FASCINATING DOMES

GROUP 12

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Dome Background

The ancient Greeks developed the area of math known as geometry. Using this branch of math they described five regular solids called the **Platonic Solids**.

The **tetrahedron** has 4 sides.
The **hexahedron** (cube) has 6 sides.
The **octahedron** has 8 sides.
The **dodecahedron** has 12 sides.
The **icosahedron** has 20 sides.

A Dome could be made from an icosahedron!

We will demonstrate how to turn an icosahedron into a dome. We start with an icosahedron. Now watch as we transform the icosahedron into a Dome.

To aid the effort of giving the icosahedron a more spherical appearance later, we can divide each triangular face of the icosahedron into 4 triangles by adding a smaller triangle (with grey lines as its side) into the big triangle (with black lines as its sides). Hence each face now has 4 triangles and the icosahedron has 20 sides, hence we now have a total of 80 triangles.
Now we cut the icosahedron into half and we should have no problem as the icosahedron divides very easily in the middle as shown in the picture on the left. Notice the new triangles combine to create pentagons (grey), connected by triangles (white). This hemispherical dome is made up of 6 pentagons joined with 10 triangles. Each pentagon is constructed with 5 triangles. Hence this dome is actually made of 40 triangles altogether (notice its exactly half of the number of sides that the icosahedron has). This structure is still very angular, to make it more "dome like", that is more spherical or rounded, it is necessary to reshape the structure by moving each "hub" (point where white triangles meet) outward. To help all of us to conceptualize all that is being said more clearly, we will attempt to build the dome, physically, using paper and glue.

Building the Dome

Domes are elegant and sophisticated structures. Lightweight and strong, they make very efficient use of materials. They are an ideal structure for use in remote areas like the Arctic. Some day we may even see dome structures on the moon or covering cities. Following are the instructions for constructing a dome with a diameter of 50 cm. The dome which we have just built is usually known as a 2V Icosa Alternate. It is created by fitting 4 triangles inside each triangular surface of an icosahedron.

Lets begin building A Dome!

*Step 1:* We begin by deciding on the diameter of the dome we would like to create. As mentioned above, we’ll choose to build a dome of 50 cm in diameter.

*Step 2:* Next, we will determine the size of the triangles that are needed to construct our dome. The triangles we are going to make require glue tabs on their edges so that we can glue them together afterwards. We would make two kinds of triangles which are only a little different from each other, by virtue of the length of it sides. The triangles that we will make should look like this:
As seen from above, we need lengths of sides for the triangles. We would call the first length “A” and the second length “B”. The 10 equilateral triangles that we will make have all three sides equal to a length "A". To determine "A" we use a number called a "Chord Factor" which has a value of 0.61803 for “A” only. To determine the length of "A" multiply the chord factor by the desired radius of the dome. Note that radius is equal to 1/2 of the length of the diameter. Our dome has a diameter of 30 cm and a radius of 15 cm. Hence:

\[ A = \text{radius of dome} \times \text{Chord Factor} \]
\[ A = 25 \text{ cm} \times 0.61803 \]
\[ A = 15.45075 \text{ cm} \]
\[ A = 15.45 \text{ cm} \]

The 30 isosceles triangles we will make have one side "A" and two sides "B". We know "A" is 15.45 cm, to calculate "B" we use a different chord factor. The chord factor we will use for "B" is 0.54653. Hence:

\[ B = \text{radius of dome} \times \text{Chord Factor} \]
\[ B = 25 \text{ cm} \times 0.54653 \]
\[ B = 13.66325 \text{ cm} \]
\[ B = 13.66 \text{ cm} \]

**Step 3:** After calculating the sides and size of each triangle, we would now make them. First, we make accurate drawings of the triangles shown below. Then we will reproduce 9 more equilateral triangle and 29 more isosceles triangle as we will need 30 of the B-A-B triangles and 10 of the A-A-A triangles. Each triangular building unit is called element. Take note that each triangle must be made accurately, the dimensions shown are very important. Remember to some space for the glue tabs. Each of the 10 equilateral
Triangles should look like the triangle on the left and each of the 30 isosceles should look like the triangle on the right.

