Brick Geometry & SNOT Building

Bricks by the Bay 2022

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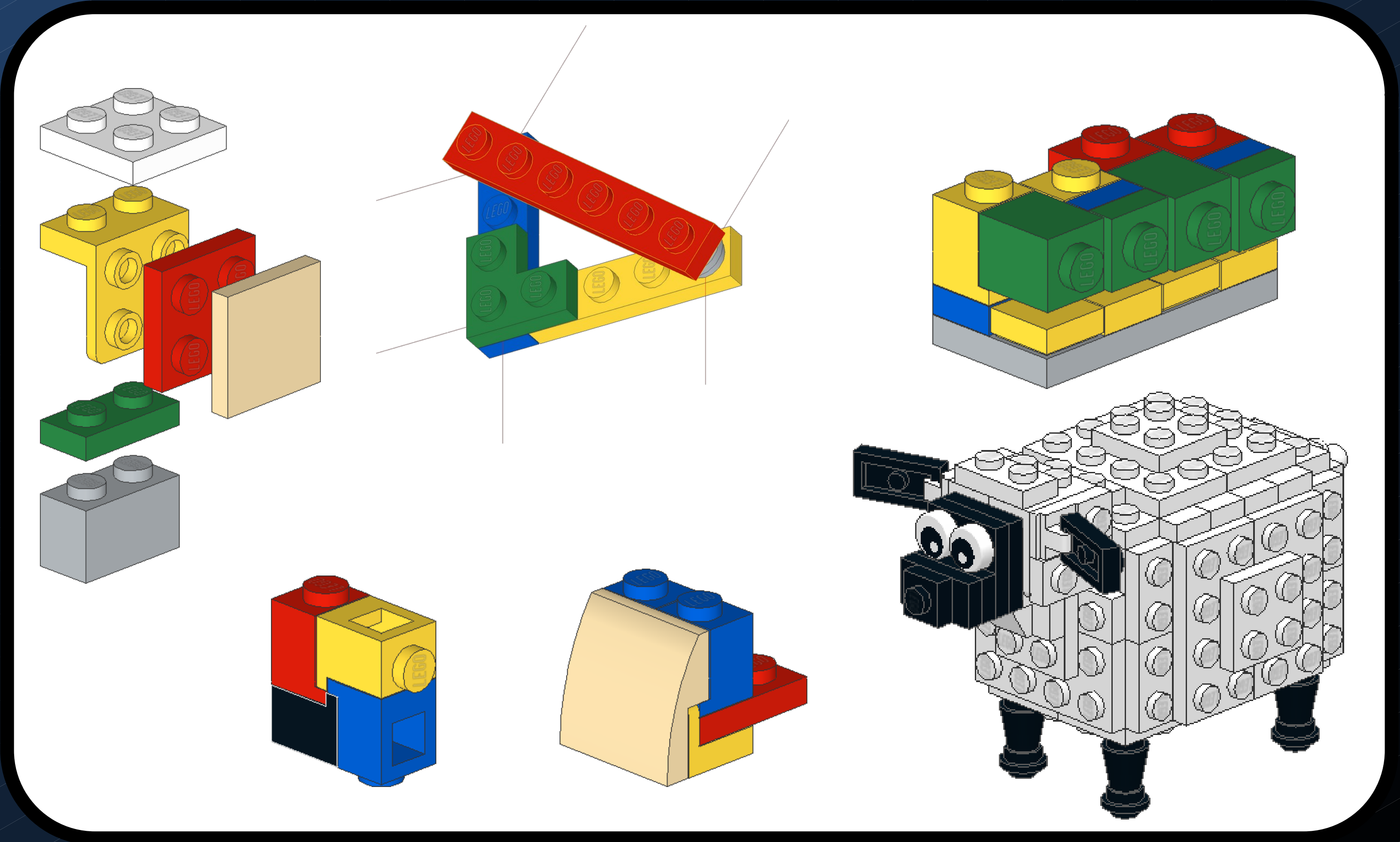
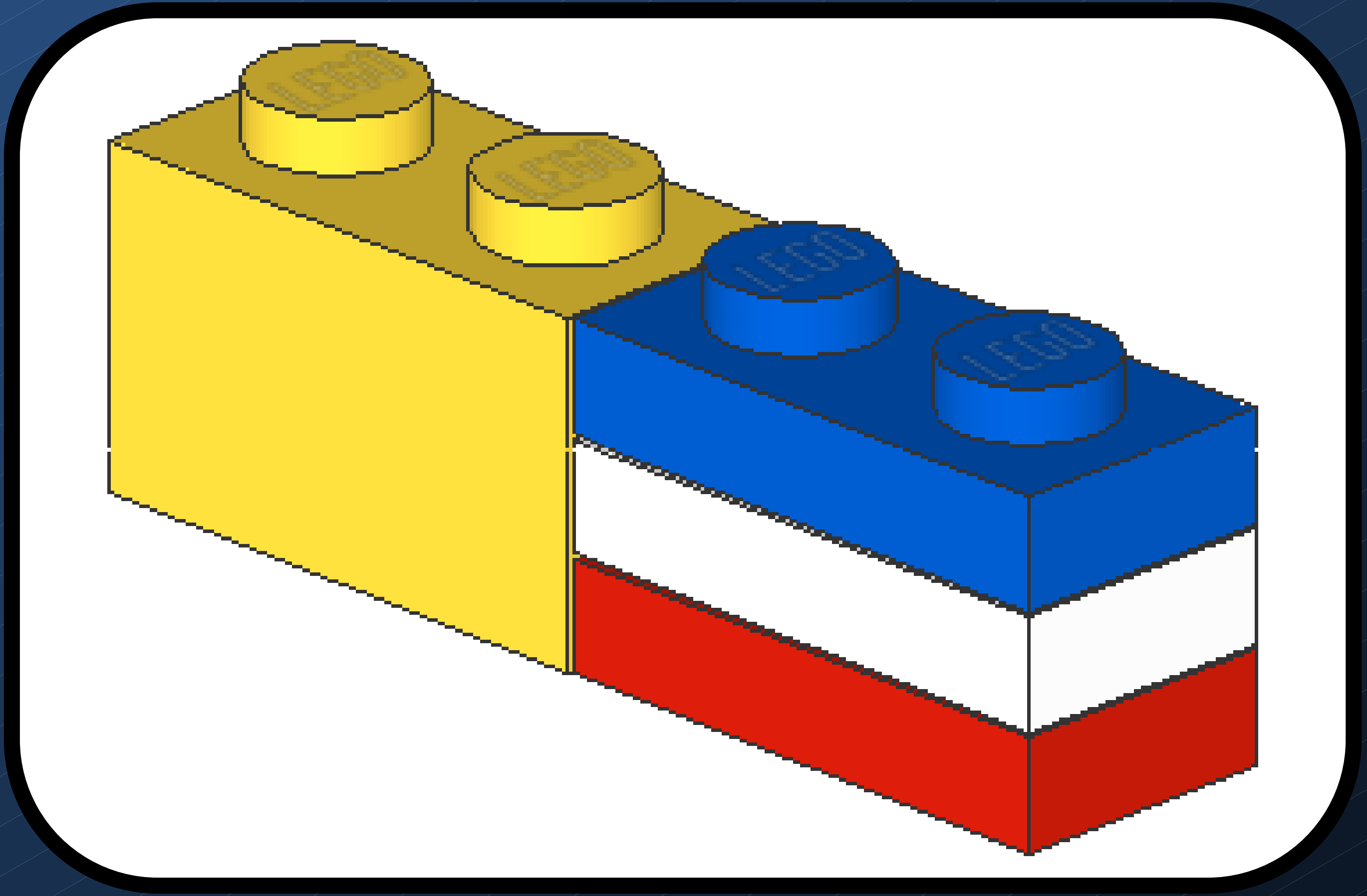


Ratios and Dimensions

Basic LEGO Geometry

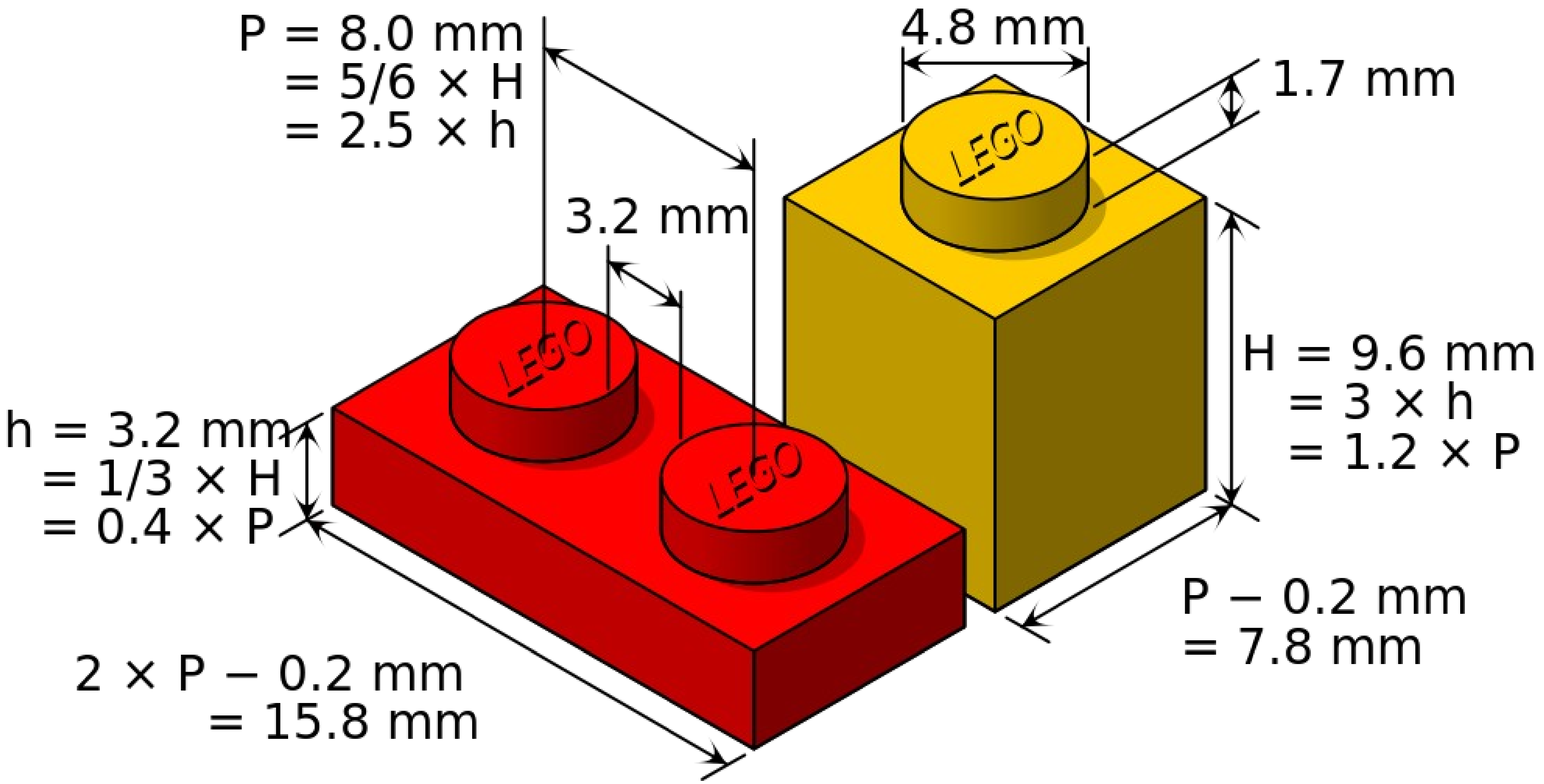
Height of 1 brick = 3 plates



You knew this already, I assume…

LEGO Dimensions

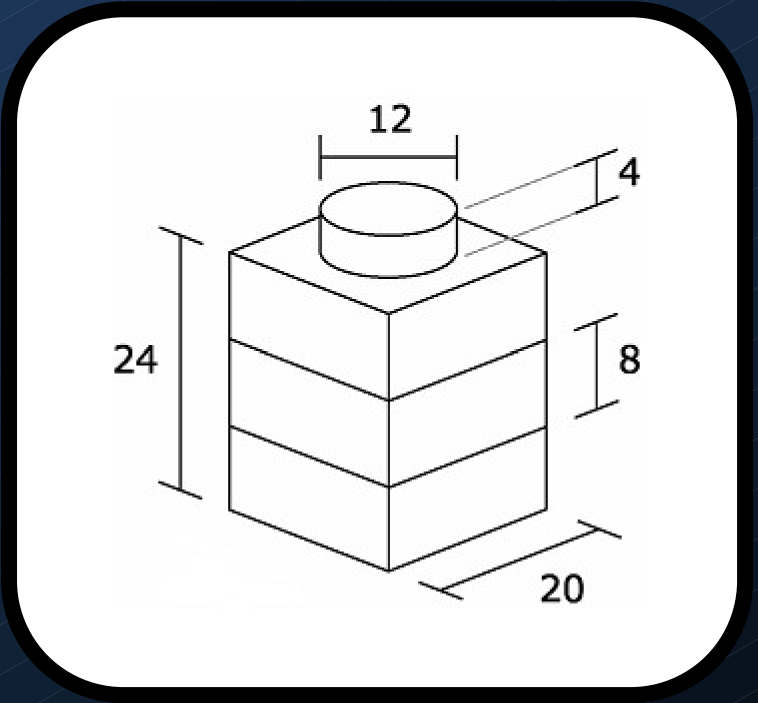
Math is hard! Can you remember all these numbers?!



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

Instead, use the 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	point
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
point	8/9	2/45	1/27	1/9	0.0353	1/72	1

https://www.lugnet.com/~330/FAQ/Build/dimensions

LEGO Bricks Are Not Square

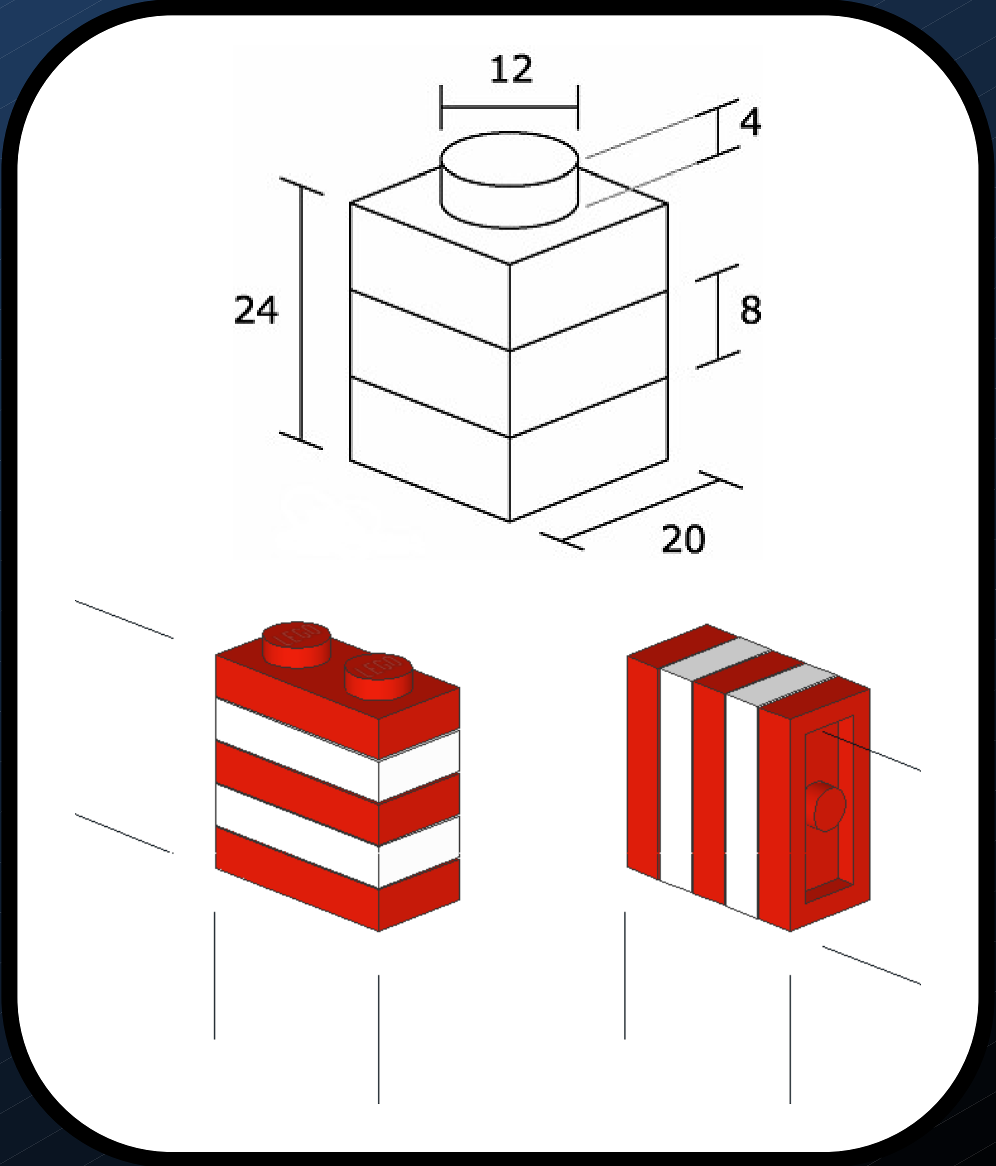
Bricks are 8mm wide by 9.6mm high

How do you make widths and heights match?

LDU makes the math easy....

How many plates = how many studs?

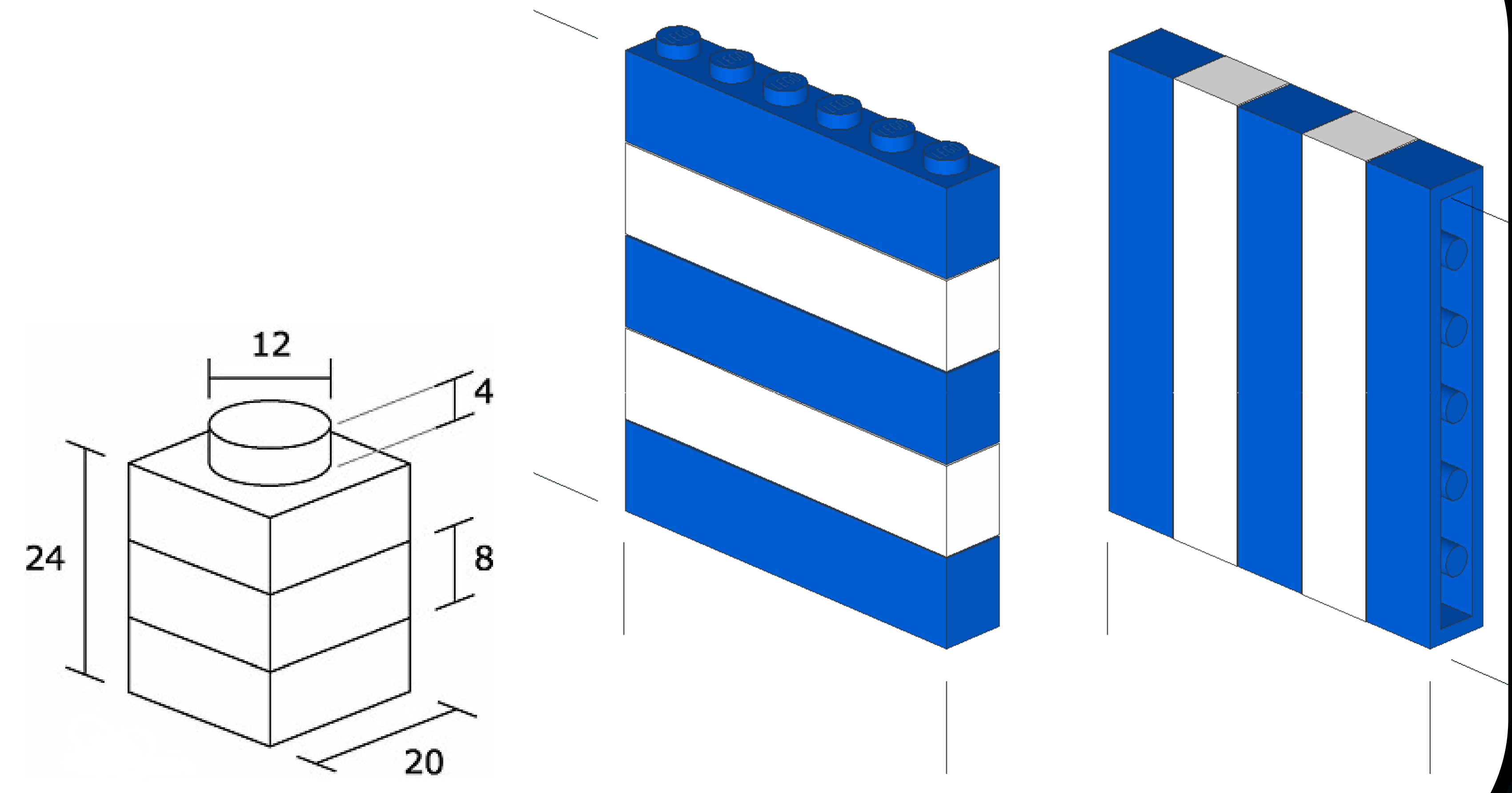
- 2 studs = 2x20 = 40 LDU
- 5 plates = 5x8 = 40 LDU



6:5 Brick Ratio

How many bricks = how many studs?

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



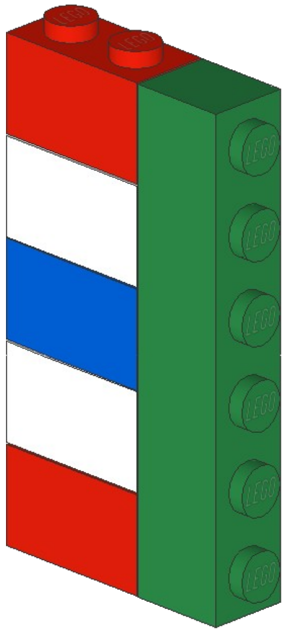
Even Numbers of Studs

An even number of studs is equivalent to an integer number of plates high.

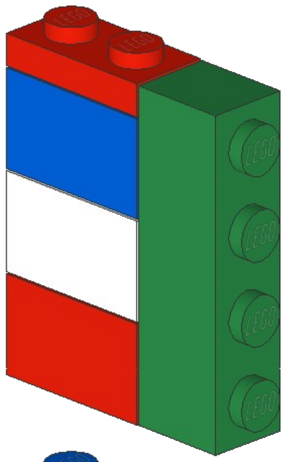
- 2 studs = 5 plates
- 2n studs = 5n plates

If n is also divisible by 3 then you also have an integer number of bricks.

