Chapter 5 – Force and Motion

- What is force?
  - different types of forces
- What do forces do?
  - acceleration and mass
- Newton's 2nd Law
  - acceleration ➡ force and mass
- Newton's 1st Law
  - inertia
- Free-body diagrams

PHYS 22: Chap. 26, Pg 1

1

Force and Newton's Laws

2

Newton's Laws

1) An object continues in its state of rest, or its state of uniform velocity, as long as no net force acts on it. (also known as the Law of Inertia)

2) $\sum \vec{F} = m\vec{a}$ What does $\sum \vec{F}$ represent?

3) When Object A exerts a force on Object B, then B exerts an equal and opposite force on A.

$$\vec{F}_{AonB} = -\vec{F}_{BonA}$$

PHYS 22: Chap. 26, Pg 3

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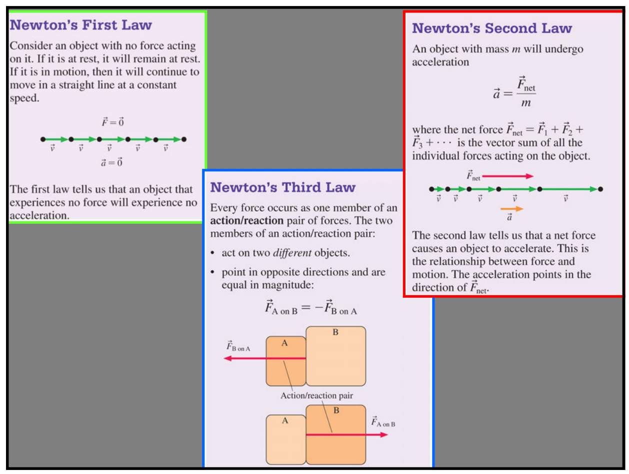

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Newton's First Law

- What is the "natural" tendency of matter?
  - old thinking: natural state is to be at rest
    - objects tend to stop if they are in motion
  - new thinking: natural state is to resist acceleration
    - objects tend to remain in their initial state

- An object will remain at rest or at constant velocity unless acted upon by a <u>net</u> external force.

  - If there is no <u>net</u> force, there is no acceleration.

How Things Work: Sec. 1.1, Pg 5

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<u>Catalog of Forces</u>

1)	1) Gravity
2)	2) Spring force (elastic)
3)	3) Tension (string or rope)
4)	4) Normal force (⊥ to a surface)
5)	5) Friction (static or kinetic)
6)	6) Drag (air or fluid resistance)
7)	7) Thrust (rocket, propeller, fan,…)
8)	8) Electric or magnetic force
9)	
10)	

PHYS 22: Chap. 26, Pg 6

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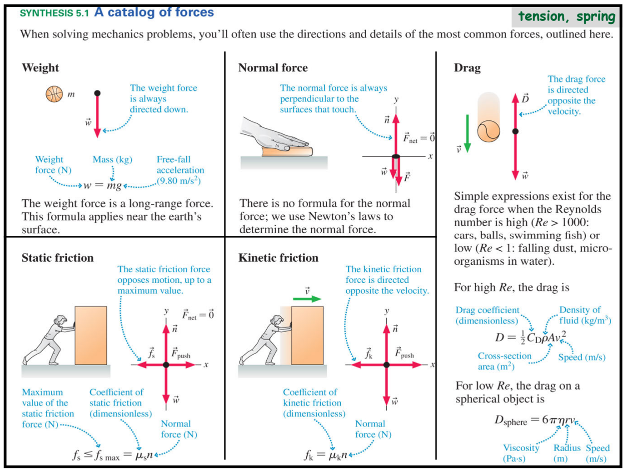

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A Tour de Force

- A force is a push or a pull that acts on an object
  - Contact forces
    - objects in contact exert forces on each other
      - » you push on a box
      - » air pushes on a car (air resistance)
      - » tension in a rope
  - Action at a distance
    - gravity
    - electricity
    - magnetism

How Things Work: Sec. 1.1, Pg 8

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Newton's First Law

1 Law of Inertia: Objects resist change in motion

Objects do not resist motion, but change in motion

How much do they resist? It depends on their MASS.
The more massive an object, the more resistant it will be.

