

Brick Geometry

BrickCon 2013

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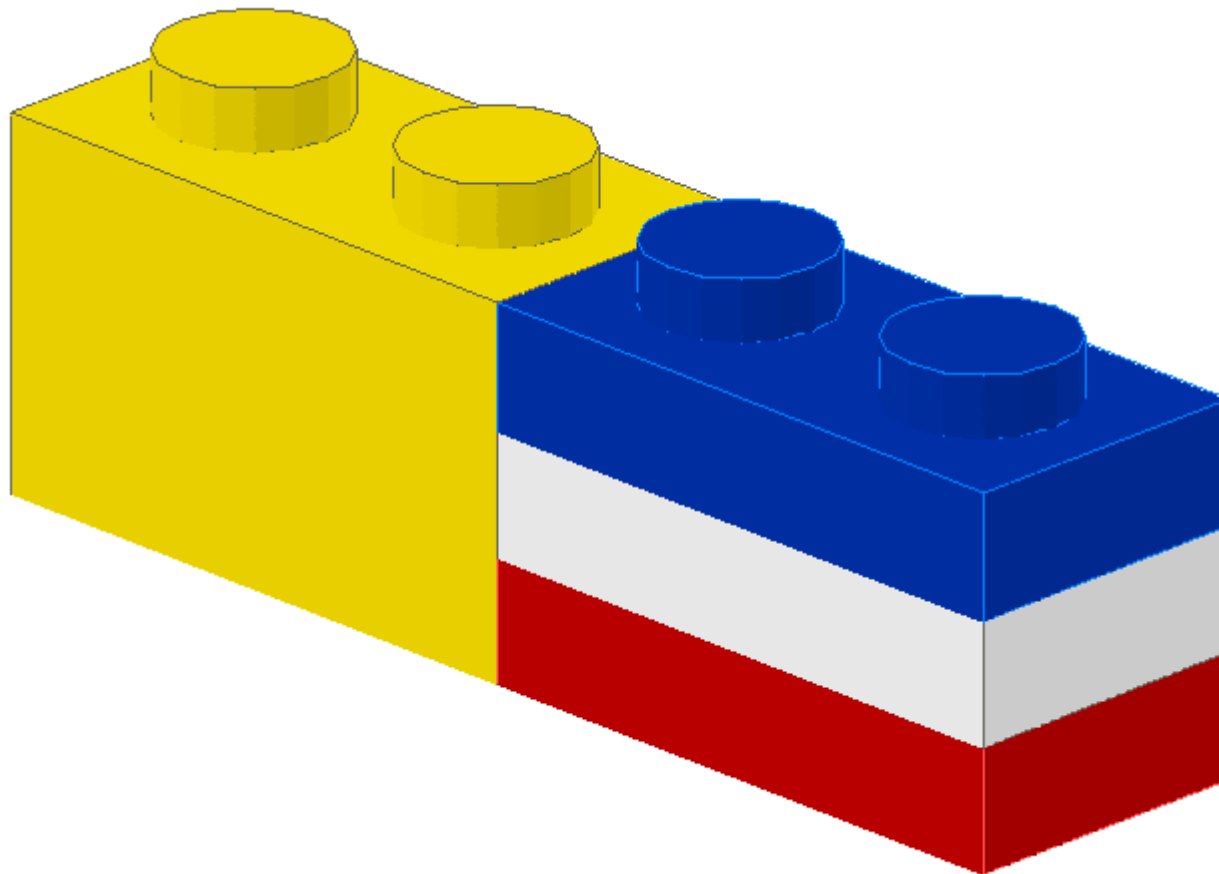
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Basic LEGO Geometry

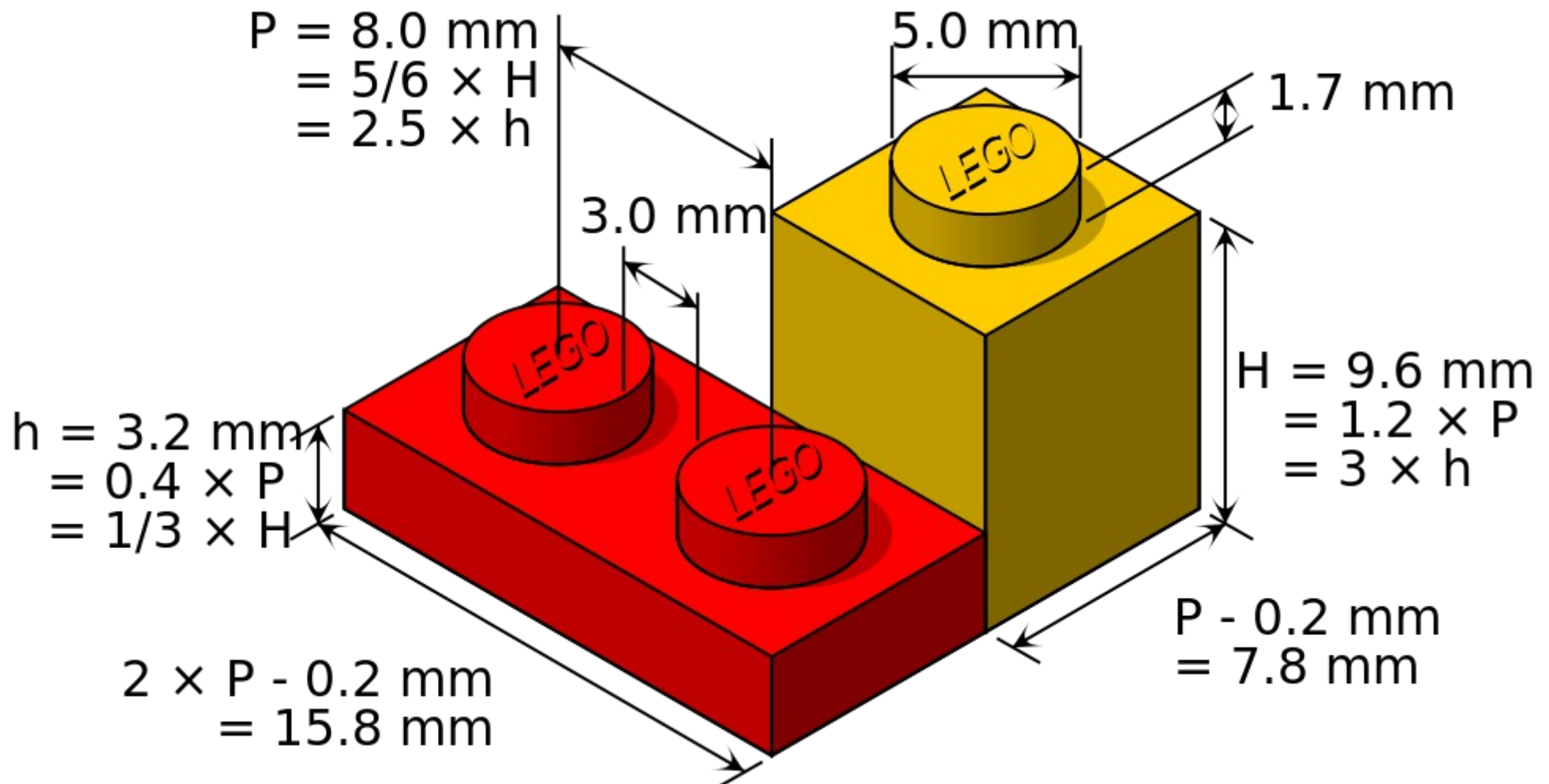
1 brick = 3 plates

Everyone knows this, I hope...



LEGO Dimensions

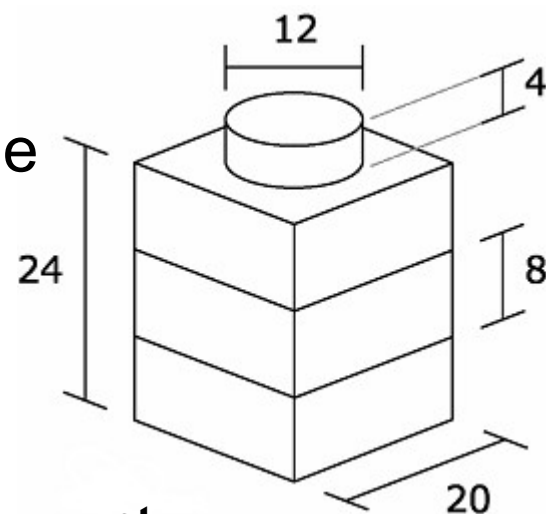
Quick! Memorize all these numbers. There will be a quiz later.



Math is Hard!

LDU = LDraw Unit

- A 1x1 stud brick or plate is $\frac{5}{16}$ " or 8mm (0.8cm)
- The height is $\frac{6}{16}$ " or 9.6mm (0.96cm)
- To make the math easier, LDraw designers came up with the LDraw Unit (LDU)
- Everything is a nice, easy integer this way!



