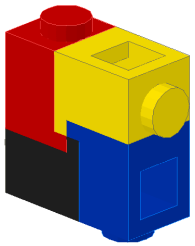
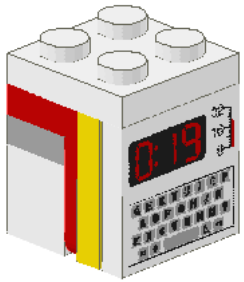
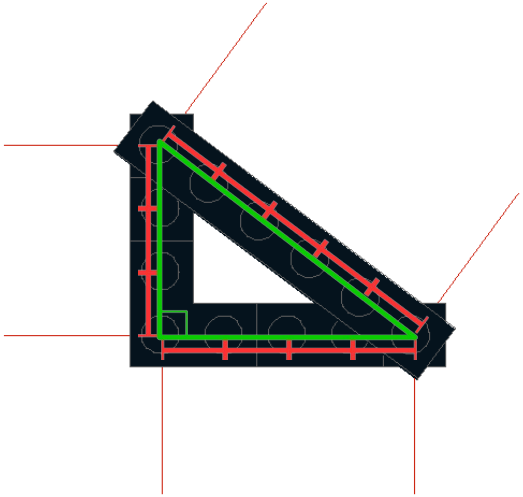
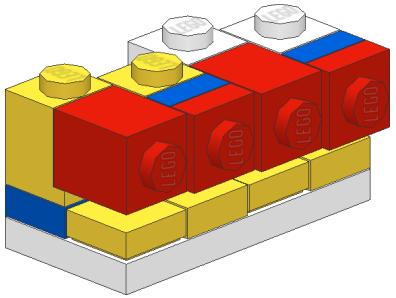
Brick Geometry



Portugal
LEGO Fan Weekend
Paredes de Coura 2017







Bill Ward

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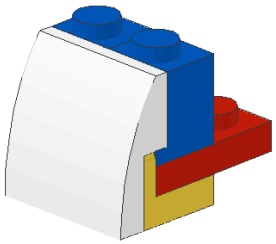
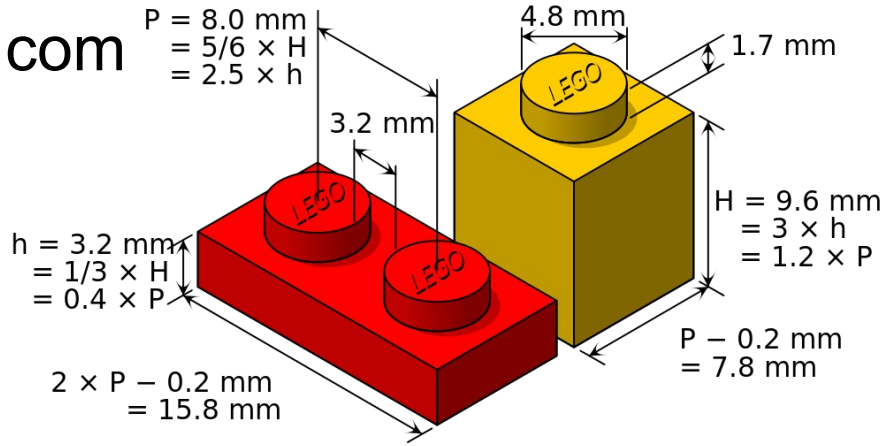
www.brickpile.com

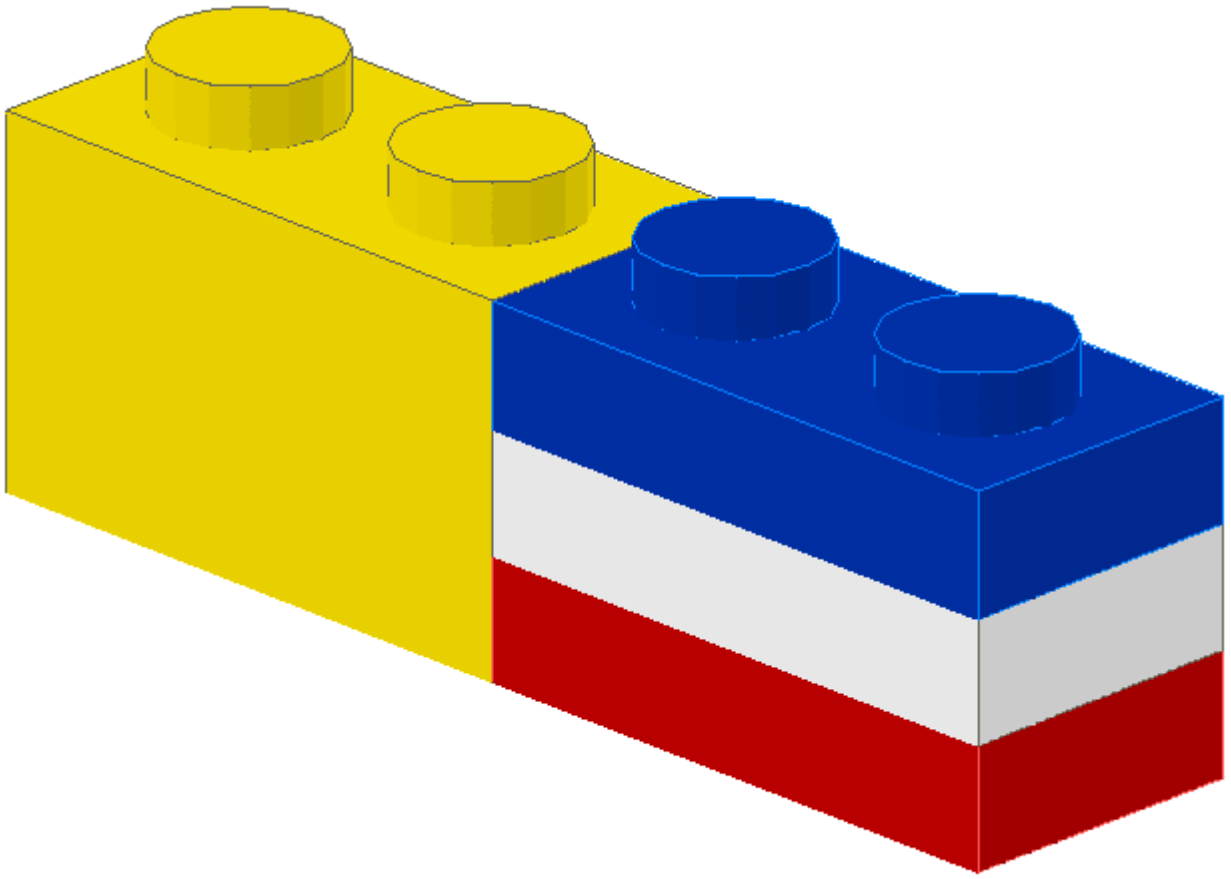




Ratios and Dimensions

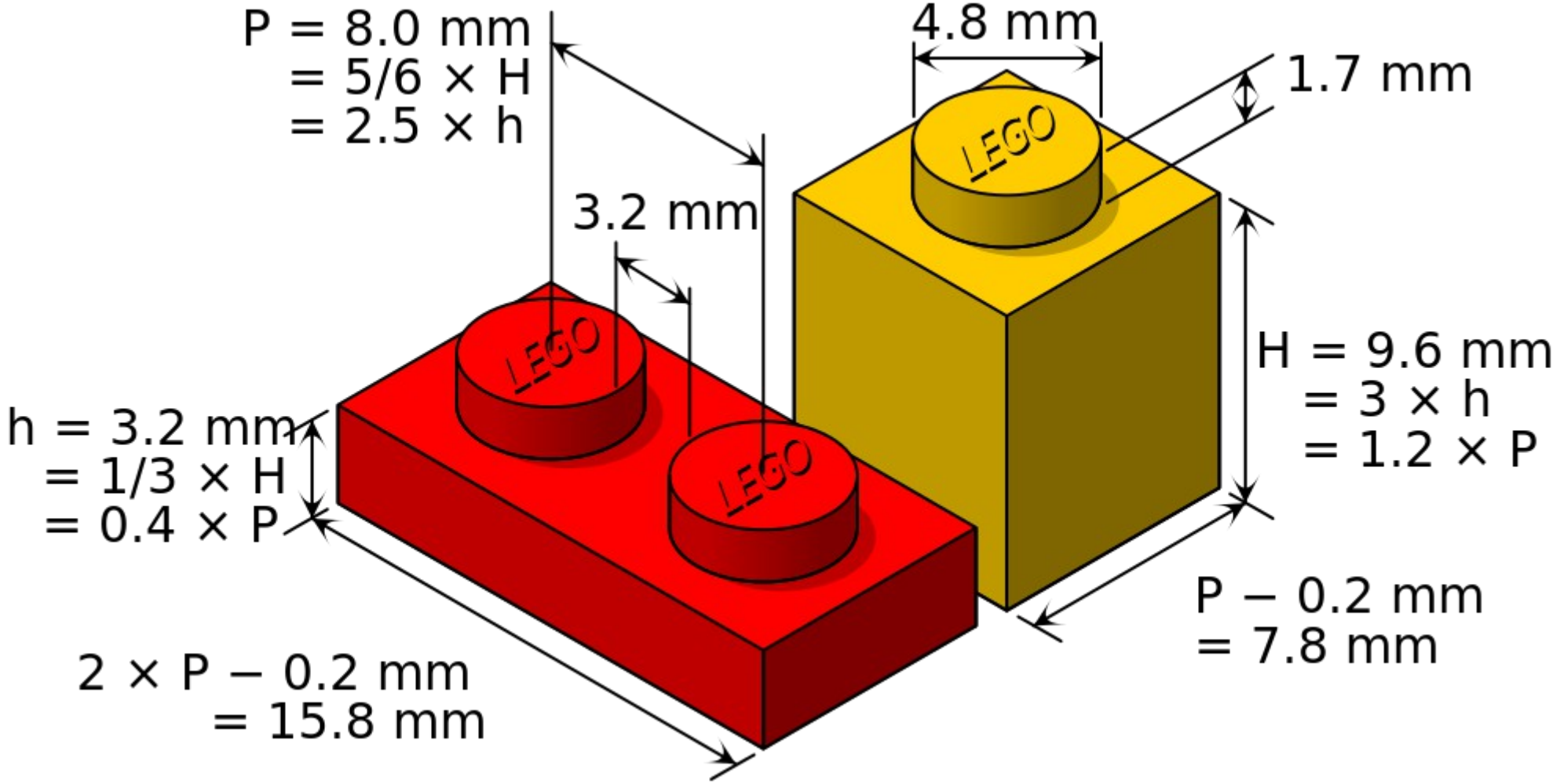
Basic LEGO Geometry
1 brick = 3 plates

Everyone knows this, I hope...



LEGO Dimensions

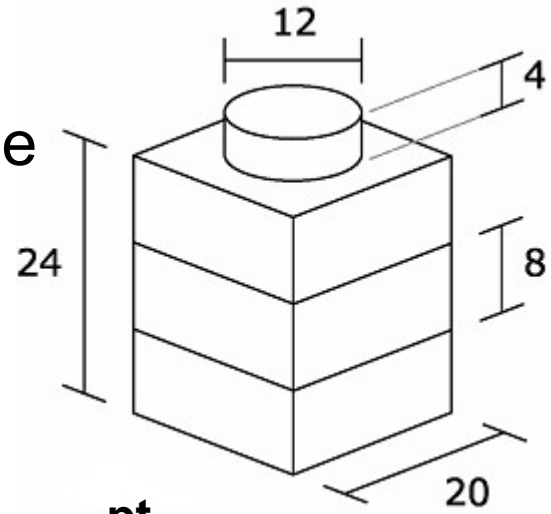
Quick! Memorize all these numbers. There will be a quiz later.



http://en.wikipedia.org/wiki/File:Lego_dimensions.svg

Math is Hard!
LDU = LDraw Unit

- A 1x1 stud brick or plate is 5/16” or 8mm (0.8cm)
- The height is 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!



