Physics 185F2013 Lecture Two

October 1, 2013

Dr. Jones[1]

[1]Department of Physics
Drexel University

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- Mass is the property of an object that corresponds to it's resistance to a change in velocity.
- Velocity is not the same as speed. Velocity is speed plus direction. A car going 20 mph is not necessarily the same as a car going 20 mph North.
- If two objects with different masses are going the same speed, the one with the higher mass has more momentum.

What is mass?

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Suppose you are floating in deep space with no gravity. Two identically painted red spheres are in front of you. One is made of lead, the other is made of a light plastic. How can you tell which is which?

Give each sphere an equal push with your finger. That push is called a force. The lead sphere will travel away from you at a much slower speed than the plastic sphere.

What is mass?

In the presence of gravity, objects with more mass will weigh more. If a bowling ball and a ping-pong ball were to hit you at the same speed, which would hurt more?

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- Average speed: $s = \frac{\Delta x}{\Delta t}$, the average speed over an entire trip; Instantaneous speed: $\frac{dx}{dt}$, how fast something is going at any given time.
- To make speed a velocity, add a direction. $v = 20$m/s North.

Newton's First Law

> "Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon."
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Objects at rest stay at rest, and objects in motion along a straight line stay at the same speed and same direction; unless an outside force acts on said objects.

Newton's Second Law

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$$\mathrm{F} = \mathrm{ma}$$

Here a means acceleration, and is the rate of change of the velocity of an object: $\mathrm{a} = \frac{\mathrm{dv}}{\mathrm{dt}}$.

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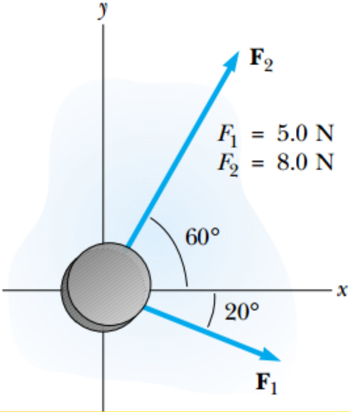
These pairs of forces are called action-reaction pairs. Note that they happen on two different bodies, not on the same body.

Our first physics problem

Forces are measured in Newtons N. A hockey puck is hit by two players at different angles as seen in the figure. Find the net force in the x direction.



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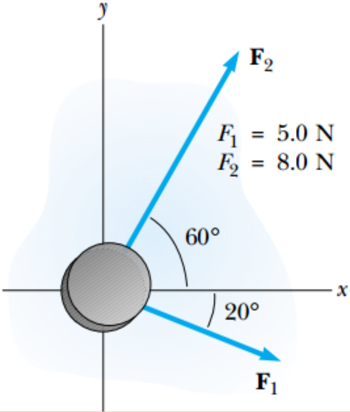
$$\begin{aligned} F_x &= F_1 \cos(-20) + F_2 \cos(60) \\ &= (5.0 \cos(-20) + 8.0 \cos(60))\ \text{N} \\ &= 4.69\ \text{N} + 4\ \text{N} = 8.7\ \text{N} \end{aligned}$$



Our second physics problem

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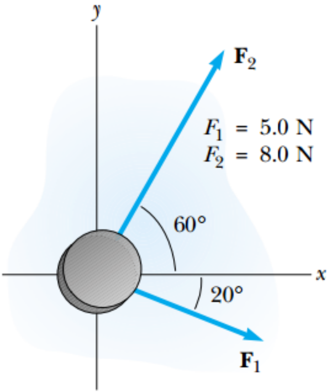

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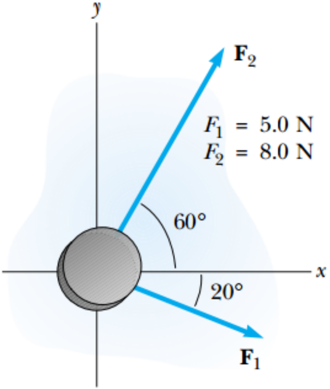
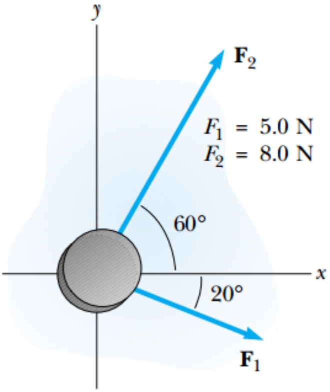
$$\begin{aligned} F_y &= F_1 \sin(-20) + F_2 \sin(60) \\ &= (5.0 \sin(-20) + 8.0 \sin(60))\ \text{N} \\ &= 5.2\ \text{N} \end{aligned}$$



Our third physics problem

Find the net
force acting on the hockey puck.