	<u>LDU</u>	<u>studs</u>	<u>bricks</u>	<u>plates</u>	<u>cm</u>	<u>inch</u>	<u>pt</u>
LDU	1	1/20	1/24	1/8	0.04	1/64	9/8
studs	20	1	5/6	5/2	0.8	5/16	45/2
bricks	24	6/5	1	3	0.96	6/16	27
plates	8	2/5	1/3	1	0.32	2/16	9
cm	25	1.25	1.04	3.125	1	0.39	28.3
inch	64	3.2	8/3	8	2.54	1	72
pt	8/9	2/45	1/27	1/9	0.0353	1/72	1

Ratio of Stud Width to Brick / Plate Height

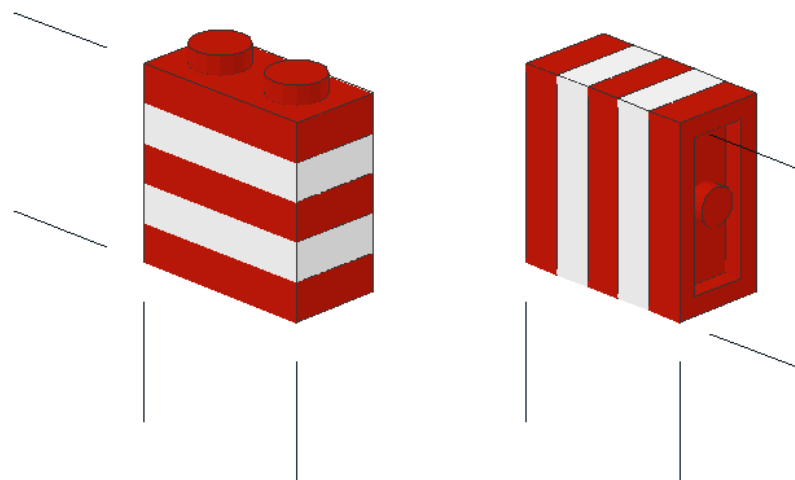
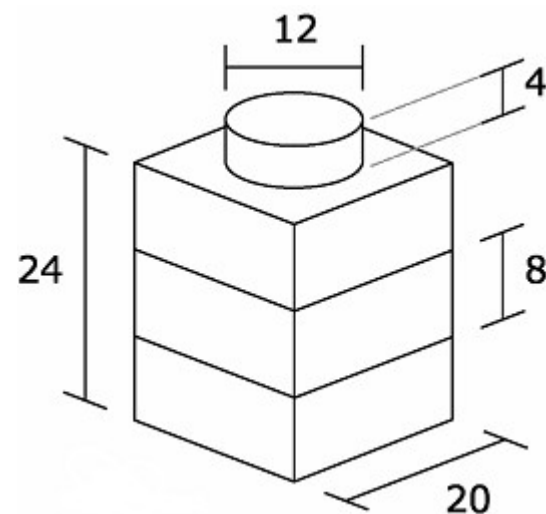
Bricks are 8mm wide by 9.6mm high

How do you make widths and heights match?

LDU makes the math easy....

How many plates = how many studs?

- 2 studs = $2 \times 20 = 40$ LDU
- 5 plates = $5 \times 8 = 40$ LDU



Examples - Mosaic Dates on LEGO Modular Sets

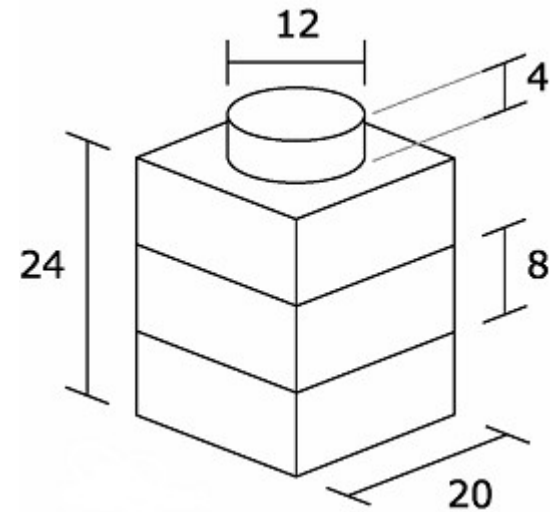
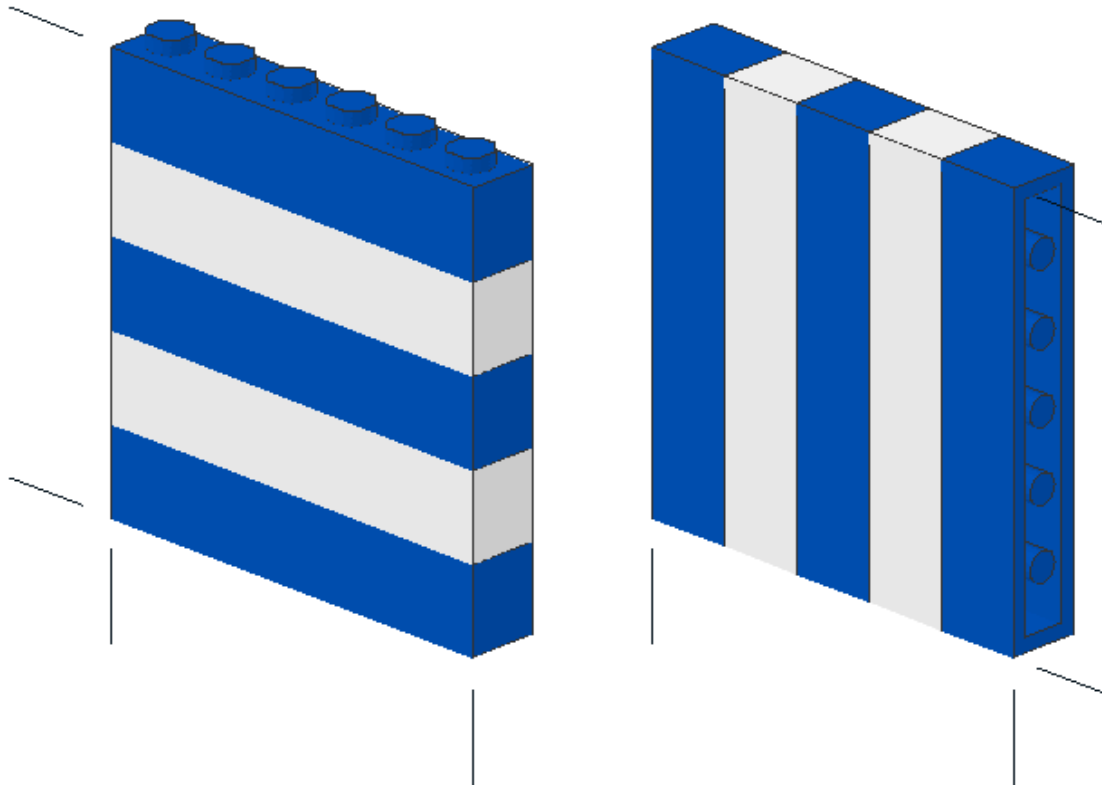


http://commons.wikimedia.org/wiki/File:Lego_Modular_-_Set_10197_Fire_Brigade_%286817665156%29.jpg
http://commons.wikimedia.org/wiki/File:Lego_Modular_-_Set_10224_Town_Hall_%288310511639%29.jpg

Ratio of Studs to Bricks

How many bricks = how many studs?

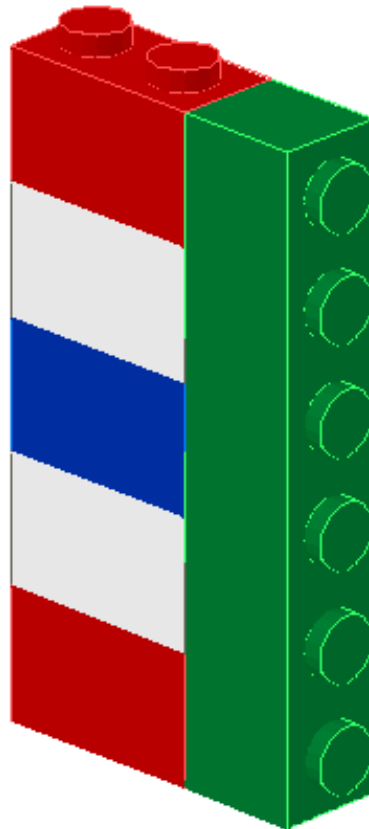
- 6 studs = $6 \times 20 = 120$ LDU
- 5 bricks = $5 \times 24 = 120$ LDU



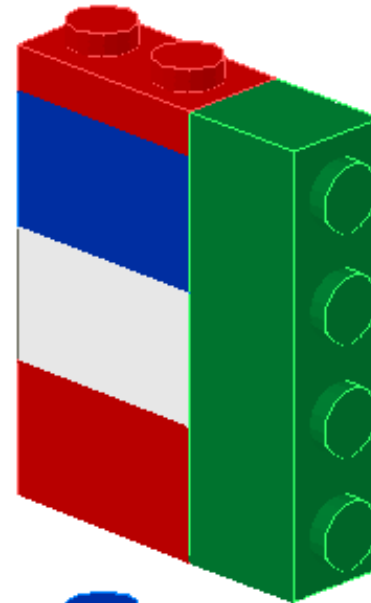
More Easy Ratios

Any even number of studs corresponds to a combination of bricks and plates, since $2 \text{ studs} = 5 \text{ plates}$