Easy to push | Hard to push

Mass: How much "stuff" (matter) an object has.

How Things Work: Sec. 1.1, Pg 9

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Inertia

Mass is an intrinsic property of a body that determines its resistance to acceleration

Inertia: resistance to change in motion
i.e. resistance to acceleration

Mass is a measure of inertia

Is mass the same as: weight ? NO
size? NO
density? NO

Our everyday experience of mass comes mainly from trying to *accelerate* things

How Things Work: Sec. 1.1, Pg 10

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Physics Concept

- Inertia
  - A body at rest tends to remain at rest
  - A body in motion tends to remain in motion

A study of inertia: a physics student at rest

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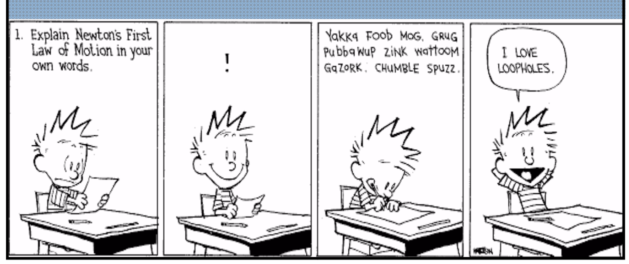
Newton's 1st Law in action!



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ConcepTest 4 — Newton's First Law

You kick a smooth flat stone out on a frozen pond. The stone slides, slows down, and then eventually stops. You conclude that:

1. the force pushing the stone forward finally stopped pushing on it
2. no net force acted on the stone
3. a net force acted on it all along
4. the stone simply "ran out of steam"
5. the stone has a natural tendency to be at rest

After the stone was kicked, no force was pushing it along! However, there must have been some force acting on the stone to slow it down and stop it. This would be friction!!

0 of 5

PHYS 21: Chap. 1, Pg 13

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ConcepTest 4b — Friction

Can a frictional force ever act in the same direction as the motion of an object?

1. yes
2. no
3. I am not really sure

0 of 5

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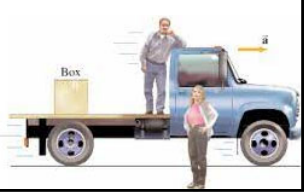
A box is sitting in the back of a flatbed truck.

a) If the truck gently accelerates, the box moves with the truck without slipping. Specifically, what is the force that makes the box move?

b) What happens if the truck accelerates too rapidly? Explain what is happening and why.

c) What would happen to the box if the truck bed was just a very smooth sheet of ice?



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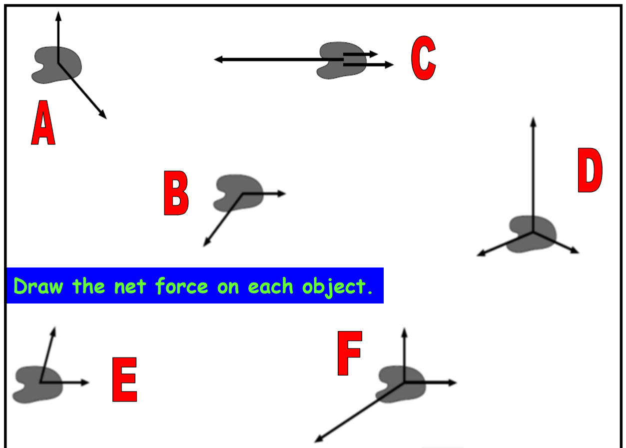

5.1,2,14 PHYS 21: Chap. 5, Pg 16

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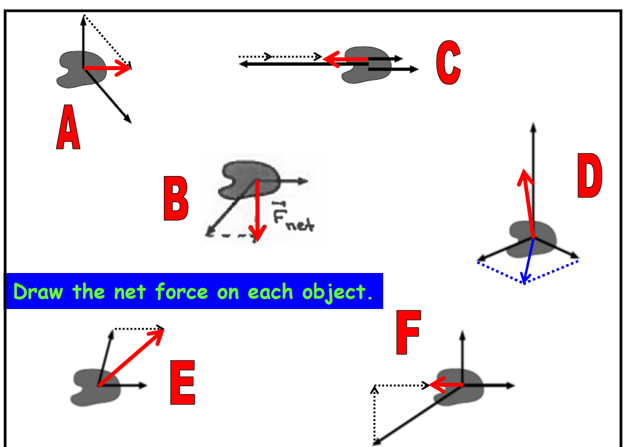

4.2-4.3

PHYS 21: Chap. 5, Pg 17

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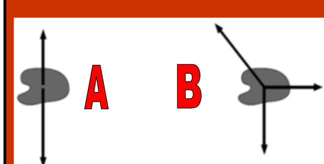
ConcepTest 2 — Forces

Which object is in equilibrium?