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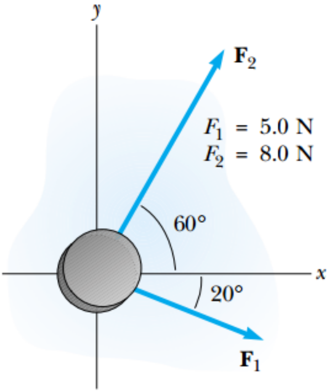
We can use
something called vector notation. Everything in the x-direction gets labeled with a i-hat, which indicates that it is a vector in the x direction; in the y-direction we label is j-hat, which indicates that it is a vector in the y direction.

$$F = 8.7\mathrm{N}\hat{\imath} + 5.2\mathrm{N}\hat{\jmath}$$



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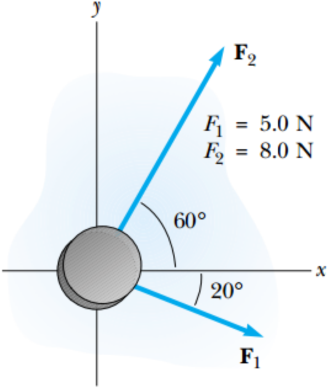


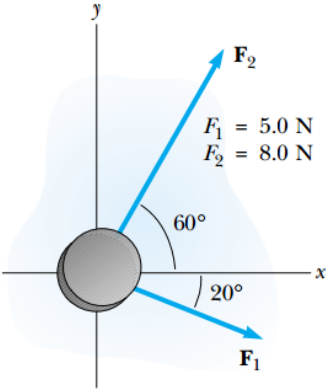
Our third physics problem

Find the net
force acting on the hockey puck.

We can also use the
Pythagorean theorem to express
the direction conventionally:

$$\mathrm{F} = \sqrt{8.7^2 + 5.2^2} = 10.\mathrm{N}$$

at an
angle of $\theta = \tan^{-1}(5.2/8.7) = 31°$.



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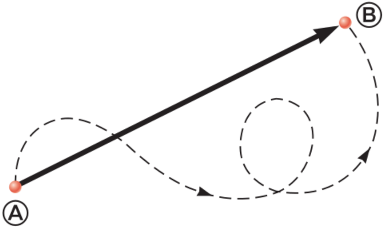
Displacement, Force, velocity, $\cdots$

Distance verses Displacement

In the figure
at left, distance traveled would be
the full length of the curved line.



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The displacement
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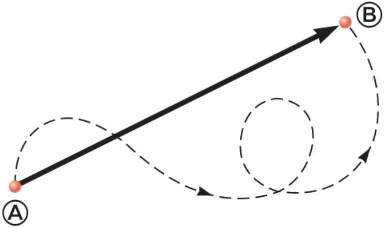

Newton's Laws in one statement

$$F = \frac{d\vec{p}}{dt}$$

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In most cases, we deal with systems where the mass of an object doesn't change so that

$$\frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}$$

acceleration is a vector–it has direction, an object gets faster in a certain direction.

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Can you think of examples where the mass of an object would change?

Rocket, bag of rice with a hole in it rolling down a hill, $\cdots$

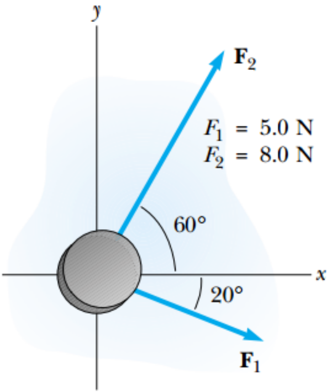
Equilibrium

Mechanical Equilibrium

An object is in mechanical equilibrium if the sum of all the forces acting on the object is zero, that is, if all the forces acting on an object cancel out, or if there are no forces acting on the body. $\sum \mathrm{F} = 0$.

Lecture problem 4:

Consider the hockey puck from our previous problems, What force must we use to put the puck into equilibrium?