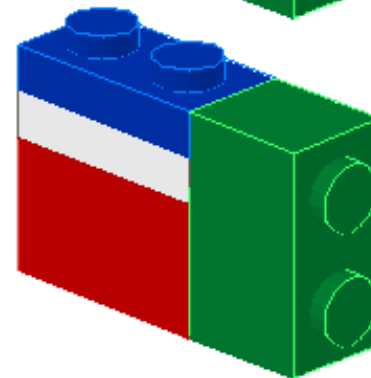
6 studs =
5 bricks
or 15 plates



4 studs =
 $3 \frac{1}{3}$ bricks
or 10 plates

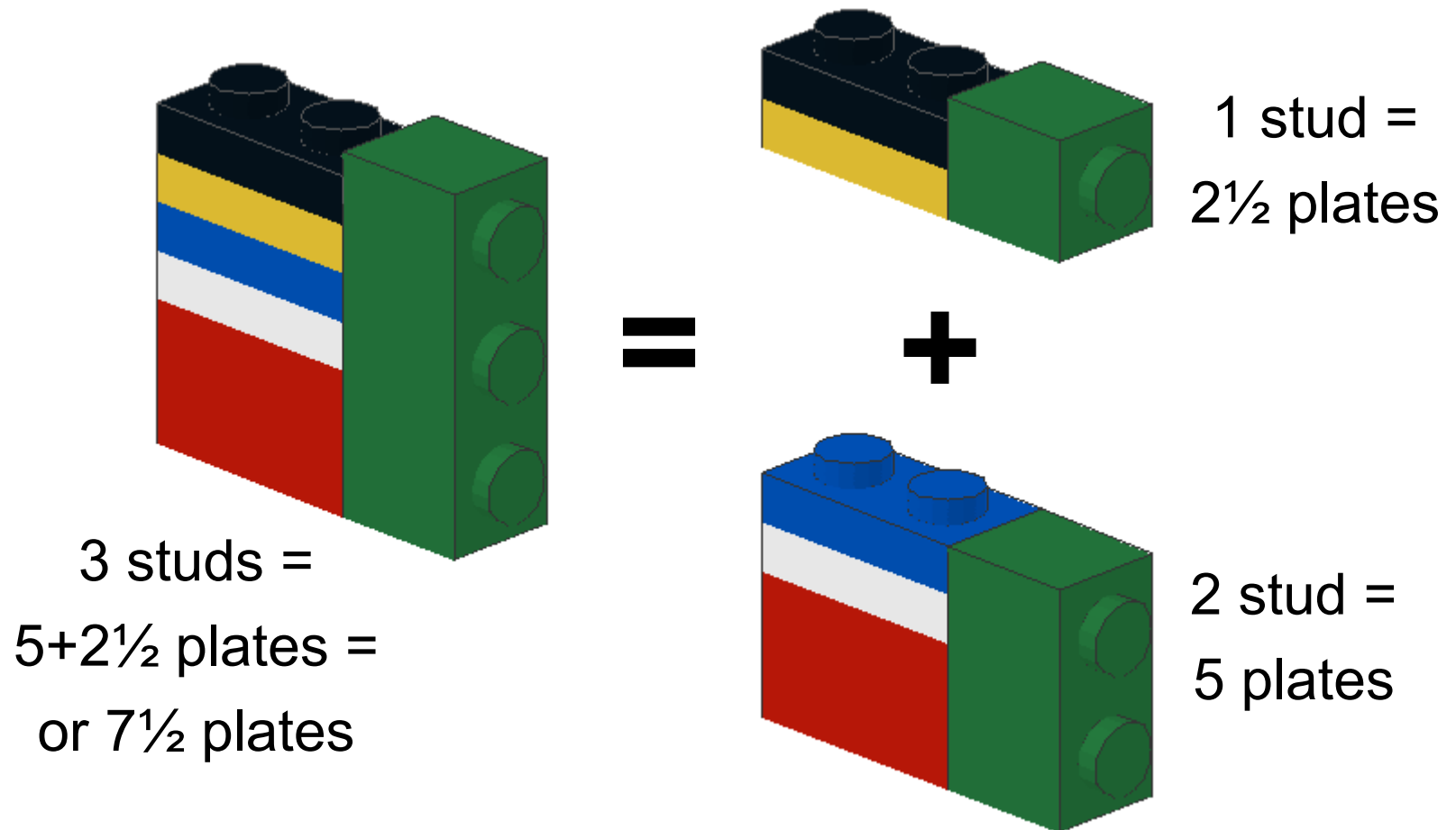


2 studs =
 $1 \frac{2}{3}$ bricks
or 5 plates



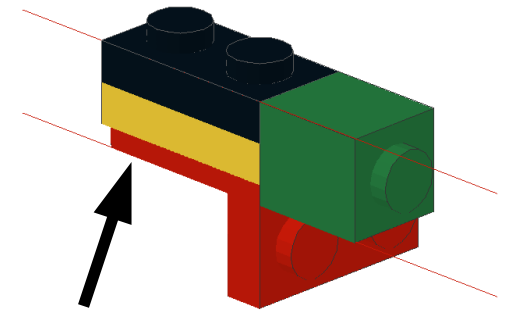
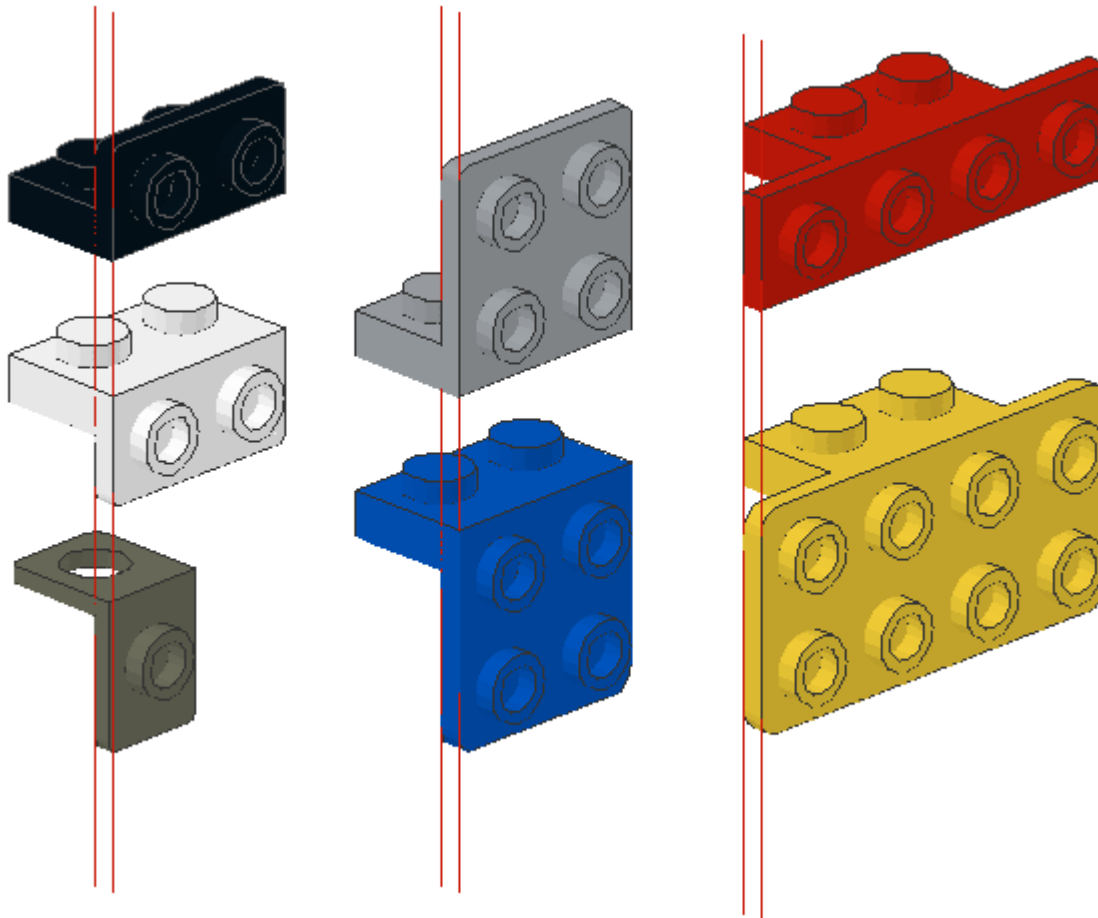
Odd numbers are harder

No combination of plates exactly adds up to one stud!



But where do you get $\frac{1}{2}$ plate?

One answer: brackets. The thin vertical plate is $\frac{1}{2}$ the thickness of a normal plate, or 4 LDU



1 plate = 8 LDU thick

1 stud brick = 20 LDU

2 plates + bracket =

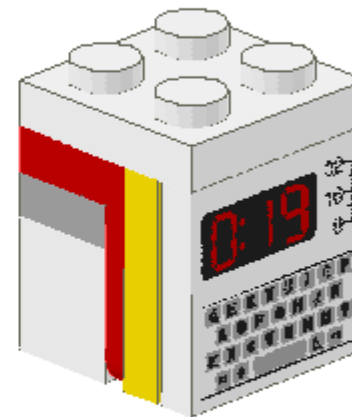
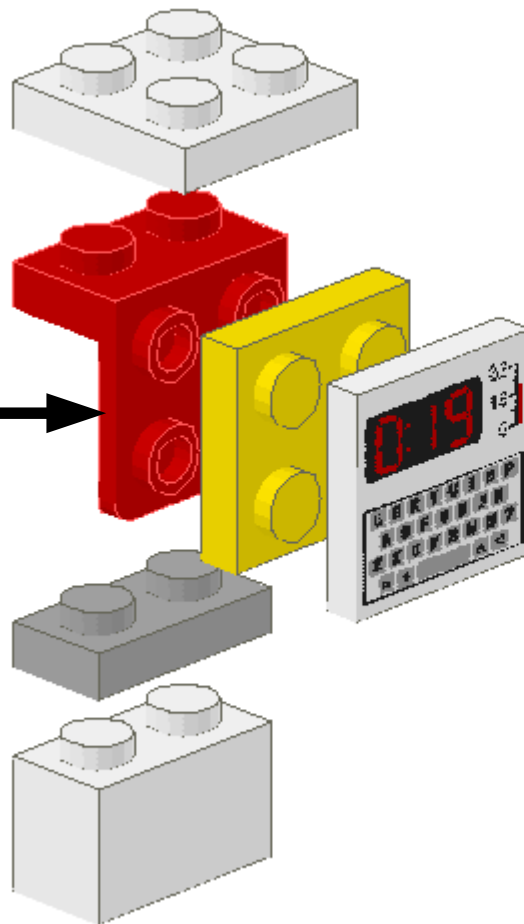
$$8 * 2 + 4 =$$

20 LDU

Using $\frac{1}{2}$ plate thickness from brackets

$\frac{1}{2}$ plate from bracket
+ 1 plate + 1 tile
= $2 \frac{1}{2}$ plates, same as 1 stud

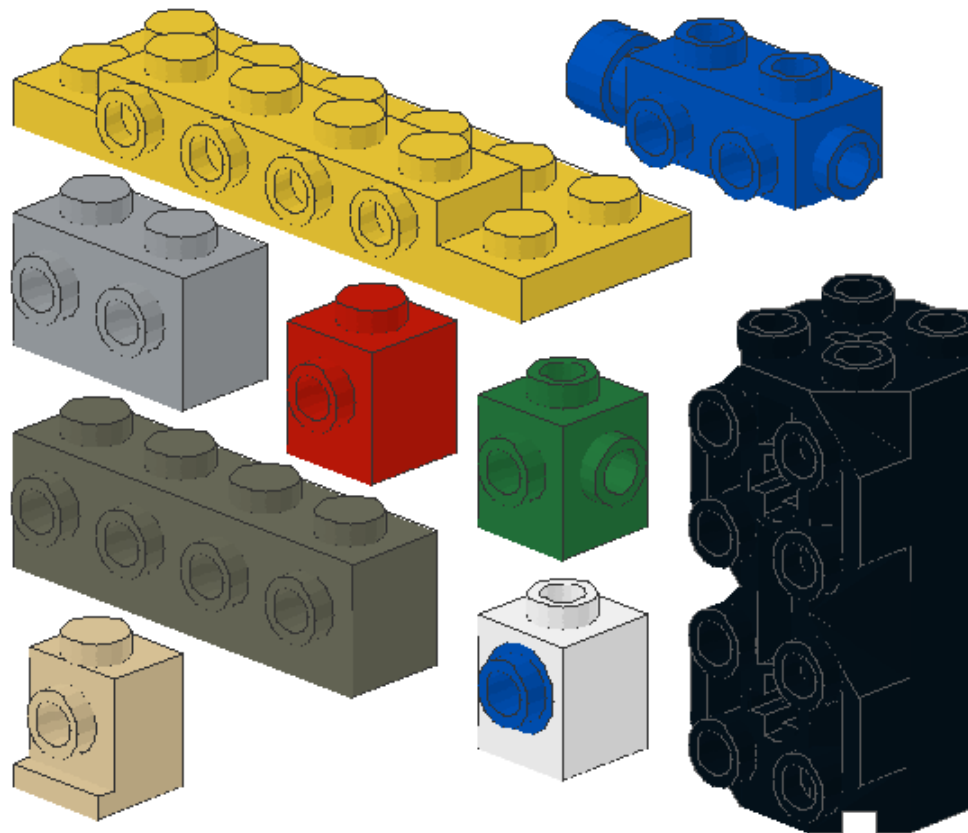
Bracket
vertical
part is
 $\frac{1}{2}$ plate
thick



Computer tile is
flush with edge
of white 2x2
plate.