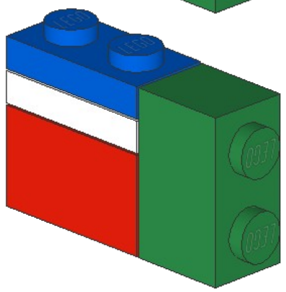
- 6 studs = 15 plates = 5 bricks



6 studs (n=3)
= 120 LDU
= 15 plates
or 5 bricks



4 studs (n=2)
= 80 LDU
= 10 plates
or 3 ⅓ bricks
(80 LDU)



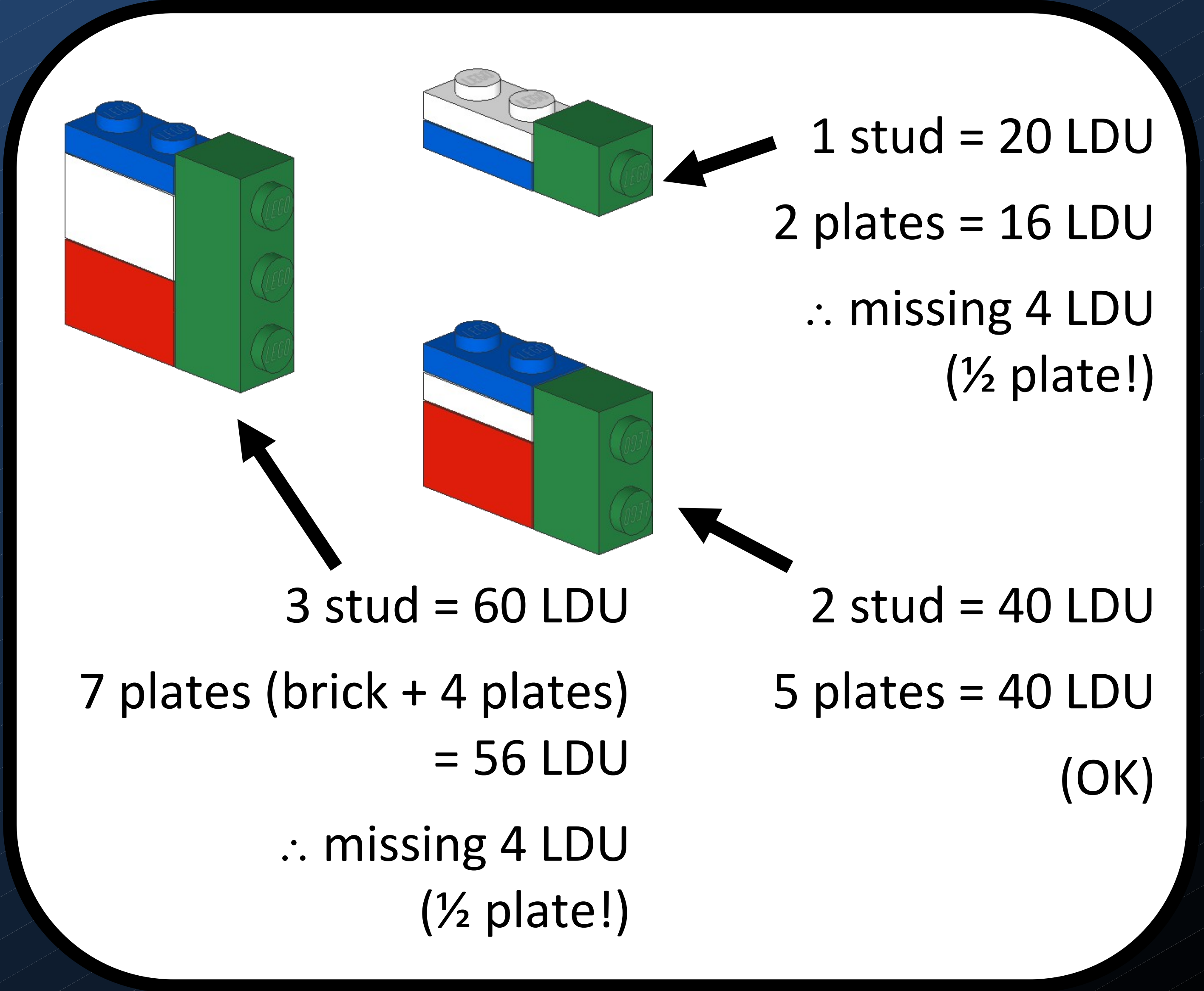
2 studs (n=1)
= 40 LDU
= 5 plates
or 1 ⅔ bricks

Odd Numbers of Studs

An odd number of studs can-not be matched by an integer number of plates!

- 1 stud = 2 ½ plates
- 3 stud = 7 ½ plates
- 5 stud = 12 ½ plates

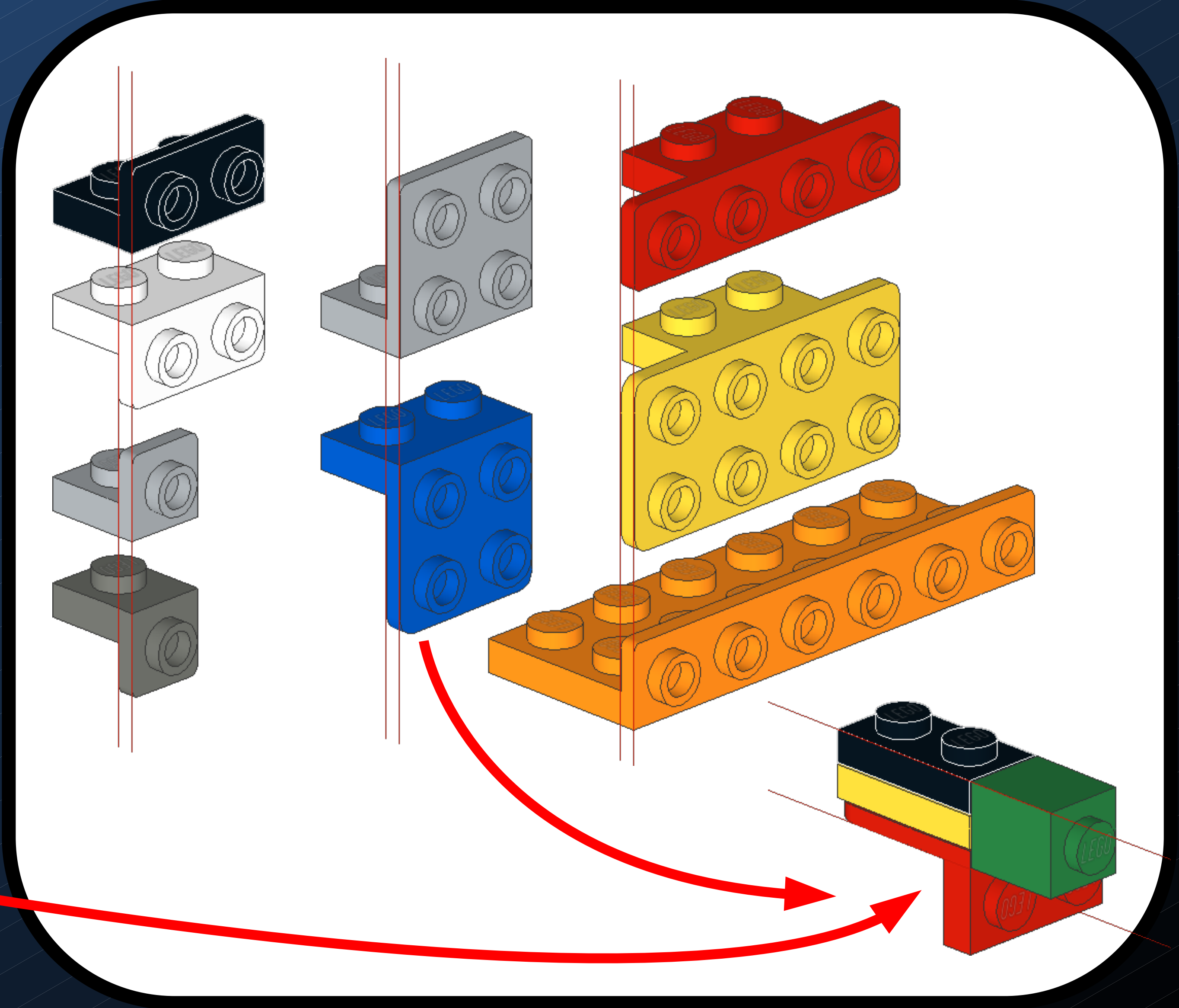
… so where do you get that ½ plate?



Half Plate?!

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

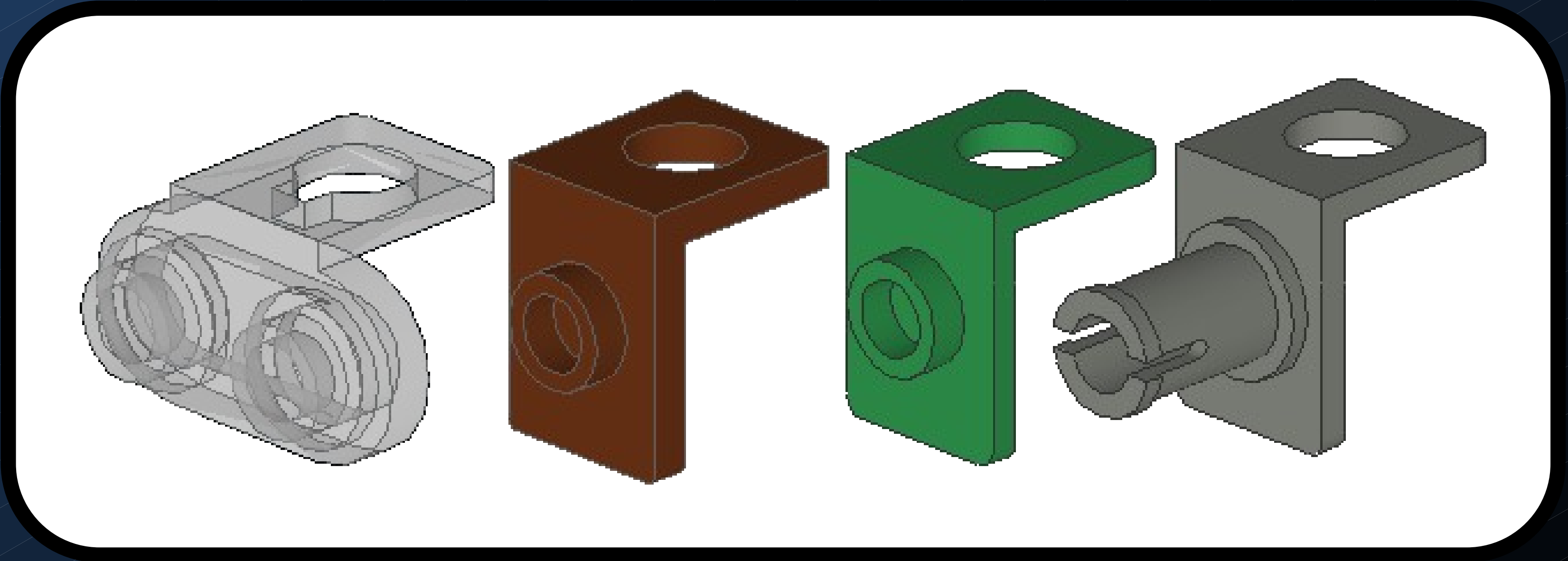
- 1 plate = 8 LDU thick
- 1 stud brick = 20 LDU
- 2 plates + thin bracket =
  8 * 2 + 4 =
  20 LDU



#notallbrackets

Most of the “neck brackets” that a minifig can wear are usable for some clever uses, but most of them are not a full ½ plate thick; they are more like 3 LDU instead of 4.

Below, the clear and brown ones are “in system” but the green and grey ones are not.

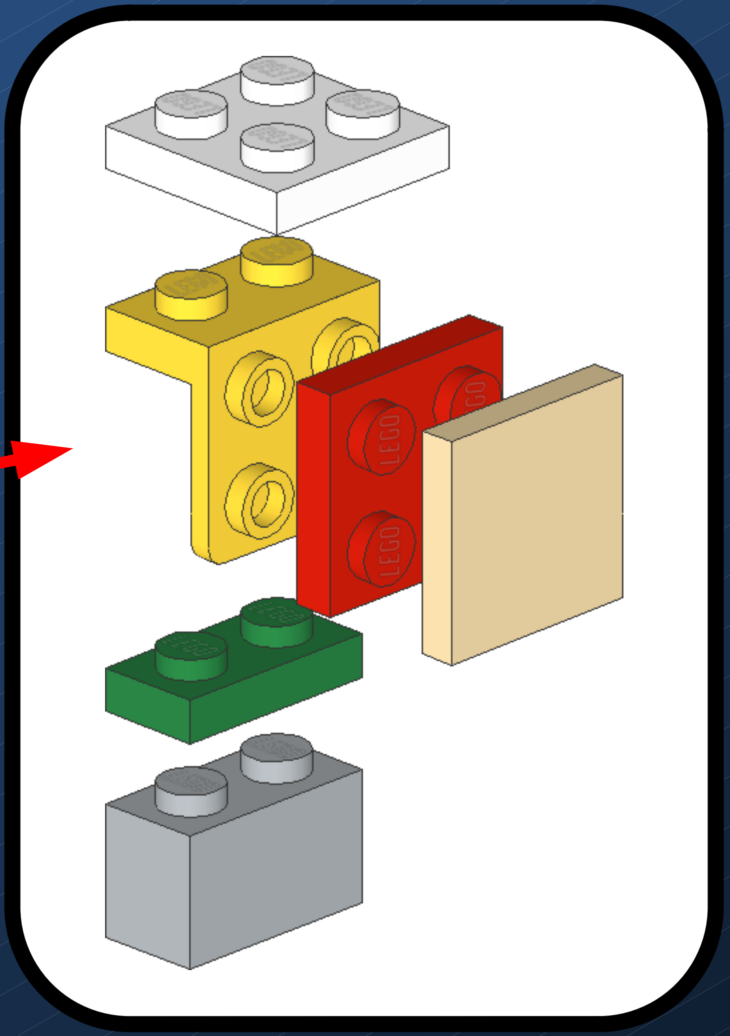


SNOT:
Studs Not On Top

Using brackets for the ½ plate thickness

Bracket's vertical part is ½ plate thick

(4 LDU)



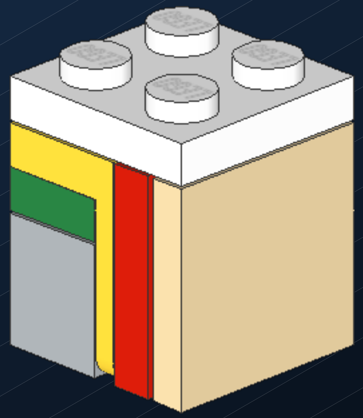
Bracket: 4 LDU (½ plate)

Red plate: 8 LDU

Tile: 8 LDU

Total: 20 LDU

(same as 1 stud)

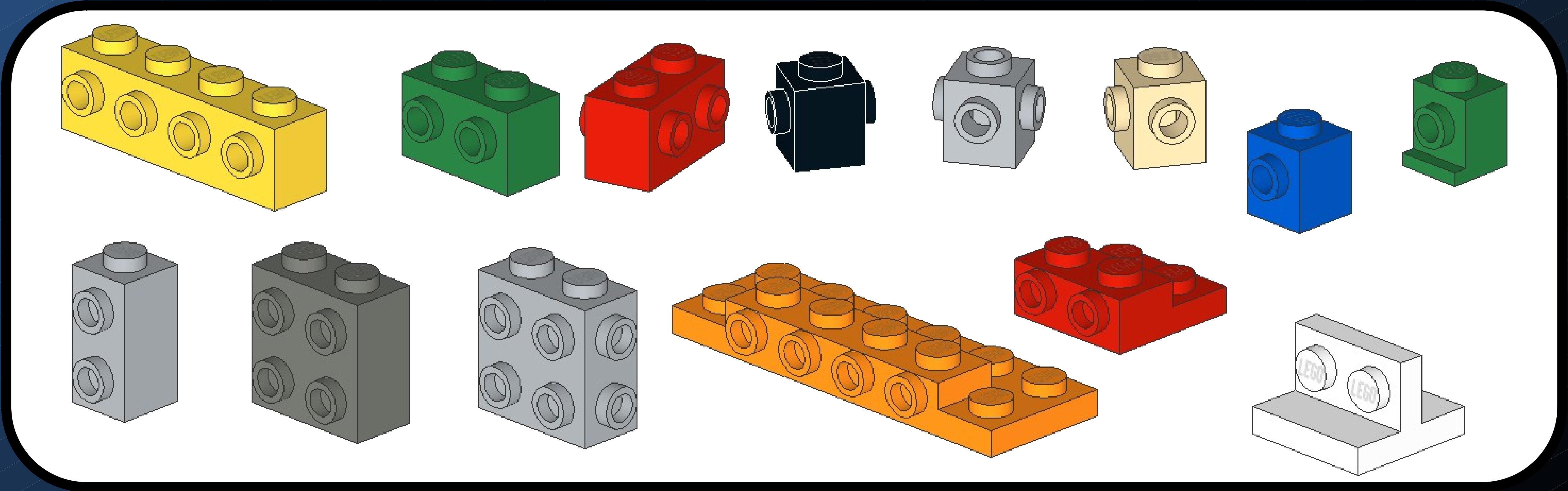


Tile's face is flush with the edge of the white 2x2 plate.

SNOT Bricks:

Bricks and plates with studs on their sides

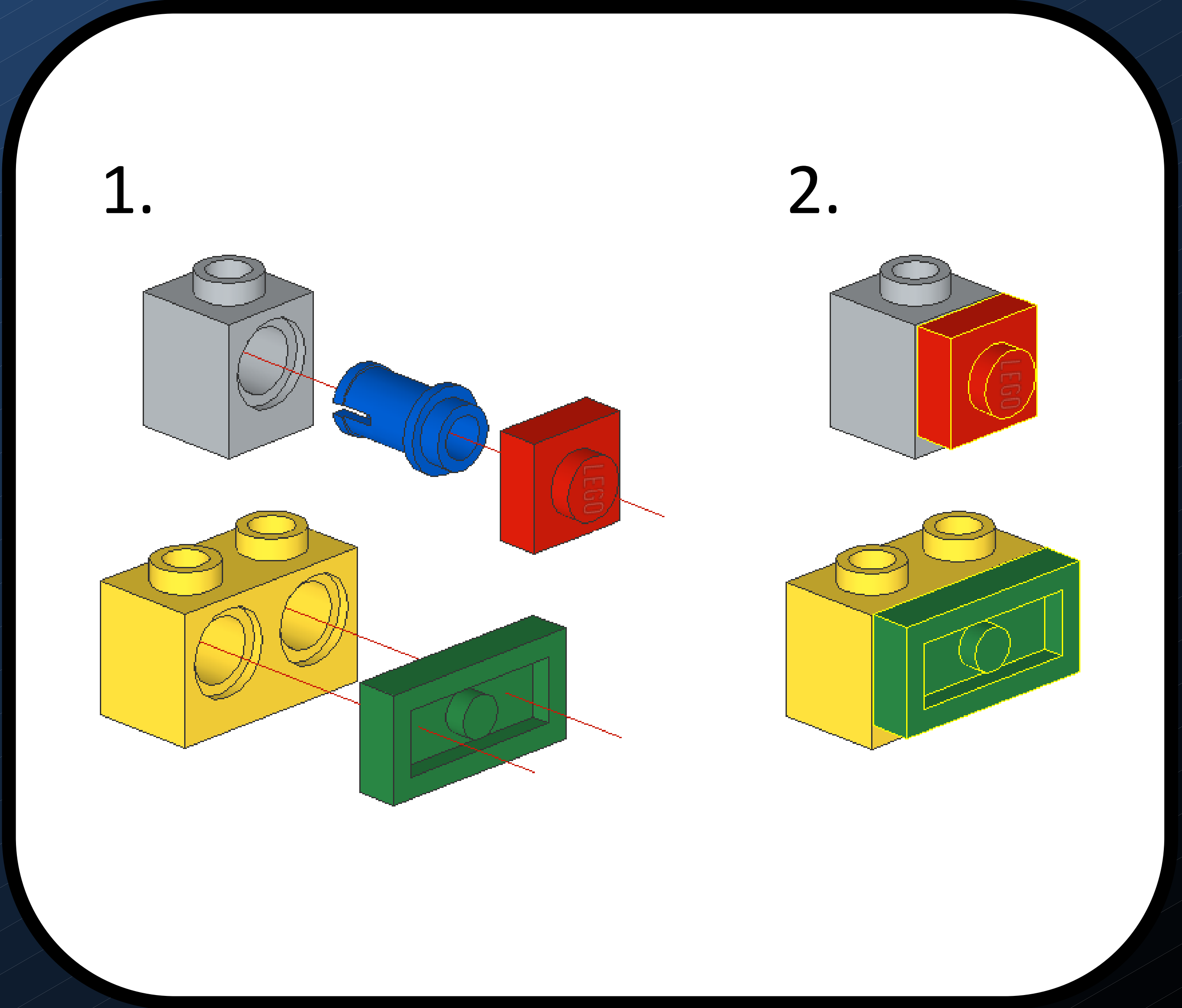
LEGO has made many parts over the years with studs on the side(s), useful for SNOT (Studs Not On Top) design. Which are your favorites?



Can we use TECHNIC for SNOT?

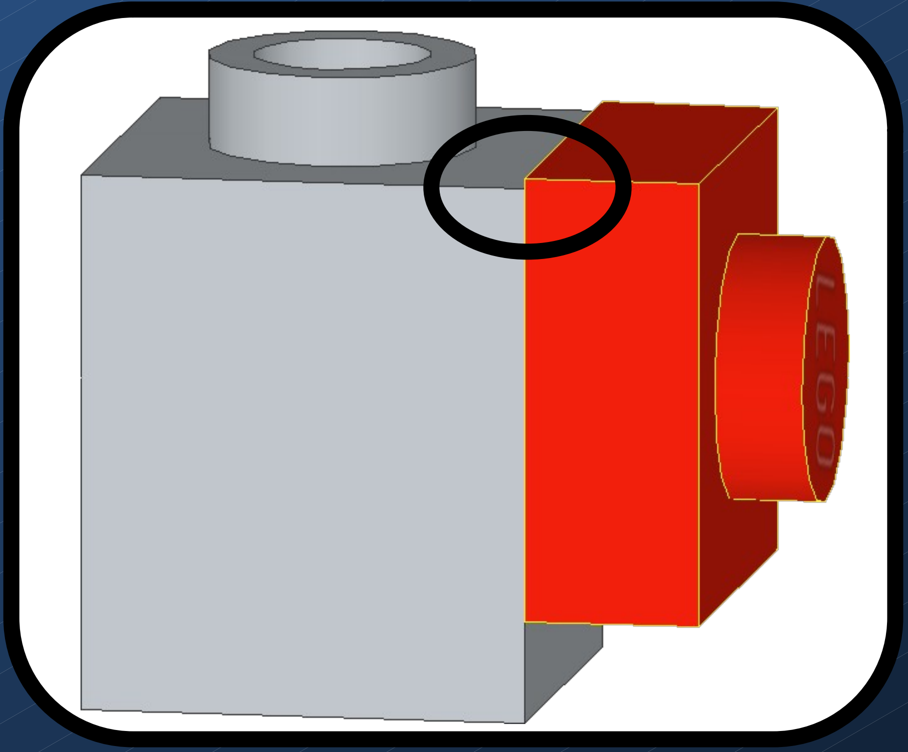
Answer: Sort of. You can use the half-pin to create your own 1x1 brick with stud on side, or push the studs of a piece into TECHNIC pin holes.