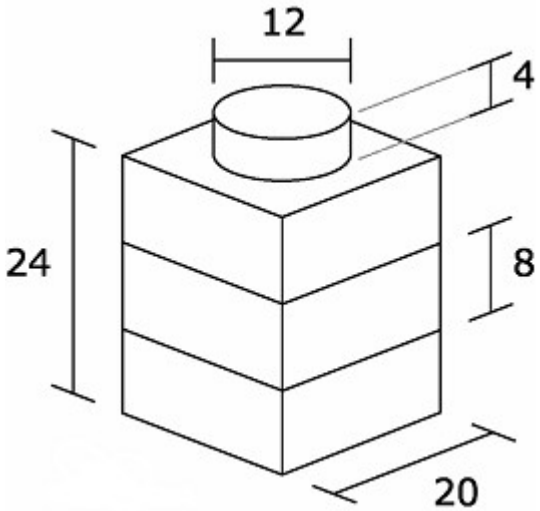
	LDU	studs	bricks	plates	cm	inch	pt
LDU	1	1/20	1/24	1/8	0.04	1/64	9/8
studs	20	1	5/6	5/2	0.8	5/16	45/2
bricks	24	6/5	1	3	0.96	6/16	27
plates	8	2/5	1/3	1	0.32	2/16	9
cm	25	1.25	1.04	3.125	1	0.39	28.3
inch	64	3.2	8/3	8	2.54	1	72
pt	8/9	2/45	1/27	1/9	0.0353	1/72	1

http://www.brickwiki.info/wiki/LDU

LEGO Bricks Are Not Square

Bricks are 8mm wide by 9.6mm high

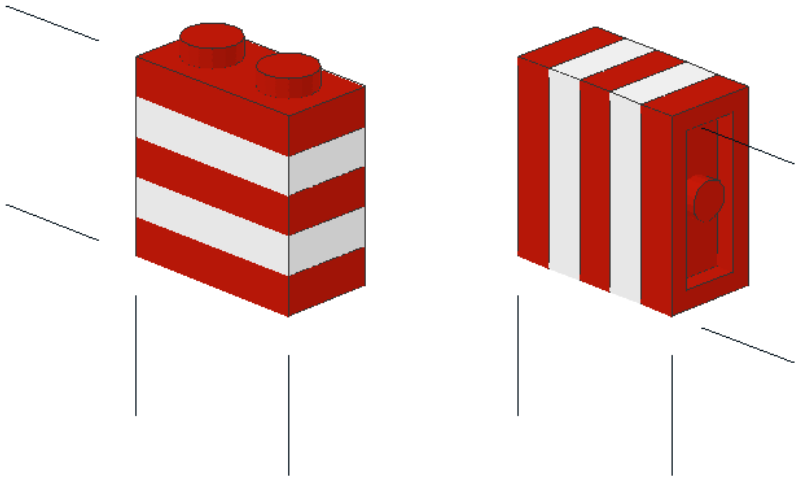
How do you make widths and heights match?



LDU makes the math easy....

How many plates = how many studs?

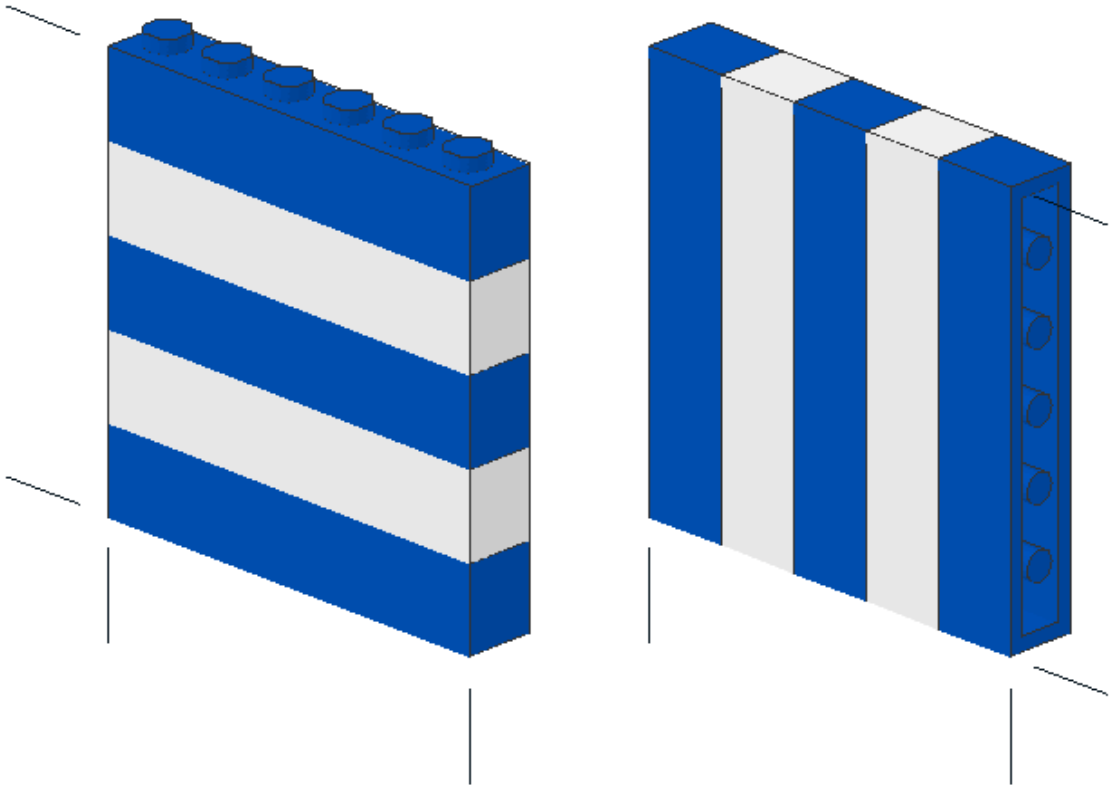
- 2 studs = 2x20 = 40 LDU
- 5 plates = 5x8 = 40 LDU

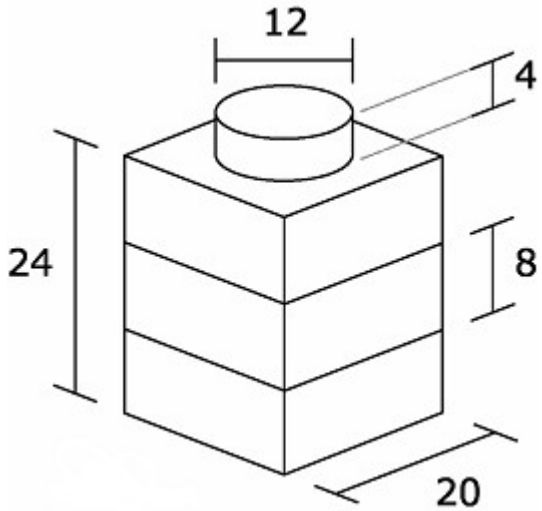


6:5 Brick Ratio

How many bricks = how many studs?

- 6 studs = 6x20 = 120 LDU
- 5 bricks = 5x24 = 120 LDU



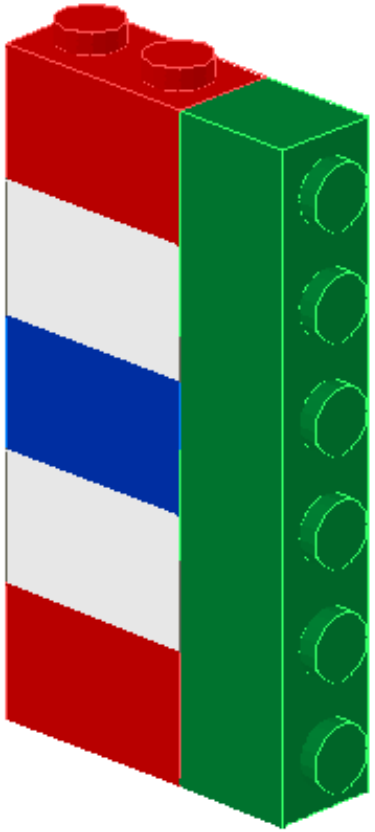


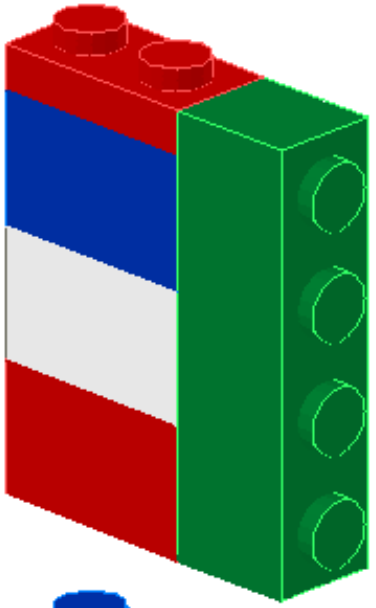
Even Numbers of Studs

Any even number of studs corresponds to a combination of bricks and plates, since 2 studs = 5 plates

6 studs =
5 bricks =
120 LDU

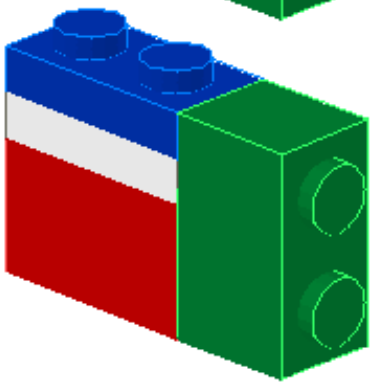
(or 15 plates)





4 studs =
3 1/3 bricks =
80 LDU

(or 10 plates)

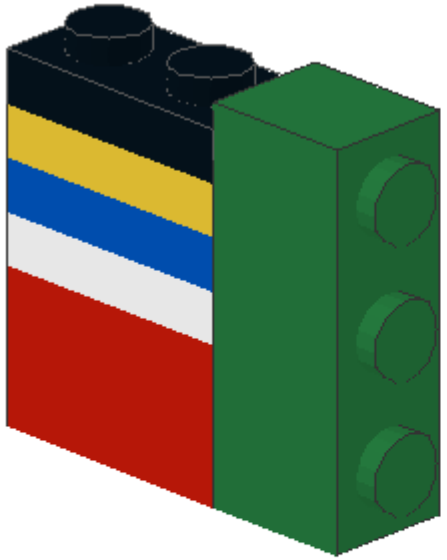


2 studs =
1 2/3 bricks =
40 LDU

(or 5 plates)

Odd Numbers of Studs

Since 1 stud = 2½ plates, no combination of plates adds up to exactly one stud

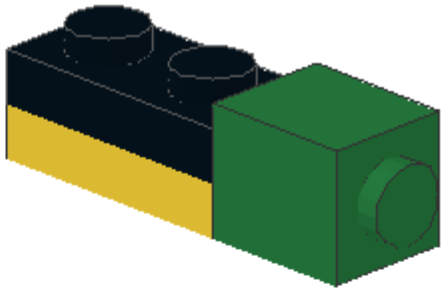


3 studs = 60 LDU

1 brick + 4 plates = 56 LDU

?? = 4 LDU

(Missing ½ plate!)

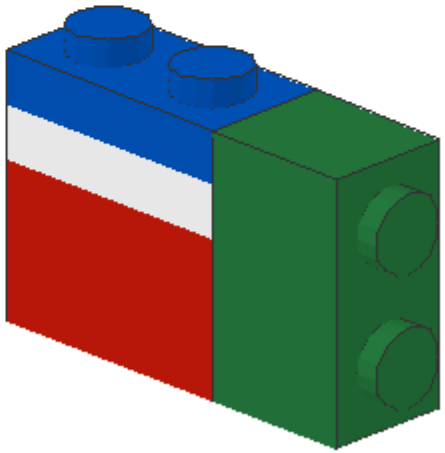


1 stud = 20 LDU

2 plates = 16 LDU

?? = 4 LDU

(Missing ½ plate!)



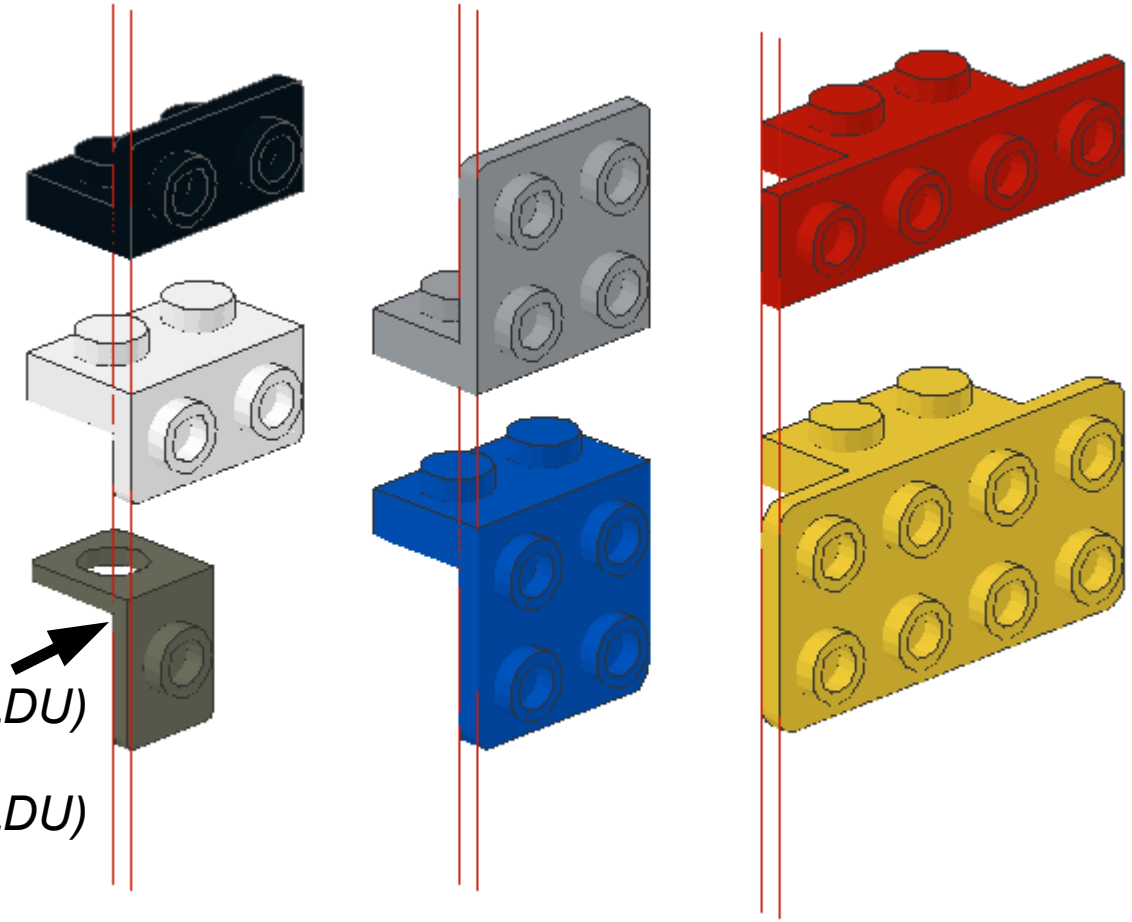
2 stud = 40 LDU

5 plates = 40 LDU

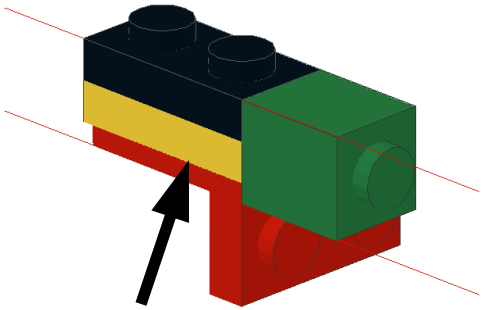
(OK)

But where do you get ½ plate?