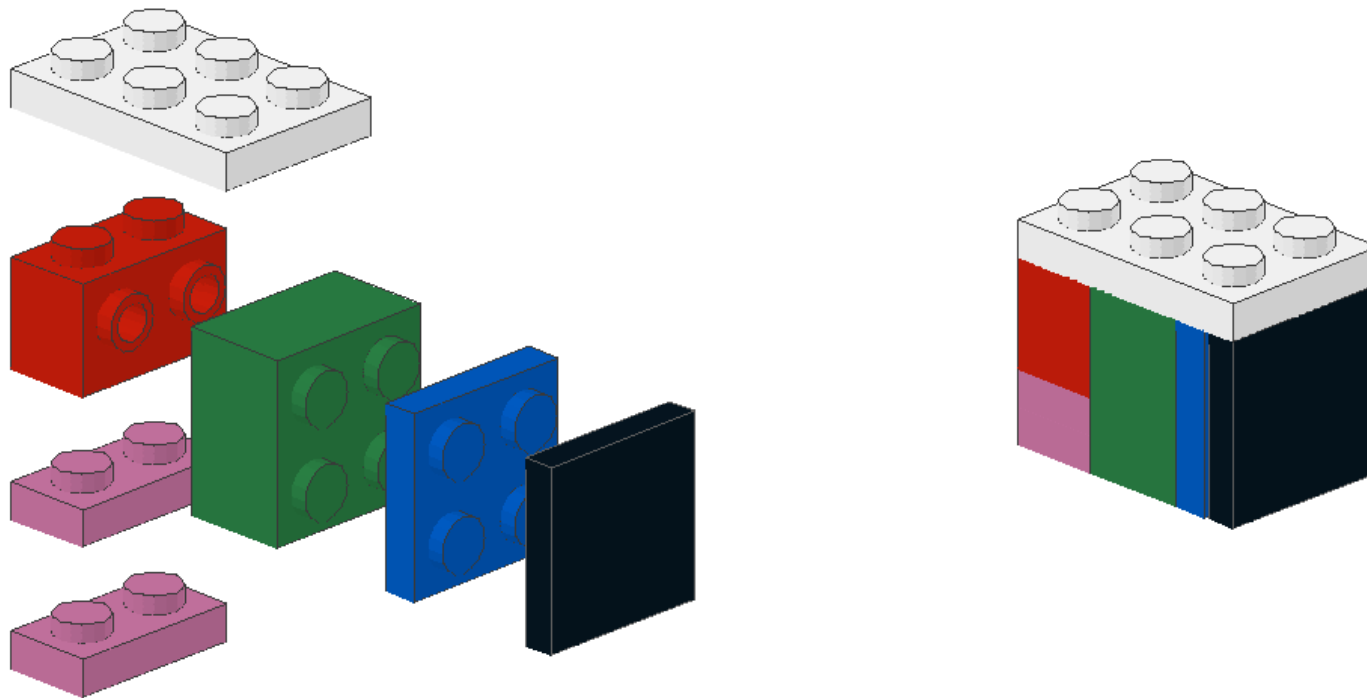
Bricks with Studs on the Side

LEGO has plenty of parts that have studs on the side, useful for SNOT (Studs Not On Top) design, similar to the brackets.

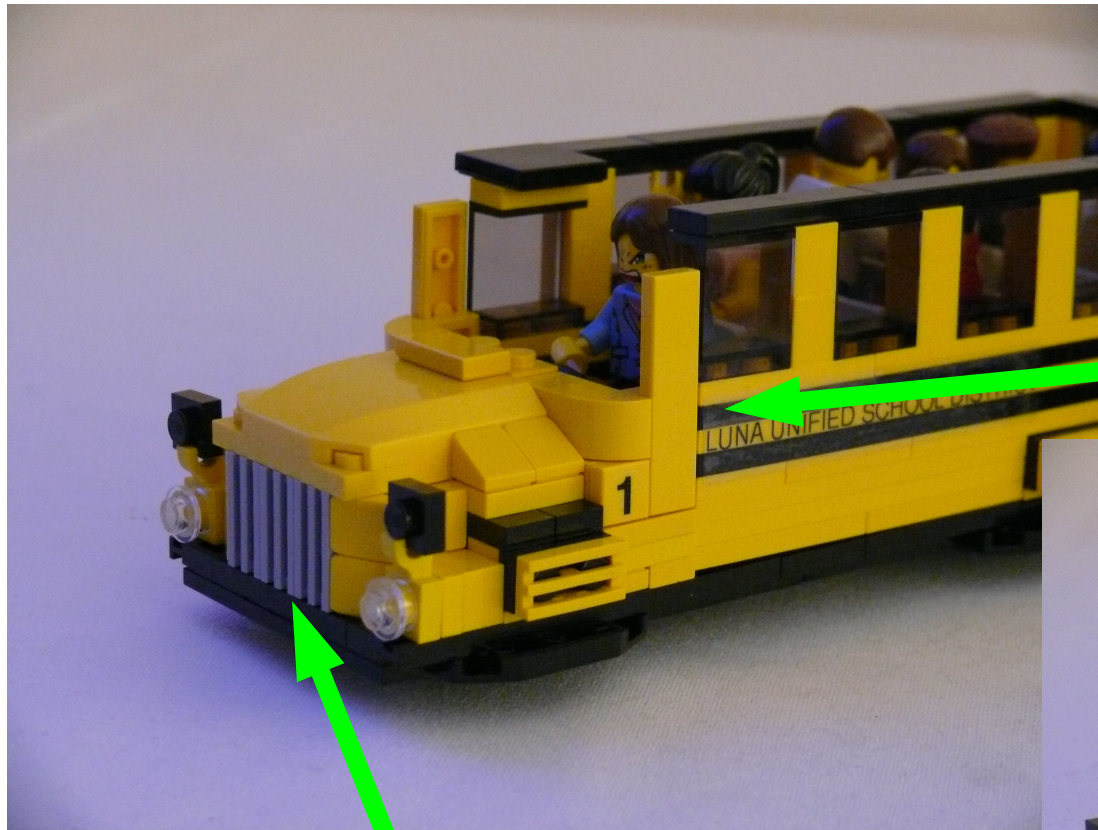


Bricks with studs on sides to mount flush

Use bricks with studs on sides to attach assemblies at 90 degrees.
To mount them flush, remember that 5 plates = 2 studs.