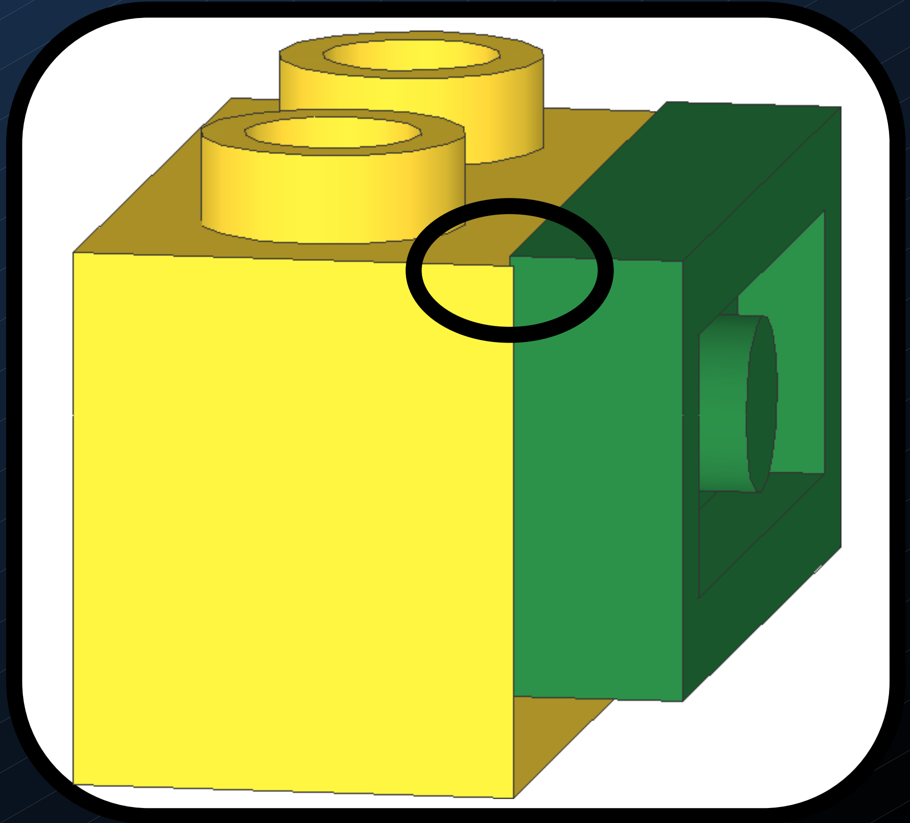
However, this is not “legal” for set designers to use in official LEGO sets, which is why we have these SNOT bricks.



The Problem with TECHNIC for SNOT

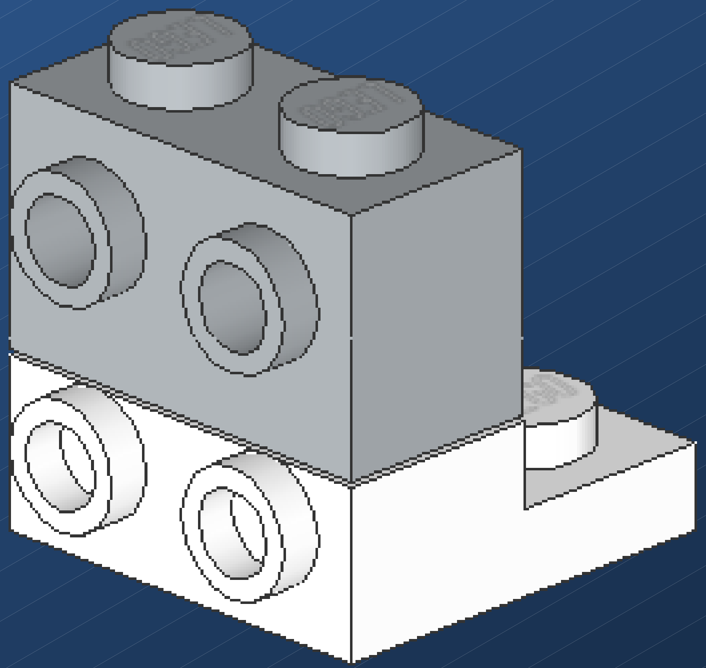
When LEGO designers made the first TECHNIC bricks, they decided to move the pin hole “up” a little bit (about 0.2mm) to make more room for studs to fit in the bottom of the bricks, and as a result if you use the TECHNIC pin holes for SNOT connections, things may not line up quite as you want!



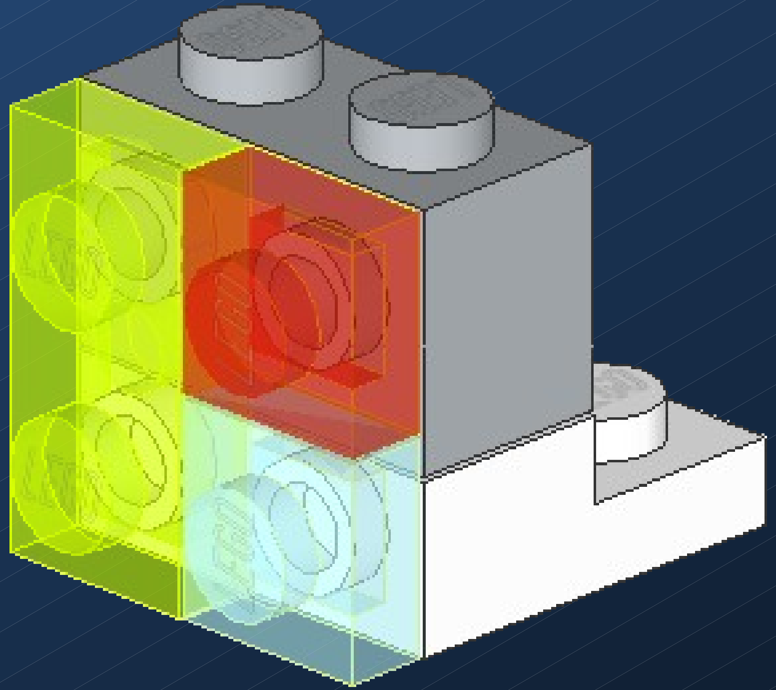


Adding SNOT Bricks: 2 + 2 = 5

1.



2.



White “Plate, Modified 2 x 2 x 2/3 with 2 Studs on Side” (part 99206)

= **2 plates high**

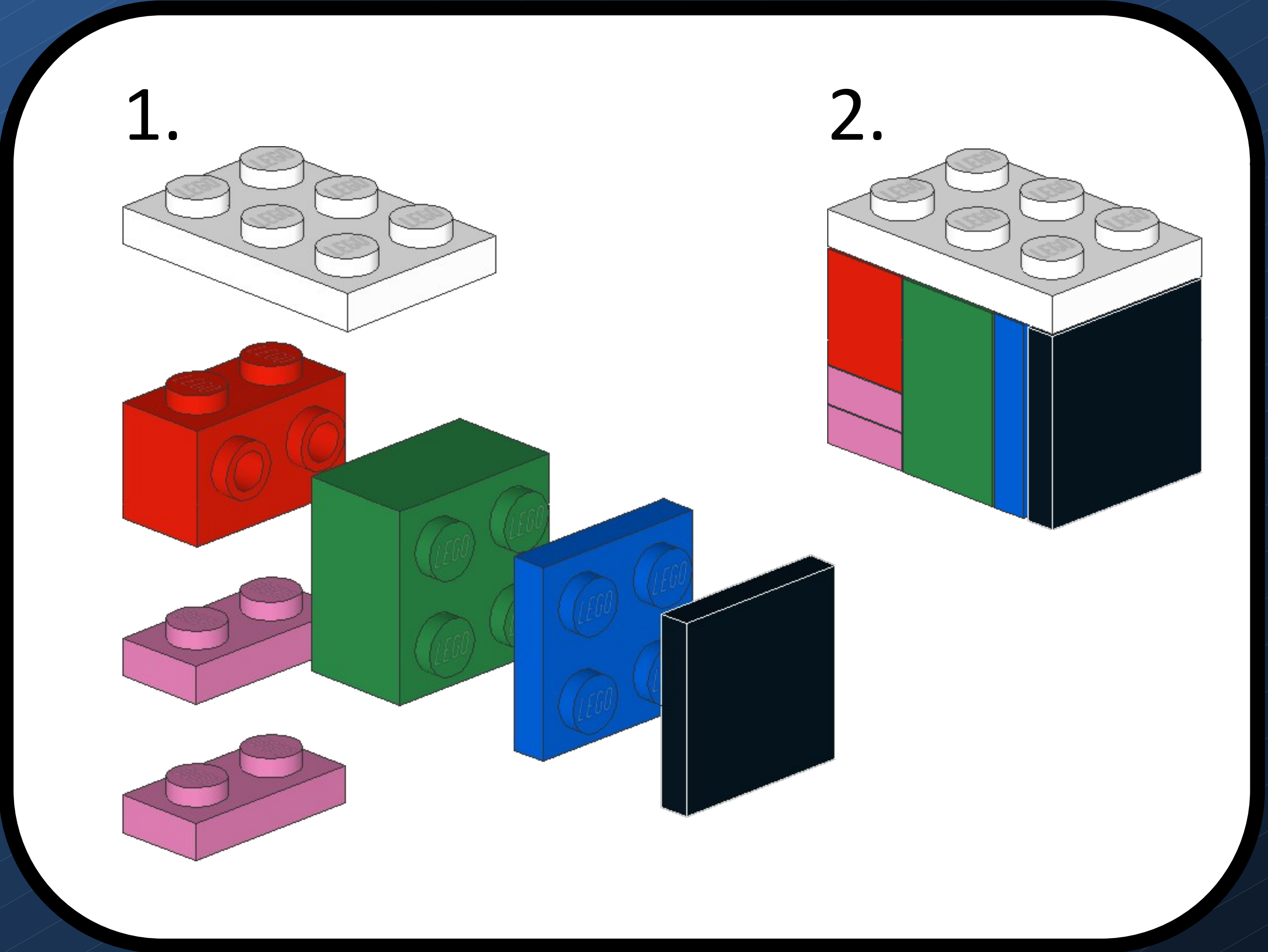
Grey “Brick, Modified 1 x 2 with Studs on 1 Side” (part 11211)

= 3 plates high

Total = 5 plates high

= 2 studs wide

Bricks with studs on sides to mount flush

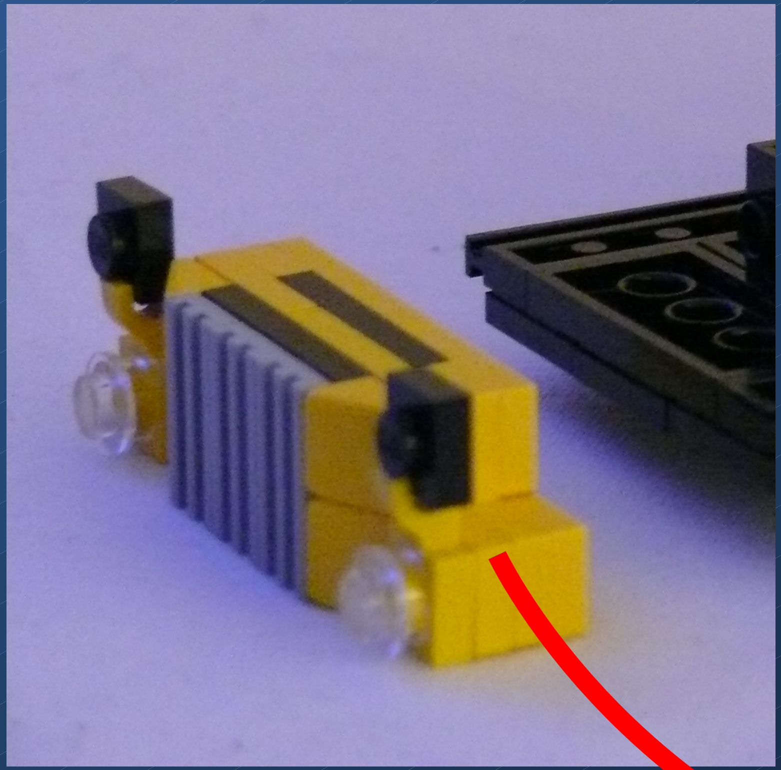


Use bricks with studs on sides to attach assemblies at 90 degrees.

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

3 bricks thick isn't too great, but we can do better.

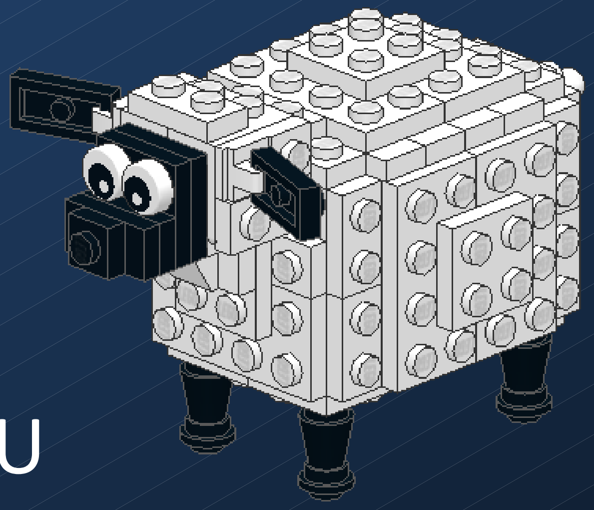
Flush tile example: Lunar School Bus



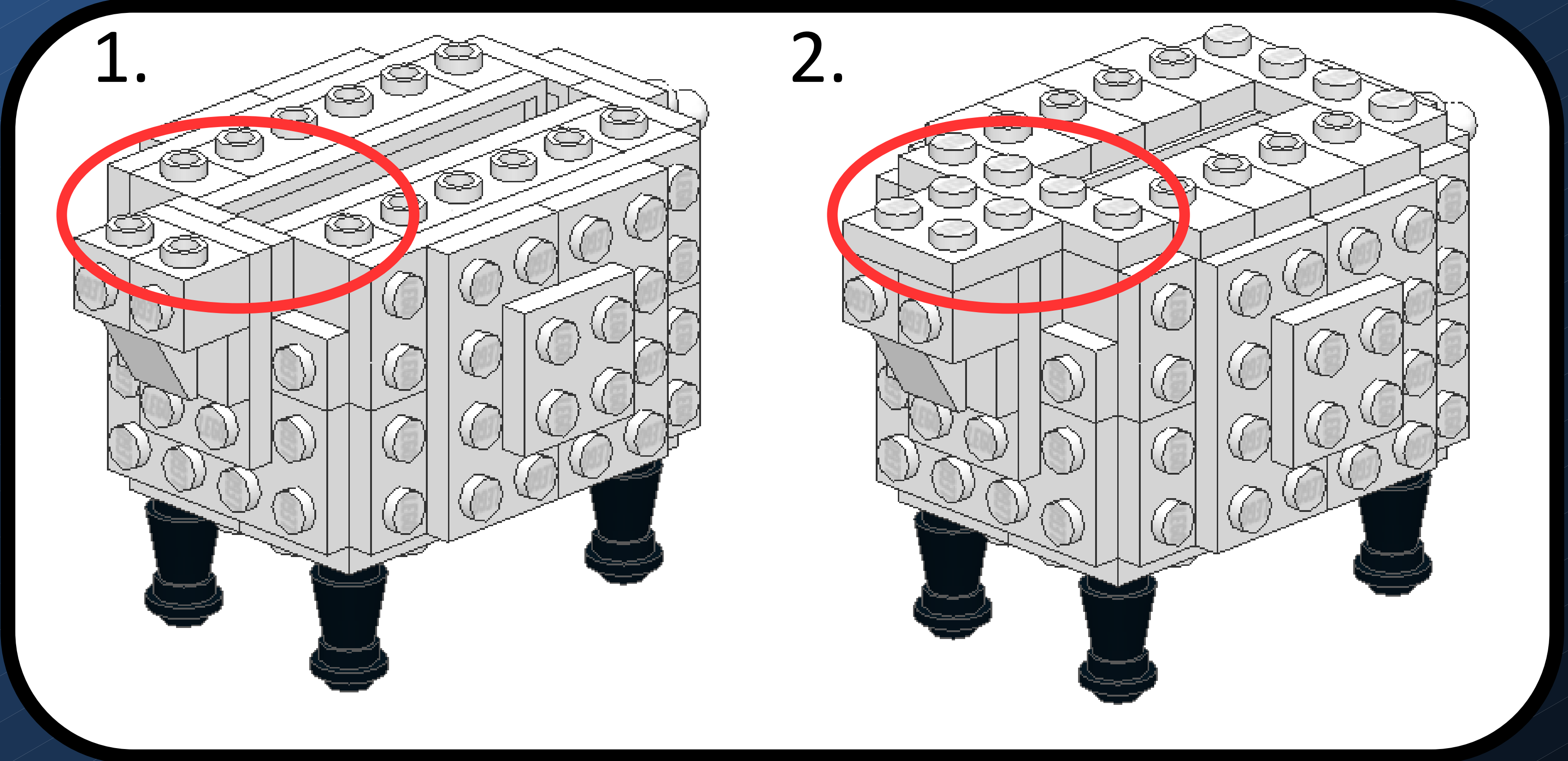
Grille and headlight sub-assembly is made of 4 plates and a tile, and fits in a 2-stud space

5 plates = 40 LDU = 2 studs

Another Example: Sheep

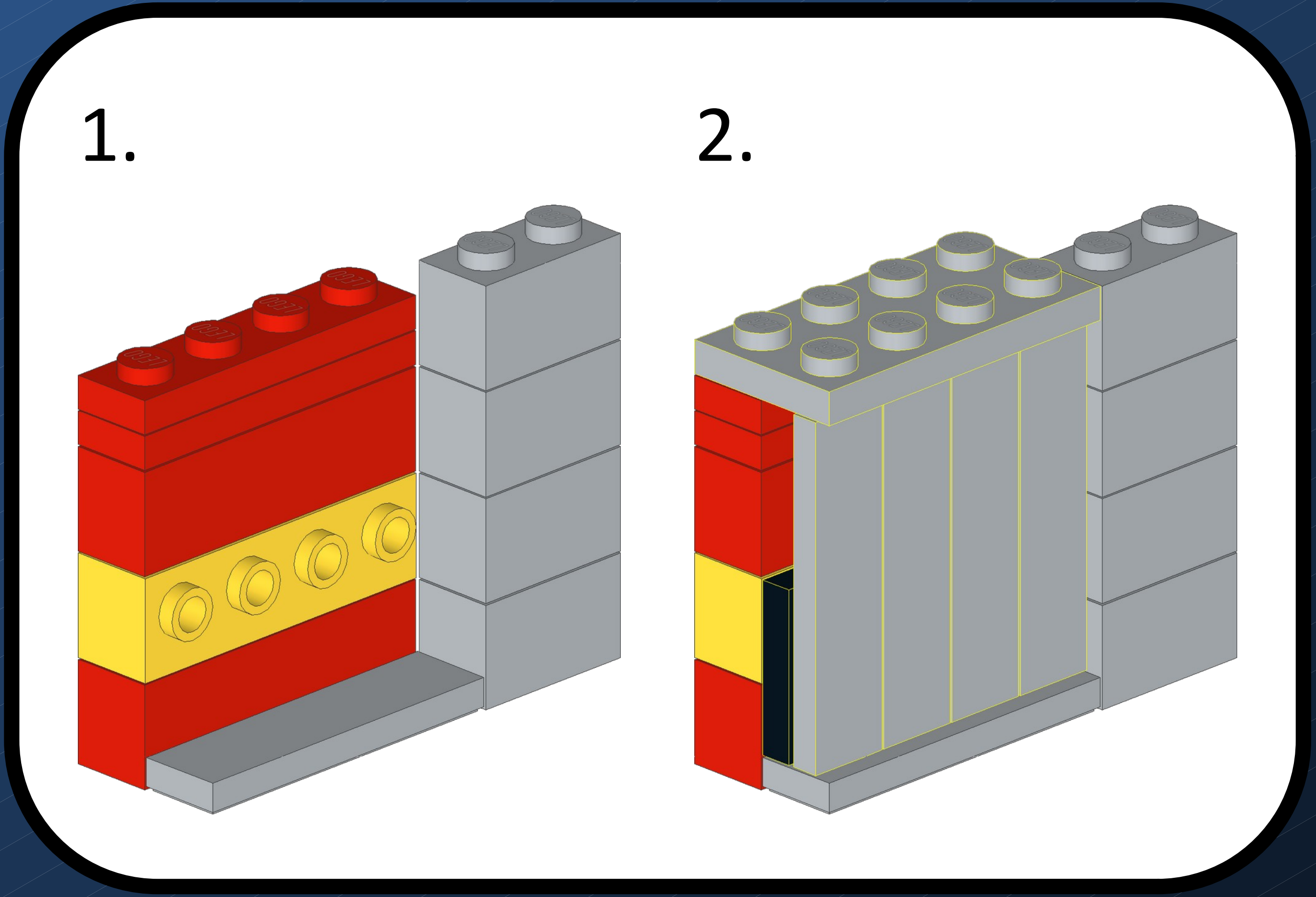


Sheep's neck is made from a brick and two plates = 40 LDU



A 2x2 plate fits on the top of the neck and the studs are "in system" with the rest of the body.

Inset Panels: Deliberately misaligned



On my Caltrain locomotive, I used half-plate offsets to add texture (access panels) to an otherwise flat wall.

Tiles are inset by ½ plate.

Inset panels on the Caltrain locomotive

Panels recessed ½ plate

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

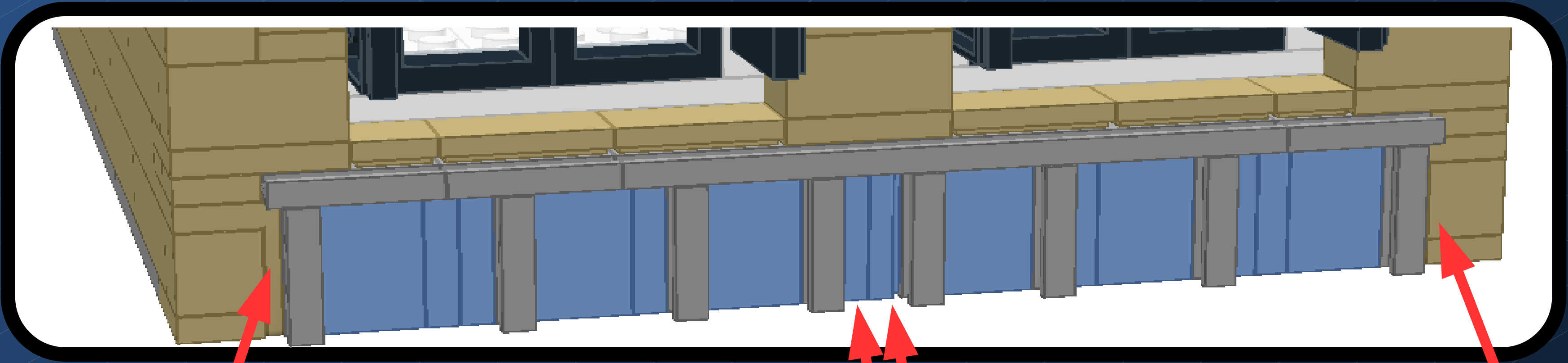
“De Vier Gekroonden” by Vincent Kessels

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

He built this model of this famous house in Gouda, the Netherlands, built in or around the year 1530, known as “De Vier Gekroonden” which means “The Four Crowned Martyrs.”