A = 15.45 cm  
B = 13.66 cm

Create 10 of these triangles.  
Create 30 of these triangles.

The triangles could be reproduced by photocopying them. Most types of paper are suitable for constructing the dome. For our project, we would use two colors of paper, one color for the A-A-A triangles (blue), another for the B-A-B triangles (white). Using different colored paper makes construction easier the dome more dramatic and beautiful.

**Step 4:**

Next, we have to cut out the triangles and carefully fold along the tab lines. A crisp fold is important.

**Step 5:**

Join five of the A-B-B isosceles triangles to create a pentagon. Do this by gluing the "B" edges together using the glue tabs. Make sure that the "A" sides of the triangles form the outside of the pentagon.

A completed pentagon should look like the image on the left. Note that it is raised in the center. Create 5 more similar pentagons.
**Step 6:**

Next, we have to create a circular base for the dome by cutting a circle of say 75cm in diameter out from cardboard. Then we have to draw a 50 cm diameter circle in the center of the base (faint grey line). Cut a 25 cm circle out of the center of the base to allow access to the interior of the dome, in case we need to, for gluing purposes.

![Image of circular base](image1)

**STEP 7:**

Join two pentagons by gluing one of the "A-A-A" triangles between them. Since the “A” side of the isosceles triangle is the side facing out, there is no problem gluing the equilateral triangle (white) to the pentagon (blue). It should fit perfectly. After gluing one white triangle a blue pentagon, add another triangle as shown.

![Image showing pentagons and triangles](image2)

**STEP 8:**

Glue this completed section to the base. Glue the completed section onto the faint grey line that marks the boundary of the 50 cm circle drawn on the base.

![Image of completed section](image3)

**STEP 9:** Continue adding pentagons and triangles, joining them with one another with glue. At the same time be careful to stick the base of each of the pentagon or triangle used to the faint grey line that marks the boundaries of the 50cm circle. The model should now look like the one in the picture on the left. Notice the triangular gaps between the top portion each pentagon?
STEP 10:

Glue the remaining equilateral triangles (white triangles) between pentagons on top to fill up the gaps between them. They too should fit perfectly with the pentagons since the “A” sides of the triangles that the pentagon is made up of is facing outwards.

STEP 11:

Glue final pentagon on top. It should fit perfectly!

STEP 12:

We’re done! The dome is completed. A Dome made of 6 regular pentagons (blue in color) and 10 other triangles (white in color). Now can you see how this dome is similar to the dome that we have first constructed from the icosahedron? Notice how the white triangles surrounds the blue pentagon as in the case of the dome made from the icosahedron?
An Introduction:

It is said that the Pantheon is to Italy what the Parthenon is to Greece. Both are tremendous monuments that reek of culture and history. But if you look closer, the two are totally different and only one has the benefit of Roman achievement.

Dedicated in its day to “all the Gods,” the pantheon today honors an unknown Roman architect whose vision created one of the most influential buildings of any era. Structural soundness and its use as a church in 609 have combined to keep the pantheon in use for nearly 1900 years. Though no longer a church, it remains the most outstanding of all ancient structures still largely intact.

Today, The Pantheon nestles in the midst of a warren of winding little streets about halfway between the Corso and the Piazza Navona, in Rome’s old central quarter. This drum shaped building capped with a saucer-like dome doesn't give you the slightest idea of what's in store for you once you step inside. In a street view, the dome is undistinguished, and the building gives few hints of the soaring spaces and grand proportions that still awe visitors stepping from the gabled porch into the rotunda.

This famous building, built some 18 centuries ago has amazingly withstood the ravages of both the elements and war permitting a firsthand view of a unique product constructed
History:

History tells us that the Pantheon is a Greek word meaning to honor all Gods (particularly the Olympian divinities). The site of the Pantheon was once home to a temple built by Marcus Agrippa, the son-in-law of the Roman Emperor Augustus, about 27 B.C. The Pantheon of the Agrippa possessed still no dome, but it seemed rectangular measuring 19.80 meters long and 43.76 meters broad temples to have been. It was dedicated to Julius Caesar and the gods Venus and Mars. Today, above the entrance carved in stone are the words "M. AGRIPPA L. F. COS. TERTIUM FECIT" which is translated, "Marcus Agrippa, son of Lucius, in his third consulate, made it."