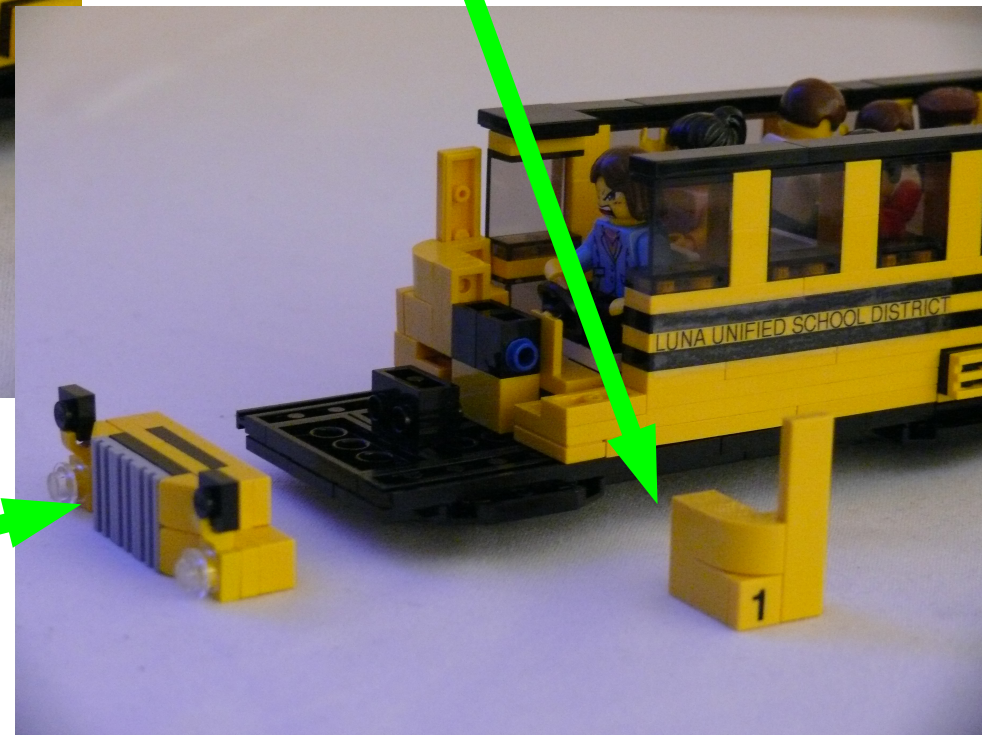
Flush tile examples



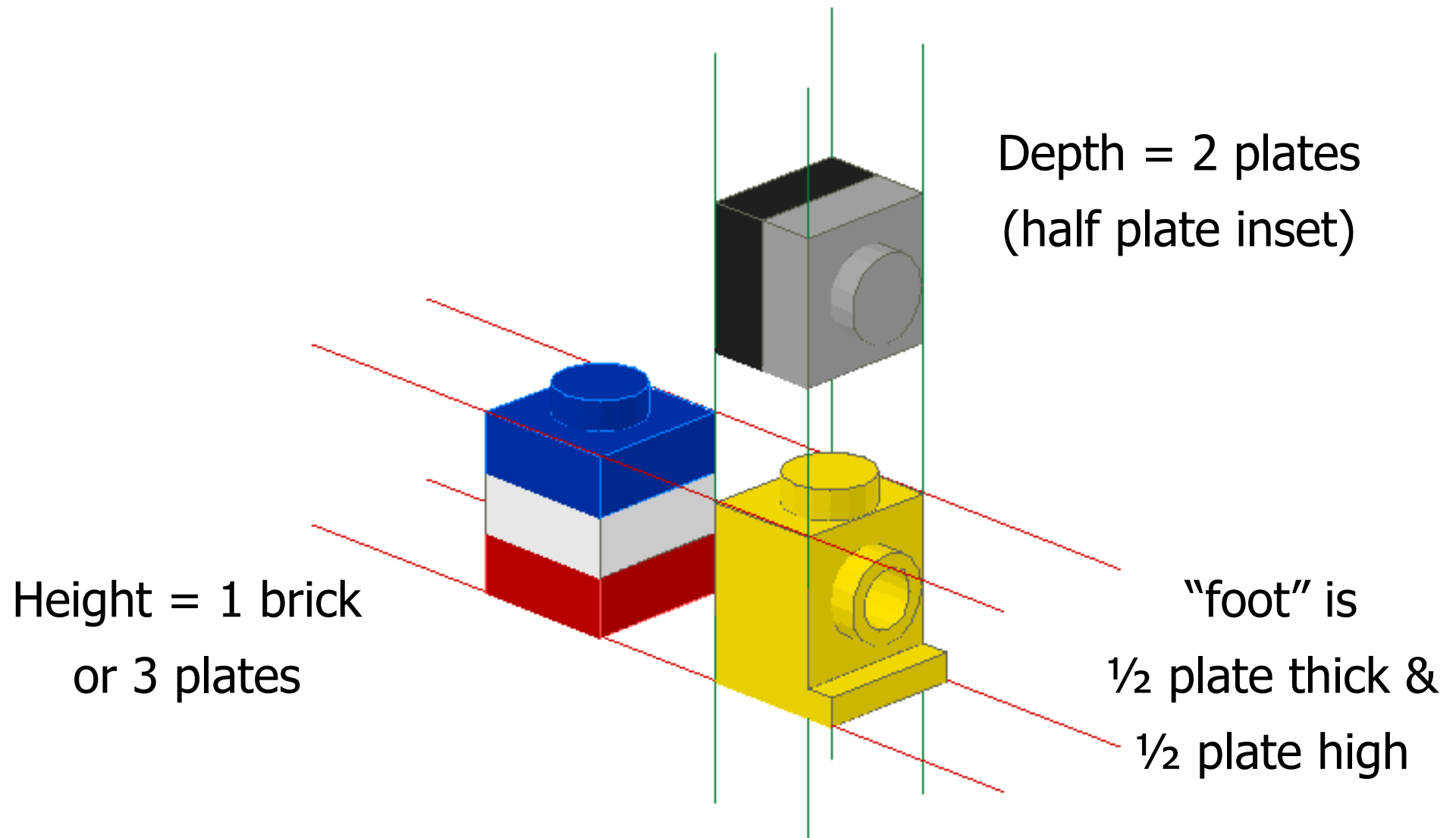
Grille and headlight assembly is 4 plates and a tile, same as 2 studs, so it lines up flush

Lunar School Bus uses this technique in two places

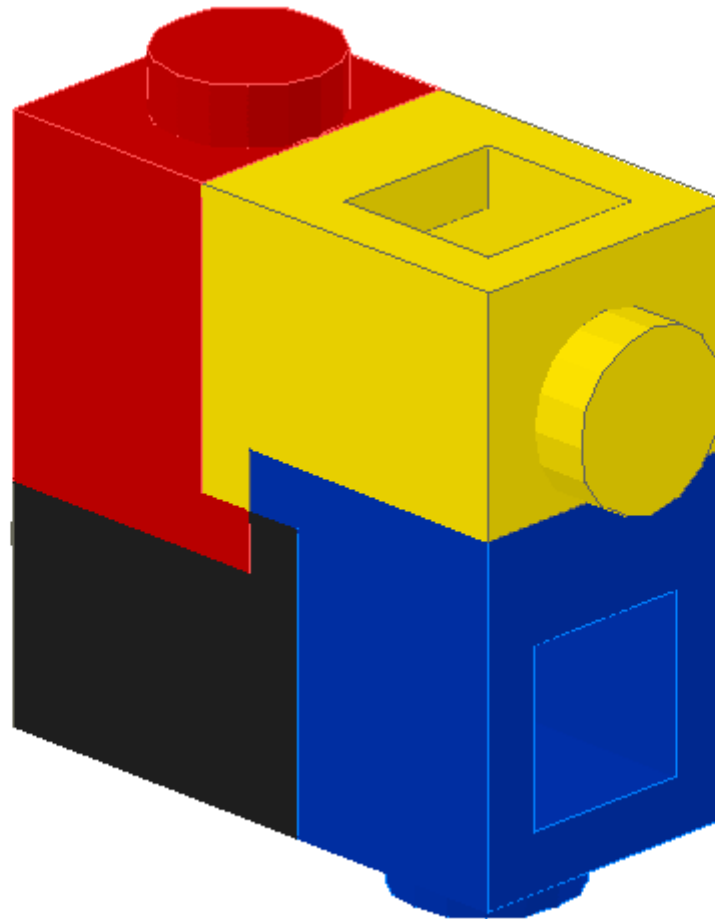
Side panel is made of bricks and plates and tiles 2 studs wide, lines up flush



Headlight Brick Dimensions



Four headlight bricks



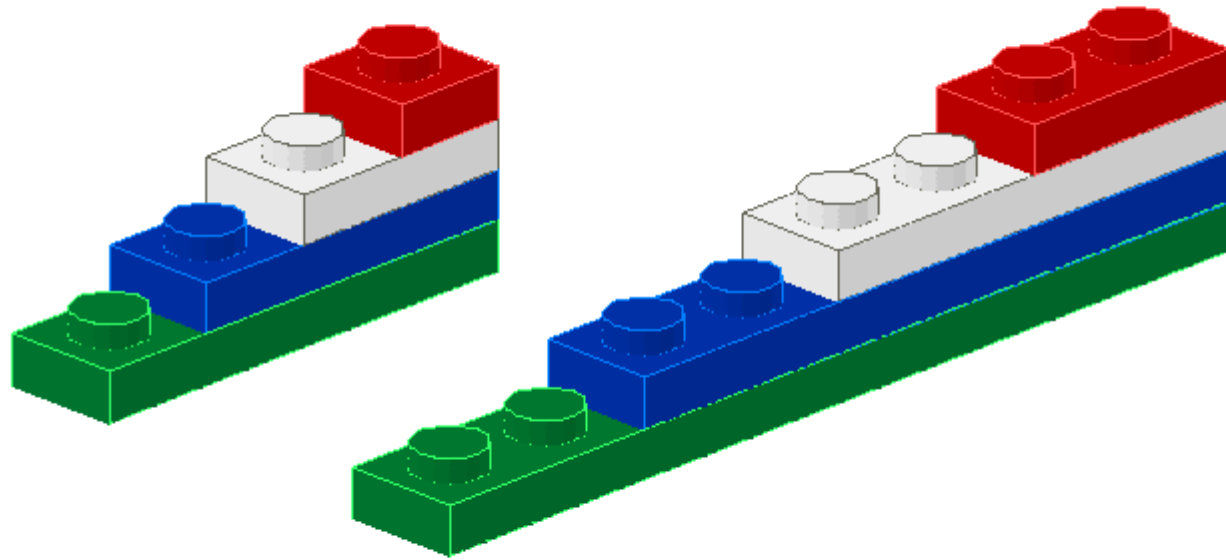
2 plates (red) +
3 plates (yellow) =
5 plates = 2 studs

Result: 5 plates or 2 studs in each of 4 directions.

Problem: Gradual Steps

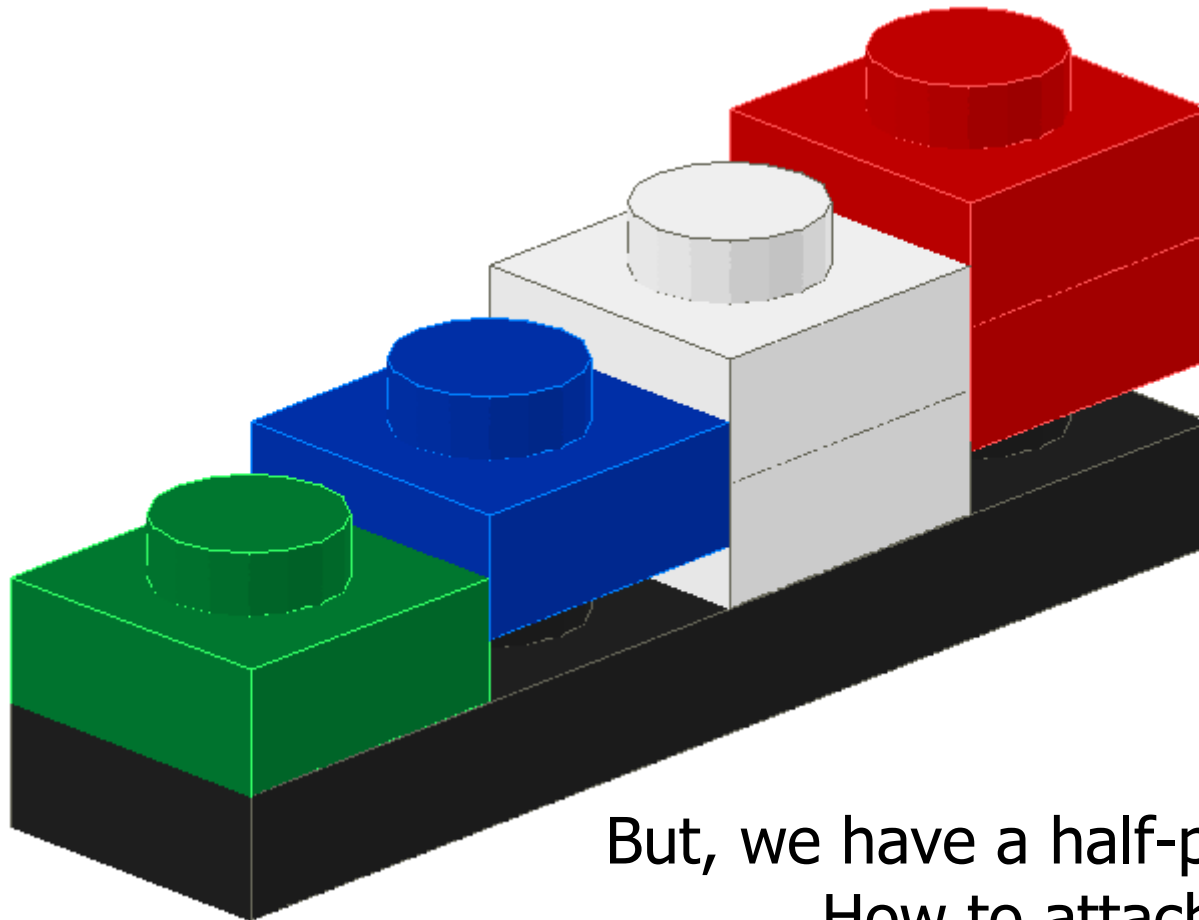
How do you make a gentle slope?