Vincent’s photos used with permis-sion.

Sideways Building with Brackets



Light blue stripe made from stacked bricks and plates, with a tile on the end, facing inward and mounted on 1x2-2x2 brackets on either end.

Each half contains 3 bricks (72 LDU), 7 plates (56 LDU), a tile (8 LDU), and brakcet (4 LDU).

Total = 140 LDU = 7 studs. With a brick added to each end, that fills the 16 studs of the façade.

Model: “De Vier Gekroonden” by Vincent Kessels

A Problem: Jumper Plates and SNOT don’t fit

The building has 2 windows per floor (5 studs each) but the arch above each one is 6 studs wide. To line them up, Vincent offset the arches by ½ stud using jumper plates. This leaves a gap on each end of ½ stud, however. His solution is to add a tile on each end, but that doesn’t quite fill the space.

Gap of ½ stud = 10 LDU. Tile = 8 LDU, leaving 2 LDU (¼ plate) that cannot be filled exactly. But it’s an old building, so he didn’t mind too much…

Model:
“De Vier Gekroonden”
by Vincent Kessels

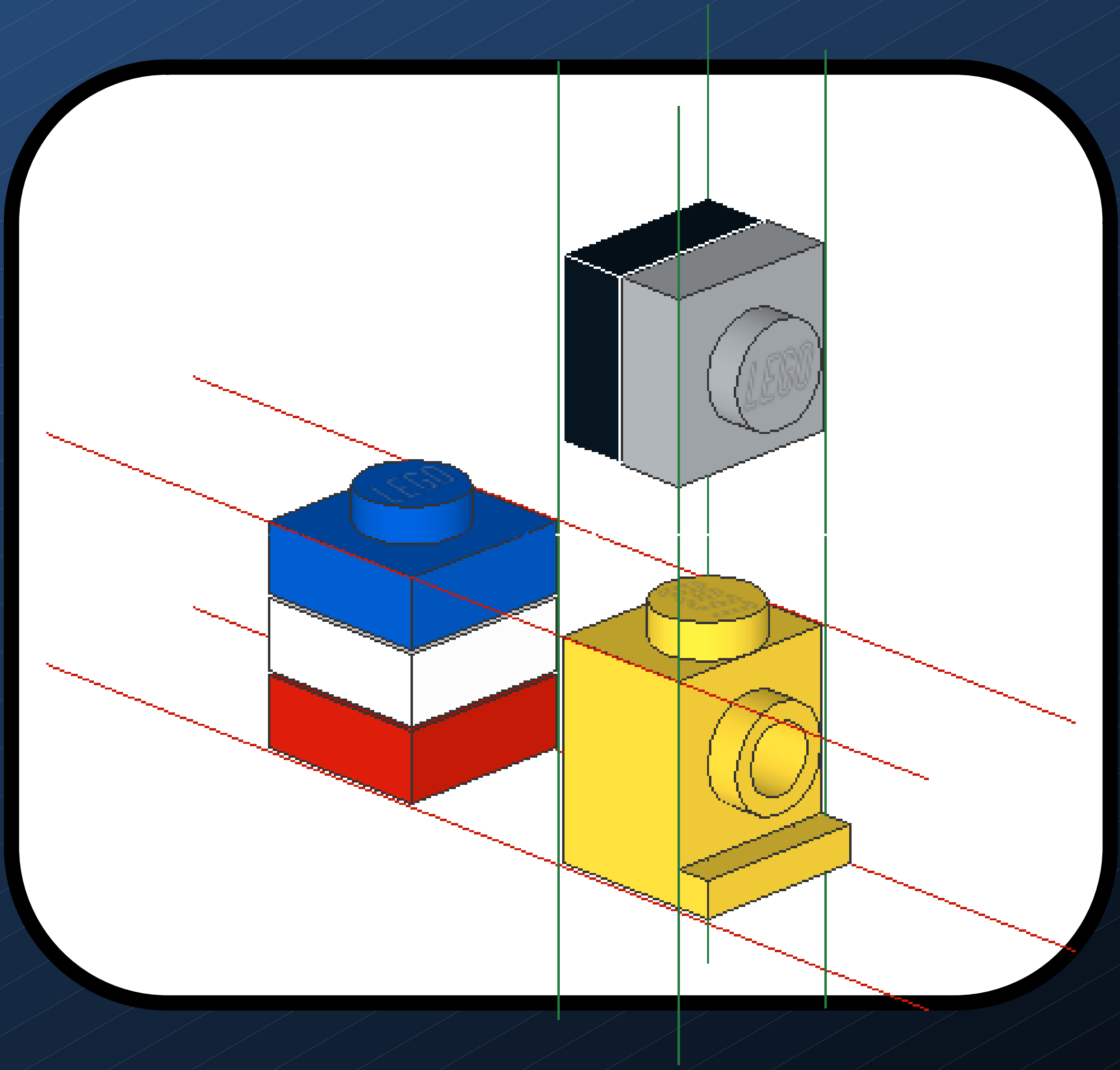
Mosaic Lettering

LEGO sets 10197 & 10224 (Fire Brigade and Town Hall) have mosaic lettering signs made using these size relationships between plates and tiles in different colors.

Image Credits:
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

Fun with Headlight Bricks

Headlight Brick Dimensions

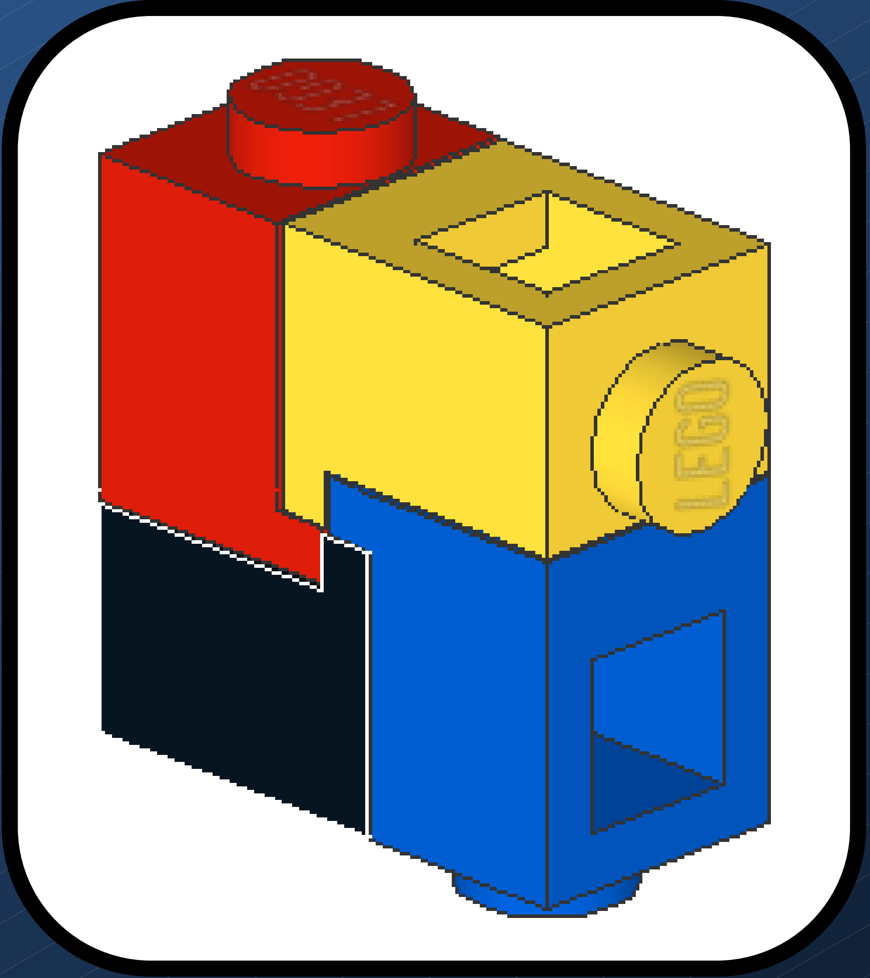


Depth = 16 LDU,
or 2 plates sideways
(½ plate inset, 4 LDU)

Height = 20 LDU,
or 1 brick high
or 3 plates high

“foot” is
½ plate thick &
½ plate high

Four headlight bricks



2 plates (red) +

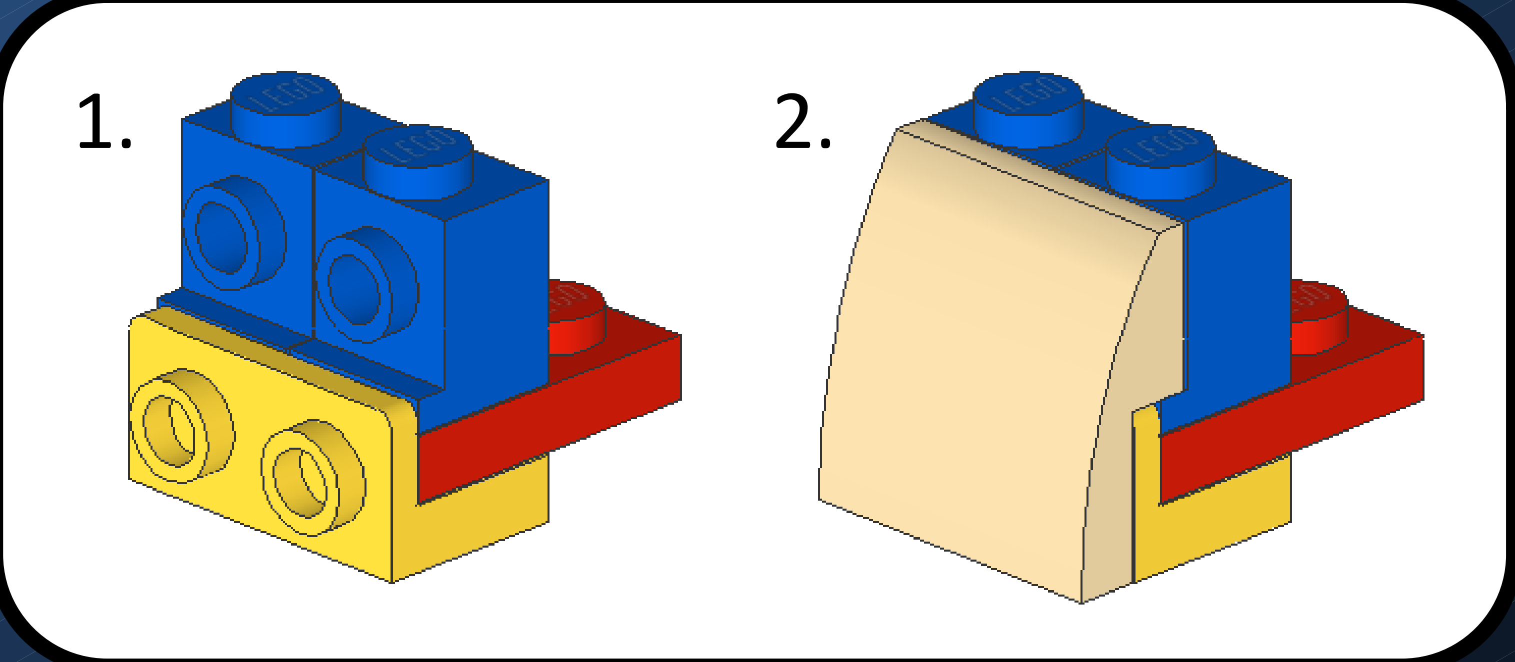
3 plates (yellow) =

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

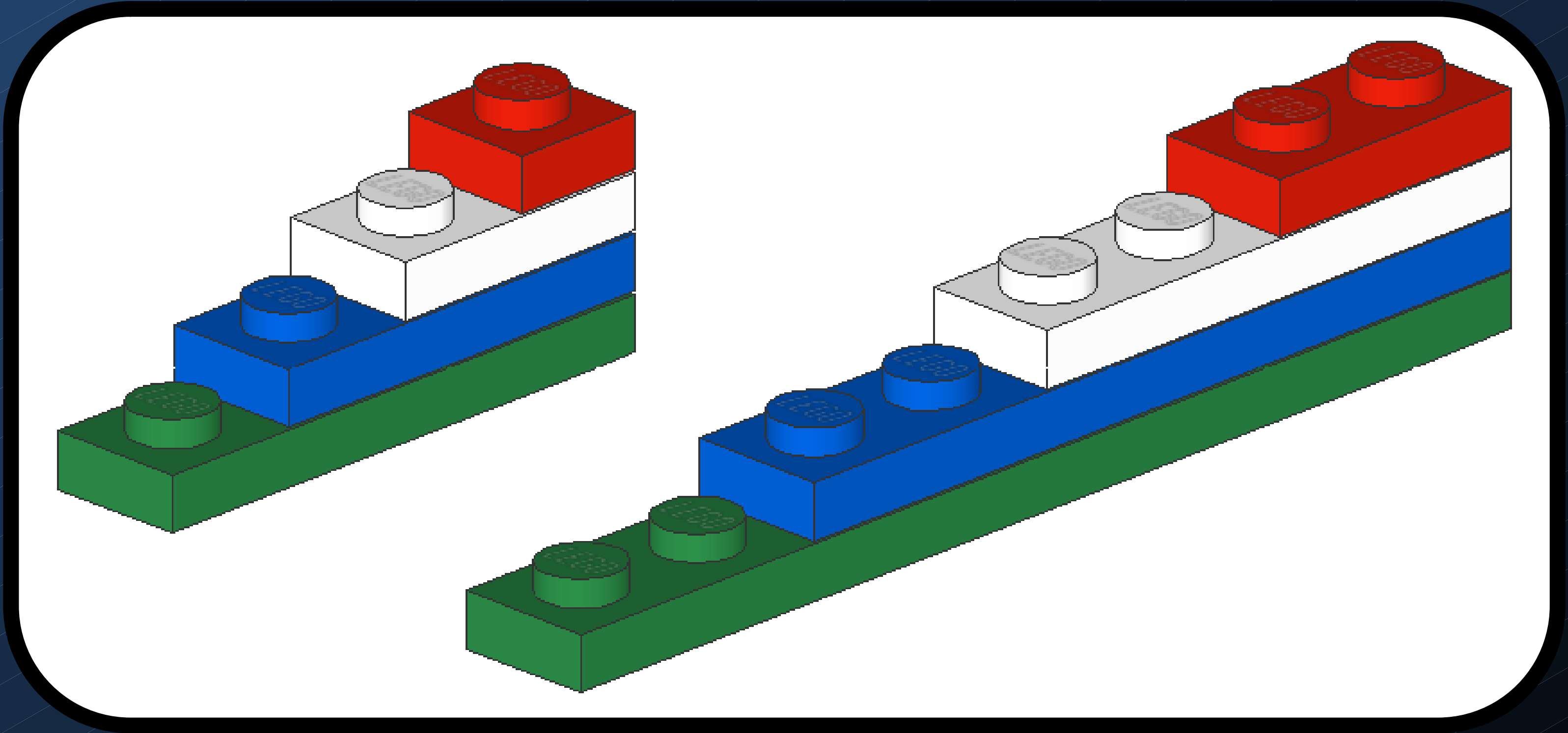


As seen in the LEGO IDEAS Ghostbusters set #21108 (minifig display)

A Problem: Gradual Steps

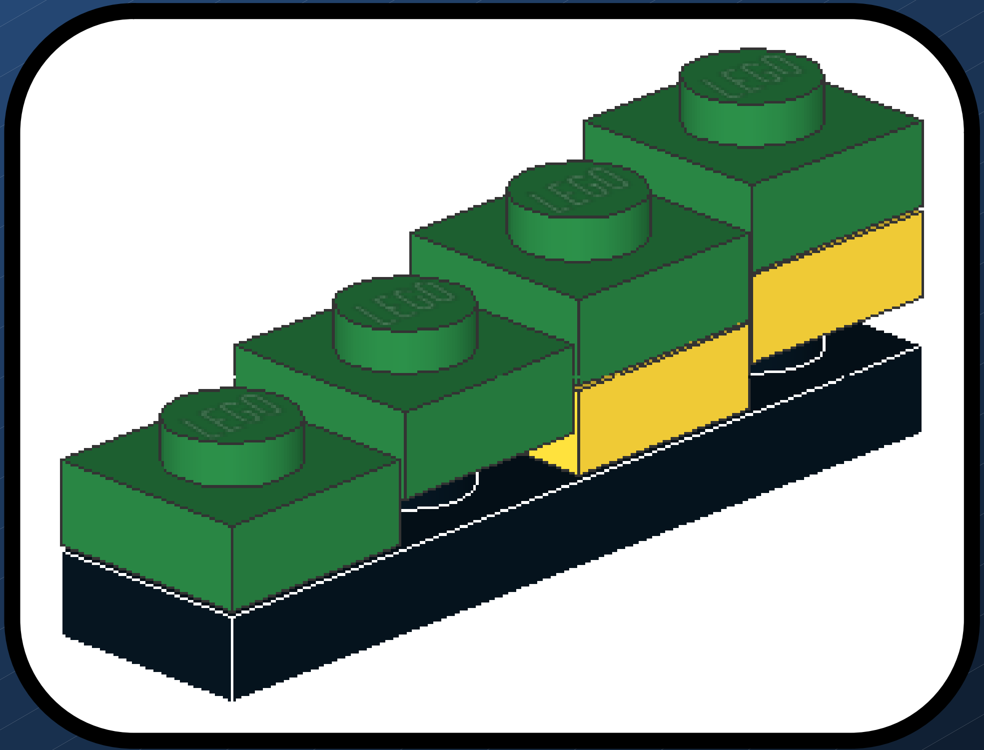
How do you make a gentle slope?

What if these are too steep?



Gradual Steps

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

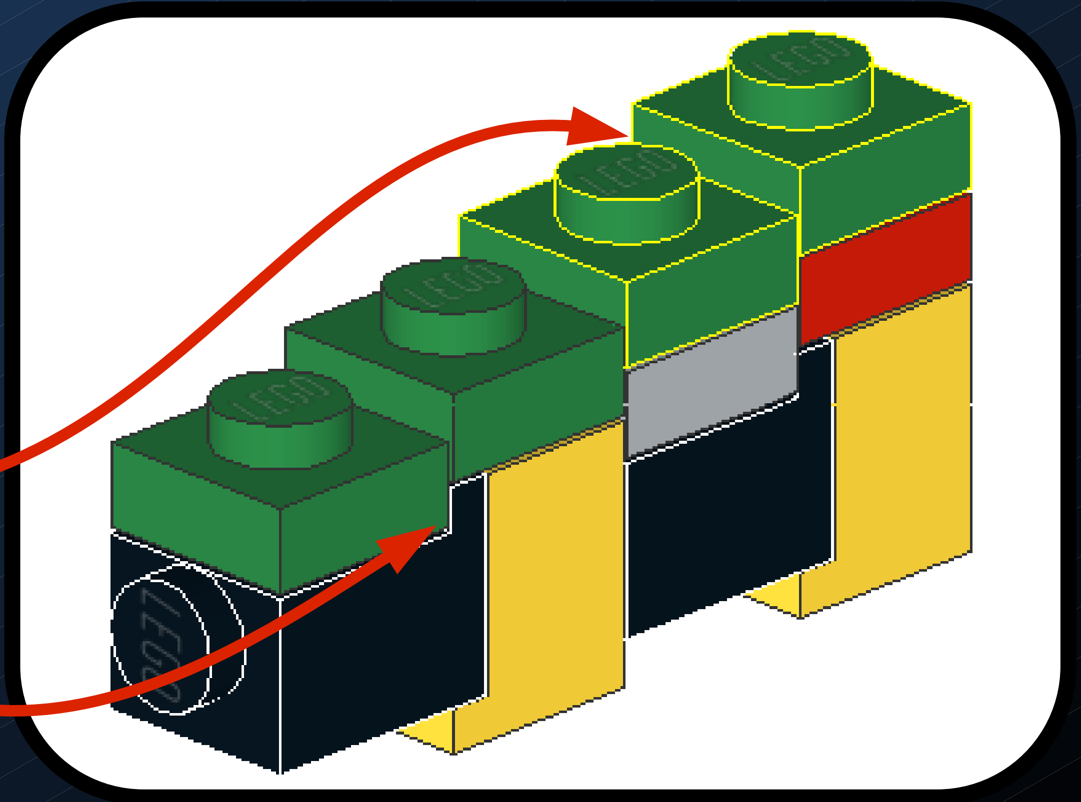


But, we have a half-plate hole to fill!
How to attach these?

