Newton's second law for the case where $\vec{a} = \vec{0}$. In component form, the requirement is

$$\sum F_x = ma_x = 0 \quad \text{and} \quad \sum F_y = ma_y = 0$$

You can find the force components that go into these sums directly from your free-body diagram. From these two equations, solve for the unknown forces in the problem.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

PROBLEM-SOLVING APPROACH 5.2 Dynamics problems

Dynamics problems use Newton's second law as the connection between forces and kinematics.

STRATEGIZE There are two basic kinds of dynamics problems. If the forces on the object are known, you can use Newton's second law to find the acceleration and then, from kinematics, the object's position and velocity. In other cases, you can calculate the object's acceleration from kinematics; using the acceleration, you can apply Newton's second law to find the forces acting on the object. In both kinds of problems the approach to the solution is the same.

PREPARE Sketch a visual overview consisting of:

- A list of values that identifies known quantities and what the problem is trying to find.
- A force identification diagram to help you identify all the forces acting on the object.
- A free-body diagram that shows all the forces acting on the object.

If you'll need to use kinematics to find velocities or positions, you'll also need to sketch:

- A motion diagram to determine the direction of the acceleration.
- A pictorial representation that establishes a coordinate system, shows important points in the motion, and defines symbols.

It's OK to go back and forth between these steps as you visualize the situation.

SOLVE Write Newton's second law in component form as

$$\sum F_x = ma_x \quad \text{and} \quad \sum F_y = ma_y$$

You can find the components of the forces directly from your free-body diagram. Depending on the problem, either:

- Solve for the acceleration, then use kinematics to find velocities and positions.
- Use kinematics to determine the acceleration, then solve for unknown forces.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

3

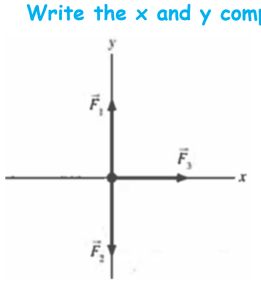
If an object is at rest, can you conclude that there are no forces acting on it?

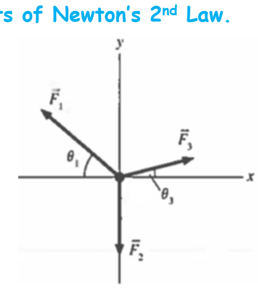
If a force is exerted on an object, is it possible for that object to be moving with constant velocity?

5.1-5.2

4

Write the x and y components of Newton's 2nd Law.





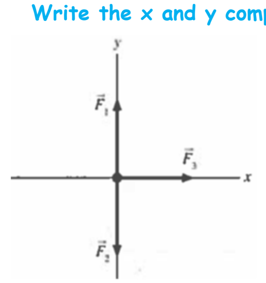
$\sum F_x =$ ______________ $= ma_x$ $\qquad$ $\sum F_x =$ ______________ $= ma_x$

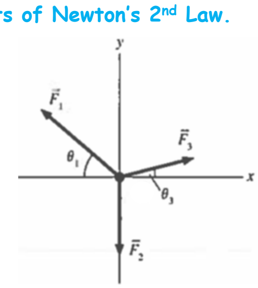
$\sum F_y =$ ______________ $= ma_y$ $\qquad$ $\sum F_y =$ ______________ $= ma_y$

5.8

5

Write the x and y components of Newton's 2nd Law.





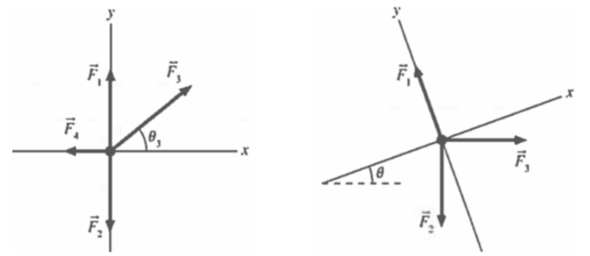
$\sum F_x = F_3 = ma_x$ $\qquad$ $\sum F_x = F_3 \cos\theta_3 - F_1 \cos\theta_1 = ma_x$

$\sum F_y = F_1 - F_2 = ma_y$ $\qquad$ $\sum F_y = F_3 \sin\theta_3 + F_1 \sin\theta_1 - F_2 = ma_y$

5.8

6

Write the x and y components of Newton's 2nd Law.



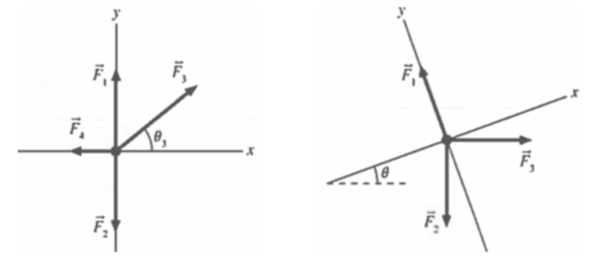
$\sum F_x =$ ______________ $= ma_x$ $\sum F_x =$ ______________ $= ma_x$

$\sum F_y =$ ______________ $= ma_y$ $\sum F_y =$ ______________ $= ma_y$

5.9 PHYS 21: Chap. 6, Pg 7

7

Write the x and y components of Newton's 2nd Law.