What if these are too steep?



Gradual Steps

For a more gradual slope, we'd like to mount every other one $\frac{1}{2}$ plate higher

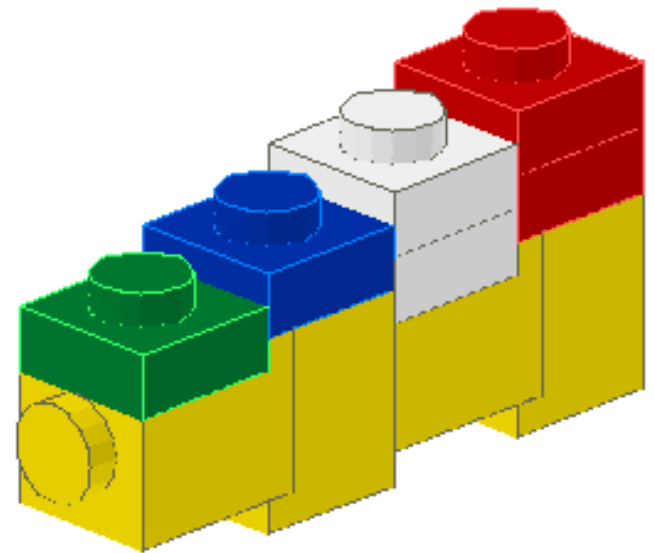
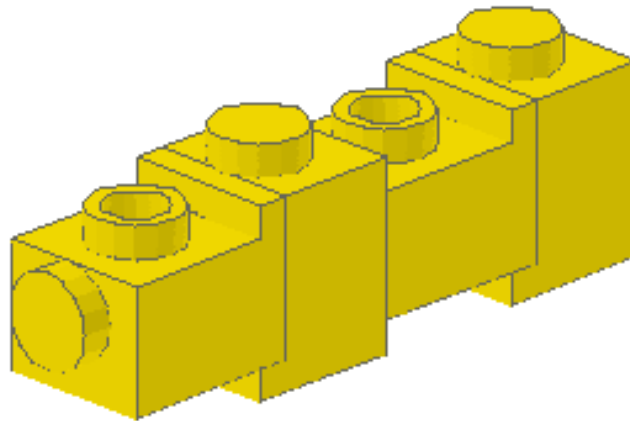


But, we have a half-plate hole to fill!
How to attach these?

Solution: Headlight Bricks

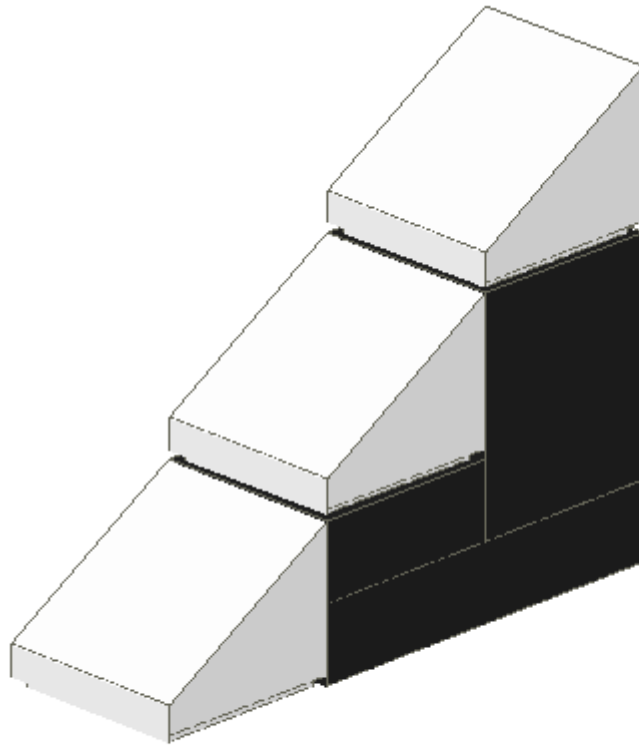
Alternate rotations for headlight bricks to take advantage of $\frac{1}{2}$ plate offset in "foot"

2 plates + $\frac{1}{2}$ plate = 1 stud



Half-plate lift from "foot"

Problem with “cheese slope”: Stairstep effect

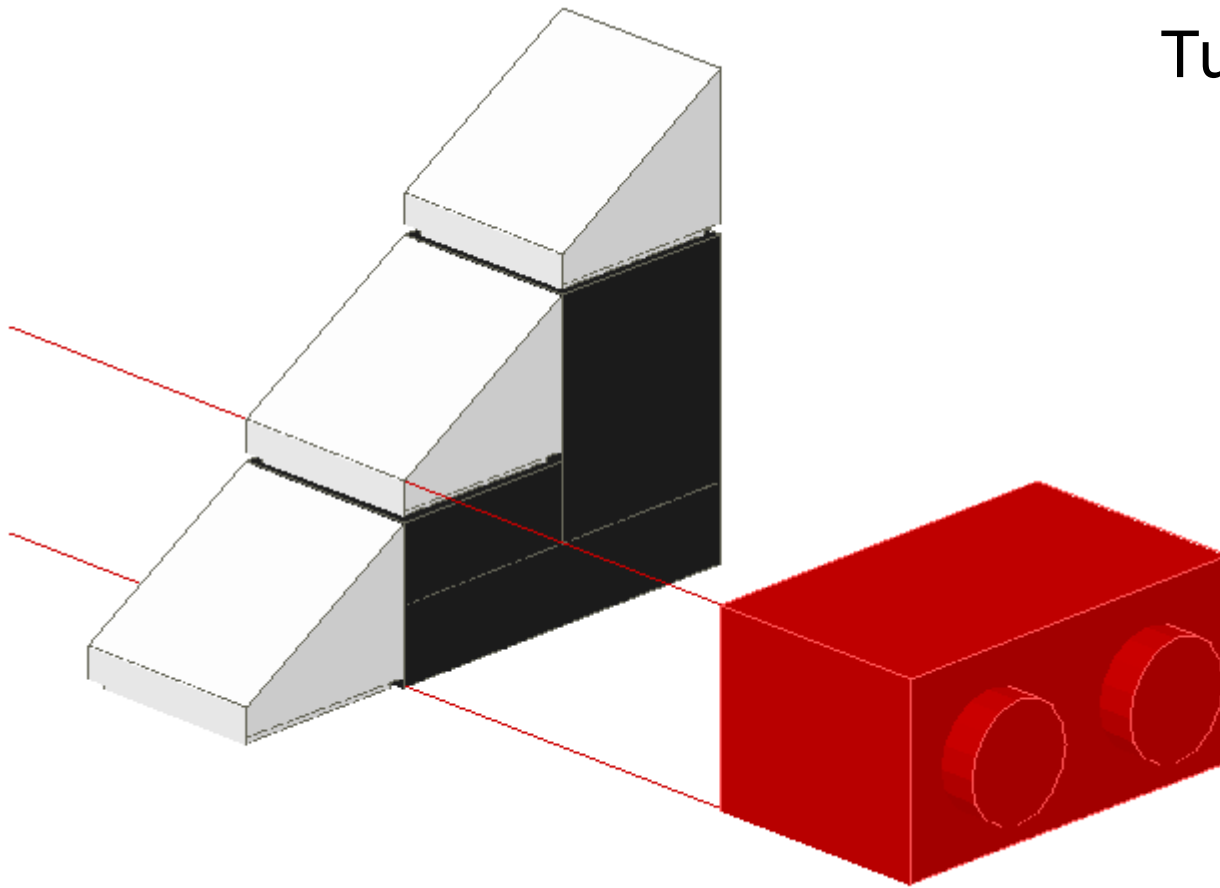


The 1x1 “cheese slope” is a very useful part but doesn't combine well with others of its kind to make a smooth slope.

This notch is needed for it to fit a stud inside, but is ugly.

Problem with “cheese slope”: Stairstep effect

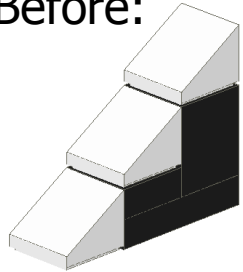
Turns out that “notch”
is $\frac{1}{2}$ plate thick.