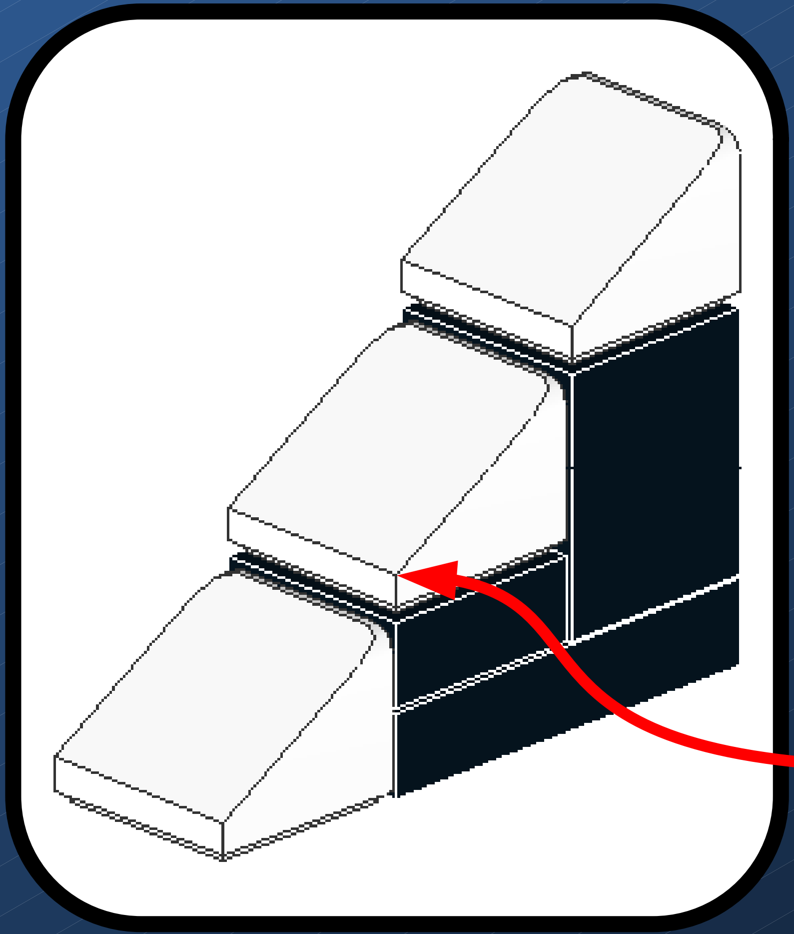
Headlight Bricks to the Rescue

Alternate studs-up and studs-sideways head-light bricksto take advantage of ½ plate offset in “foot” (2 plates + ½ plate = 1 stud)

Half-plate offset due to“foot” of headlight bricks



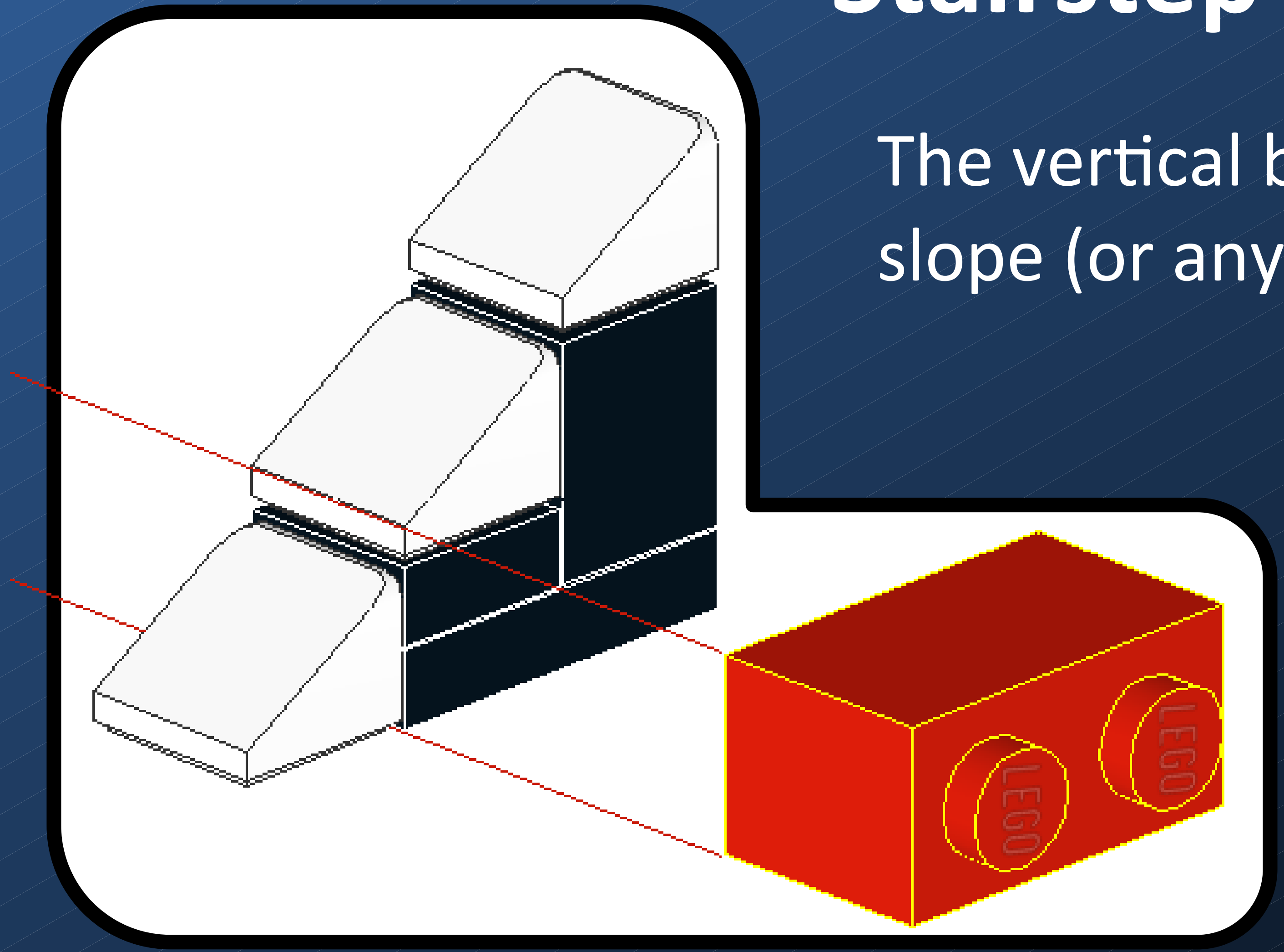
Problem with “cheese slope”: Stairstep effect



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

There is a “step” in order to fit a stud inside, but it is ugly.

Problem with "cheese slope": Stairstep effect



The vertical bit at the bottom of the cheese slope (or any slope) is ½ plate thick or 4 LDU!

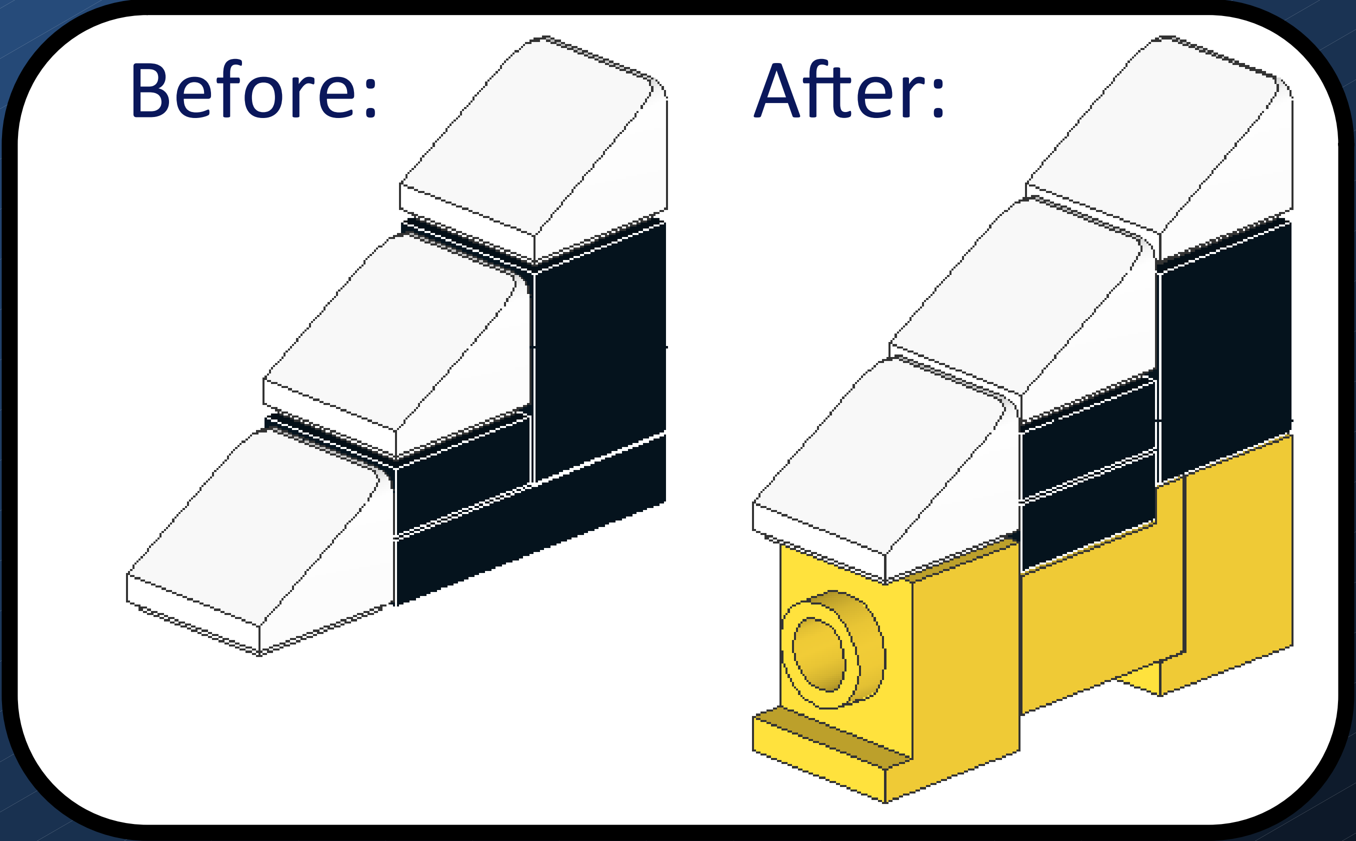
2 plates: 16 LDU

Vertical portion of cheese slope: 4 LDU

Total: 20 LDU or 1 stud

Solving the stairstep effect

Use headlight bricks to mount every other cheese slope ½ plate lower for a smooth surface!

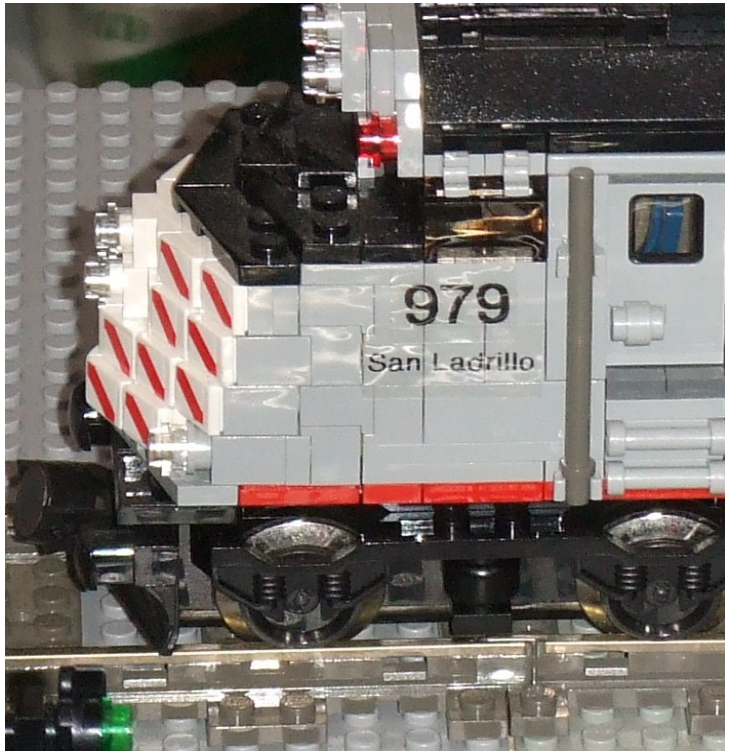


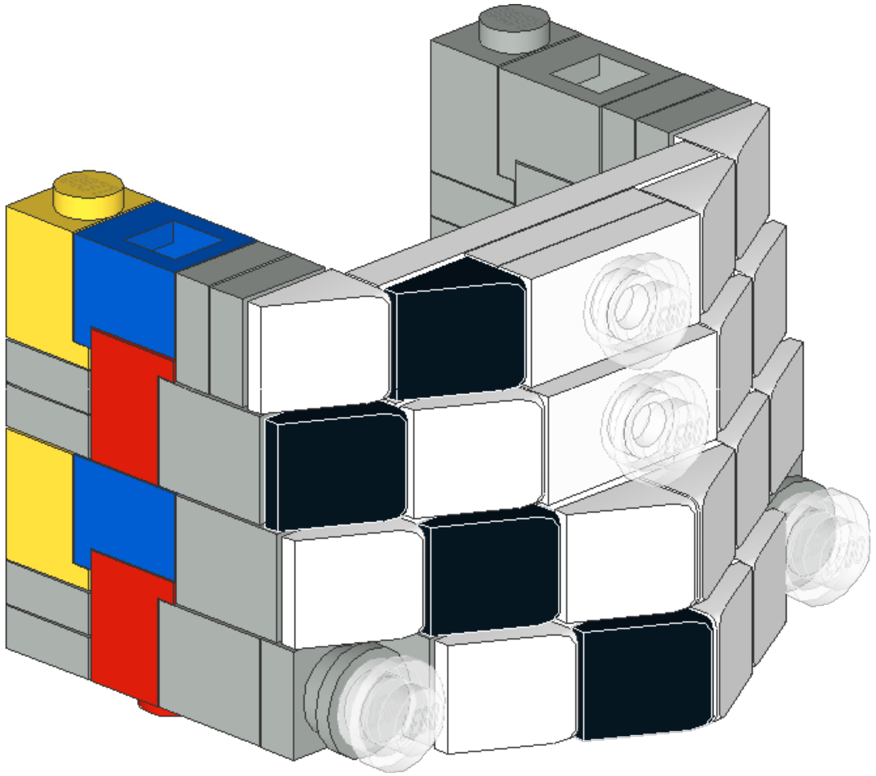
Used in Bram Lambrecht's "Legoland Spacelines 979"

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

Photo used with permission

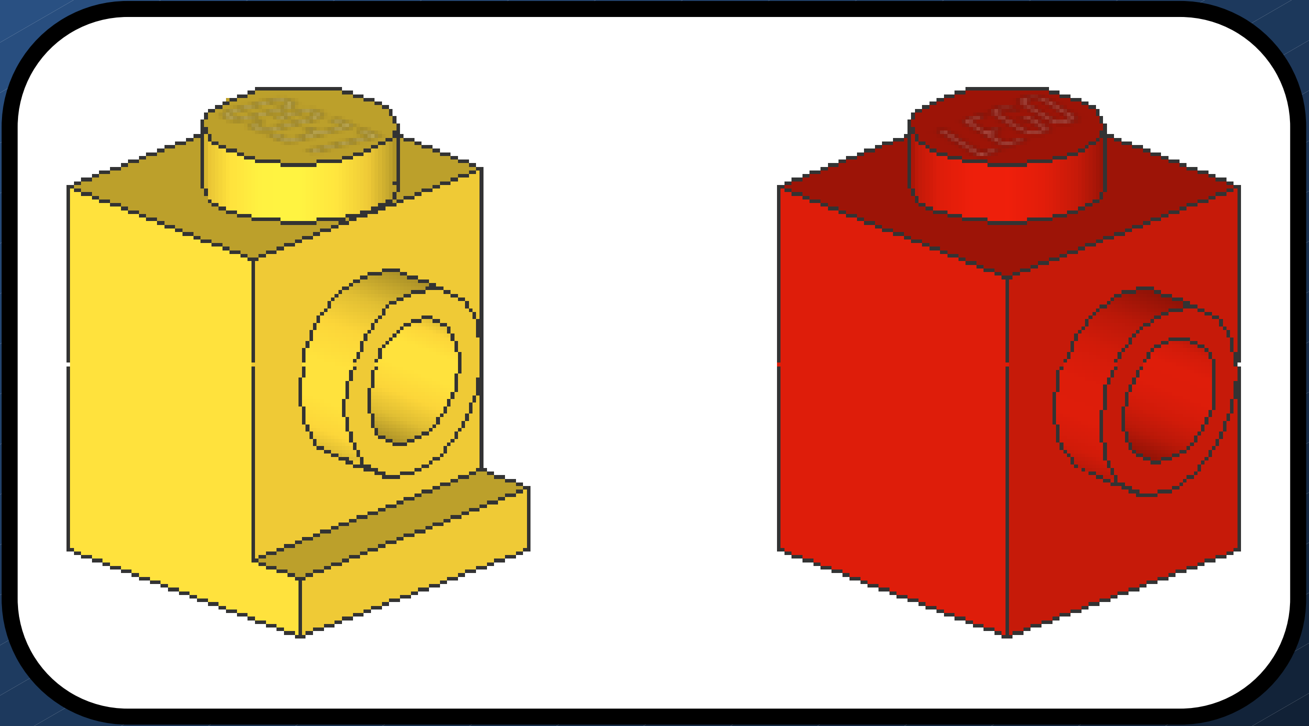
Useful for trains, too





My Caltrain F40PH locomotive uses this technique in 2 dimensions to create the double angle in the nose.

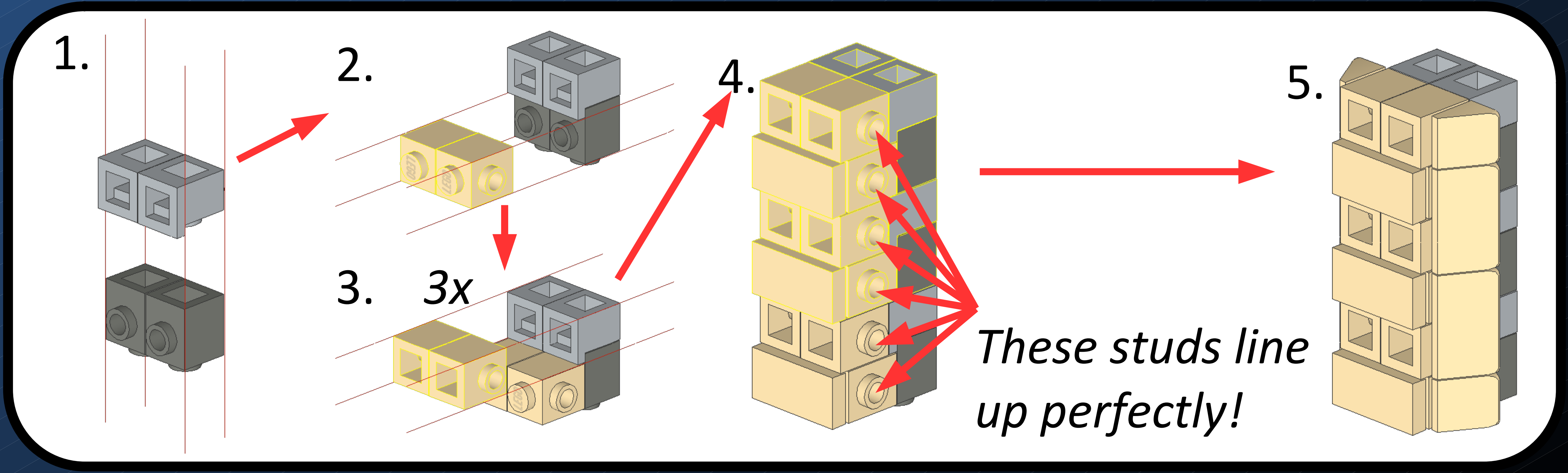
“Headlight Brick” vs. “Brick 1 x 1 with Stud on 1 Side”



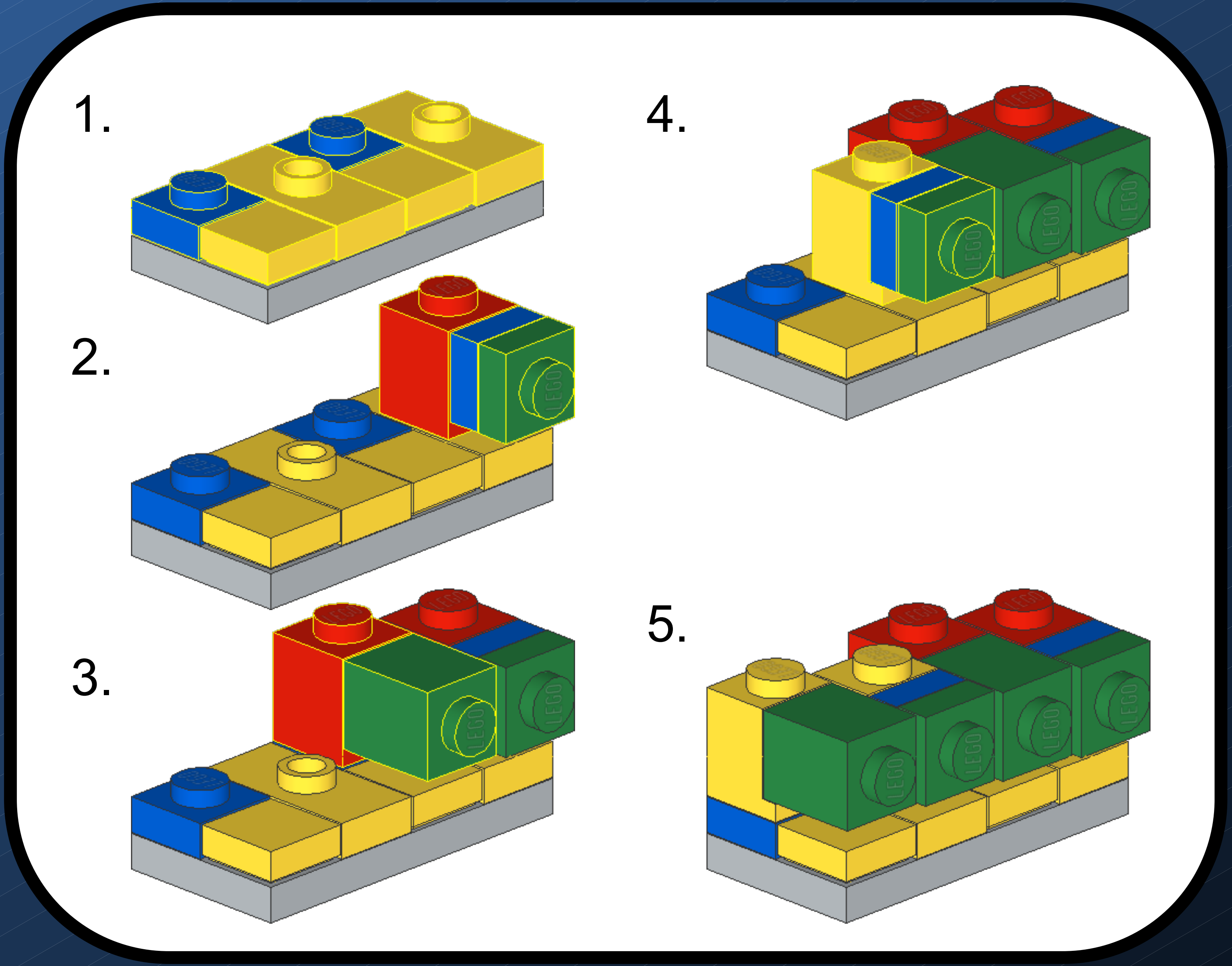
- Yellow headlight brick depth = 2 plates = 16 LDU
- Red brick depth = 2 ½ plates = 20 LDU
- Combine these to achieve ½ plate differences in depth!

Hospital Bay Window example

In my Micropolis hospital the I used the headlight bricks and bricks with studs on one side to produce a bay window and balcony effect. The windows (exposed bottoms of bricks) are inset by ½ plate from the tile beneath.



How about QUARTER plate offsets?



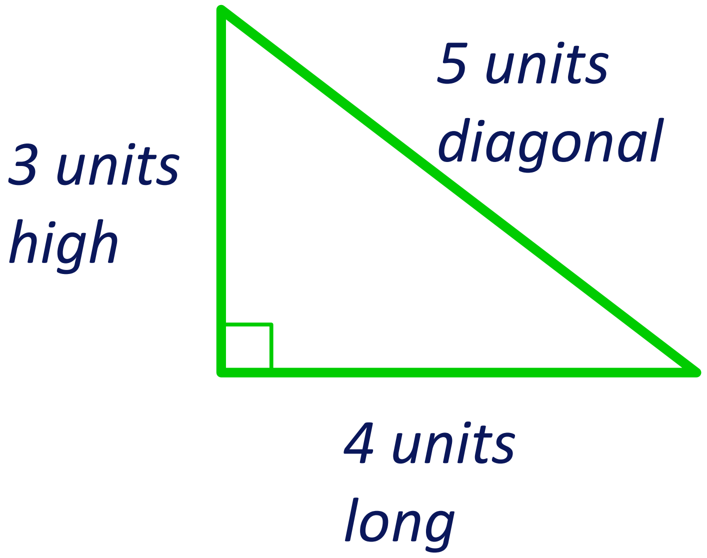
Mix the ½ stud offset of a jumper plate with the ½ plate difference between headlight bricks and bricks with a stud on one side, and you can get down to ¼ of a plate difference!