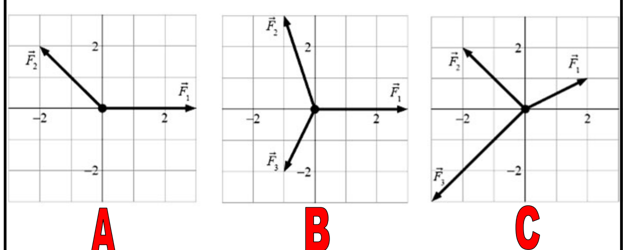
$\sum F_x = F_3\cos\theta_3 - F_4 = ma_x$ $\sum F_x = -F_2\sin\theta + F_3\cos\theta = ma_x$

$\sum F_y = F_1 - F_2 + F_3\sin\theta_3 = ma_y$ $\sum F_y = F_1 - F_2\cos\theta - F_3\sin\theta = ma_y$

5.9 PHYS 21: Chap. 6, Pg 8

8

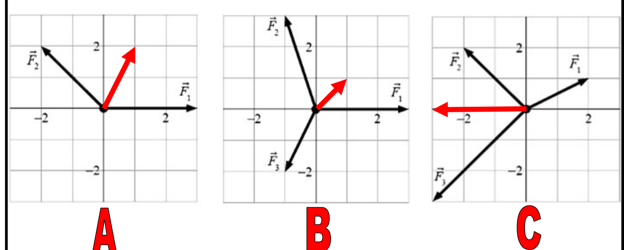
Draw a vector to show the net force — it should be on the grid and have the correct length. Then find a_x and a_y given that m = 2 kg.



6.7-6.9 PHYS 21: Chap. 6, Pg 9

9

Draw a vector to show the net force — it should be on the grid and have the correct length. Then find a_x and a_y given that m = 2 kg.



A: a_x = 0.5 m/s^2, a_y = 1.0 m/s^2

B: a_x = 0.5 m/s^2, a_y = 0.5 m/s^2

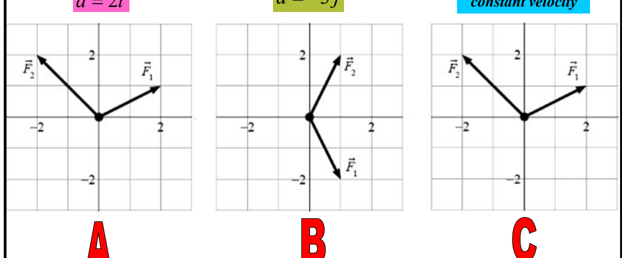
C: a_x = −1.5 m/s^2, a_y = 0.0 m/s^2

6.7-6.9 PHYS 21: Chap. 6, Pg 10

10

Three forces act on a 1 kg object to accelerate it as shown. Draw in the missing force vector.

$\vec{a} = 2\hat{i}$ $\vec{a} = -3\hat{j}$ constant velocity

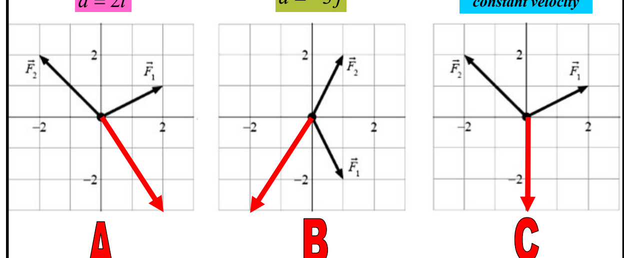


6.10-6.12 PHYS 21: Chap. 6, Pg 11

11

Three forces act on a 1 kg object to accelerate it as shown. Draw in the missing force vector.

$\vec{a} = 2\hat{i}$ $\vec{a} = -3\hat{j}$ constant velocity



6.10-6.12 PHYS 21: Chap. 6, Pg 12

12

A **20 kg** loudspeaker is suspended **2 m** below the ceiling by a vertical cable. **What is the tension in the cable?**

T = 196 N

A **20 kg** loudspeaker is suspended **2 m** below the ceiling by two vertical cables.

What is the tension in each cable?

T = 98 N

A **20 kg** loudspeaker is suspended **2 m** below the ceiling by two cables that are each **30°** from vertical.

What is the tension in each cable?

T = 113 N

3+2:5 5.3, 5.19

PHYS 21: Chap. 6, Pg 13

13

PHYS 21: Chap. 6, Pg 14

14

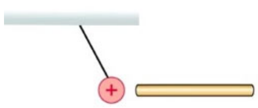
In an electricity experiment, an electrically charged plastic ball (mass = **100 g**) is suspended on a **60 cm** long string. When a charged rod is brought near the ball, the rod exerts a horizontal electrical force F_{elec} on it, causing the ball to swing out to a **20°** angle and remain at rest there.