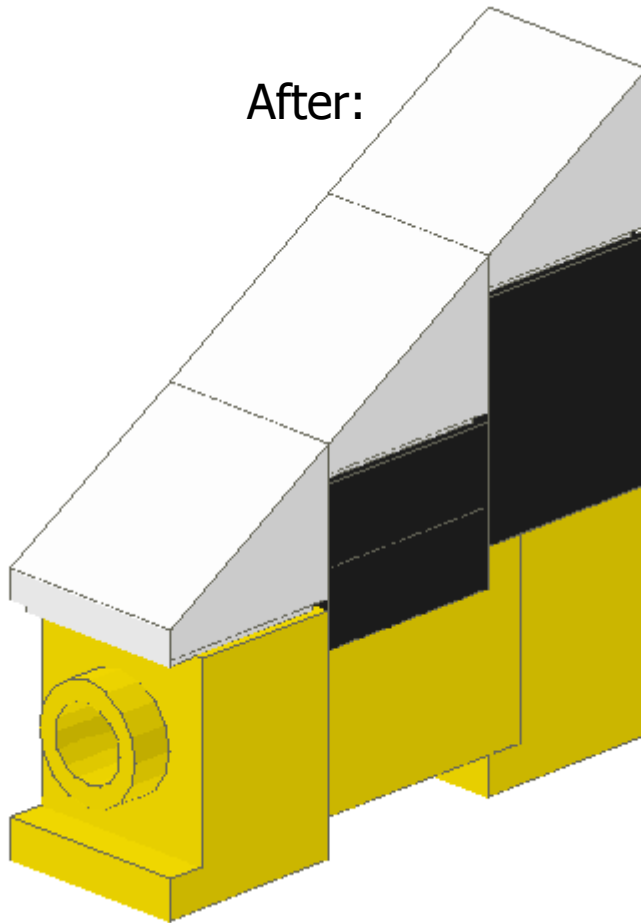
2 plates (height of cheese slope) + $\frac{1}{2}$ plate
= 1 stud

Solving the stairstep effect

Before:



After:



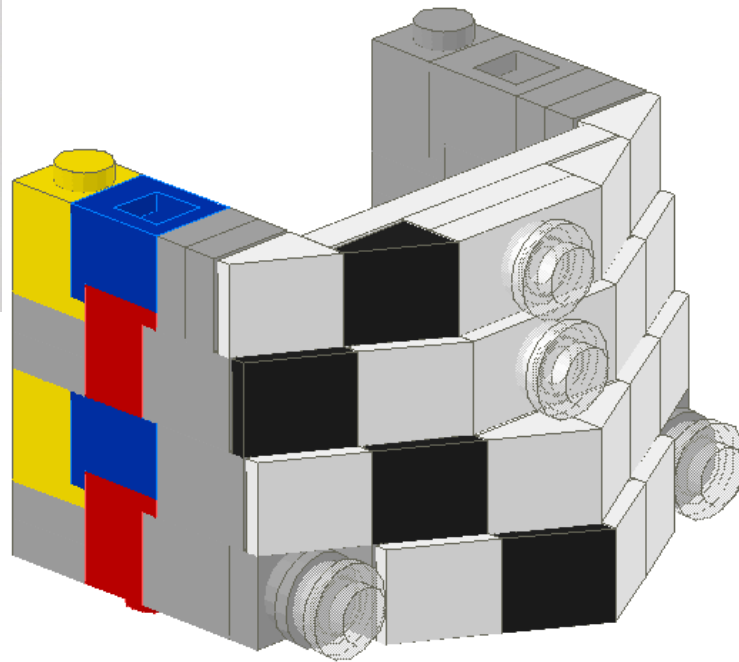
Used in Bram Lambrecht's
"Legoland Spacelines 979"
seen at BrickCon 2007

<http://www.flickr.com/photos/bram/1461137007/>

(used with permission)

Mount the center slope 1/2 plate lower for a smooth surface!

Useful for trains, too



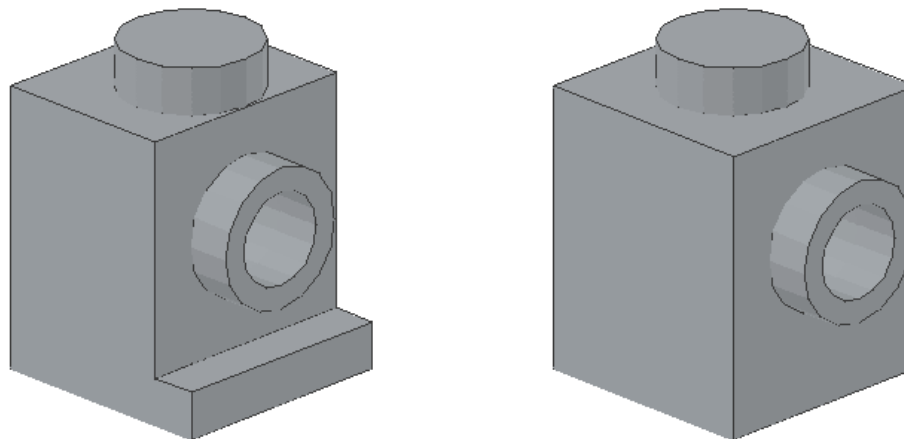
My F40PH Caltrain locomotive

“Headlight Brick” vs. “Brick 1 x 1 with Stud on 1 Side”

Headlight Brick depth = 2 plates = 16 LDU

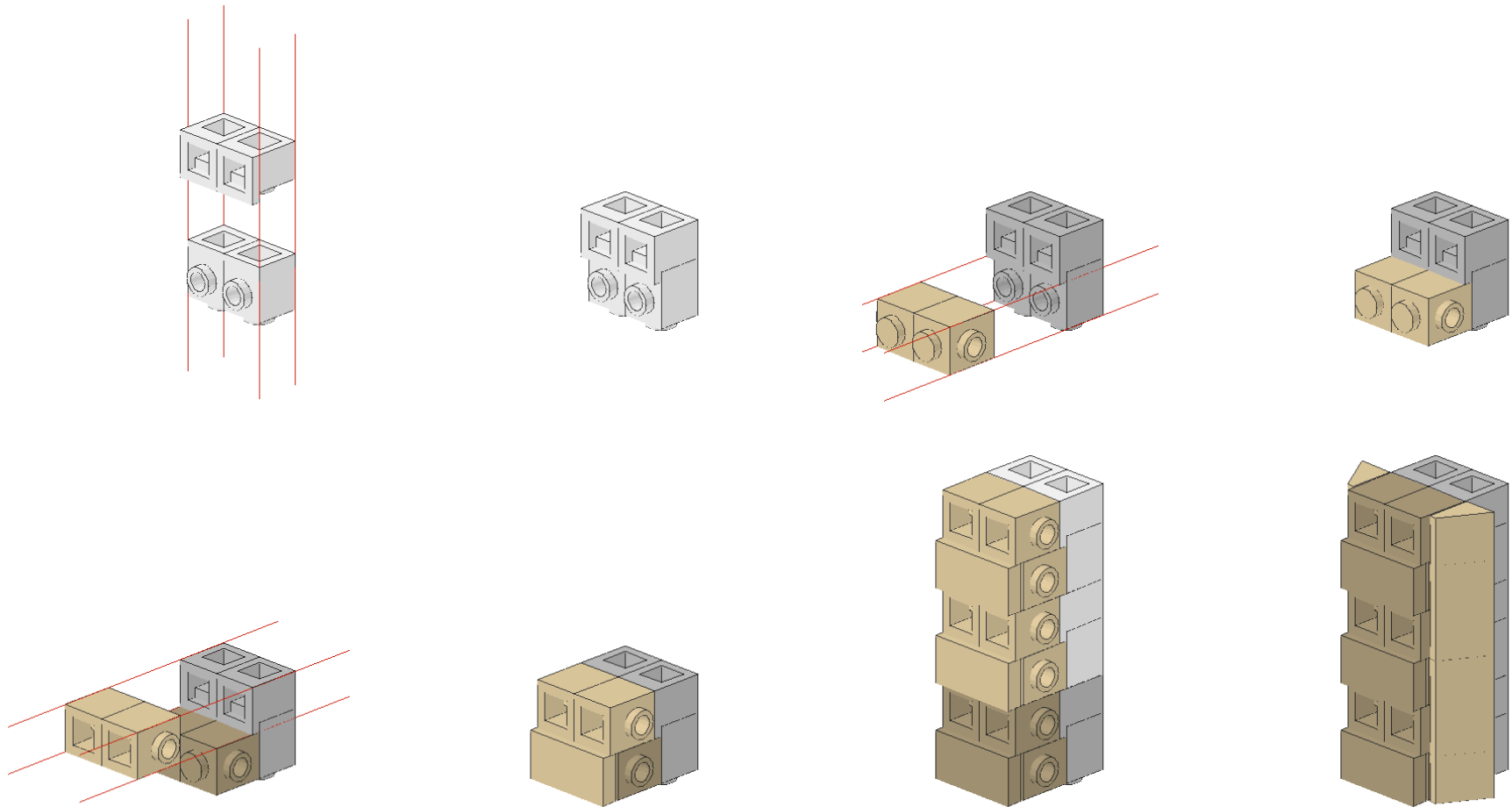
Brick depth = 2 ½ plates = 20 LDU

Combine these to achieve ½ plate differences in depth!