One answer: brackets. The thin vertical plate is ½ the thickness of a normal plate, or 4 LDU



Exception:
12mm (3 LDU)
instead of
16mm (4 LDU)



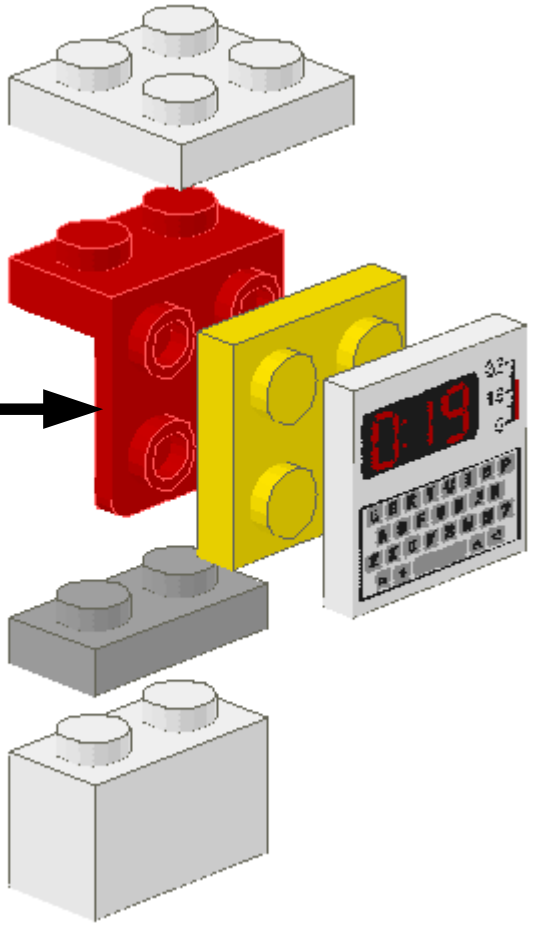
1 plate = 8 LDU thick
1 stud brick = 20 LDU

2 plates + bracket =
8 * 2 + 4 =
20 LDU

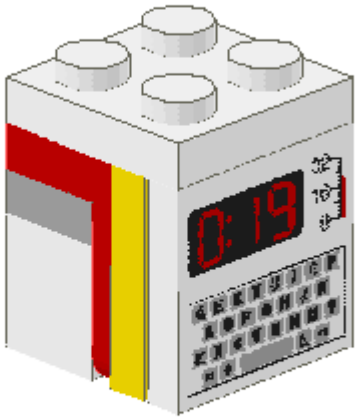
SNOT
Studs Not On Top

Using ½ plate thickness from brackets

Bracket vertical part is ½ plate thick



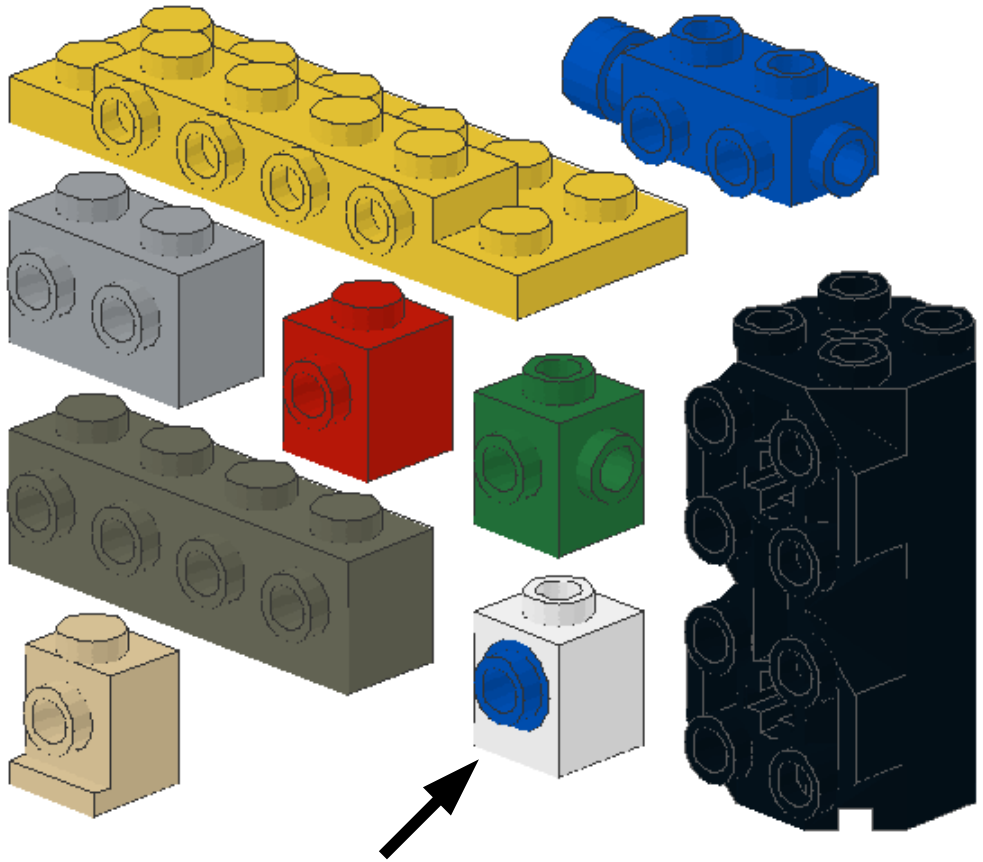
½ plate from bracket
+ 1 plate + 1 tile
= 2 ½ plates, same as 1 stud



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

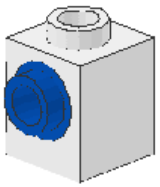
Bricks with Studs on the Side

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

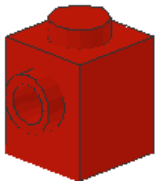


** Technic brick with ½ pin is not quite the same – see next page*

Caveat – Technic Pin Alignment



vs.



Technic pin hole placement is just a little higher (about 0.2mm) than stud-on-side placement.

Some models may have alignment problems due to this.

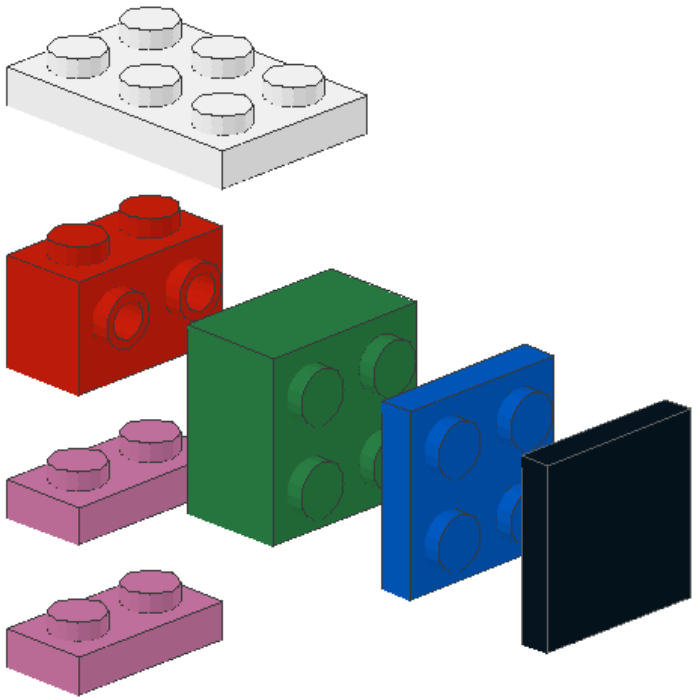
Reason: early Technic brick molds needed thicker plastic between pinhole and bottom of brick.

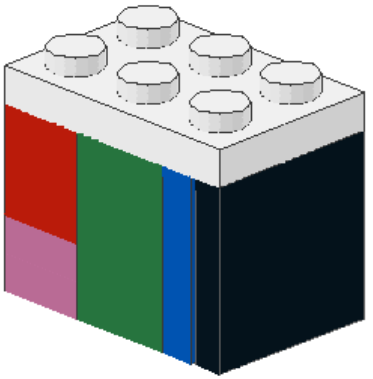
Result: LEGO now produces more bricks with studs on side instead of using ½ pins in Technic bricks – better for us anyway

Bricks with studs on sides to mount flush

Use bricks with studs on sides to attach assemblies at 90 degrees.

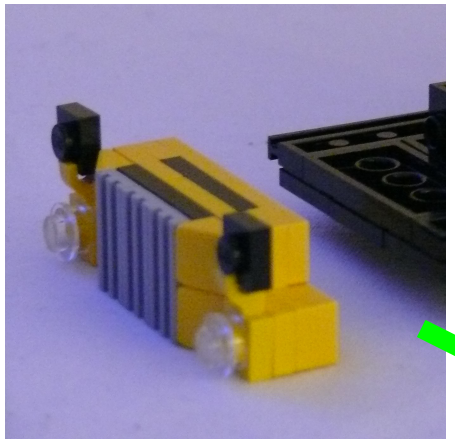
To mount them flush, remember that 5 plates = 2 studs = 40 LDU.





Flush tile examples

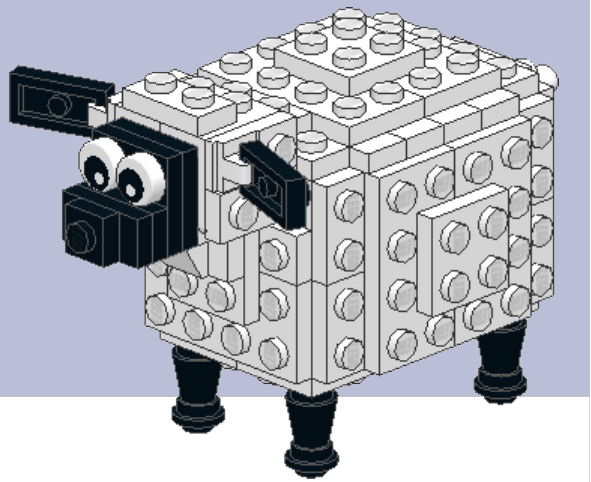
My Lunar School Bus model used this technique.