As with many cities, tragedies in the form of large fires, such as those of 60, 64, 79, 100 and 110 A.D. seemed to strike Rome. Originally, many Roman buildings contained travertine (limestone rock) which easily cracked in fires. The Pantheon was severely damaged in 80 A.D. and required replacement except for some parts of the lower porch section and foundation.

The Pantheon was extensively restored by the Emperor Hadrian between A.D118 to 128. Emperor Hadrian’s new Pantheon was dedicated to all the Gods of the Roman Empire. It was a place where people went to worship when they needed help from a certain God. It was also used as a burial site. Not that many people were buried in the Pantheon, but those who were, were of great significance. Among the most famous is the artist Raphael, whose wish was to be buried here opposed to the Vatican. Several others were the first two kings and the first queen of Italy. Several of the Catholic Church’s most famous popes were also buried here.

The Pantheon was closed, abandoned, and forgotten when the first Christian emperors came into rule; until finally the Byzantine Emperor Phocas gave the Pantheon to Boniface IV who converted it into a Christian church in 609A.D. Its name was changed to Santa Maria ad Martyres. The Pantheon became the first temple in Rome to be Christianized.

During the Renaissance, Urban VIII, also known as Barberini, employed a man named Bernini to add two turrets in the front of the Santa Maria (Pantheon), near the portico. Many thought they were an ugly addition, and became popularly known as the "ass ears of Bernini". They were removed in 1883A.D. Barberini was not done with the Pantheon yet though, he melted down the bronze ceiling of the portico for St. Peter's, an act of vandalism. This took part in inspiring Pasquino's saying "what the barbarians didn't do, Barberini did."
Today, the Pantheon is no longer a church. However, it continues to serve as a symbol and reminder of the Roman Empire, one of the greatest empires that ever existed in History.

**A Brief Description of the Pantheon’s overall Design:**

Michelangelo the great painter of the Sistine chapel once described the design of the Pantheon as an "Angelic and not human design." Rightly so, for it is indeed one of the most unusual structures ever built by human hands. The ancient Roman's ability to draw the intricate plans and select only the most successful time-proven construction techniques made this complex building possible. Again, it is truly a credit to their mental prowess and organizational skills.

The Pantheon is a circular building of concrete faced with brick, with a great concrete dome rising from the walls and with a front porch of Corinthian columns supporting a gabled roof with triangular pediment. Fig 1 shows the floor plan of the Pantheon. The rotunda (a description of the round nature of the Pantheon) has a rather awesome inner diameter of 43.4 m, made mostly of concrete. From the floor to the top of the opening in the dome is the same distance. The design is not entirely unusual because there are other Roman buildings which have a similar configuration, but the size is unusual.

The portico:

The portico consists of three rows of eight columns, 14 m high of Egyptian granite with Corinthian capitals. They support an entablature (the triangular structure that lies horizontally on the pillars supporting it) facing the square, which bears the famous inscription in Latin, attributing the construction to Agrippa, although the temple was rebuilt later by Hadrian. The beams in the roof structure of the porch (covered entrance) are wooden. They were substituted for bronze members stripped-out by those in later
years needing metal for their canons. Below the Porch (covered entrance) lies the main entrance which is thoroughly impressive: double bronze doors 6.4 meters, a lasting and fitting contribution from their metal smiths.

The Dome:

The building design is one of a large round shape very much like a large barrel with a dome covering the top. The dome was the largest built until modern times, measuring about 43 m in diameter and rising to a height of about 22 m above its base. The dome, seen as from the interior, is different from that as seen from the exterior. From the exterior, the dome seems to be made of 7 concentric steps piling one on top of another. From the interior of the building, one can see the bands of waffle like depressions called coffers which are not visible form the exterior. The reason for this difference in appearance is just that the outer surface and the inner surface are separated by a concrete layer, which builds the dome, and is crafted differently on both sides. These will be elaborated later on. There is an oculus (eye or opening) at the center of the dome which allows the sunlight and moonlight to shine into the Pantheon. Professional Roman surveyors located the inlaid marble floor to conform to a convex contour which drained away the rain from the oculus for these hundreds of years.