1. A
2. B
3. both
4. neither

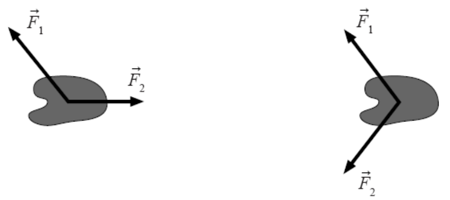


0 of 5

PHYS 21: Chap. 5, Pg 18

18

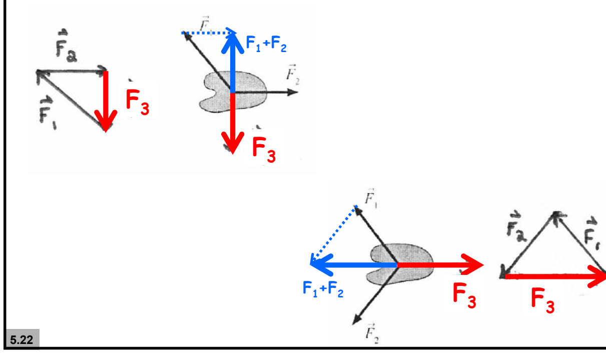
Two forces are shown acting on each object. Draw a third force such that the object is in equilibrium.



5.22 PHYS 21: Chap. 5, Pg 19

19

Two forces are shown acting on each object. Draw a third force such that the object is in equilibrium.



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Newton's 2nd Law

PHYS 22: Chap. 26, Pg 21

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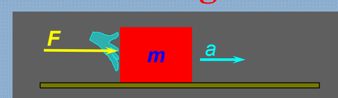
Pushing a box



- consider pushing a box
  - more force leads to more acceleration → $a \propto F$
  - more mass leads to less acceleration → $a \propto 1/m$

conclude that: $a \propto F/m$

How Things Work: Sec. 1.1, Pg 22

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Newton's Second Law

$\sum F = ma$

Acceleration is proportional to the *net* force applied

The constant of proportionality is the mass.
(Definition of mass can be thought of as m = F/a)

Remember from Newton's 1st Law
- mass is a measure of inertia
- an object's *"resistance"* to acceleration

The mass of an object is an intrinsic property
- it is independent of external influences
- mass is different from weight

How Things Work: Sec. 1.1, Pg 23

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ConcepTest 2 Forces

A steady force applied to a 2 kg mass causes it to accelerate at 4 m/s². If the same force is applied to a 4 kg mass, what is the resulting acceleration?

1. 1 m/s²
2. 2 m/s²
3. 4 m/s²
4. 8 m/s²
5. 16 m/s²

0 of 5

PHYS 11: Chap. 4, Pg 24

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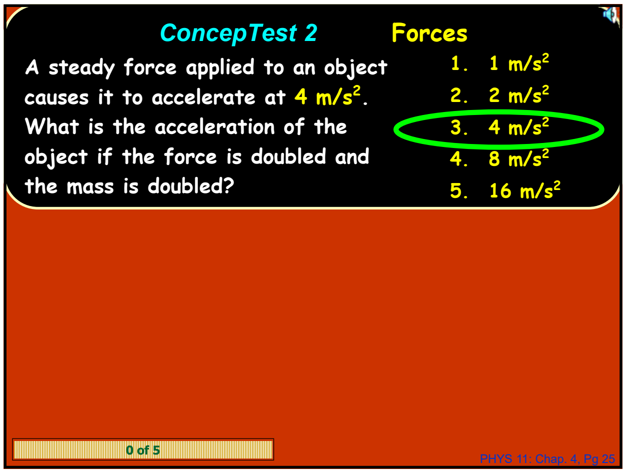