Lecture problem 4:

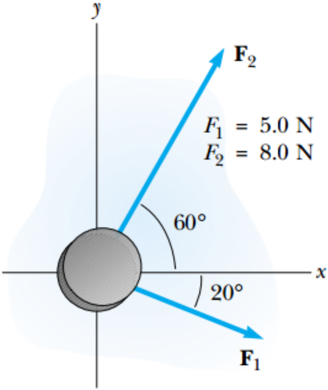
Consider the hockey puck from our previous problems, What force must we use to put the puck into equilibrium? The original force is:

$$\mathrm{F_i} = 8.7\mathrm{N}\hat{\mathrm{i}} + 5.2\mathrm{N}\hat{\mathrm{j}}$$

To "zero-out" this force, we apply opposite charges:

$$\mathrm{F_a} = -8.7\mathrm{N}\hat{\mathrm{i}} - 5.2\mathrm{N}\hat{\mathrm{j}}$$

So that $\mathrm{F_1} + \mathrm{F_2} = 0\hat{\mathrm{i}} + 0\hat{\mathrm{j}}$



Gravitational Force

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$$\mathrm{a} = 9.8\frac{\mathrm{m}}{\mathrm{s}^2} \equiv \mathrm{g}$$

Since $\mathrm{F} = \mathrm{ma}$, then the gravitational force is $\mathrm{F} = \mathrm{mg}$.

To turn a mass into a weight,
multiply by 9.8.

Free body diagram

Since forces are vectors, draw a picture of the forces acting on a ball sitting on a table, and on a ball that is just about to roll off a table.

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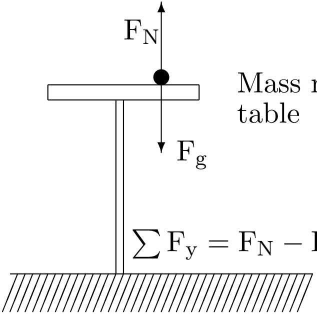
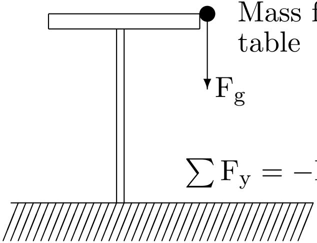


Mass resting on table

$$\sum F_y = F_N - F_g = 0$$



Mass falling off table

$$\sum F_y = -F_g \neq 0$$

Normal Force

A normal force is a reaction force. The ball on the table is held up by the normal force exerted on the ball by the table. The ball is pushing down on the table with its weight, the table is pushing back up in reaction to that force.

Normal forces always act perpendicular to the surface of contact.

Lecture problem 5

Consider a block sitting on an inclined plane that has an angle of 30°. There is enough friction between the block and the inclined plane that the block will not slide down. The mass of the block is 3.0 kilograms. Draw the free body diagram of this system. What is the force of friction and the normal force?

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- For those forces which arent parallel to the x or y axis, we have to decompose them into vectors which are parallel to the x and y axis such that the sum of the decomposed vectors adds up to the original vector.
- Now you can find the sum of all vectors in the x direction and the y direction.
- By Newtons laws, the sums $\sum \mathrm{F_x}$ and $\sum \mathrm{F_y}$ should add to zero if the system is under equilibrium. If the sum of the vectors dont add to zero, then there will be a net acceleration in that direction.

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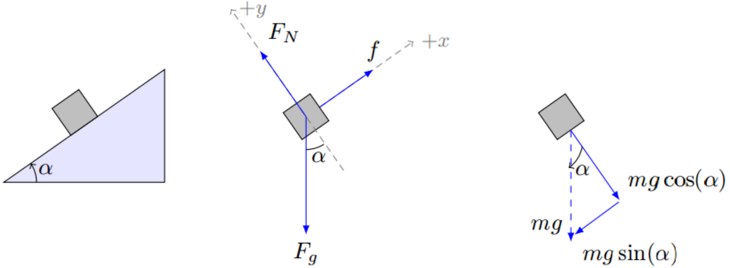

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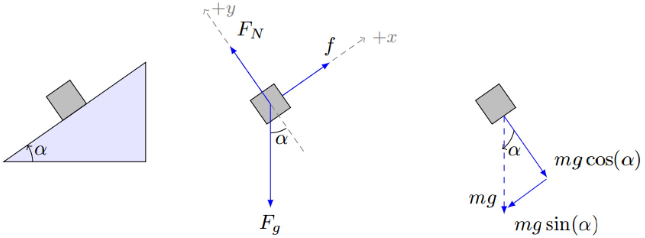

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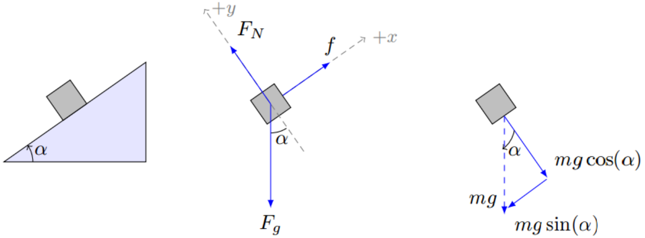