The Interior:

The interior of the building has six distyle (2 columned) niches at the sides and a semicircular exedra (semi-circular stone or marble seat) at the back. The niches around the wall originally held statues of the divinities. Buried here are Victor Emmanuel II (first king of Unified Italy), King Umberto I and the great Renaissance artist, Raffaello.

The pavement of the interior is finely polished marble in patterns of the style called "Opus Sectile" which was popular in ancient Rome. From the floor plan in figure 3, we can observe the positions of the semicircular exedra (semi-circular stone or marble seat), and the 6 distyle (2 columned) niches.

Two factors, however, are known to have contributed to the Pantheon’s success: the excellent quality of the mortar used in the concrete and the careful selection and grading of the aggregate material, which ranges from heavy basalt in the foundations of the building and the lower part of the walls, through brick and tufa (a stone formed from volcanic dust), to the lightest of pumice toward the centre of the vault.

Fig 3: Floor Plan
Figure 4 gives us a view of the interior of the Pantheon. In the left picture, we can see the semicircular exedra flanked by two distyle (2 columned) niches. The right picture shows the interior side of the dome. Notice the five tiers of coffering all around the dome, except for a smooth band near the oculus. This picture also shows the view oculus from the interior of the Pantheon.

**The Dome**

The spherical shape of the dome:
The dome is hemispherical in shape as seen in the picture in Fig 6. The radius of the dome is 21.7 m which serves as the basis for the original design. The relative thickness of the dome is reduced from 5.9 m at the base to nearly 1.5 m at the top. The Dome culminates in an 8.7m open oculus or eye, lined with brick and sheathed in glazed bronze that floods the Pantheon with light. The distance from the floor to the oculus is 43.3m, This is the same as the interiors diameter. Hence, it is logical to conclude that the hemispherical dome would touch the floor if it was extended to a complete sphere. Fig 5 shown below will help you to visualize this.
As mentioned before, on the outside surface, there is a series of seven step-rings half way up the dome, and then the dome line changes into a circular line. On the inside surface the dome contains a series of 5 bands made of waffle-like depressions called coffers. There are 140 coffers which required special forming for the waffle shape. Figure 6 shows what coffers would have looked like from the exterior if the outer layer of the dome did not hide it. At mid-point the dome contour changes from these coffers to a circular line. In the center of the dome is a large opening, the oculus.

The Construction of the Dome:

Roman engineers have built domed buildings before, but the dome of the Pantheon, was to be by far the largest ever. It demanded a formidable support system. Possibly, workers began with a 7.3m wide circular foundational wall. Above it, they built 6.1m thick support walls: effectively a cylinder to contain the dome’s outward thrust. Tough thick, the encapsulated walls are riddled with voids (Fig 7); inside them a complete web of vaults and arches channels the vertical load from the dome down eight massive pillars. (Figure 7)

The brick-faced concrete dome uses lighter aggregates as it rises, lightening the load on the supports below. At the crown of the dome, the monolithic shell tapers to 1.5m thick. Though chunky, Roman concrete was so supple that, when wet, it could be curved and shaped at will over the timber framework used to support the dome while it was under construction. Cemented by excellent mortars of volcanic sand, it contained varying mixes of aggregates; stone volcanic rock, brick, even rubble from demolished buildings. These turned concrete airier or weightier, allowing builders to regulate the density of their structures. Rising layer by horizontal layer, the Pantheon’s concrete lightens, reducing loadings in the material to roughly half that of heavier aggregates.

Figure 7: Diagrams showing
The Outer layer of the Dome:

The outside rings are not uniform, there are 7 rings. The first ring has its outside edge resting on the center of the main wall. It appears to be some 2.3 m thick with a horizontal distance to the next ring about this same distance. The remaining 6 step-rings are stepped inward much like placing a series of machine washers, one above the other with their diameters decreasing as they are stacked. The height of these 6 rings varies, and they are estimated to be 0.8 m on the average. The horizontal distance to the next of these smaller rings is estimated to be 1.2 m. There is an exterior stairway leading through these rings to the oculus.