Grille and headlight sub-assembly fits flush in 2-stud space

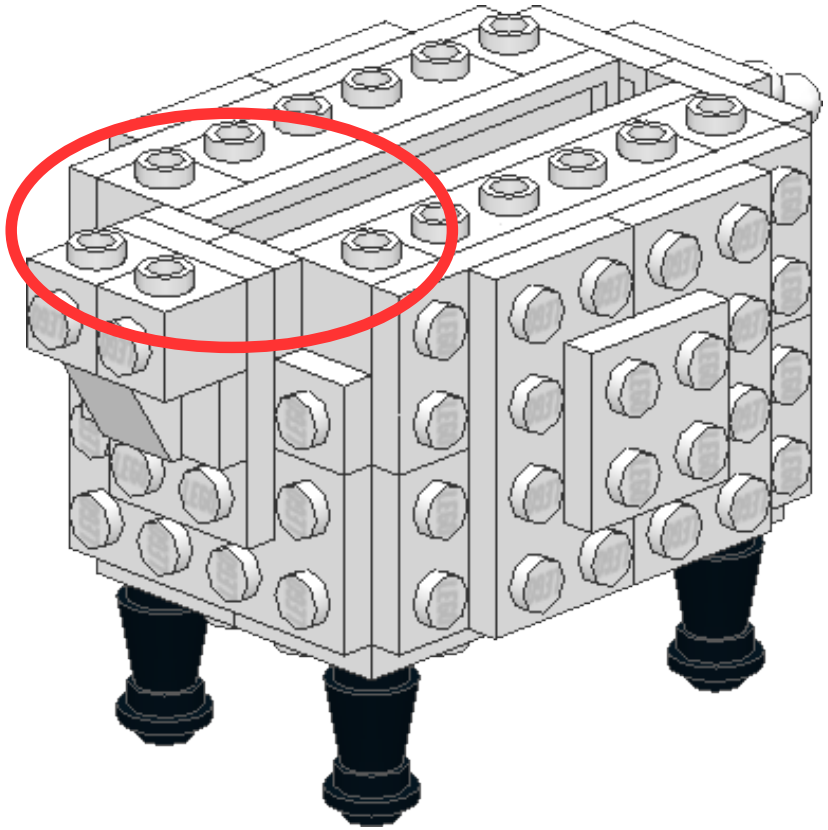
5 plates
= 40 LDU
= 2 studs

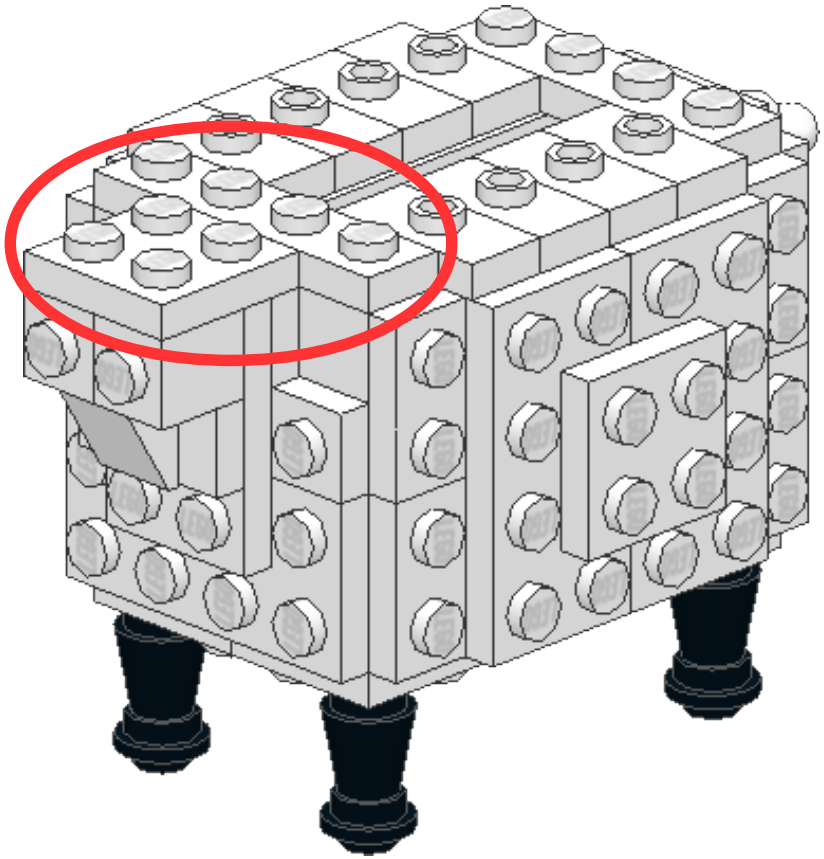
Another Alignment Example



Note how the neck is made from a brick and two plates = 40 LDU

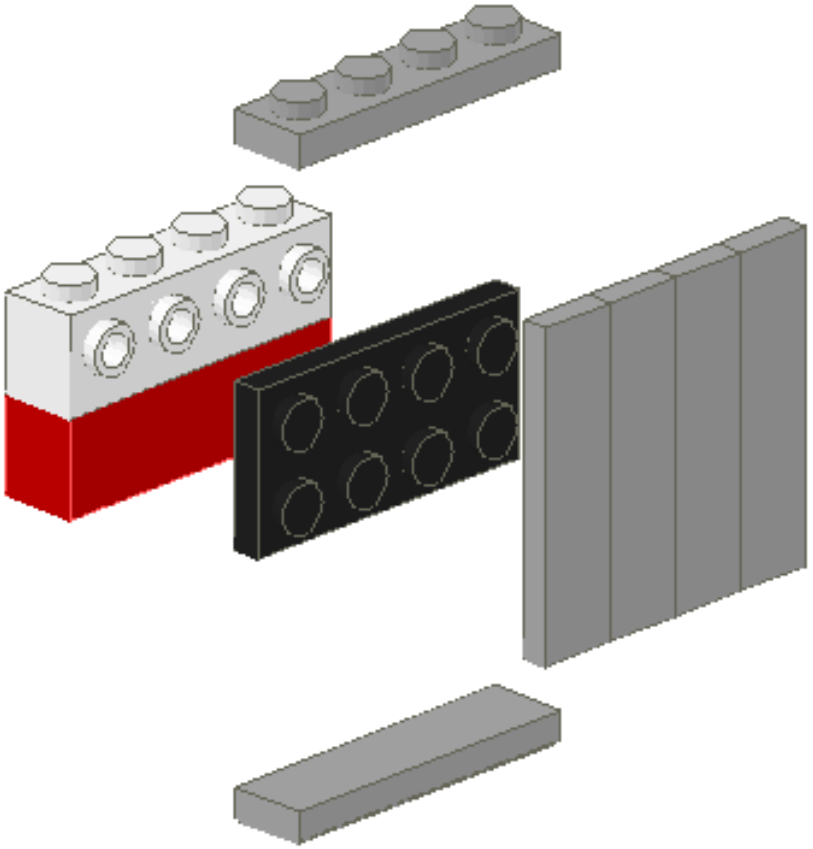
So we can place a 2x2 plate on top and the studs line up with the rest of the body



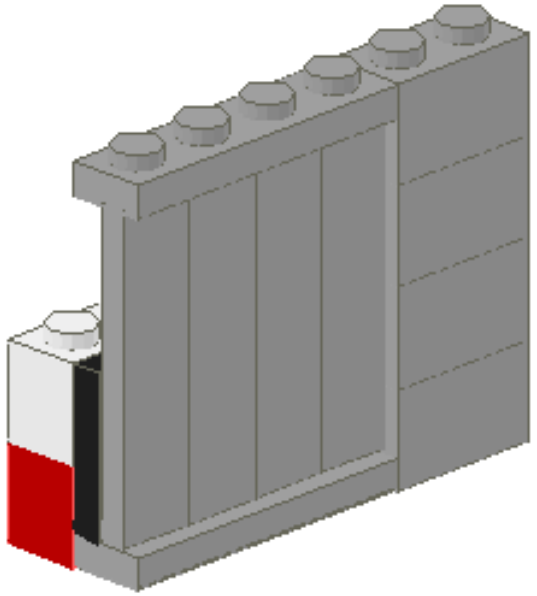


Inset Panels

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



1 plate + 2 studs (1 2/3 brick)
= 2 bricks



2 plates + 4 studs (3 1/3 bricks)
= 4 bricks

Tiles are ½ plate inset

Inset panels example

Panels inset by ½ plate

My F40PH Caltrain locomotive

Photo by Drew Dirschell: https://www.flickr.com/photos/7333042@N06/4639456044

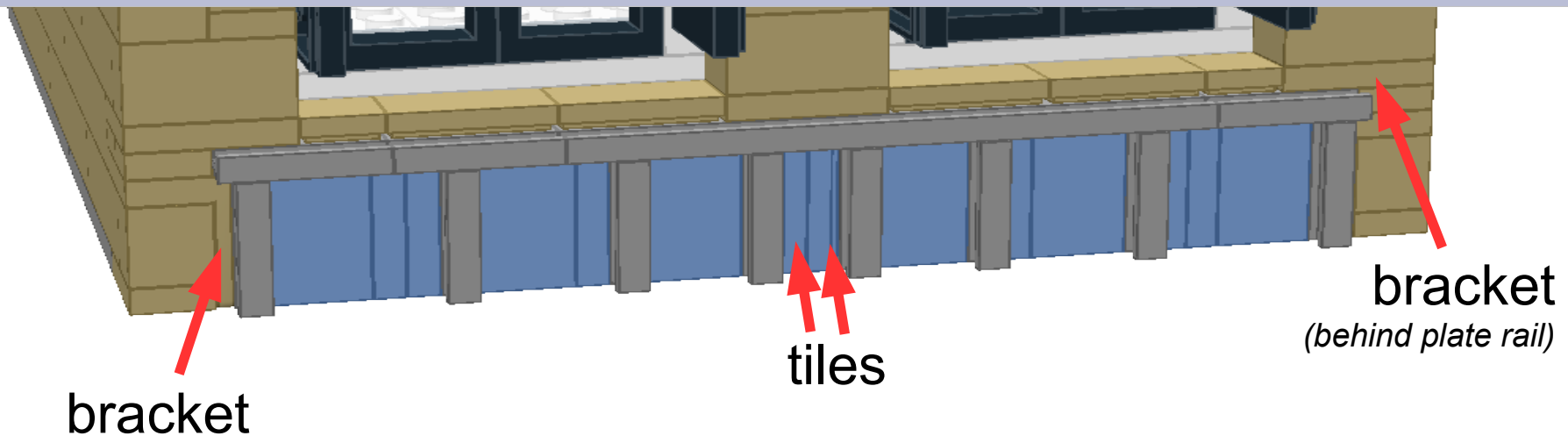
“De Vier Gekroonden”

This model by Vincent “Mr. Tomato Bread” Kessels uses some of these techniques.

Photos used with permission

Model:
“De Vier Gekroonden”
by Vincent Kessels
a.k.a.
“Mr. Tomato Bread”

Sideways Building with Brackets



Stack bricks and plates with a tile on the end

Mount on bracket on each side facing inward

3 bricks = 3 x 24 = 72 LDU
7 plates + 1 tile = 8 x 8 = 64 LDU
bracket = 4 LDU
Total = 140 LDU = 7 studs

Tiles on the ends press together and friction holds it all together

Model:
"De Vier Gekroonden"
by Vincent Kessels
a.k.a.
"Mr. Tomato Bread"

The Problem with Jumper Plates

Requirement: 5-stud wide window openings with 6-stud wide arches above.

Solution: offset the arches by ½ stud using jumper plates

Side effect: How to fill ½ stud gap on ends?

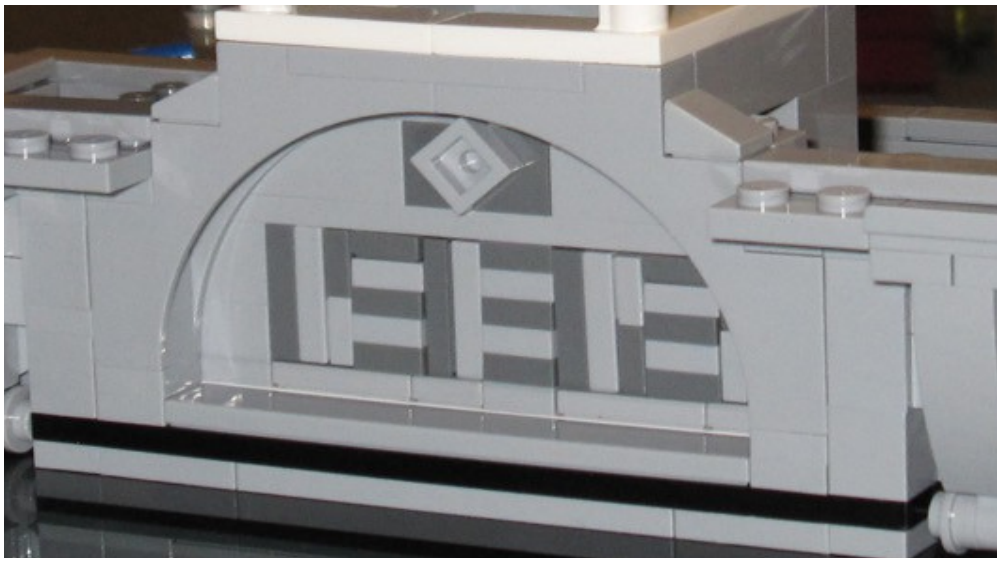
Imperfect solution: attach tile mounted sideways.

½ stud = 10 LDU. Tile = 8 LDU. Gap of 2 LDU (¼ plate) cannot be filled by any LEGO part. Any better ideas to fill a 10 LDU space?

Model:
"De Vier Gekroonden"
by Vincent Kessels
a.k.a.
"Mr. Tomato Bread"

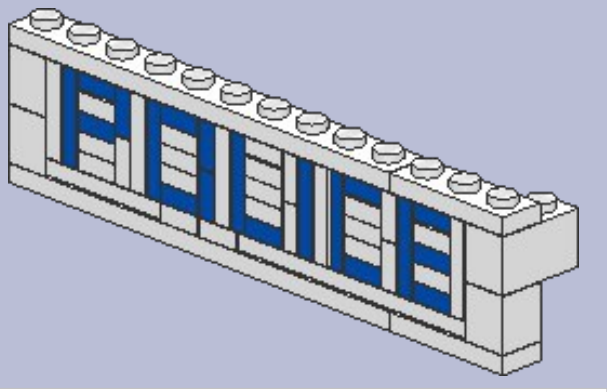
Mosaic Dates on LEGO Modular Sets

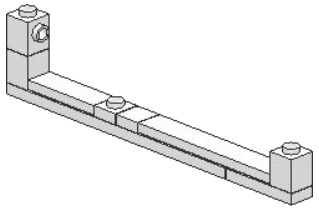
These sets (#10197 & 10224) use plates and tiles to create SNOT dates on the buildings.