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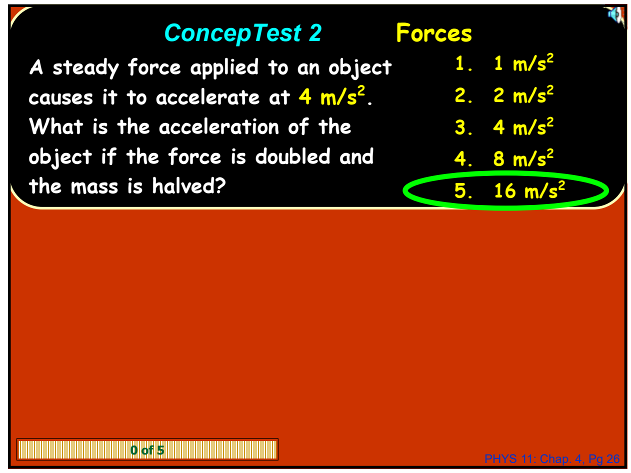

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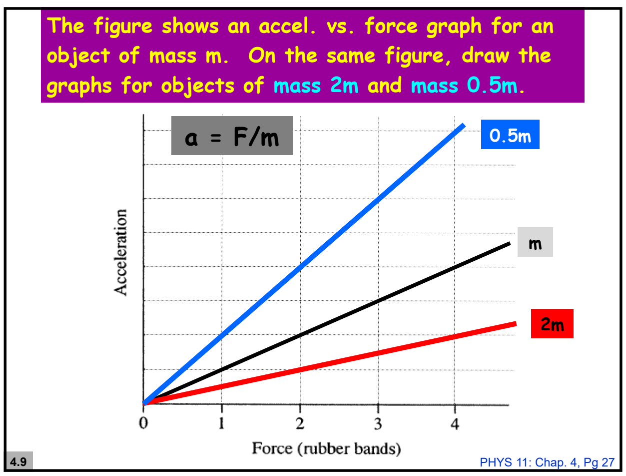

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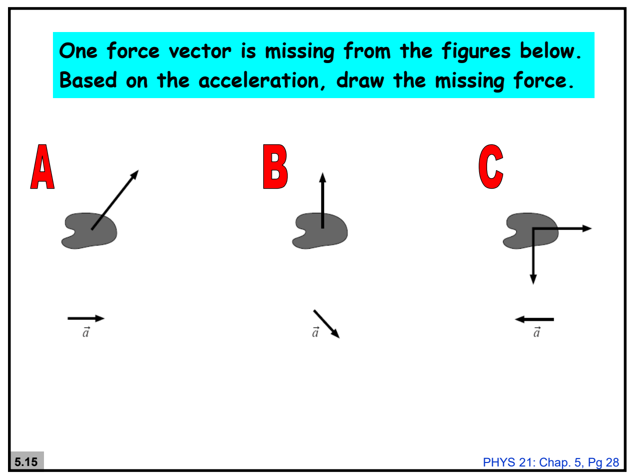

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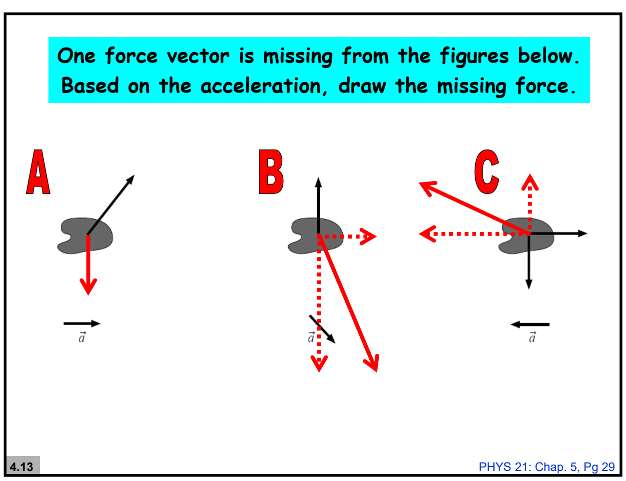