It is known that the very old Mycenaean tombs in Greece were made by corbelling stone slabs over one another. Following this example, it is likely that the Romans used this principle in placing one step-ring on another in building this section of the dome. This work took a long time. The cementing materials properly cured and gained strength to support the next upper ring. The smaller step-rings are faced with bricks which gives credibility to the corbelling method. Each ring was built like a low Roman wall. The circular part of the upper dome was likely placed by using wooden scaffolding.

The Dome as seen from the interior of the Pantheon:

When the dome of the Pantheon is viewed from the interior of the structure, its shape, alike that of the dome as viewed from the exterior of the structure, is also hemispherical. However, except for a smooth band near the oculus, the interior of the dome is decorated with five rows of twenty-eight square coffers in waffle like pattern, each diminishing in size and depth, creating an illusion of space. At the smooth band near the oculus, the dome contour changes from these coffers to a circular line. Since the coffers are hollow they reduce the weight of the dome. Each coffer had once been adorned with gilded bronze rosettes that were later removed or possibly stolen.
Born in East Knoyle, Wiltshire, on October 20, 1632, Sir Christopher Wren is considered by many to be the greatest British architect of all time.

Along with his associates, he represented the dominant force in late seventeenth and early eighteenth-century architecture. By far his greatest work, St. Paul's Cathedral in London, was begun in 1675 and completed in 1711. Thirty-five years in the making, Saint Paul's features one of the largest domes ever built, second only to that of Saint Peter's Basilica in Rome. Both domes were based on the one in the Pantheon built by the ancient Romans. For the next two centuries, and until the advent of the modern skyscraper, St. Paul's dominated the London skyline as a symbol of the stability of the Church of England and English government and society.

Modern St. Paul's is packed with memorials to notable Britons. Wren's original cathedral had no memorials, but these began to appear in the late 18th century, and now there are hundreds.

St. Paul's Cathedral (1675-1710)

Origins

When most people think of St. Paul's Cathedral in London the image of Christopher Wren's magnificent classical church rises in their minds, but there was a cathedral dedicated to St. Paul long before the able Mr. Wren put his stamp on the skyline of Stuart London.
The first church on this spot was erected in 604 AD, just 8 short years after the first Christian mission under St. Augustine landed in Kent. This wooden church was established by King Ethelbert of Kent as home to the first bishop of the East Saxons, Mellitus.

That first church was destroyed by fire and rebuilt by St. Erkenwald, then bishop, in 675-85. Fire was not the only danger faced by buildings in those dark centuries of Anglo-Saxon England - the Vikings destroyed the second St. Paul's in 962 during one of their periodic invasions.

Once again, fire destroyed the church in 1087. The new Norman building, now called Old St. Paul's, took over 150 years to complete, the final touches being applied in 1240. Well, not quite final touches - a new Gothic choir was added by 1313, making St. Paul's the third longest church in Europe at 596 feet. The following year the spire was completed. At 489 feet it was the tallest in all Europe.

In the Tudor period an open-air pulpit called Paul's Cross was established by the south wall of St. Paul's. There crowds gathered to hear rabble-rousing Protestant sermons. In 1549 the preachers incited a mob to sack the cathedral itself. They rampaged through the interior, destroying the high altar and ravaging the tombs, wall-hangings, and tombs.

St. Paul's bad luck continued. The spire was struck by lightning (not too surprising, considering how it towered over the city). The cathedral became a centre of trade, with merchants selling their wares in the nave of the church itself. Architect Inigo Jones was called in to resurrect the decaying building, but his efforts, hampered by lack of funds, only delayed the inevitable.

During the English Civil War, Parliamentary troops commandeered the cathedral and used the nave as cavalry barracks. They broke up the scaffolding and sold the material.

The fortunes of Old St. Paul's seemed to take a turn for the better with the Restoration of the Monarchy in 1660. Charles II appointed a young architect named Christopher Wren to undertake major repairs to the building. Wren had only begun his work when final calamity struck.

On September 4, 1666, fire broke out in a bakehouse in Pudding Lane. Fanned by a fierce wind, the fire spread through the close-packed streets of London, destroying everything in its path. For four days the fire raged, and when the smoke finally cleared, Old St. Paul's was nothing but charred timbers and rubble.

The calamity of the Great Fire of London proved the opportunity of a lifetime for Christopher Wren, and the young architect did not hesitate to seize his chance.