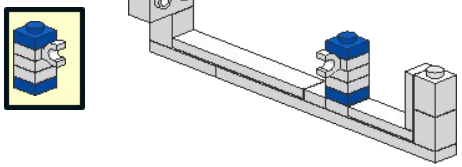


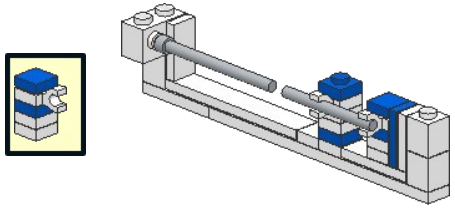
http://commons.wikimedia.org/wiki/File:Lego_Modular_-_Set_10197_Fire_Brigade_%286817665156%29.jpg
http://commons.wikimedia.org/wiki/File:Lego_Modular_-_Set_10224_Town_Hall_%288310511639%29.jpg

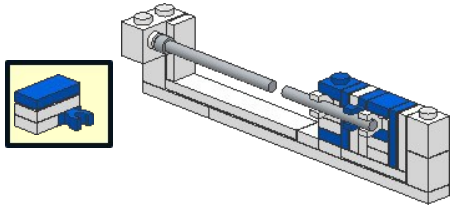
Clip and Bar Lettering

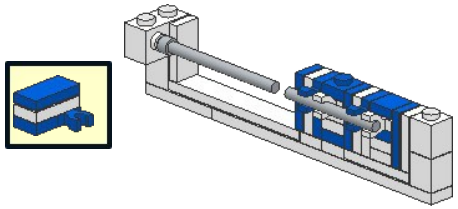


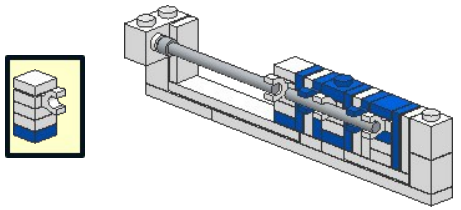
1. 

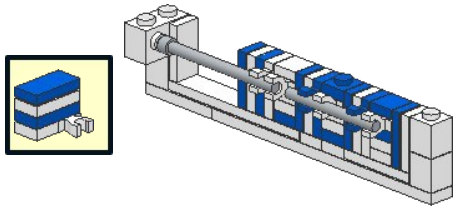
2. 

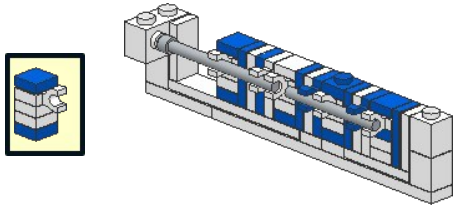
3. 

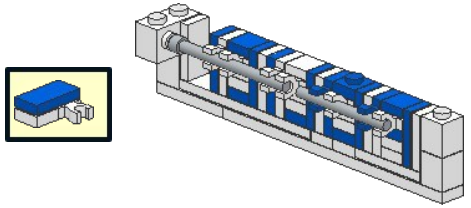
4. 

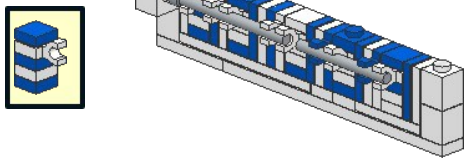
5. 

6. 

7. 

8. 

9. 



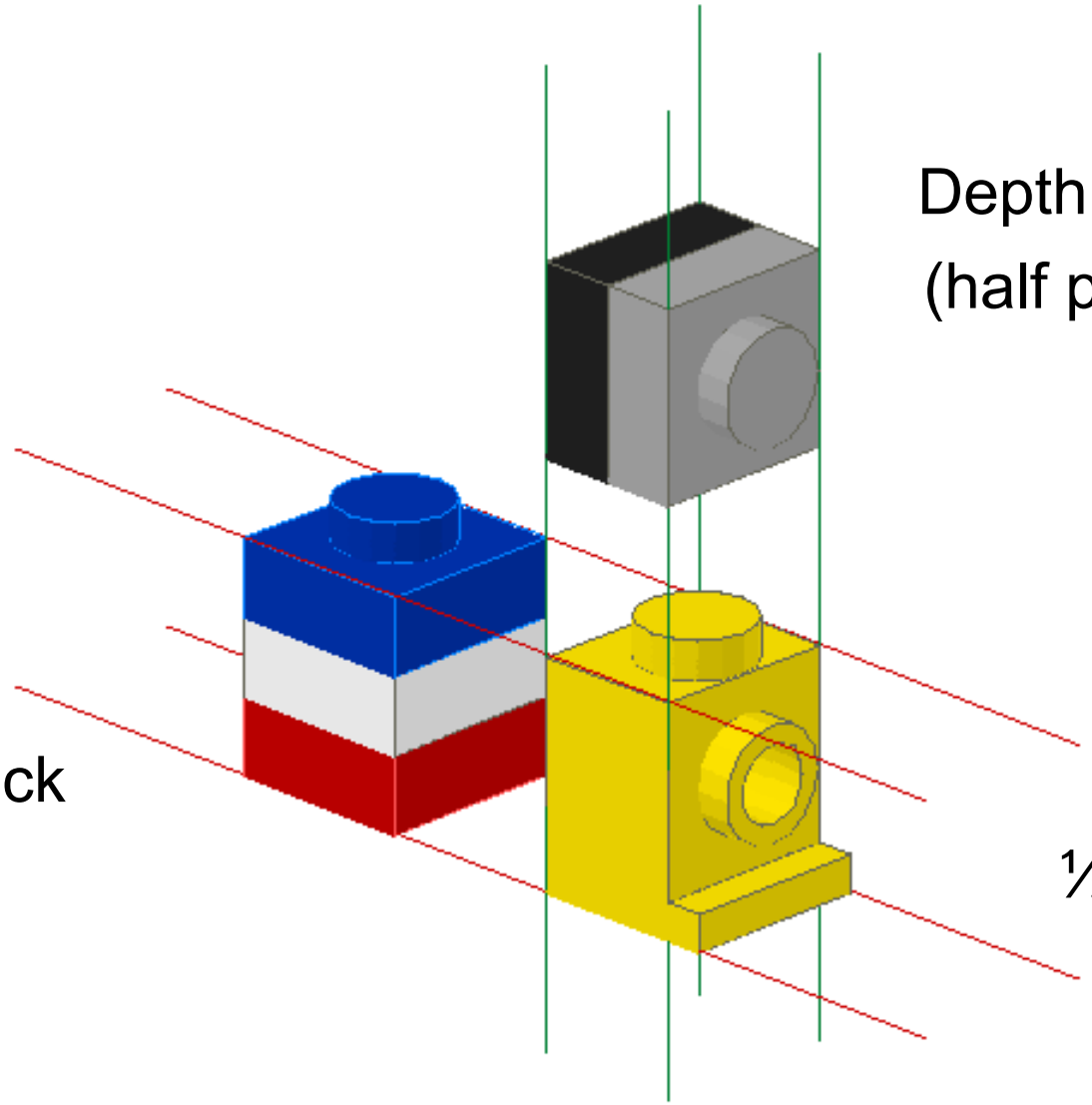
Example of lettering style similar to that from the fire house and town hall sets.

Using this clip and bar technique frees you from worrying about spacing.

Only the middle of the "O" lines up with the studs above and below!

Fun with Headlight Bricks

Headlight Brick Dimensions

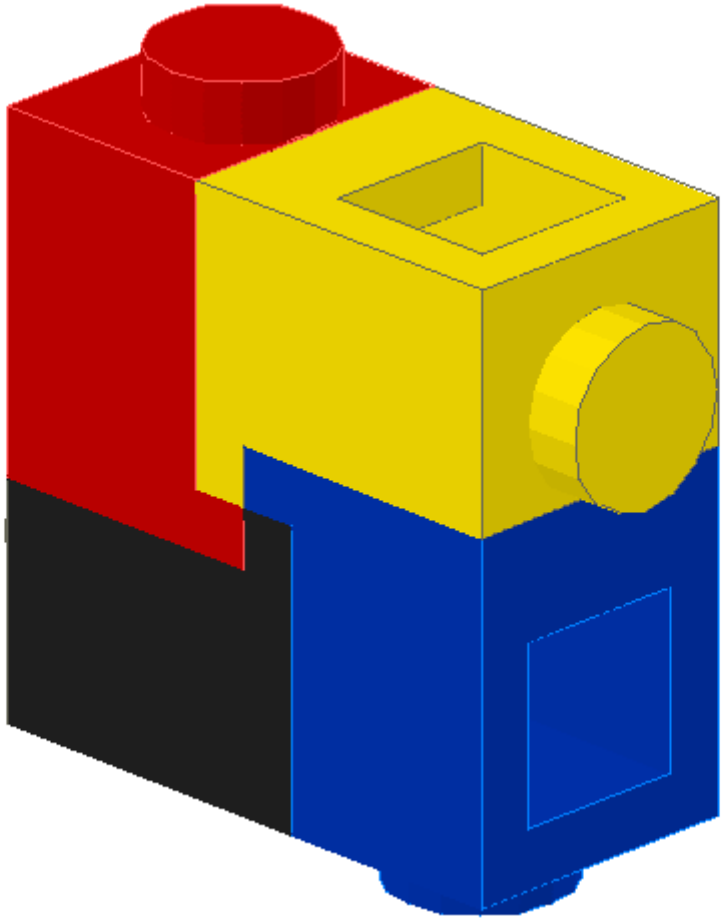


Depth = 2 plates
(half plate inset)

Height = 1 brick
or 3 Plates

“foot” is
½ plate thick &
½ plate high

Four headlight bricks

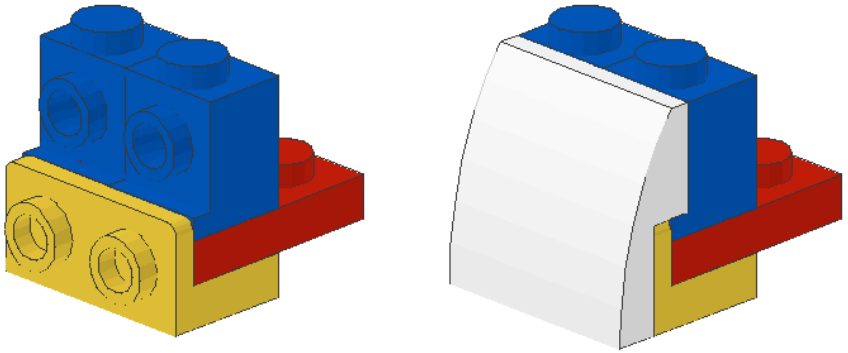


2 plates (red) +
3 plates (yellow) =
5 plates = 2 studs

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

Combining Brackets & Headlight Bricks

½ plate offset on headlight bricks +
½ plate thickness on bracket =
1 plate thickness, suitable for 2x2 curved slope

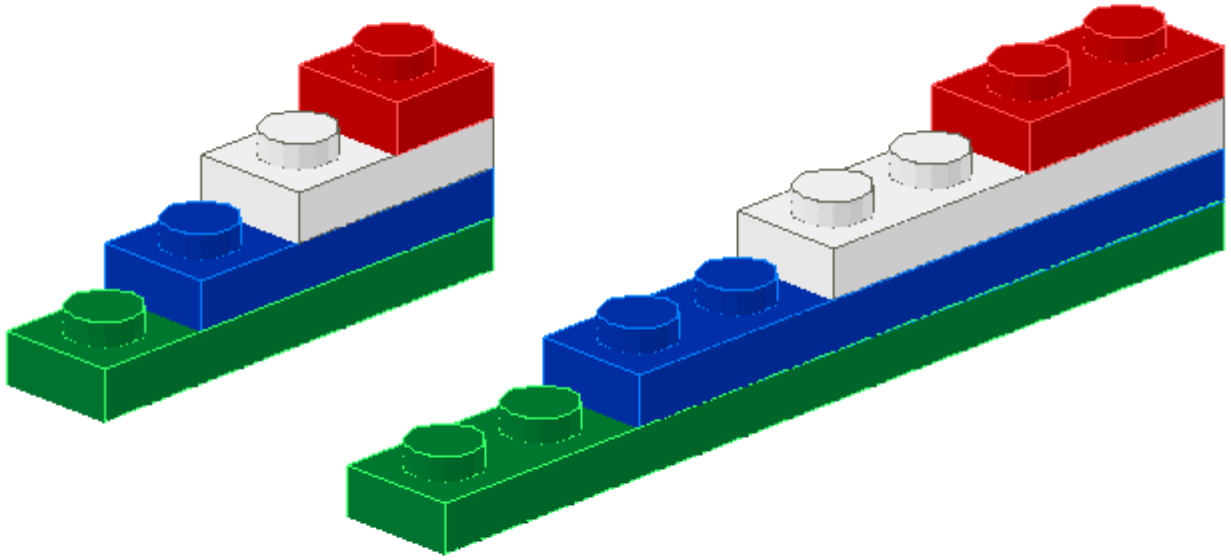


As seen in the LEGO IDEAS Ghostbusters set #21108 (minifig display)