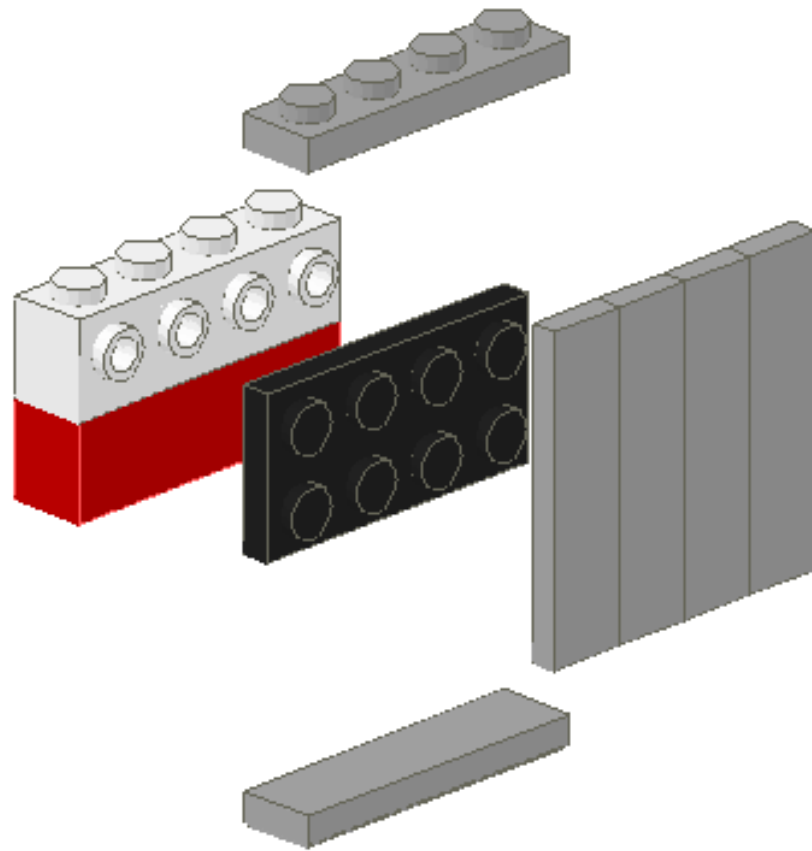


Hospital Bay Window example

Windows (bottoms of bricks) are inset by $\frac{1}{2}$ plate

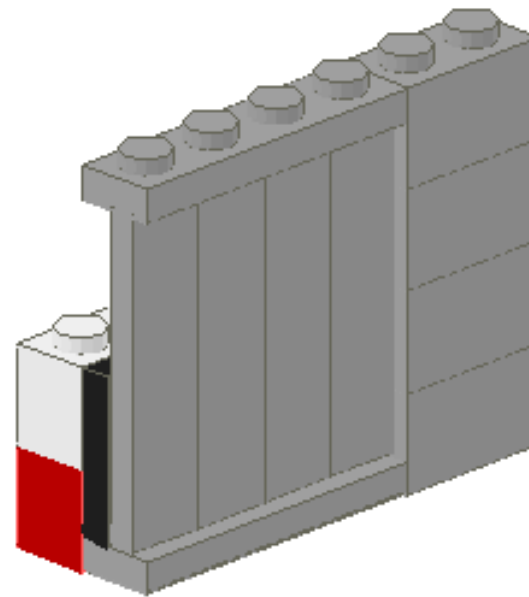


Inset Panels



1 plate + 2 studs (1 $\frac{2}{3}$ brick)
= 2 bricks

Use half-plate offsets to add texture to an otherwise flat wall



Tiles are $\frac{1}{2}$ plate inset

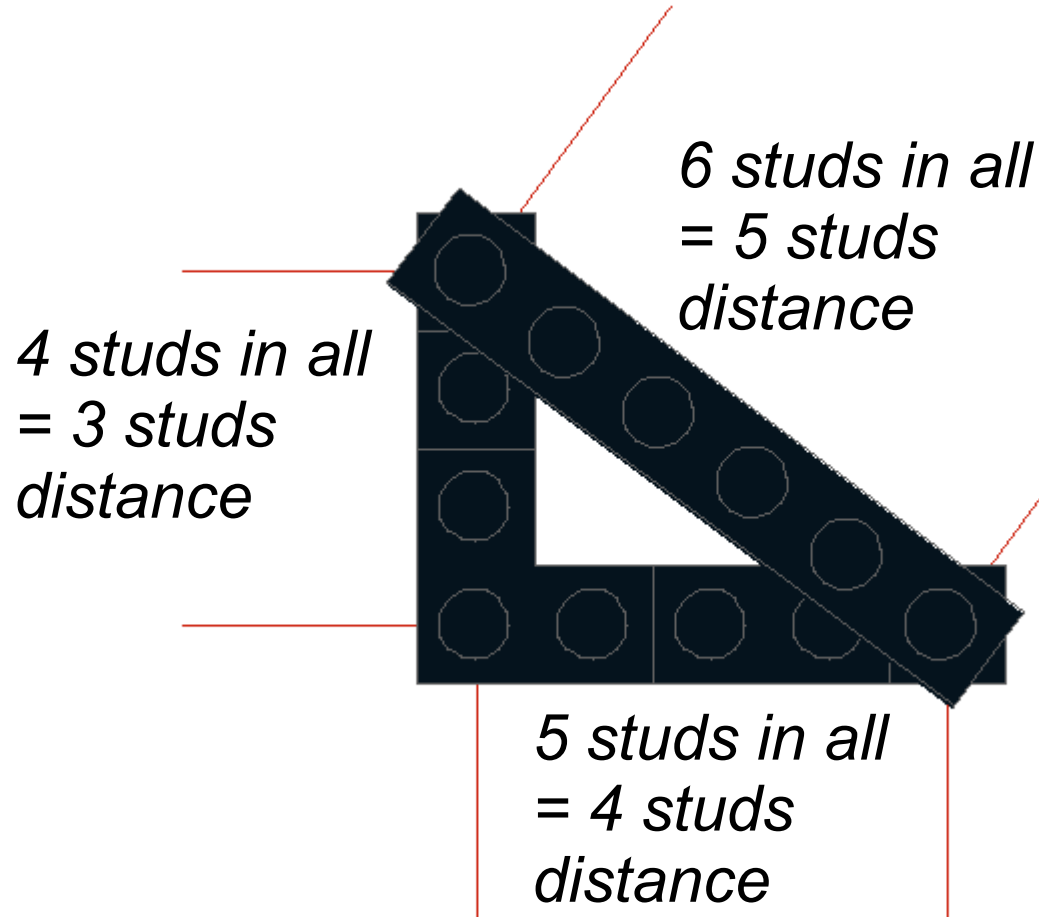
2 plates + 4 studs (3 $\frac{1}{3}$ bricks)
= 4 bricks

Inset panels example



My F40PH Caltrain locomotive

Pythagorean Triples



Pythagorean Triples are right triangles where the sides are all integers. The 3-4-5 triangle is easy to make in LEGO.

Trick is, count between the *centers* of the studs! Each side is one stud longer than you might expect.

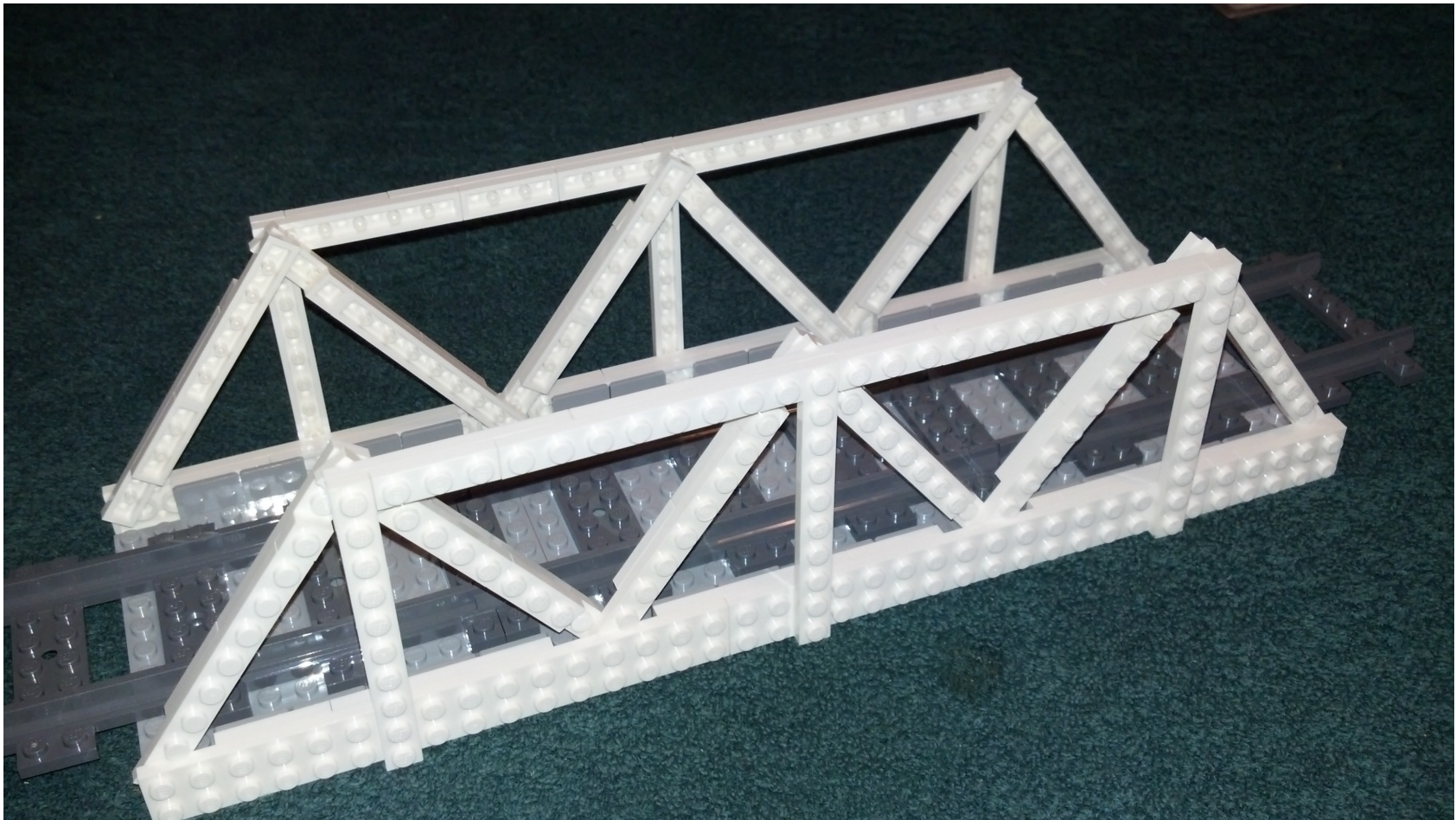
Note: You may need spacer plates for the diagonal to clear the studs.

More Pythagorean Triples

- There are only 4 triples with the diagonal of length 25 or less:
 - (3, 4, 5); (5, 12, 13); (8, 15, 17); (7, 24, 25)
- Additional ones can be made by multiplying these values by a scaling factor.
 - Example: $(6, 8, 10) = 2 \times (3, 4, 5)$
- Any other triangle with integer sides will *not* be a right triangle!

Pythagorean Triple Example: Truss Bridge

Trusses made from (6, 8, 10) Pythagorean triangles





Q&A



Thank you

Contact me if you have any further questions...

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