Within days of the fire, Wren presented a visionary plan to King Charles II for turning the crowded shambles of Stuart London into a sunlight city blessed with wide avenues and open plazas. The enthusiastic Charles liked Wren's ideas, but he lacked the money to
carry them out, and impatient Londoners had already begun to rebuild along the old street patterns.

Instead, Charles gave Wren the commission to rebuild the cities churches, including Old St. Paul's Cathedral. To finance this rebuilding a special tax was levied on coal arriving at the port of London.

Wren's original design for the cathedral was rejected by the church as being too modern. The second design, submitted in 1675, was a domed church in the shape of a Greek Cross. This, too, was rejected. This time the reason given was that it was too modern and too Italian (read Catholic). The scale model of this design, called the Great Model, can be viewed in the crypt of the present St. Paul's.

Finally in 1675 Wren gave the clergy what they wanted; a traditional English church design with a long nave and spire. The king granted Wren a royal warrant approving this design with the interesting proviso that the architect was free to make "variations, rather ornamental than essential".

**Construction**

On the strength of the Royal Warrant Wren proceeded to quietly change just about every essential element of the design the clergy thought they were getting. He got rid of three bays in the nave, did away with the spire, enlarged the dome, and raised the aisle walls.

Much of this work proceeded behind scaffolding and protected from prying eyes. By the time the furious clergy realised what Wren had done the church was too far gone to be altered.

When stone was laid for the centre of the new building, stones from the Old St. Paul's were used. Wren noticed that one of the stones was marked with the Latin inscription "resurgam", "I shall rise again". He had the word inscribed on the pediment of the south door, beneath a carved phoenix.

Portland stone was used for the bulk of the cathedral, and from the laying of the first stone in 1675 to the final touches in 1708, the cathedral was finished in a mere 33 years. This means that St. Paul’s, alone among English cathedrals, is the result of one man's creative vision.

Of course, that vision stretched to hiring some very good help. Master woodcarver Grinling Gibbons carved the choirstalls, and sanctuary gates were added by wrought-iron genius Jean Tijou.

**The Overall Design**
St. Paul’s Cathedral is something of an encyclopedia of Wren's impressions of the architecture of the continent. Wren fashioned the façade of St. Paul's with two tiers of paired Corinthian columns like those of the Louvre and framed them between towers inspired by those of Borromini’s Roman church of S. Agnese. Above the two-story base rises a tremendous peripteral dome that reinterprets Bramante's Tempietto of 1502. Pietro da Cortona's projecting curved porches of Santa Maria della Pace have become St. Paul's transept porches.

The interior of the church consists of a 3-aisled nave and choir, of equal lengths, extending east and west from a great central space at the crossing. Porticoes project north and south from the centre of the building. The crossing is covered by a great dome, pierced at the crown to allow a view of the lantern above. Over this dome rises a concealed conical dome of brick that acts as a support for the timber framework of the exterior dome, the entire domical structure thus constructed in three shells. The Western front of the church has a central motif – a double-storied portico of doubled columns, flanked by two finely designed towers. The exterior dome rises above a colonnaded drum and supports a stone lantern terminating with a cross. The Portland stone constructed dome has a diameter of 112 feet. The height from the ground to the top of the surmounting cross reaches an impressive 365 feet.

Exhibiting exact symmetry, Classical and Baroque design is also evident in St. Paul’s.
Nave

Crossing

The Dome

Looking up at Wren's great dome 112 feet across, soaring 368 feet in the air, you realize that you are actually looking through it - or them. You are looking through a dome to a further dome - from sphere to sphere. The triple-layered dome that crowns the cathedral is the second largest in the world. The dome is divided into four stages from the outside supporting dome. The design took great skill. Wren's architectural design required that the dome rest on eight piers, and to hold it without buttresses, Wren girdled it with a huge iron chain hidden by the facing stone.