What is the magnitude of the electric force F_{elec}?

F_{elec} = 0.36 N

What is the tension in the string?

T = 1.04 N



3+2:5 6.29

Draw a free-body diagram!!

PHYS 21: Chap. 6, Pg 15

15

In an electricity experiment, an electrically charged plastic ball (mass = **100 g**) is suspended on a **60 cm** long string. When a charged rod is brought near the ball, the rod exerts a horizontal electrical force F_{elec} on it, causing the ball to swing out to a **20°** angle and remain at rest there.

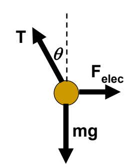
What is the magnitude of the electric force F_{elec}? F_{elec} = 0.36 N

What is the tension in the string? T = 1.04 N

SOLUTION

$$\sum F_x = F_{elec} - T\sin\theta = 0 \quad \Rightarrow \quad F_{elec} = T\sin\theta$$

$$\sum F_y = T\cos\theta - mg = 0 \quad \Rightarrow \quad mg = T\cos\theta$$



$$T = \frac{mg}{\cos\theta} = \frac{(0.1kg)g}{\cos(20°)} = 1.04N$$

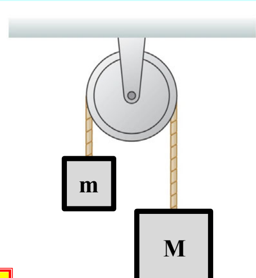
$$F_{elec} = T\sin\theta = \left(\frac{mg}{\cos\theta}\right)\sin\theta = mg\tan\theta = 0.36N$$

PHYS 21: Chap. 6, Pg 16

16

Two blocks (M > m) are connected by a string passing over a pulley. The heavy block (M) is falling and pulling the lighter block up.

Set up the equations for Newton's 2nd Law for each block.



Draw a free-body diagram!!

3+2:5

PHYS 21: Chap. 6, Pg 17

17

Two blocks (M > m) are connected by a string passing over a pulley. The heavy block (M) is falling and pulling the lighter block up.

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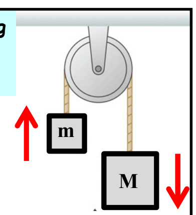


$$\sum F_y = T - mg = ma \qquad \sum F_y = T - Mg = -Ma$$

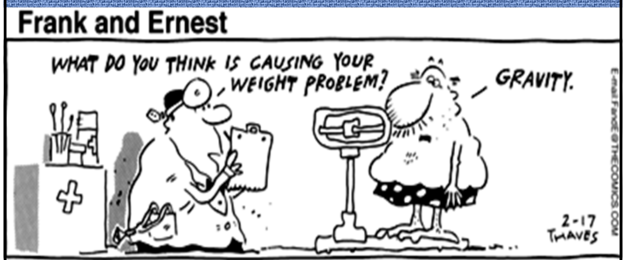
$$T = mg + ma \qquad T = Mg - Ma$$

$$mg + ma = Mg - Ma$$

now solve for acceleration a

PHYS 21: Chap. 6, Pg 18

18



19

Mass and Weight

20

ConcepTest 1 — Mass and Weight

An astronaut on Earth kicks a bowling ball and hurts his foot. A year later, the same astronaut kicks a bowling ball on the Moon with the same force. His foot hurts ...

1. more
2. less
3. the same

$F_{grav} = \text{"weight"} = mg$

0 of 5

21

Suppose you had a flying platform that can move straight up and down. For each of the cases below, is your apparent weight equal to, greater than, or less than your true weight?

a) ascending and speeding up — N > W

b) descending and speeding up — N < W

c) ascending at constant speed — N = W

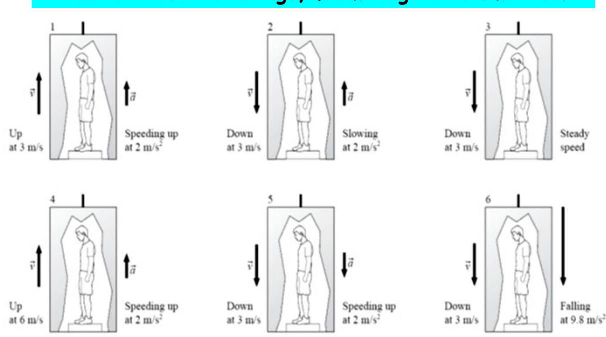
d) ascending and slowing down — N < W

e) descending and slowing down — N > W

5.16 — PHYS 11: Chap. 5, Pg 22

22

You stand on a scale in six elevators moving as shown. Rank the scale readings, from largest to smallest.



(1=2=4) > 3 > 5 > 6

5.19 — PHYS 21: Chap. 6, Pg 23

23