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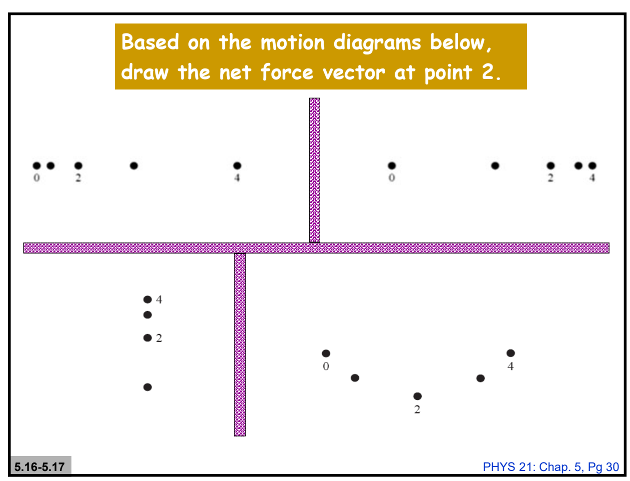

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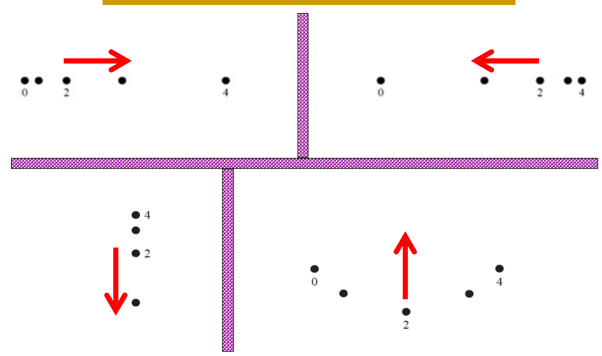
Based on the motion diagrams below, draw the net force vector at point 2.



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Free-Body Diagrams

32

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) An elevator suspected by a cable is descending at constant velocity

2) A car on a very slippery icy road is sliding headfirst into a snowbank, where it gently comes to rest with no one injured.

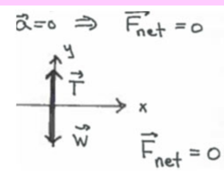
3) A compressed spring is pushing a block across a rough horizontal table at a steadily increasing speed.

4) A brick is falling from the roof of a three-story building.

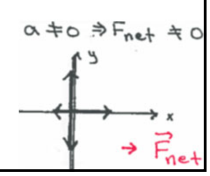
33

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) An elevator suspended by a cable is descending at constant velocity.

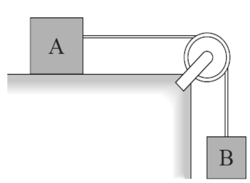


3) A compressed spring is pushing a block across a rough horizontal table at a steadily increasing speed.



34

Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a rough surface.
Draw a free-body diagram for each block.



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Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a rough surface.
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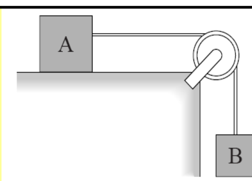
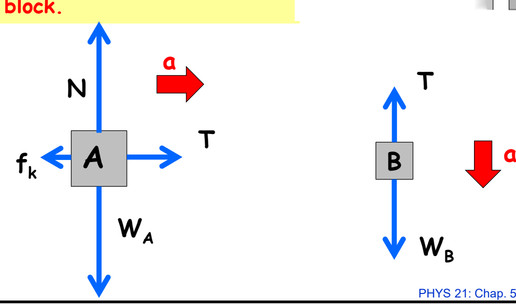
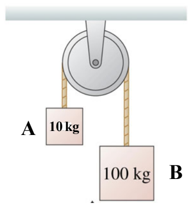




36

Blocks A and B are connected by a string passing over a pulley. Block B is falling and pulling block A up. Draw a free-body diagram for each block.

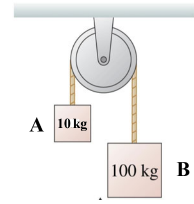


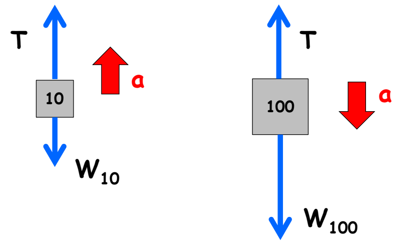
4.22

PHYS 21: Chap. 5, Pg 37

37

Blocks A and B are connected by a string passing over a pulley. Block B is falling and pulling block A up. Draw a free-body diagram for each block.