Triangles

Pythagorean Triples

Pythagorean Formula

$$a^2 + b^2 = c^2$$



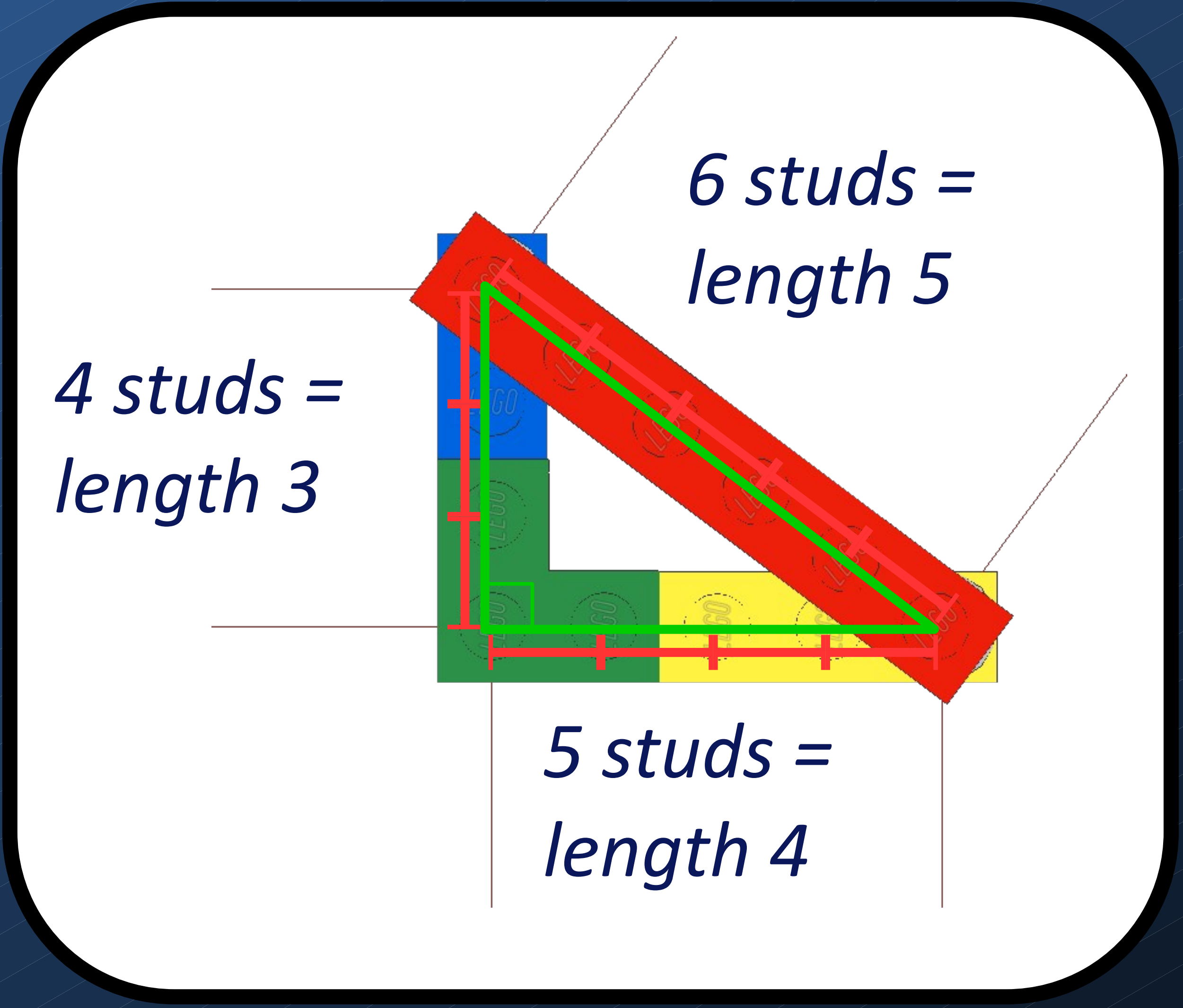
$$3^2 + 4^2 = 9 + 16 = 25 = 5^2$$

Pythagorean Triples are numbers representing the length of the sides of right triangles where all sides are 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



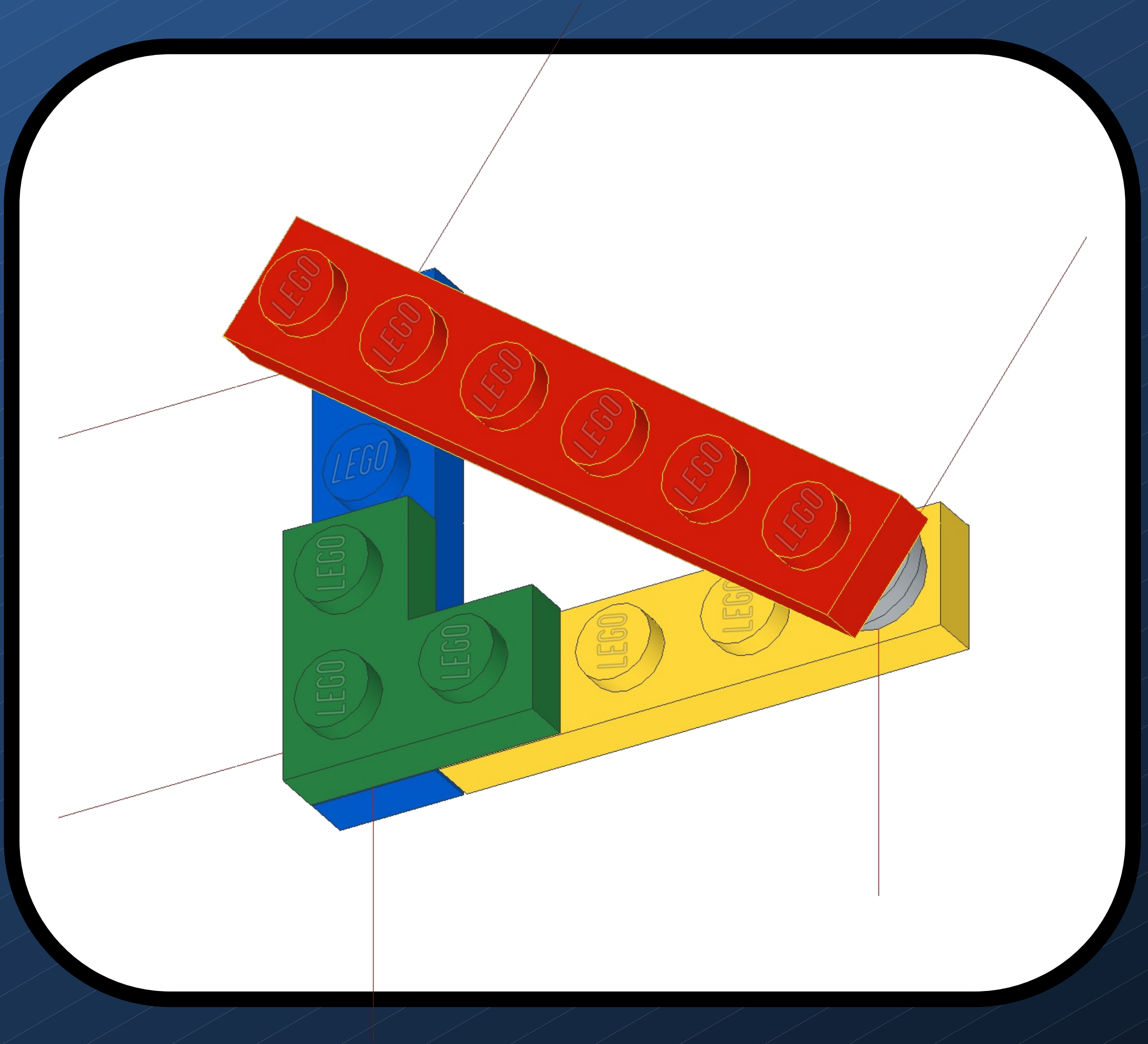
When making a Pythagorean Triple in LEGO, add one stud to each side!

Why? Count distance *between* the midpoints of each corner stud!

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

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

Building Triangles in LEGO

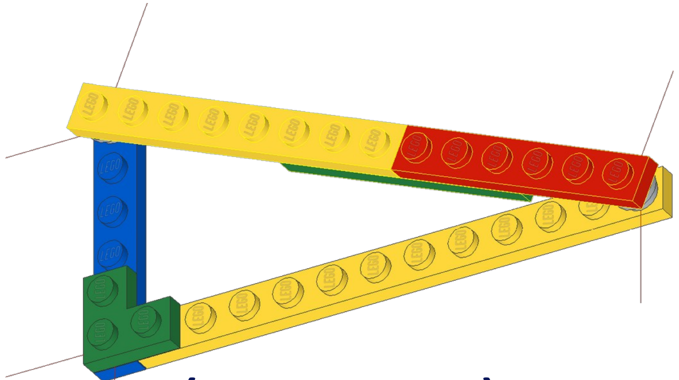


At these angles, studs will get in your way. You must either make the triangle with smooth parts, such as the 1x4 with only 2 studs, or a Technic design, or insert spacer plates as we have done here. This makes the triangle at least 3 plates thick. And don't forget, each side has to have 1 extra stud!

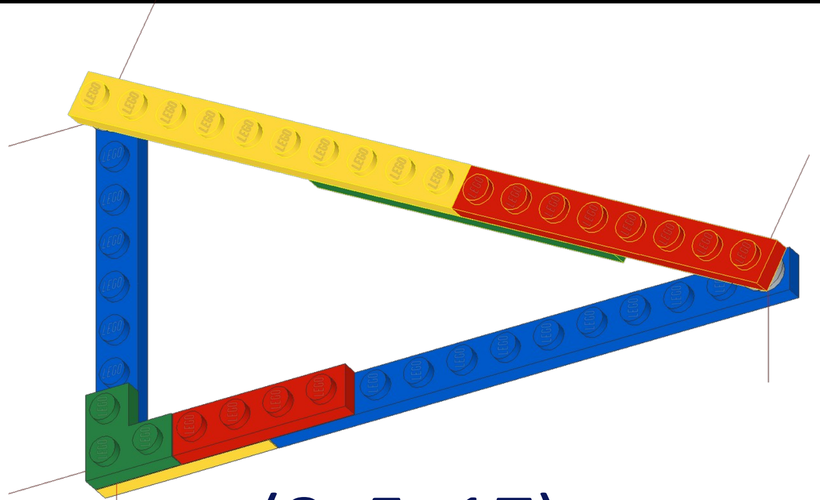
More Pythagorean Triples

- 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)



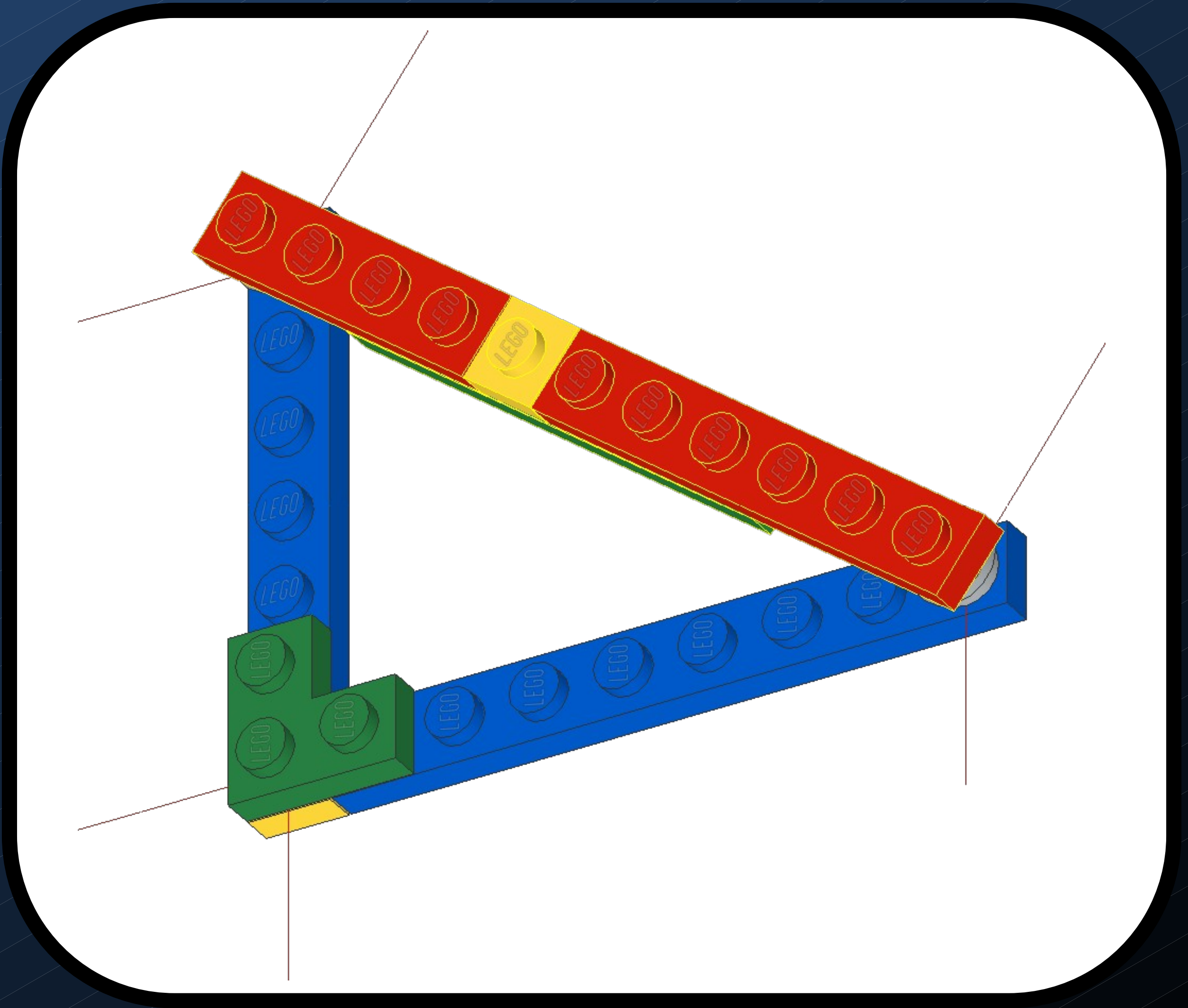
(8, 5, 17)

Multiples of Pythagorean Triples

- Unit does not have to be only a single stud! Additional triangles can be made by multiplying these values by the same scaling factor.
  - Example:

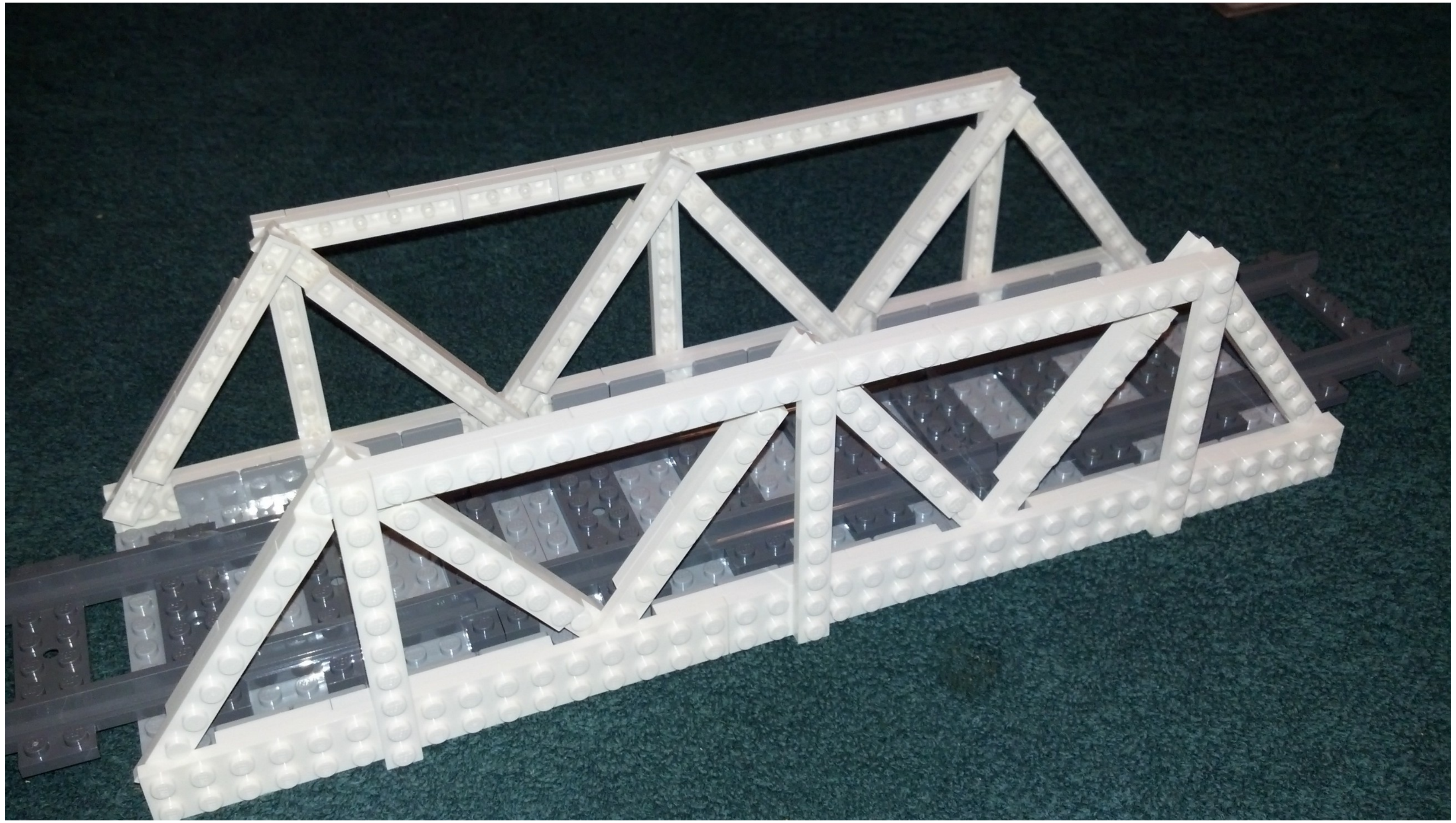
    2x(3, 4, 5) = (6, 8, 10)

    add 1: *(7, 9, 11) studs*



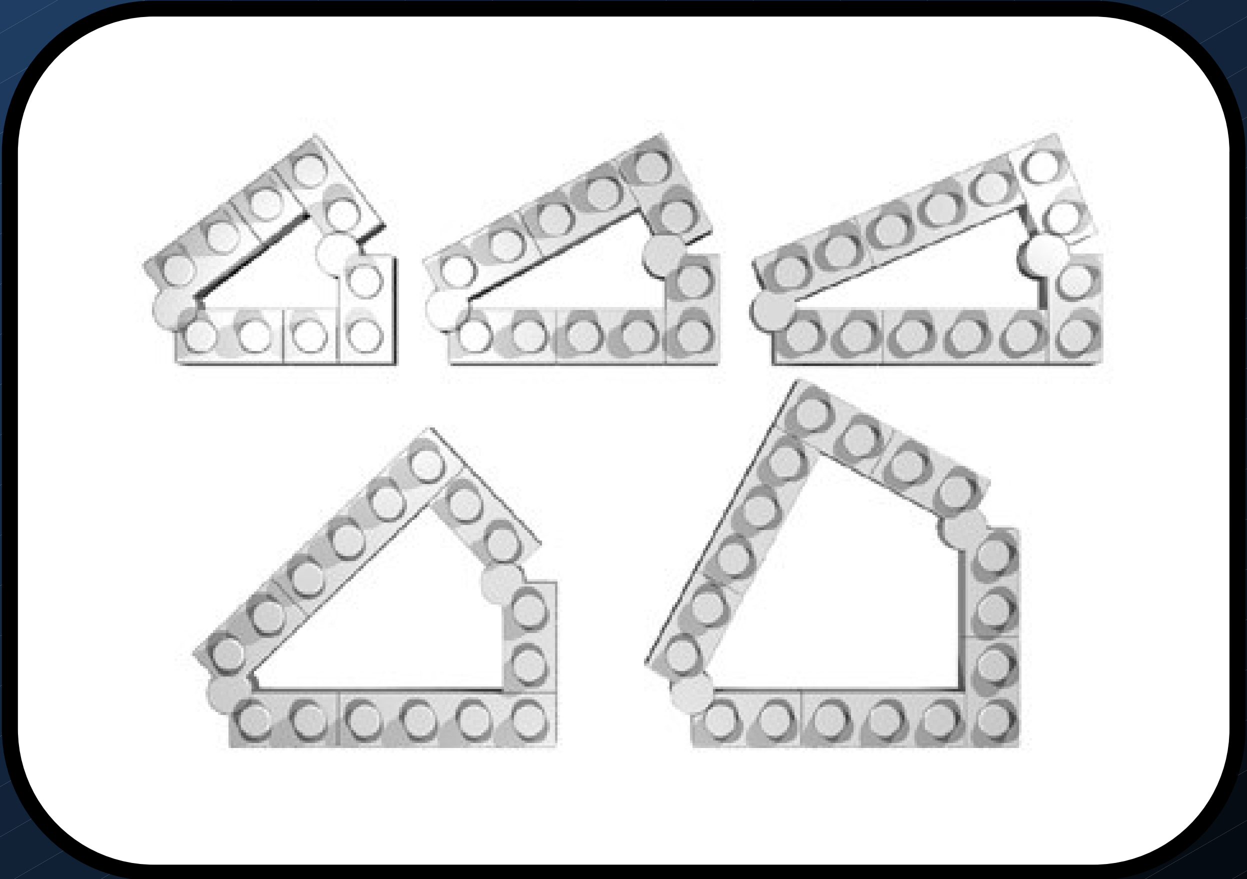
Pythagorean Bridge

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.