Problem: Gradual Steps

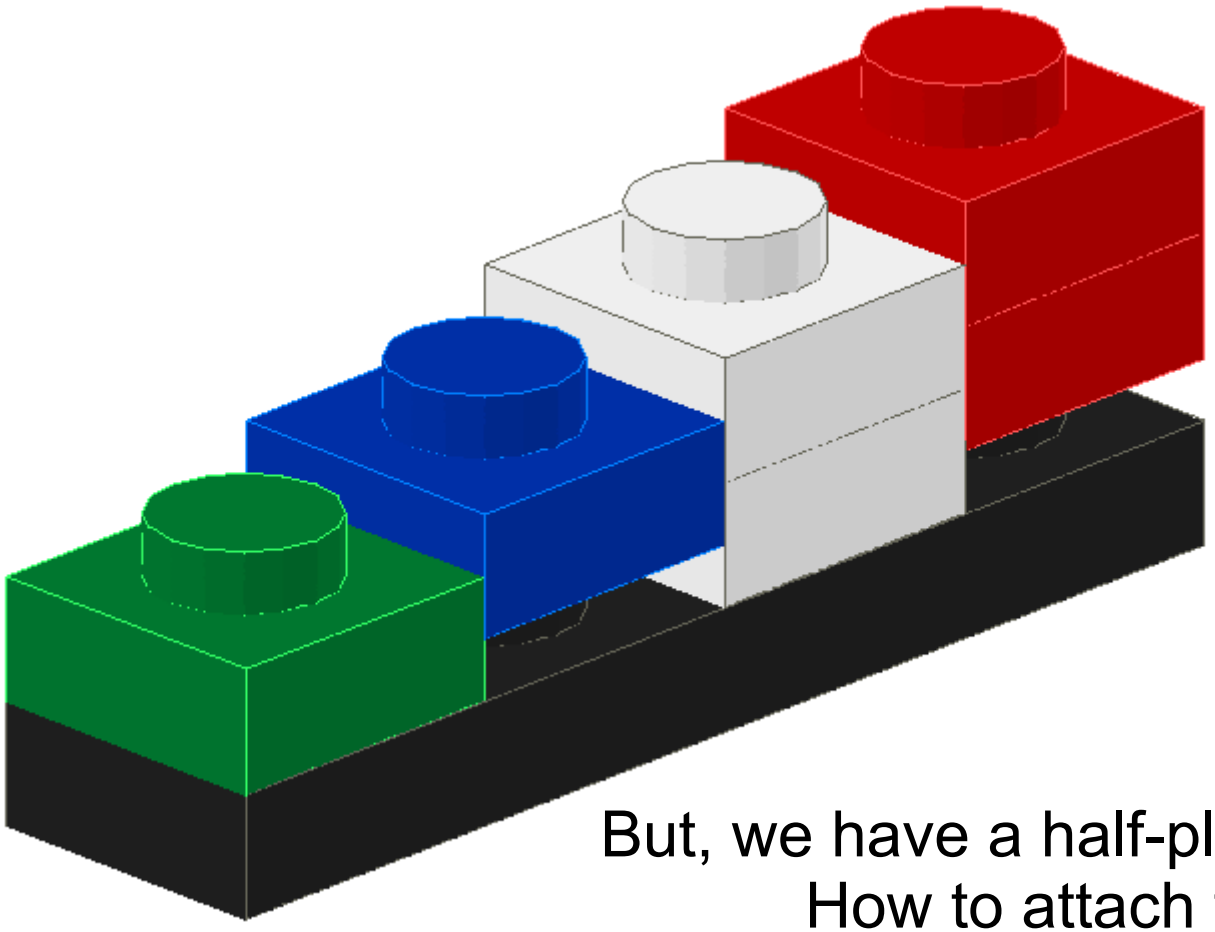
How do you make a gentle slope?

What if these are too steep?



Gradual Steps

For a more gradual slope, we'd like to mount every other one ½ plate higher

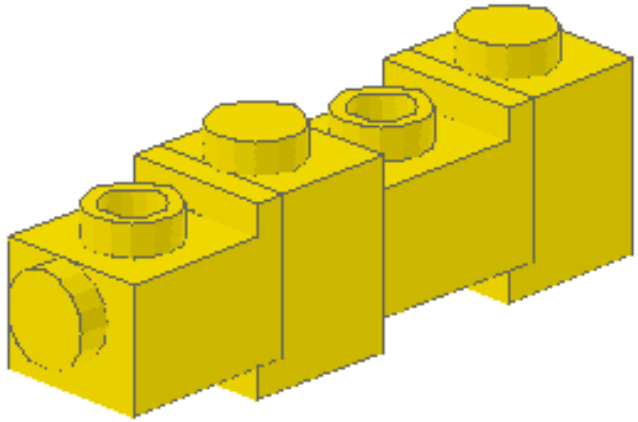


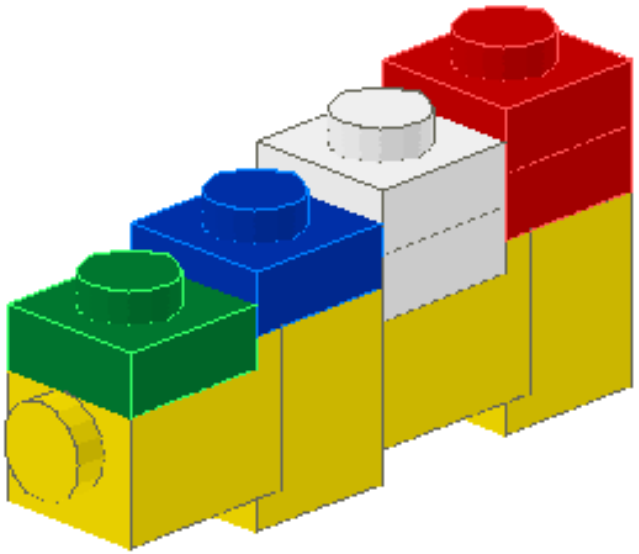
But, we have a half-plate hole to fill!
How to attach these?

Solution: Headlight Bricks

Alternate rotations for headlight bricks to take advantage of ½ plate offset in “foot”

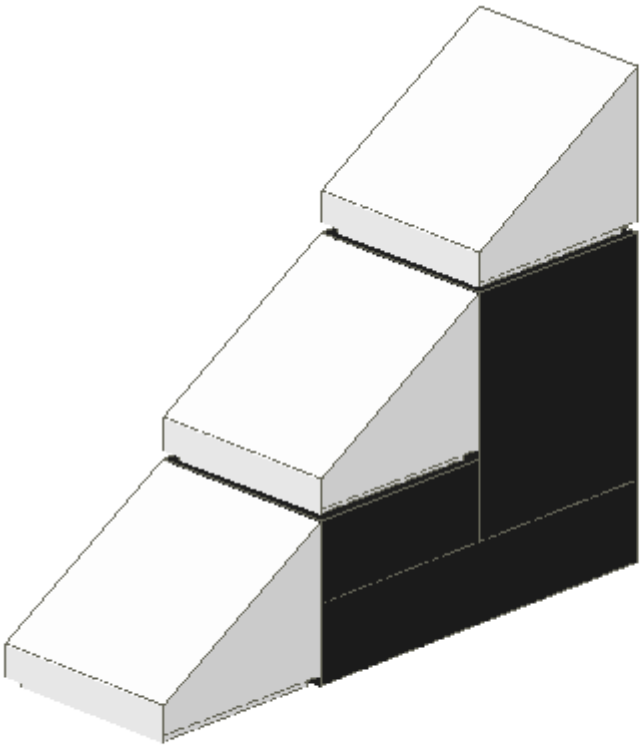
2 plates + ½ plate = 1 stud





Half-plate lift from “foot”

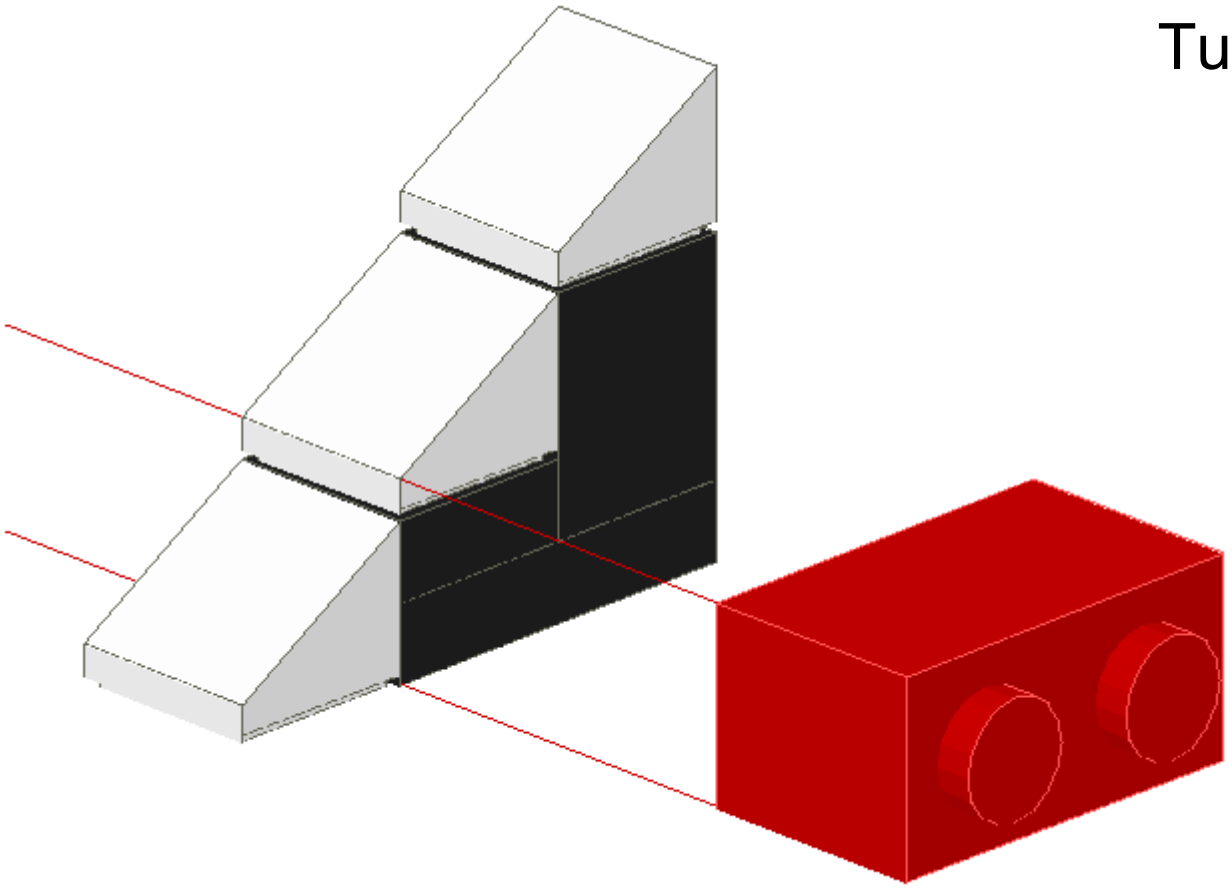
Problem with “cheese slope”: Stairstep effect



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



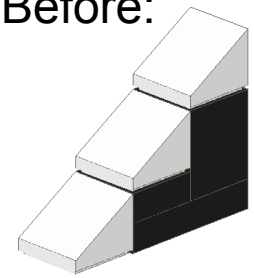
Turns out that “notch” is ½ plate thick.

2 plates (height of cheese slope) + ½ plate

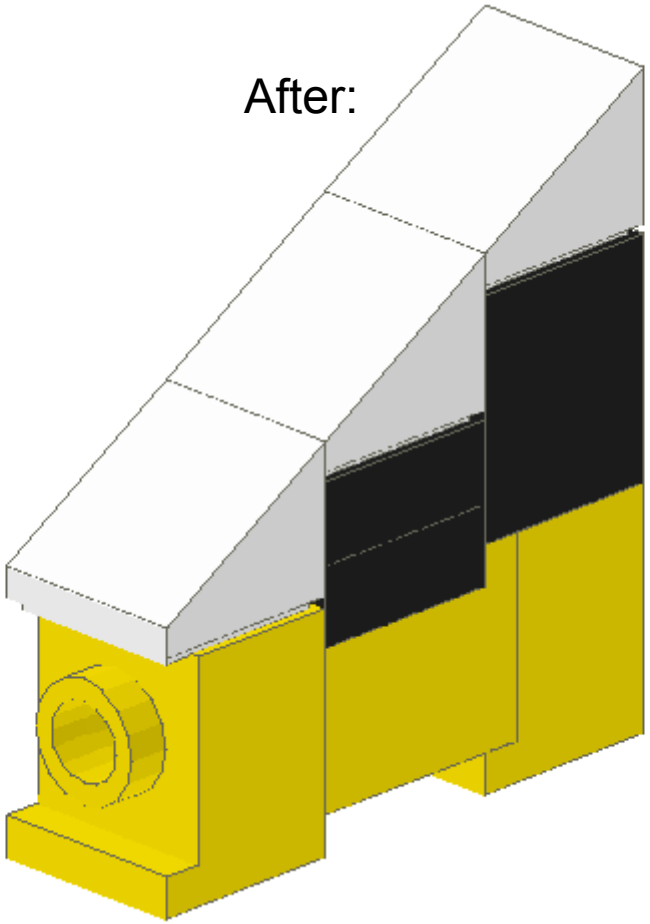
= 1 stud

Solving the stairstep effect

Before:



After:

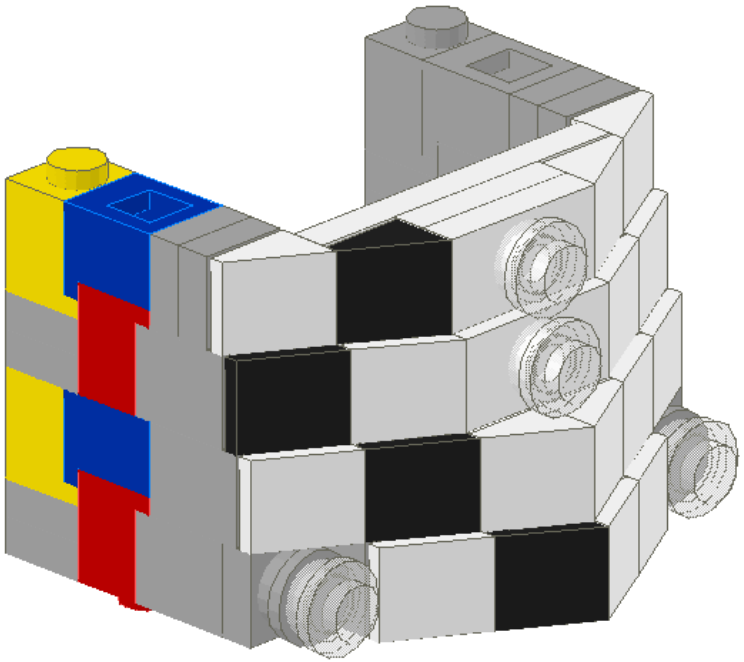


Used in Bram Lambrecht's
"Legoland Spacelines 979"

http://www.flickr.com/photos/bram/1461137007/
(used with permission)

Mount the center slope ½ plate lower for a smooth surface!