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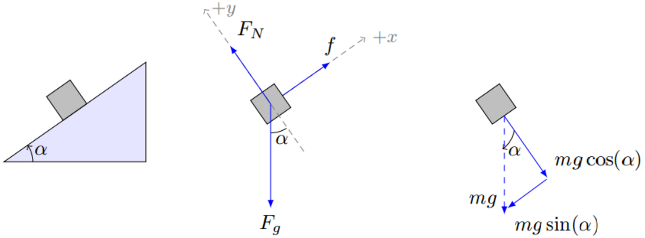

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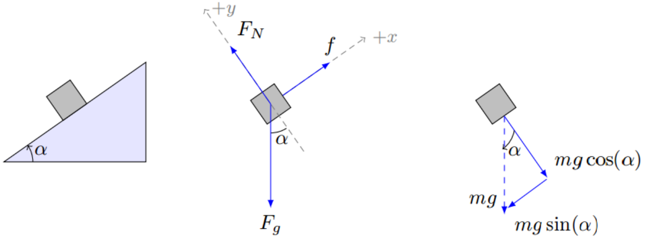

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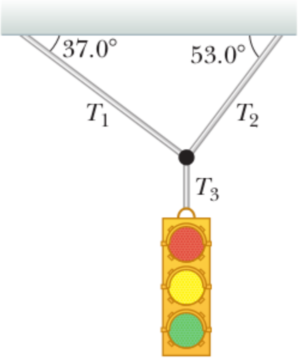
$$\sum \mathrm{F_y = F_N - F_g}\cos(30) = 0 \;\rightarrow\; \mathrm{F_N = F_g}\cos(30) = 25\mathrm{N}$$

Tension

Tension is the force felt in a cable, string, spring, chain, or other such object which can pull but not push.

Lecture problem 6

A 12.4 kg traffic light is held up by three cables as shown in the figure. The upper two cables are weaker than the lower cable and can't hold a tension of more than 100 N. Will one of the two cables snap?



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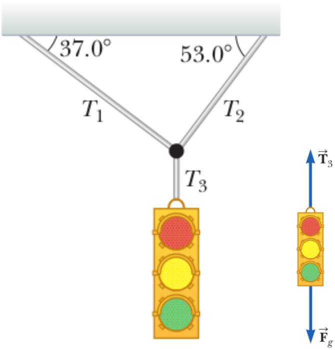
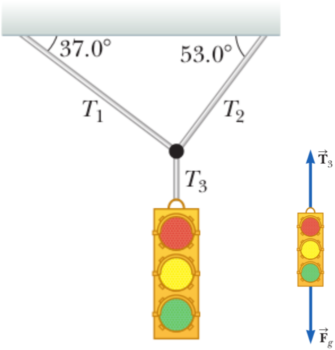


First, draw
the free body of the light with only the cable attached to it.

Lecture problem 6



First, draw
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This tells us that $T_3 = F_g$.

$$\begin{aligned} F_g &= mg \\ &= (12.4\ \text{kg})\left(9.8\frac{\text{m}}{\text{s}^2}\right) \\ &= 122\ \text{N} \end{aligned}$$

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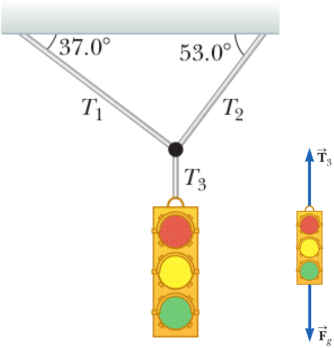

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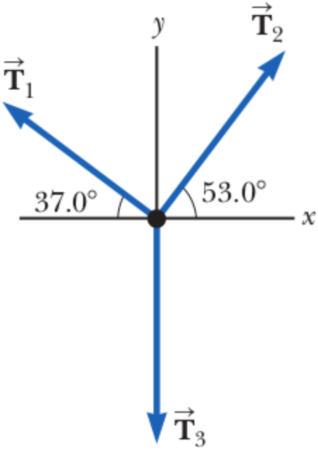

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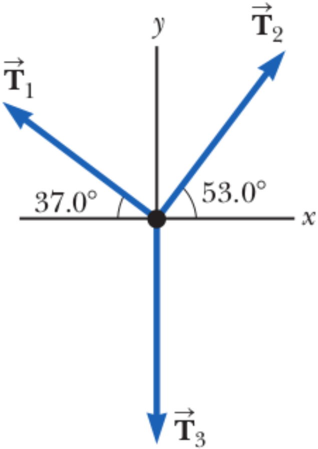

Now draw the free body diagram for the intersection of the three cables.