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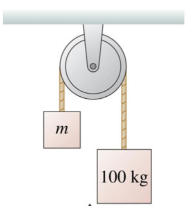
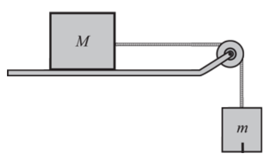
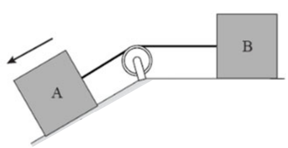
38

Draw separate free-body diagrams for these cases.







PHYS 21: Chap. 5, Pg 39

39

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) A heavy crate is being lowered straight down at constant speed by a steel cable.

2) A boy is pushing a box across the floor at a steadily increasing speed.

3) A bicycle is coasting down a hill and speeding up. Friction is negligible, but air resistance is not.

4) You've slammed on the car brakes while going down a hill, and you are skidding to a halt.

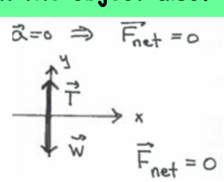
5.24-5.27

PHYS 21: Chap. 5, Pg 40

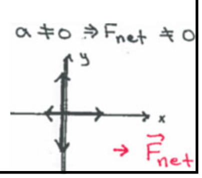
40

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) A heavy crate is being lowered straight down at constant speed by a steel cable.



2) A boy is pushing a box across the floor at a steadily increasing speed.

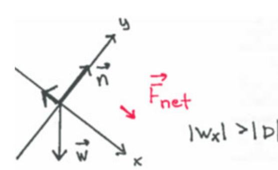


4.17-4.20

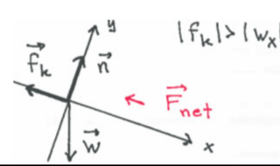
41

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

3) A bicycle is speeding up as it goes down a hill. Friction is negligible, but air resistance is not.



4) You've slammed on the car brakes while going down a hill, and you are skidding to a halt.



4.17-4.20

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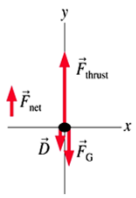
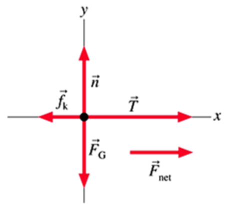
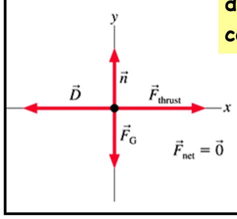
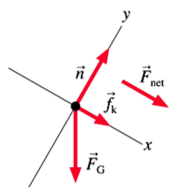


Write a short description of a real object to which these free-body diagrams correspond.







PHYS 21: Chap. 5, Pg 43

43

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) An elevator, suspended by a cable, has just left the 10th floor and is speeding up as it descends.

2) A jet plane is speeding down the runway during takeoff. Air resistance is not negligible.

3) You've just kicked a rock on the sidewalk and it is now sliding along the concrete.

4) A styrofoam ball has just been shot straight up. Air resistance is not negligible.

PHYS 21: Chap. 5, Pg 44

44

Draw a free-body diagram for each case. Be sure to show the net force on the object also.

1) A spring-loaded gun shoots a plastic ball. The trigger has just been pulled and the ball is starting to move down the horizontal barrel.

2) A person on a bridge throws a rock straight down toward the water. The rock has just been released.

3) A gymnast has just landed on a trampoline. She is still moving downward as the trampoline stretches.

4) A rocket is being launched straight up. Air resistance is not negligible.

PHYS 21: Chap. 5, Pg 45

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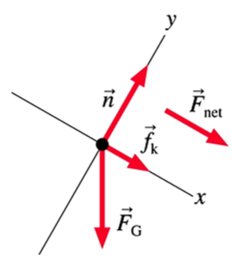
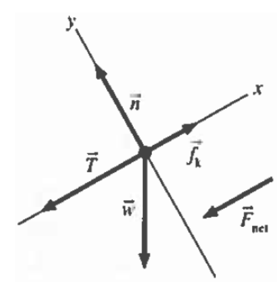
Write a description to match the free-body diagrams. Show the direction of the acceleration of the object.





4.31-4.32

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