Useful for trains, too



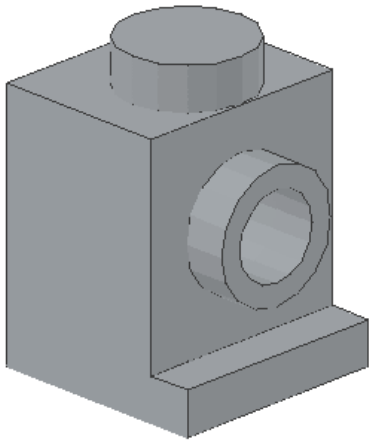
My F40PH Caltrain locomotive

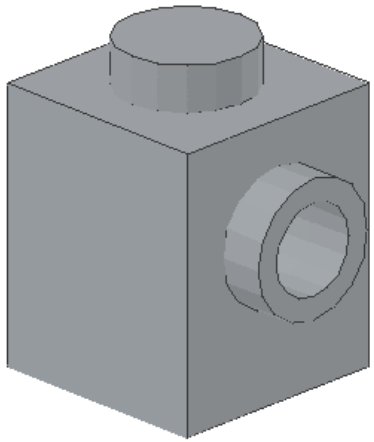
“Headlight Brick”
vs.
“Brick 1 x 1 with Stud on 1 Side”

Headlight Brick depth = 2 plates = 16 LDU

Brick depth = 2 ½ plates = 20 LDU

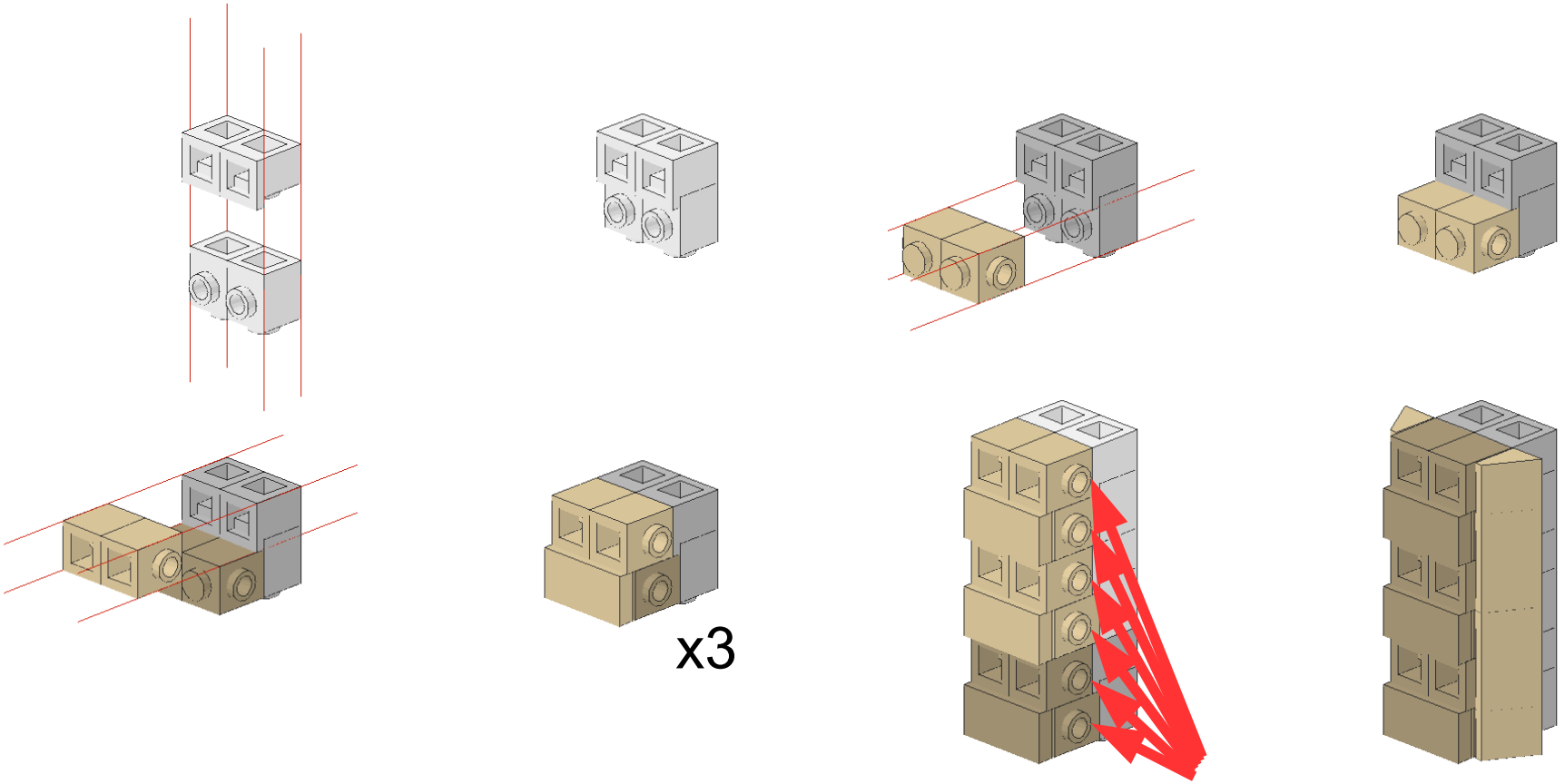
Combine these to achieve ½ plate differences in depth!





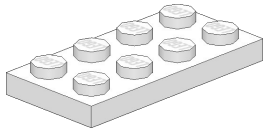
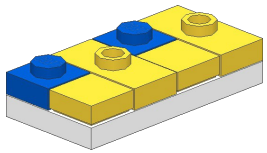
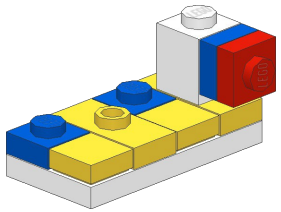
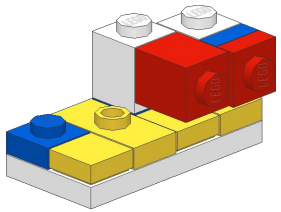
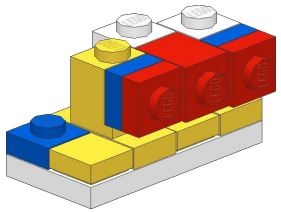
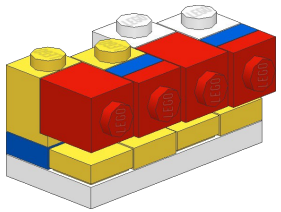
Hospital Bay Window example

Windows (bottoms of bricks) are inset by ½ plate



These studs line up perfectly!

How about QUARTER plate offsets?

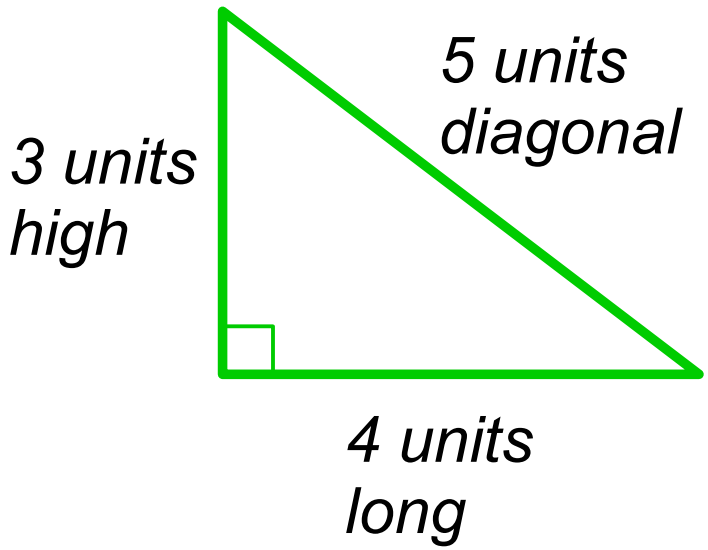
1. 
2. 
3. 
4. 
5. 
6. 

Remember from Vincent Kessels' building that a jumper plate adds a ¼ plate offset?

Combine that with the ½ plate difference between the “headlight brick” and the “brick with stud on one side” and get a *very* gradual step.

Triangles

Pythagorean Triples

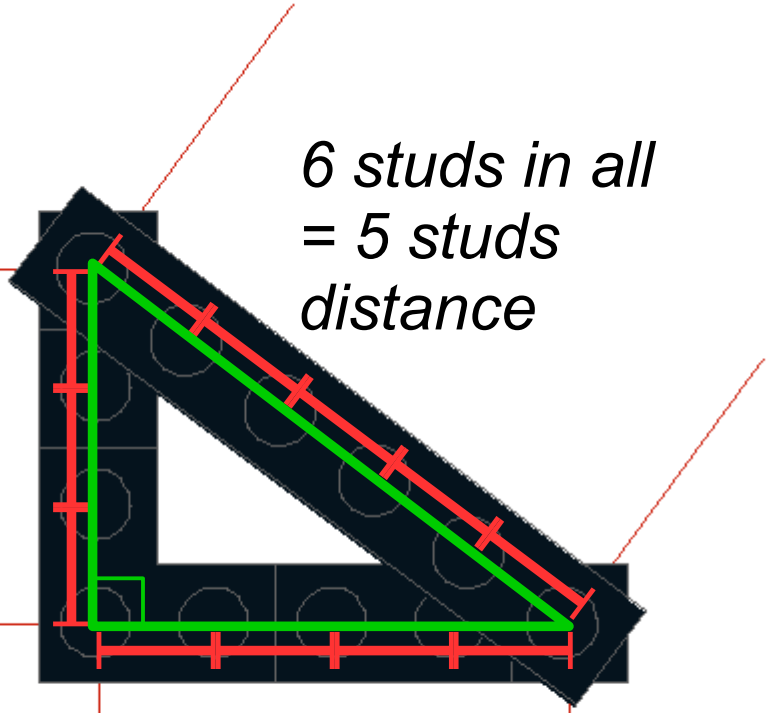


Pythagorean Triples are right triangles where the sides are all integers.

The first Pythagorean Triple is the 3-4-5 triangle. As long as the 3 sides have this ratio it will have a perfect right angle.

Multiples also work: 6-8-10, 9-12-15, etc.

Pythagorean Triples in LEGO



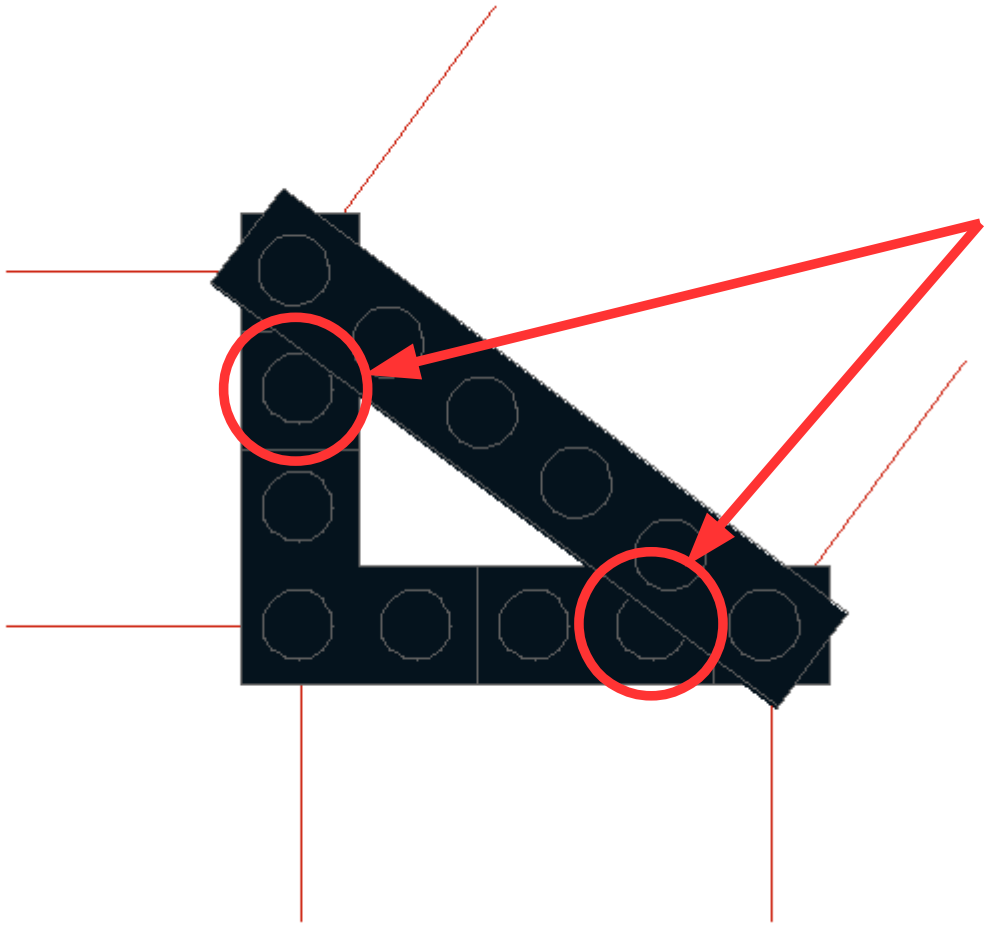
When making a Pythagorean Triple in LEGO, add one stud to each side!