Force	x comp.	y comp.
$\vec{T}_1$	$-T_1 \cos(37)$	$T_1 \sin(37)$
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Assuming equilibrium:

$$\sum F_x = -T_1\cos(37) + T_2\cos(53) = 0$$

$$T_1 = T_2\frac{\cos(53)}{\cos(37)} = 0.75355T_2$$

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$$T_2\left(0.75355\sin(37) + \sin(53)\right) = 122\ \mathrm{N}$$

$$T_2 = 97.4\ \mathrm{N}$$

Lecture problem 6

Force	x comp.	y comp.
$\vec{T}_1$	$-T_1 \cos(37)$	$T_1 \sin(37)$
$\vec{T}_2$	$T_2 \cos(53)$	$T_2 \sin(53)$
$\vec{T}_3$	0	-122 N

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$$T_2\,(0.75355\sin(37)+\sin(53)) = 122\text{ N}$$

$$T_2 = 97.4\text{ N}$$

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$$T_2\,(0.75355\sin(37)+\sin(53)) = 122\text{ N}$$

$$T_2 = 97.4\text{ N}$$

Finally we go back and solve for T_1:

$$T_1 = 0.75355\,(97.4\text{ N}) = 73.4\text{ N}$$

Chapter 1: Problem 1

The base SI units are:

- meter for length

(c): Energy is a derived SI unit:

$$\frac{\text{kg} \cdot \text{m}}{\text{s}^2}\text{m}$$

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- ampere for electric current
- kelvin for temperature
- candela for luminous intensity
- mole for the amount of substance.

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Chapter 1: Problem 5

A quick google search for "cm in foot" gives the conversion: 1 foot = 30.48 cm. A similar search for "cm in mile" gives the conversion: 1 mile = 160934 cm, 1 inch = 2.54 cm, and 5280 feet = 1 mile.

Chapter 1: Problem 5

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$$1 \text{ foot} = 12 \text{ inches} = (12 \cancel{\text{ inches}}) \left(\frac{2.54 \text{ cm}}{1 \cancel{\text{ inch}}} \right) = 30.48 \text{ cm}$$

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$$(1 \cancel{\text{ mile}}) \times \left(\frac{5280\cancel{\text{feet}}}{1\cancel{\text{mile}}}\right) \times \left(\frac{30.48 \text{ cm}}{1 \cancel{\text{ foot}}}\right) = 160934 \text{ cm} \rightarrow 1.609 \times 10^5 \text{ cm}$$

Chapter 1: Problem 7

23.0040: decimal point is Present so count from left to right, giving us 6 sig figs since the first number on the left is non-zero.

Chapter 1: Problem 17

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Three diapers per day means about 18.4 million diapers per day. Take a guess on how much space a diaper taxes up when compressed. About half a foot by half a foot by 1 cm gives (we converted feet to cm previously): $0.01 \times 0.3048 \times 0.3048 = 9.3 \times 10^{-4}\mathrm{m}^3$.

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The estimated volume from diapers is:
$6 \times 10^6 \times 9.3 \times 10^{-4}\text{m}^3 = 5580\text{m}^3$ per day, or $2 \times 10^6\text{m}^3$ per year. At 10 m high, this is $2 \times 10^5\text{m}^2$ in area. Since 1 square mile equals $2.6 \times 10^6\text{m}^2$, this works out to 0.8 square miles.

Chapter 1: 21

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$25\ \mathrm{km} = 25 \times 10^{3}\mathrm{m}$

Chapter 1: 27

A basketball player is 6'10.5" tall. How tall in centimeters?

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$$6.875 \text{ feet}) \times \left(\frac{30.48 \text{ cm}}{\text{foot}}\right) = 210 \text{ cm}$$

Chapter 1: 45

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$$2.17 \times 10^5 = 217000$$

Chapter 1: 47

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Homework for next week

Read Chapter 1 Sections 1-6 and 1-7 and do problems:

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Chapter 1: 53, 57

Homework for next week

Read Chapter 1 Sections 1-6 and 1-7 and do problems:

Chapter 1: 53, 57

Read Chapter 4 and do problems:

Homework for next week

Read Chapter 1 Sections 1-6 and 1-7 and do problems:

Chapter 1: 53, 57

Read Chapter 4 and do problems:

Chapter 4: 47, 51, 53