The internal and external domes of St Paul's are quite different - the internal structure sits within the cylinder visible from outside, and the external dome is actually a relatively lightweight weather shield that is cunningly designed with gaps in its upper surface to admit daylight to the interior. The middle dome is almost conic, but not visible. To carry the outer dome, it was constructed using robust bricks and girdled with thick iron chains. The outer dome carries a big cross which weighs an astonishing 700 tons. The three domes in all weigh 15,000 tons.
Partway up the inside of the dome is the Whispering Gallery, so named because a whisper breathed against one wall is audible against the far wall 112 feet away. If you take a spiral staircase up from the Whispering Gallery you reach the Stone Gallery, 378 steps and 173 ft above ground level, running around the base of this external dome on the exterior. The Golden Gallery encircles the base of the "ball and lantern" tower atop the external dome, which is supported internally by a brick cone structure hidden between the internal and external domes.

The interior of the Cathedral may be a shock if you are used to the bare Gothic stone of medierval British cathedrals. Ornately curved and brilliantly coloured decoration abounds, and in a symmetry that is nearly overwhelming. As a place of worship St. Paul's may not be to everyone's taste, but as an architectural work, St. Paul's is a masterpiece.

530 steps up to the Golden Gallery, an observation platform sits atop the dome of the cathedral. From there you can look out over the modern skyline of the city of London.

On the way, the climb leads through the Whispering Gallery, a circular walkway halfway up the inside of the dome. Due to the acoustics of the curved surface, a phrase whispered against one wall can be heard against the far wall 112 feet away.

The mosaics that decorate the dome were not a part of Wren's design. They were added after Queen Victoria complained on a 1872 visit that she found the building "dirty, dark, and undevotional".

No one could today accuse St. Paul's of being dark; indeed the nave and dome sparkle with colour and light. Just before the south transept is an unusual feature - artist Holman Hunt's own copy of his work "The Light of the World". The original is in Keble College, Oxford.
Cross Section, Showing Design of Dome

Dome

Interior view of dome

Inside Dome of St. Paul's
Ceiling frescoes painted by Sir James Thornhill
Duomo of Florence

Duomo of Florence, or The Cathedral is the end result of years of work that covered over six centuries of history. It is the third and last Florentine cathedral and named Santa Maria del Fiore (Holy Mary of the Flower) in 1412 in clear allusion to the lily symbol of the city.

Location:

The city of Tuscany, Italy, due north of the Piazza della Signoria

History of Architecture:

Prior to its building, the Florentine Republic in 1923, at the suggestion of the notary Ser Mino de Cantoribus, decided to replace Santa Reparata with a larger and more magnificent cathedral to accommodate future needs, and was also prepared to finance its construction: "so that the industry and power of man are unable to invent or ever attempt again anything that is larger or more beautiful". The population was expected to participate in the costs (although a plague hit Florence in the summer of 1348): all last wills and testaments bore a tax which was then put towards the "Building" of the Cathedral. The cathedral's width would remain the same, but the walls were to be raised twenty-one feet higher, and the length was to be increased by one third.
• In 1924, the project was assigned to sculptor Arnolfo di Cambio and he ceremoniously laid the first stone on September 8th 1296. Arnolfo worked on the Cathedral from 1296 to 1302, the year of his death, and although the dominating style of the period was Gothic, he conceived a basilica of classical grandeur, with three wide naves that meet in the vast chancel where the high altar stands, surrounded in its turn by the "trefoil" shaped tribune (a schematic representation of the petals of a flower) on which the cupola rests.

• In 1334, the painter Giotto designed its sturdy bell tower (campanile).

• From 1336, the design of The Cathedral followed Roman forms.
• 1420-1426, of Filippo Brunelleschi, master architect and sculptor, created a massive octagonal cupola that truly dominates both the church and the city. It is an octagonal dome 42 metres in span be built at the east end of the nave.

• In the late 19th century, The Cathedral’s facade that completed it was carried out. It included the construction of two sacristies.
to the 16th century marble flooring, and the execution of the sculptures

- to the frescoes, signed by Paolo Uccello, Andrea del Castagno, Giorgio Vasari and Federico Zuccari

The Dome a.k.a Cupola

Its Significance…

The large octagonal dome over the transept was a technical accomplishment that had not been tackled since ancient Roman times. It is an inspiration from the classical
forms of the early Romans and Greeks and became a distinctive feature of Florence's skyline and its construction became one of the most imposing tasks of the Renaissance as it kept the Florentines engaged in debates and competitions for years but, once it was completed, it became the symbol of the city itself and the new, revolutionary Renaissance architecture. Because many of the architects are also sculptors and painters, they think that the way a building looks is more important artistically than the way it is structured. Hence, they do not hesitate to conceal the inner workings of their structures for the sake of outward appearance and accomplished this with false columns and facades or even paintings.