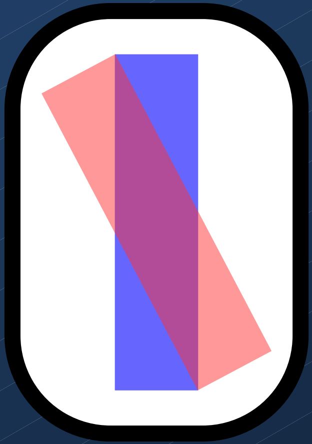


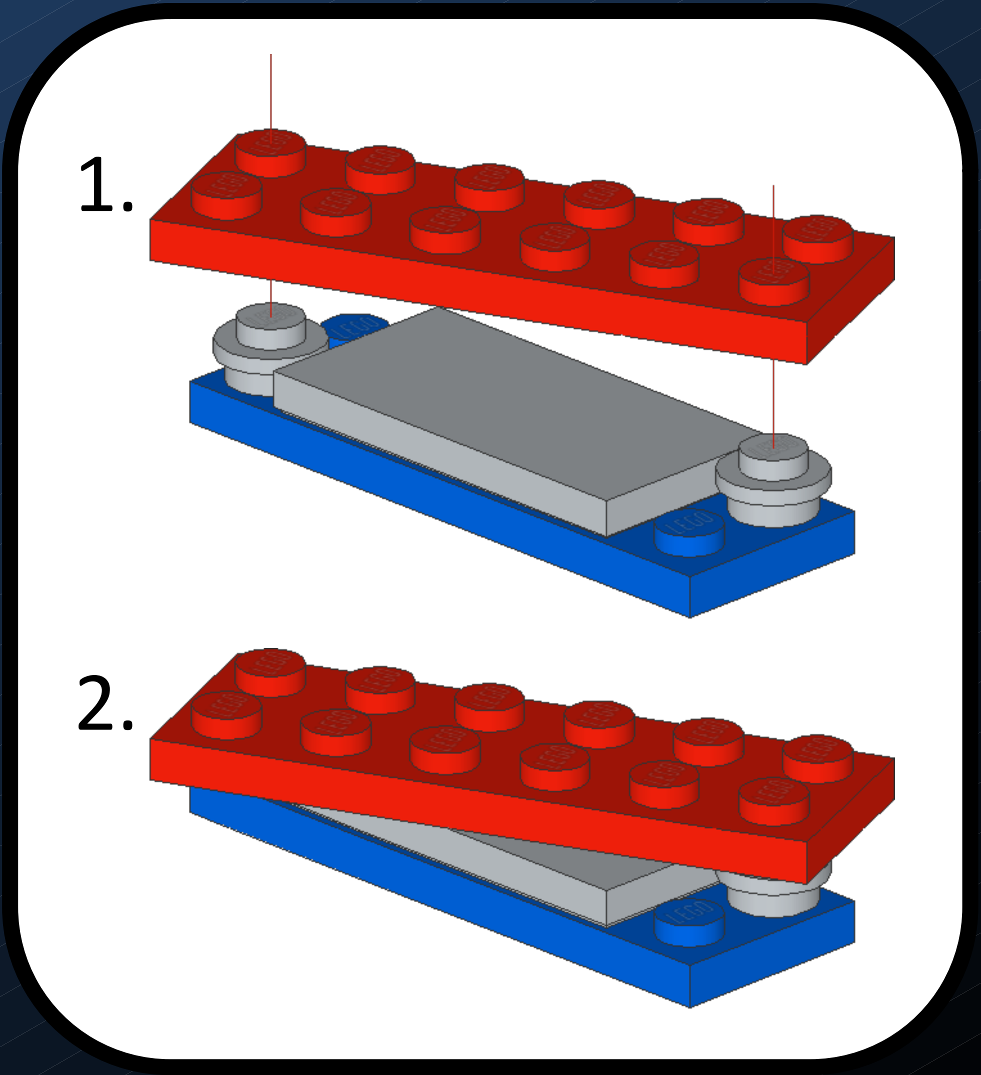
For more information including a list of possible angles, see: http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml

Swap Corners Technique

Two identical rectangles have identical diagonal length. You can therefore place one atop the other, rotated so the corners touch.

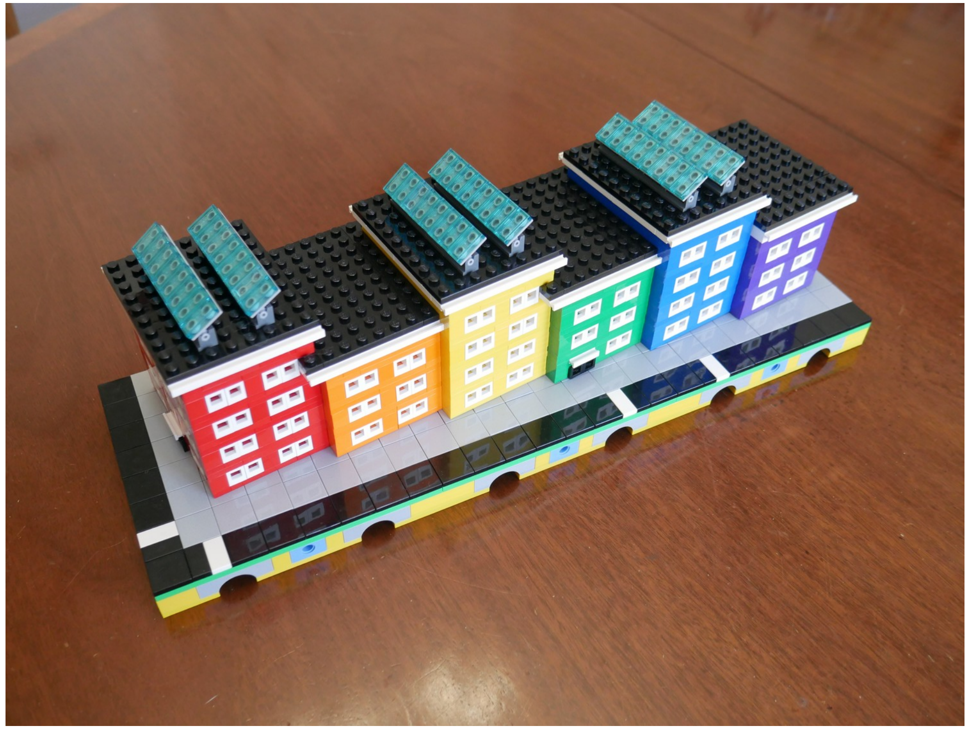
In LEGO, you can do this by connecting the corner studs.

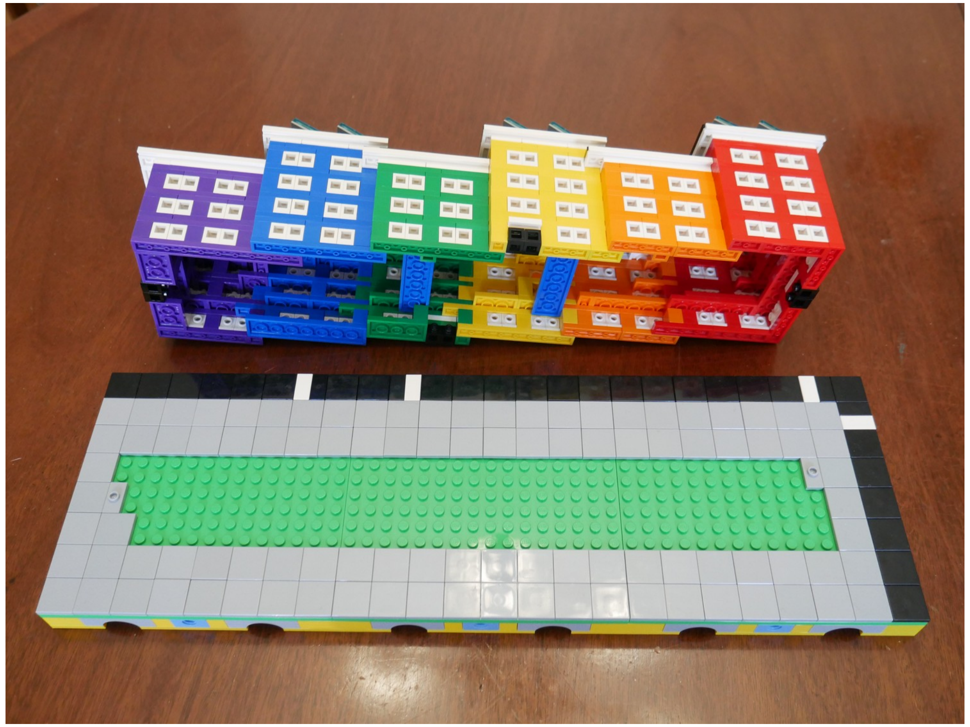




Swap Corners Example

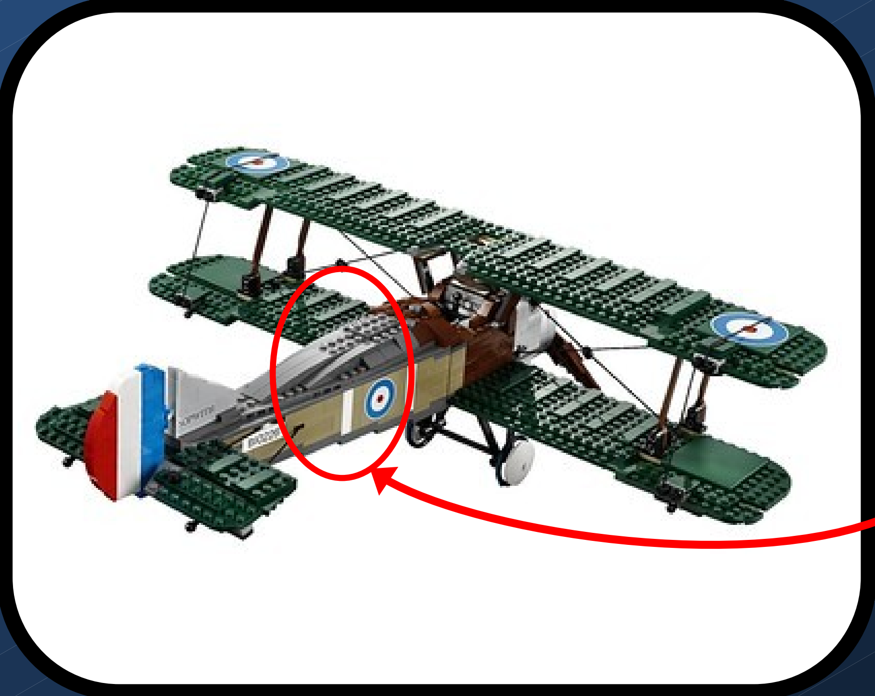
You can even mount an entire building this way…





Swap Corners using Hinges

A related technique can be done using hinges, since the rotation point of the hinge is exactly on the corner of the brick.



Example: tapered rear of fuselage on LEGO aircraft such as Sopwith Camel (set 10226)

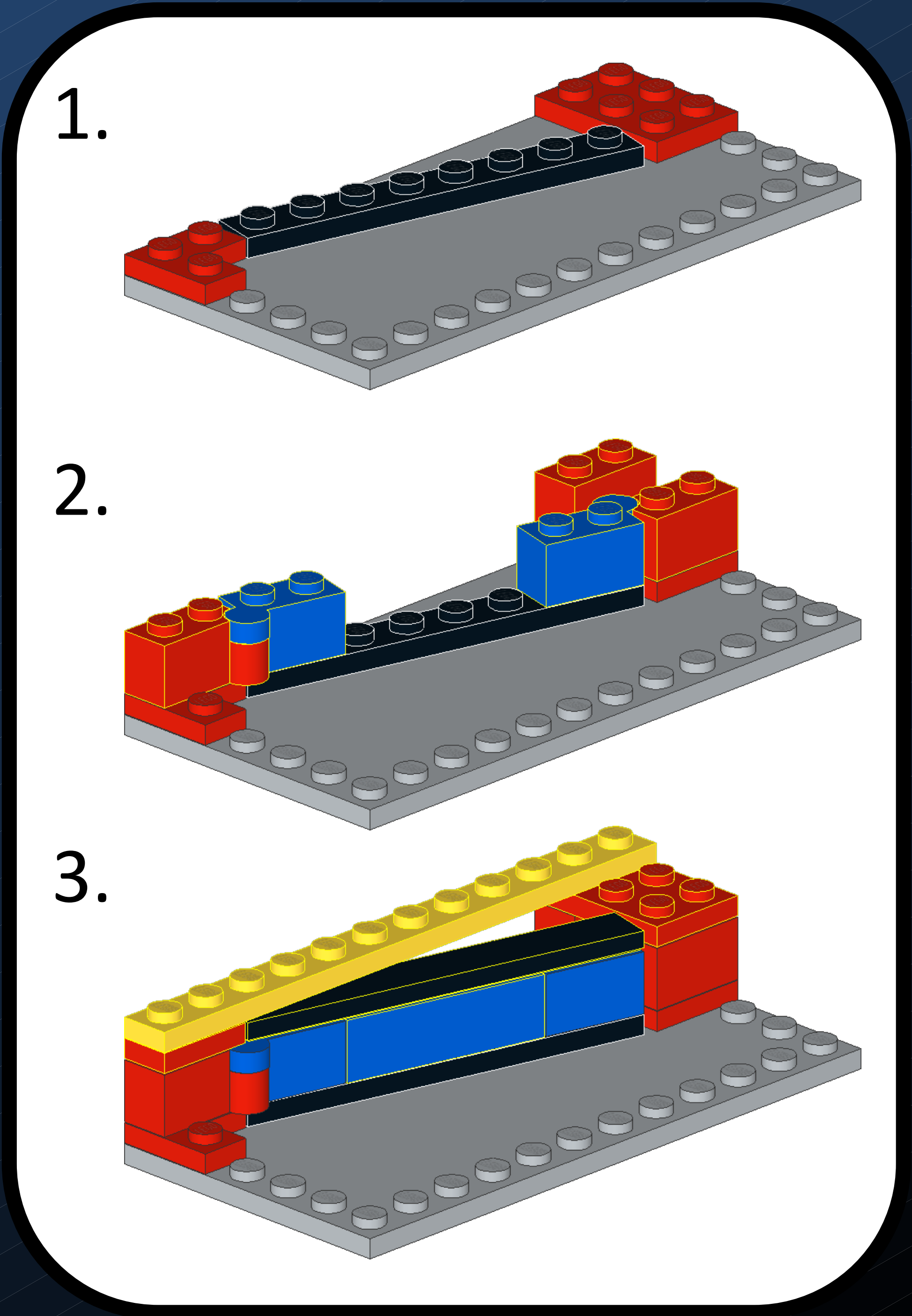


Photo: https://www.flickr.com/photos/dunechaser/7006873810/

Studs in All Directions

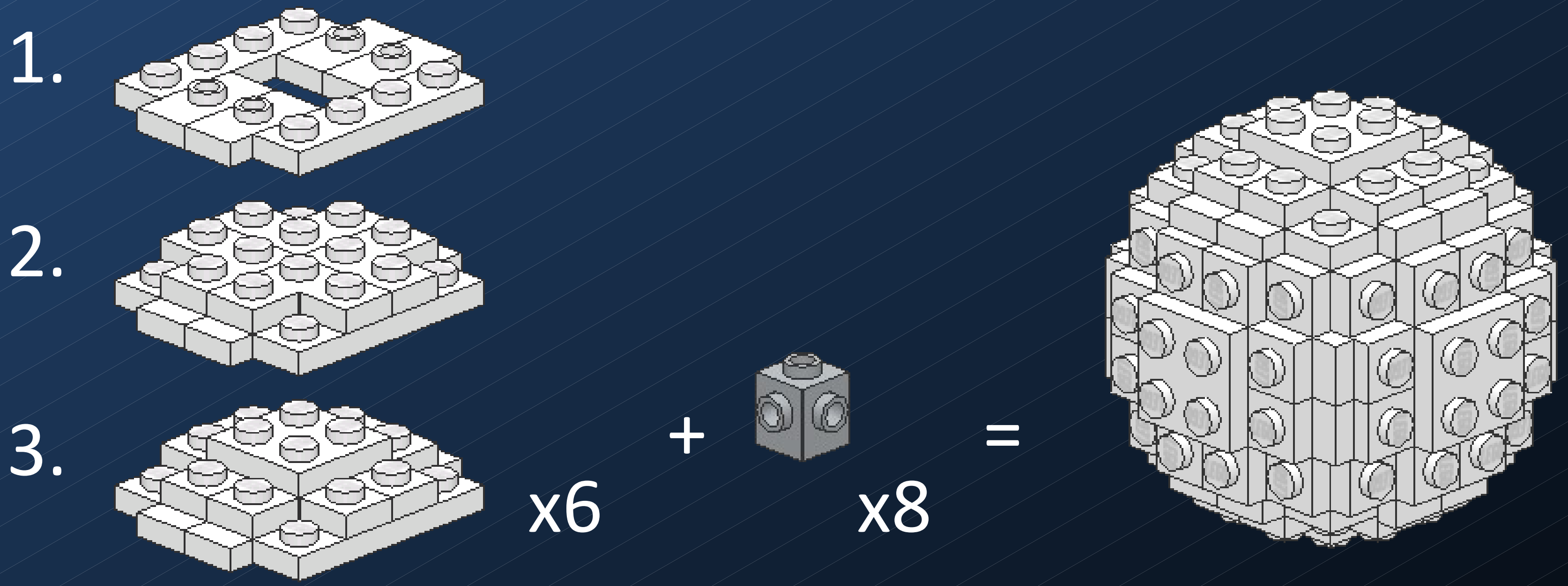
Travis Brick

- a.k.a. “Brick, Modified 1 x 1 with Studs on 4 Sides”
- Named the “Travis Brick” by the LEGO fan community after the late Space builder Travis Kunce, who had it tattooed on his arm
- Many “Studs on All Sides” techniques use this piece

Photo by Travis Kunce
https://brickshelf.com/cgi-bin/gallery.cgi?i=522387

Lowell Sphere

- How do you build a sphere out of LEGO?
- Solution designed by Bruce Lowell for a 6.8-stud diameter sphere (4 studs + 6 plates)
- Basis for many MOCs by many people



Bram's Sphere Generator

- Bram Lambrecht wrote a program to generate LDraw instructions for a Lowell Sphere of any diameter:

- http://lego.bldesign.org/sphere/

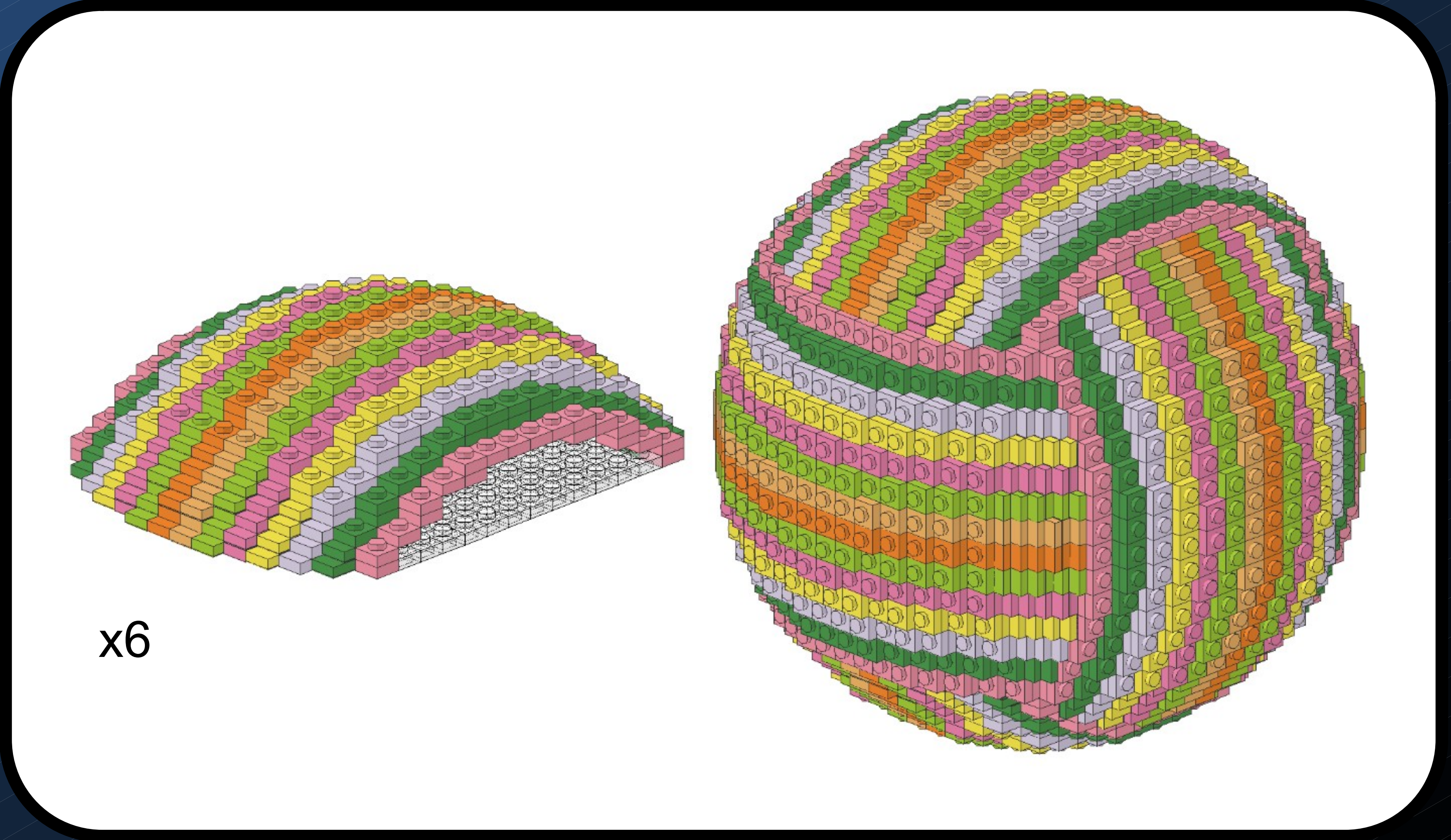
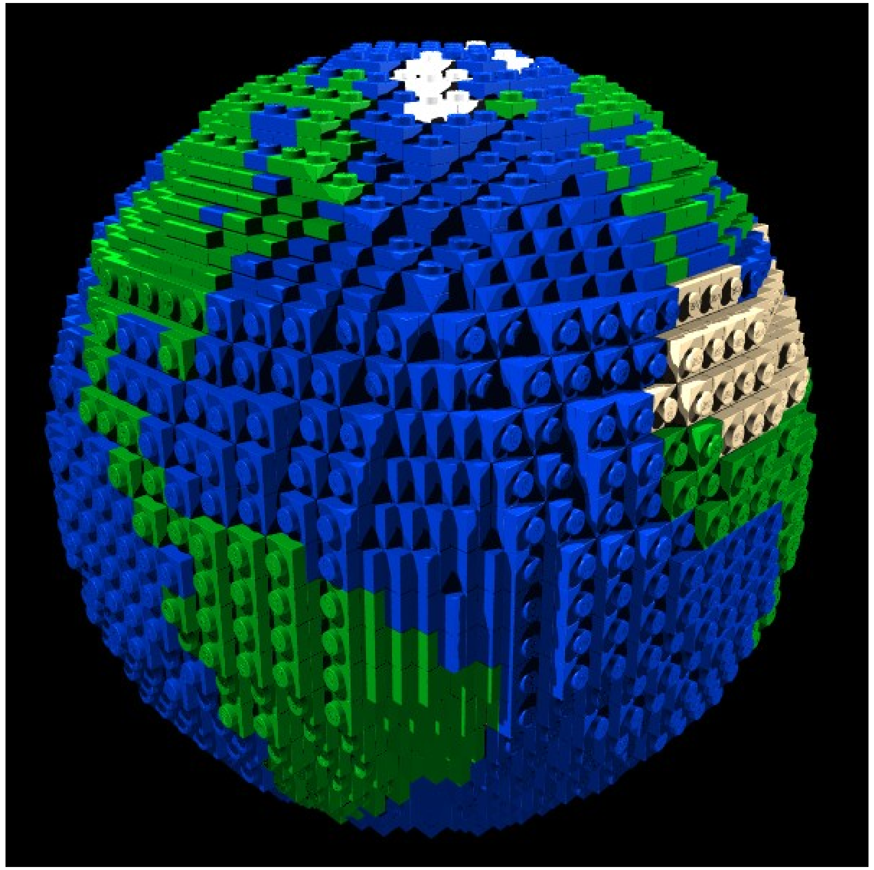