Why? Count *between the centers* of the studs!

(3, 4, 5) triangle
= (4, 5, 6) studs

(6, 8, 10) triangle
= (7, 9, 11) studs

Pythagorean Triples in LEGO



Note: See how the studs are partly blocked by the diagonal.

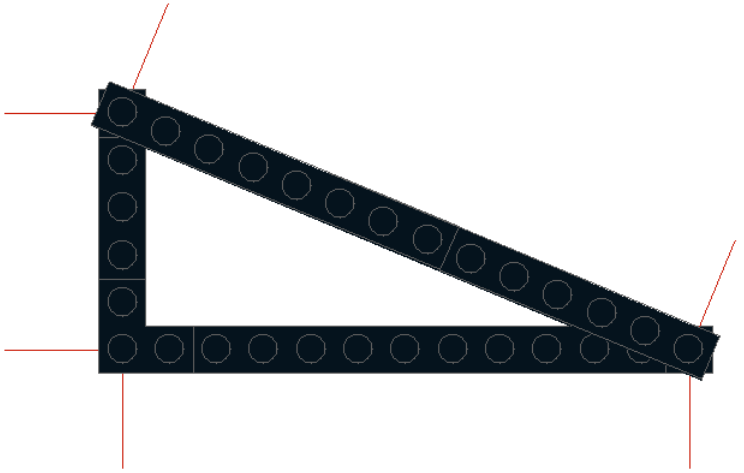
This triangle must be at least three plates thick, due to the spacer plates needed between the diagonal and the horizontal or vertical plates.

More Pythagorean Triples

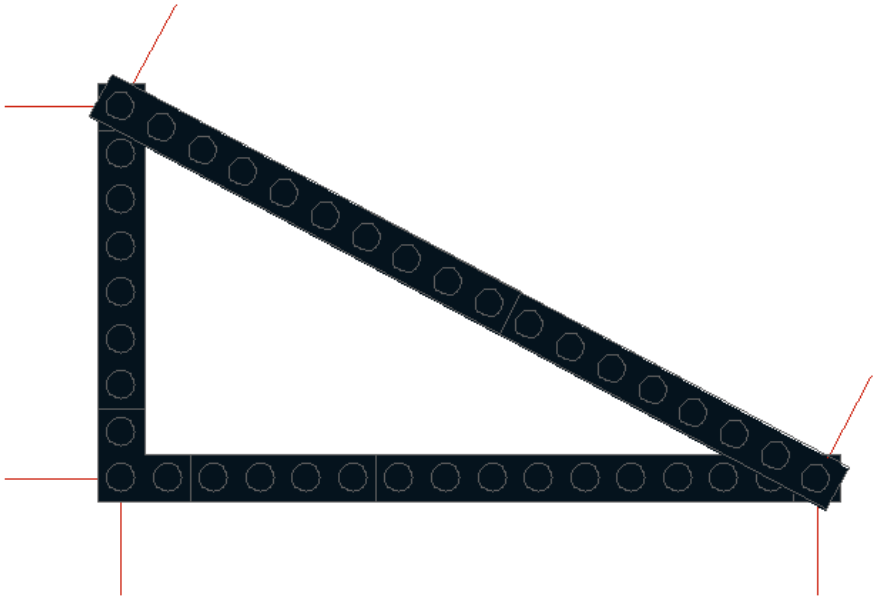
- There are only 4 triples of diagonal length 25 or less:

  (3, 4, 5); (5, 12, 13); (8, 15, 17); (7, 24, 25)

- Any other triangle with integer sides will *not* be a right triangle!
- LEGO Examples:



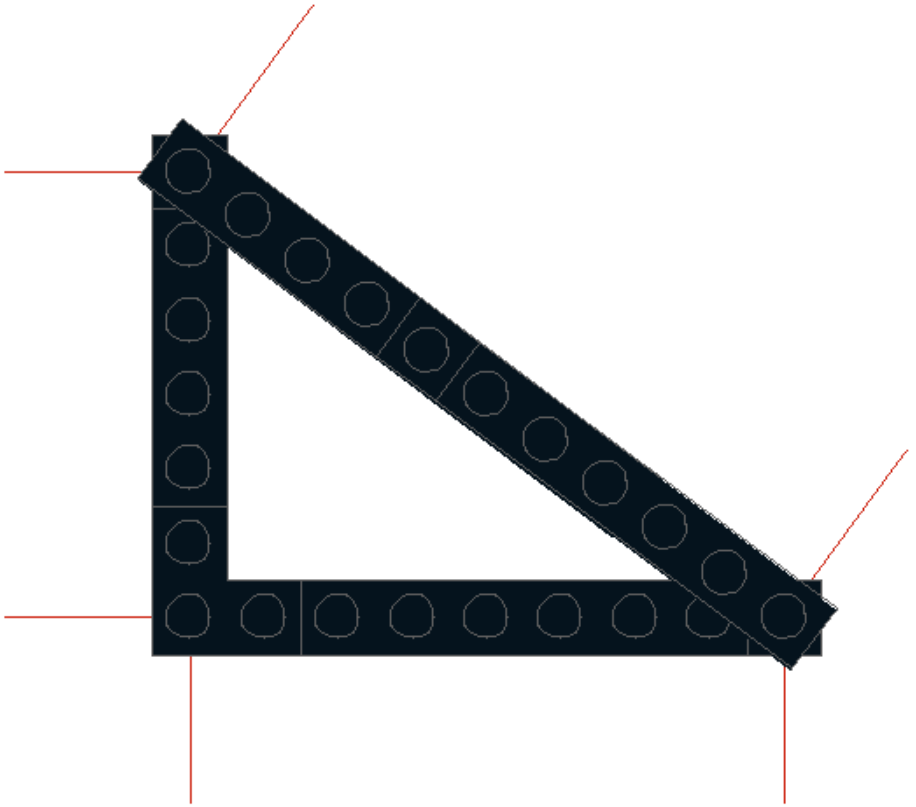
(5, 12, 13) = (6, 13, 14) studs



(8, 15, 17) = (9, 16, 18) studs

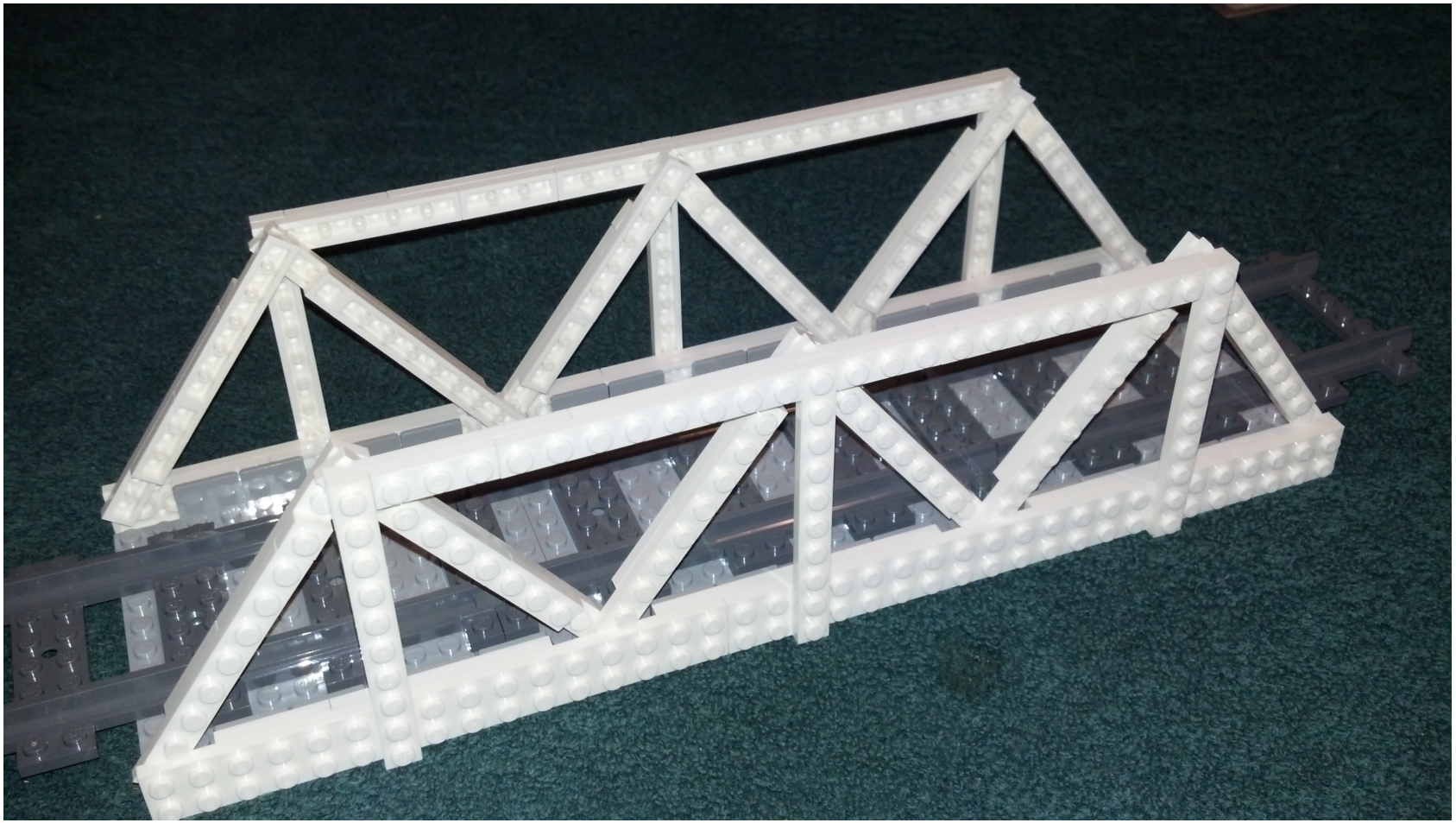
Multiples of Pythagorean Triples

- Unit does not have to be 1 stud! Additional ones can be made by multiplying these values by a scaling factor.
  - Example: 2x(3, 4, 5) = (6, 8, 10) = *(7, 9, 11) studs*



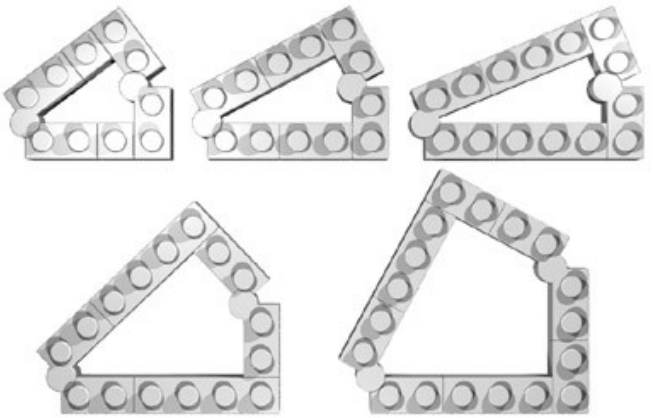
Pythagorean Triple Example: Truss Bridge

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



Triangles from Hinges

Another way to achieve triangles is to use a hinge element. You can achieve many more possible angles using this technique.



For more information including a list of possible angles, see:
http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml

Additional Resources

- “Offset” page on brickwiki
  http://www.brickwiki.info/wiki/Offset
- Reinhard Beneke, BrickFest PDX '04
  http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539
- MOC Recipes: LEGO Brick Dimensions
  http://mocrecipes.com/2015/09/19/snot-1-lego-brick-dimensions/
- Sir Bugge's Hypo-Techniques (traingles from hinges):
  http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml
- The New Elementary, blog about new parts
  http://www.newelementary.com/
- This and previous versions of this presentation available on my website, www.brickpile.com
  http://www.brickpile.com/tag/brick-geometry/

Q & A

Thank you

Contact me if you have any further questions...

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www.brickpile.com