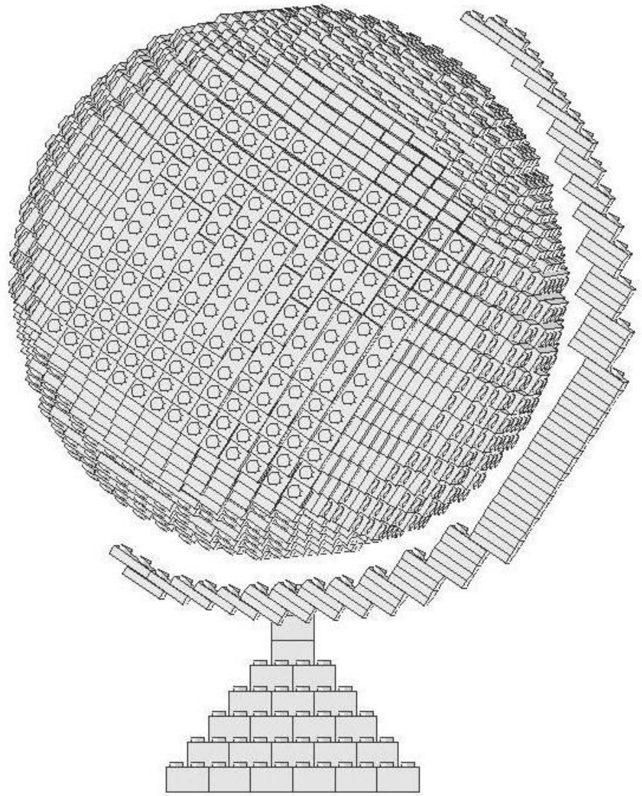
Image from https://ideas.lego.com/projects/16205 by “WWWally”

Old LEGO IDEAS project: Globe

https://ideas.lego.com/projects/16205 (got 699 votes in 2012)

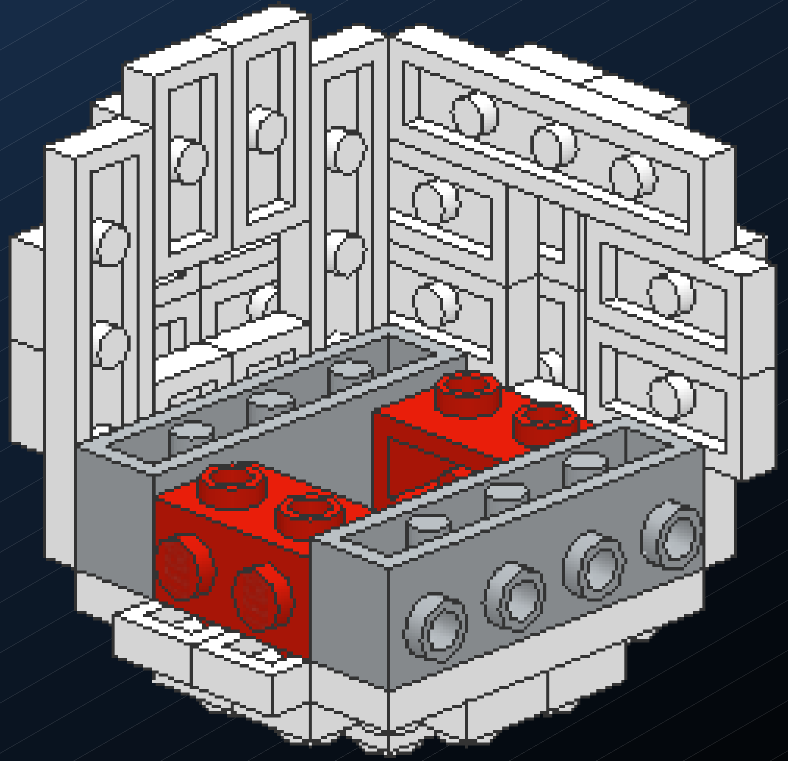
Globe design based on Lowell Sphere by “WWWally” from 2012





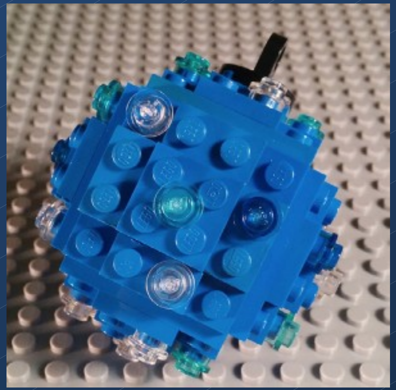
Travis Brick Not Required

- Note: For the 6.8 stud diameter Lowell Sphere and up, you can use other SNOT parts for the connection instead of the Travis Bricks.
- Tip: you can center the jumper plates on the hollow studs if using old style jumper plates.

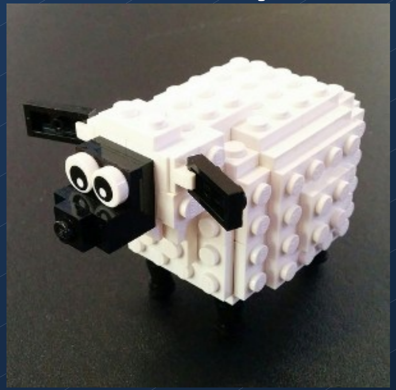


Some of my
Lowell Sphere based MOCs

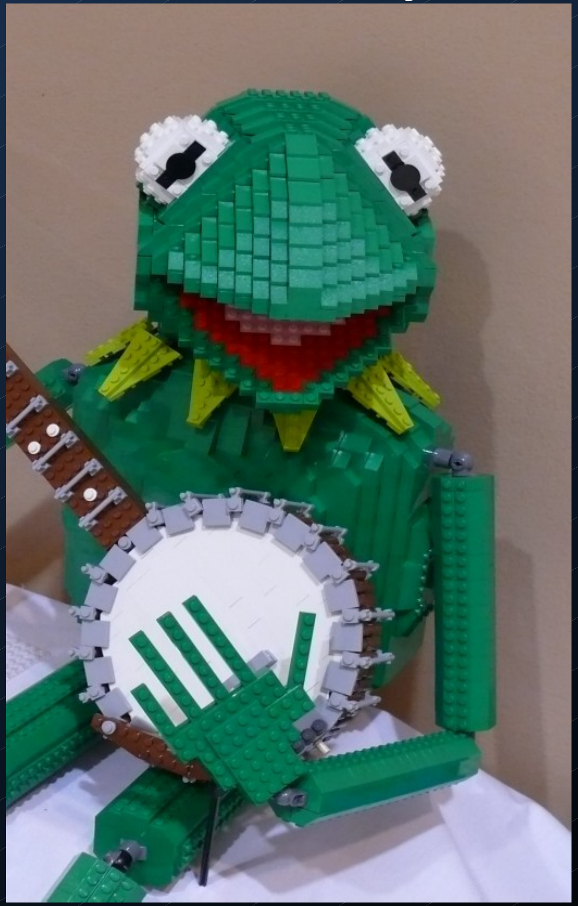
Christmas Ornaments



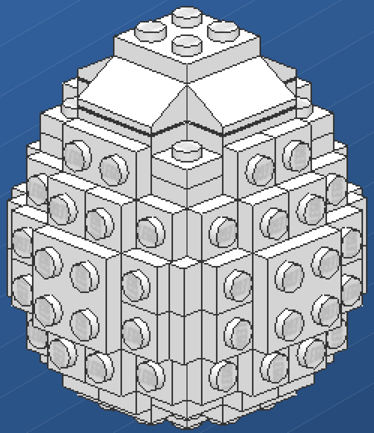
Sheep



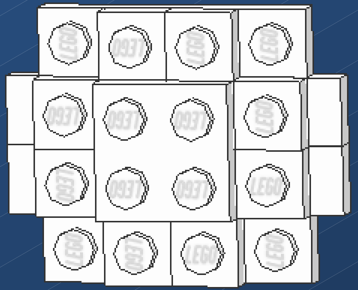
Kermit's eyes



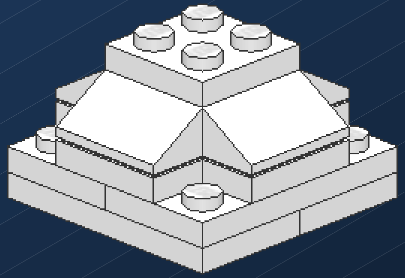
Easter Eggs



Breaking Eggs: Going from Sphere to Oval



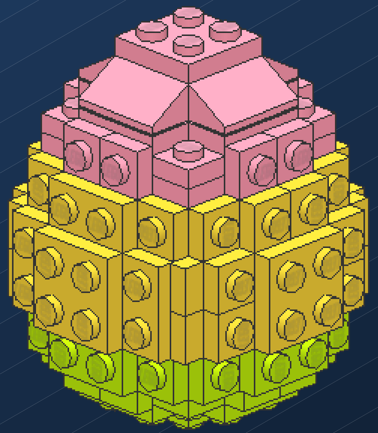
The round end (bottom) of egg is the same as on a standard Travis Sphere



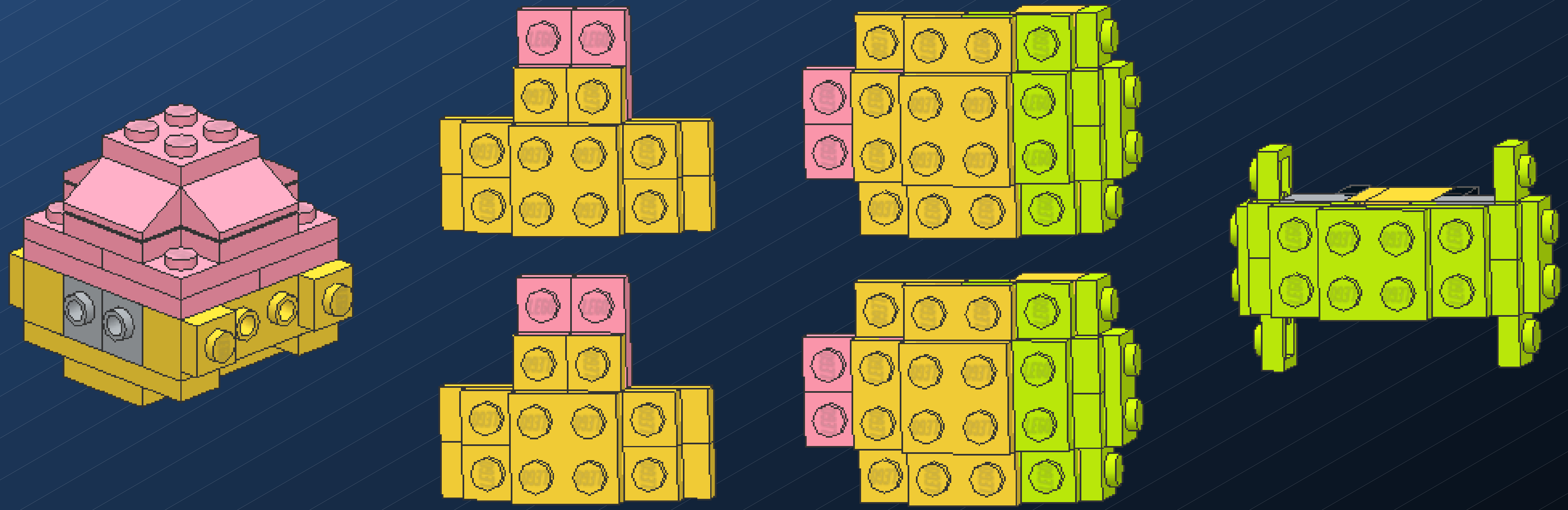
The pointy end (top) of the egg is my own original design

The sides (2 of each version) are the same as on a standard Travis Sphere but with one edge extended

Coloring Eggs



This egg has the *exact same shape* as the white one, but to get the colors to work, and to work around the limited range of parts in pink, the structure is very different!



Taking it to the Next Level

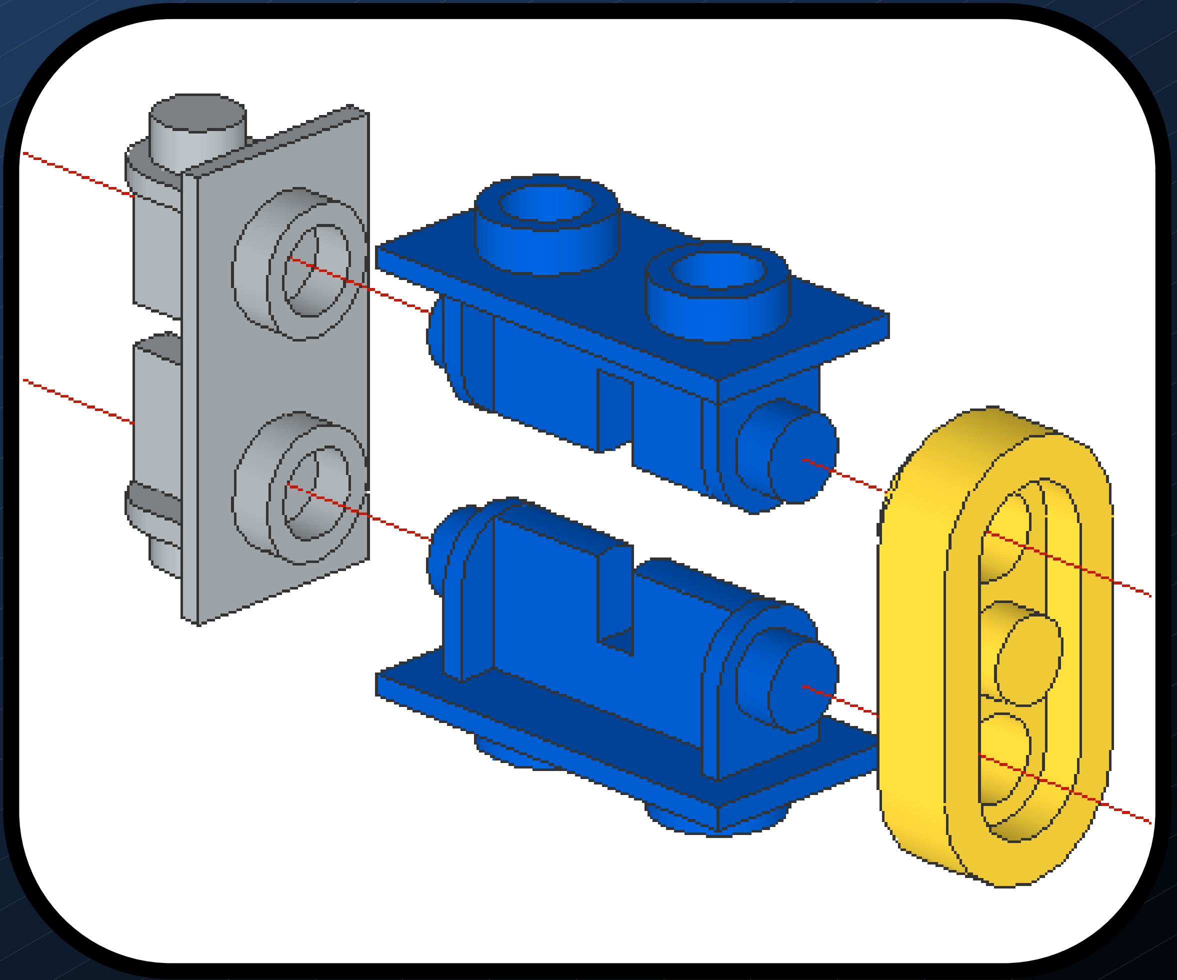
Parts of the Easter Bunny, Stay-Puft, and Teddy Bear are built in a similar way, just not a spherical shape...

Miscellaneous Brick Techniques

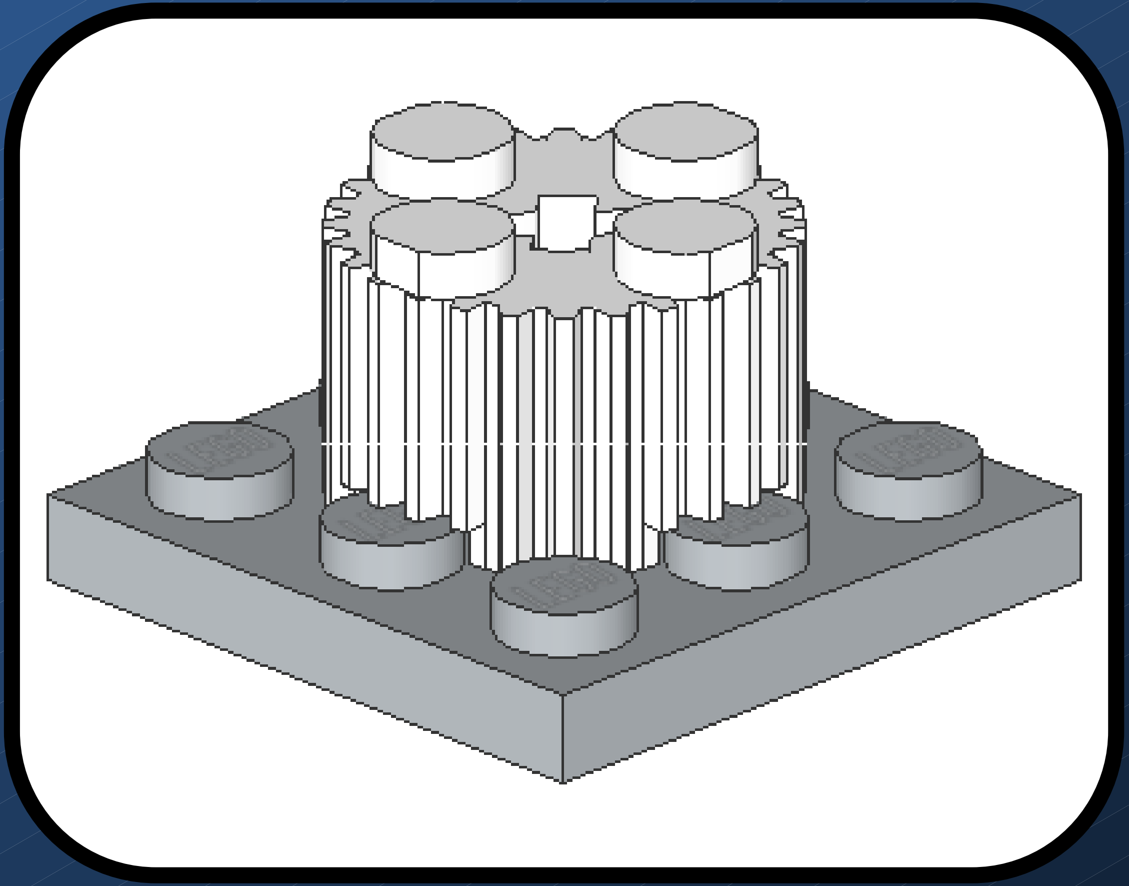
DSnot

"DSnot" technique from swooshable.com shows a fun use of the 1x2 hinge

- Can use any hollow stud parts on ends. I replaced one hinge with a "Plate, Modified 1 x 2 Rounded with 2 Open Studs" (Part 35480)
- Hinges can still be rotated!



Surprise 45° Connection



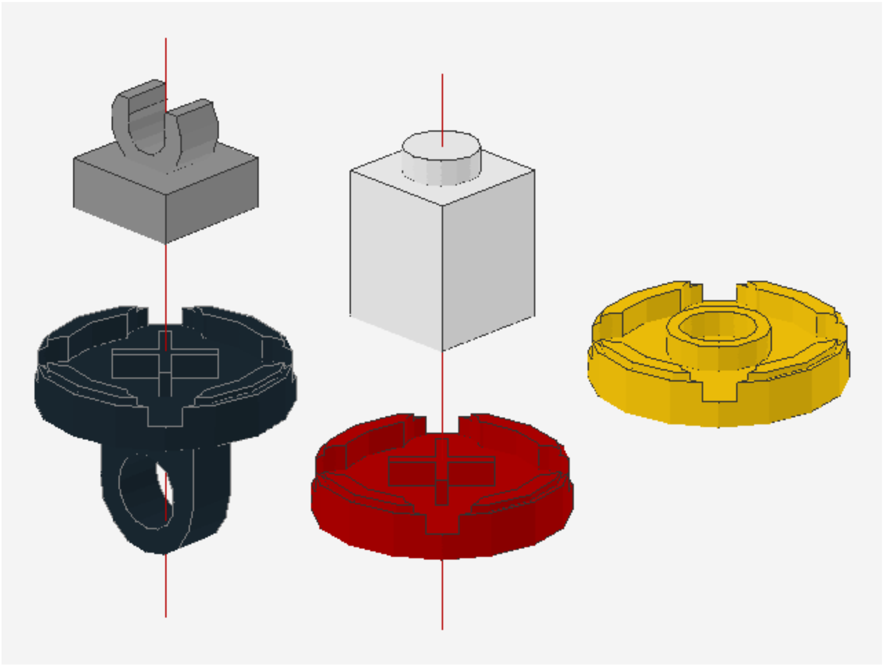
Brick, Round 2 x 2 with Flutes (Grille) and Axle Hole (92947) fits on studs at a 45 degree angle!

- Due to the "flutes" the cutouts in the corners on the bottom are just the right size
- Does not work with smooth round parts

Another Weird & Illegal 2x2 Round Part Connection

The old style 2x2 round tile with "cross" (and the version with Lifting Ring) can attach to a 1x1 brick

- Can connect to any 1x1 square part
- They changed it though – the modern 2x2 round tile has a circle on the underside instead.



Additional Resources

- Reinhard Beneke, BrickFest PDX '04
  - http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539
- Sir Bugge's Hypo-Techniques (traingles from hinges):
  - http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml
- The New Elementary, blog about new parts
  - https://www.newelementary.com/
- Swooshable, website about clever building techniques
  - https://swooshable.com/
- Bruce Lowell's “Lowell Sphere” page
  - http://www.brucelowell.com/lowell-sphere/
- Bram Lambrecht's sphere generator
  - http://lego.bldesign.org/sphere/
- Slides from this talk (and previous versions), from my website:
  - http://www.brickpile.com/tag/brick-geometry/

Q & A

Thank You!

Contact me if you have any further questions...

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