Its Complexities …

Arnolfo's project for Santa Maria del Fiore had left the basilica with an enormous problem of closing the chancel with a roof. Arnolfo's project included a cupola, but a low one. The cathedral was so huge that the usual methods of fixed scaffolding from the ground could not be used. It was seemingly impossible to roof over a space of 45.5 metres in diameter without some sort of reinforcement. An eight-sided drum was surrounding its large central crossing which is 136 feet in diameter. Normally to build a dome, architects would use a hemispherical wooden framework to support the construction, but there were no trees long enough to span the large space. Even if a dome could be constructed with this traditional method, the weight of it would push out the walls. There was limited space.

The Man behind it…

In the early 15th century, Filippo Brunelleschi (1377-1446), a goldsmith, architect, perspectivist and sculptor, began to make statues for the cathedral. He was also engaged in constructing the Spedale degli Innocenti and the churches of San Lorenzo and Santo Spirito.
Filippo Brunelleschi

He got his final inspiration from an attentive Roman study of the cupola of the Pantheon, which had also been carried out without scaffolding and with a double wall. When he returned to Florence, the artist suggested that a drum be built above the chancel and then, when this structure was complete (in actual fact making it even more complicated to construct the cupola), he returned to Rome, chased by desperate messages from the Opera del Duomo. Eventually the Guild of Wool Merchants in Florence decided to hold a competition in 1418 for the project of a cupola with the following requisites: it had to be octagonal, measure 46 metres in diameter at the base, be built without scaffolding and appear to be at least double in size: he was quite sure that he would win.

The Shape and Design…

In about 1415, Brunelleschi prepared a design for the dome that he daringly proposed to build without the aid of formwork or any wooden centering, which had been absolutely necessary in all previous Roman and Gothic construction. He built a 1:12 model of the dome in brick to demonstrate his method; the design was accepted and built under his supervision from 1420 to 1436. If a visitor looks up from the floor of the interior of the cathedral, he will see an octagon shape spanned up above him and not supported in any form in the middle. The exterior of the dome is typical of an octagon in that a person standing at any point in front of it will either see 3 or 4 of its 8 faces. Furthermore, the faces of the octagon are more prominent as each boundary between two
faces is clearly marked by a white, cemented slab. Tiles specially designed for easy assembly and maintenance were laid on the exterior surface.

Meanwhile, the dome’s peak is slightly pointed such that it resembles little of a half-sphere, but somehow like an inverted pine nut. There are also two basic shapes for an octagon known as a crown or a pavilion. The Cupola’s design tends towards that of a pavilion.

![Brunelleschi’s design](image)

**The Math and Architecture…**

Polygonal domes, are more complex in their design than round domes. Combining the techniques of the Roman arch and vault with the Gothic method of stone ribbing, Brunelleschi's dome consists of two layers, an inner dome spanning the diameter and a parallel outer shell to protect it from the weather and give it a more pleasing external form. The double shells were of stone and brick. The octagonal drum also carries eight "shells" with empty spaces left inside each of these to lighten the massive structure.

He had concealed structural ribs both inside and outside the dome for added strength. Inside the double shell, there were also narrow stairs to allow workers to perform safety
checks and repairs. Both domes are supported by 24 stone half arches, or ribs, of circular form, 2.1 metres (7 feet) thick at the base and tapering to 1.5 metres (5 feet), which meet at an open stone compression ring at the top. The masonry (stonework) rings were laid in a method known as a model of the masonry layers. To resist outward thrust, he tied rings of stone held together with metal cramps run horizontally between the ribs. The angle ribs are not intended to provide structural support.

There are also rings of oak timbers joined by metal connectors. The spaces between the ribs and tie rings are spanned by the inner and outer shells, which are of stone for the first 7.1 metres and brick above. The bricks were laid on sloping beds. Before closing each ring of bricks, the workmen placed a row of bricks whose longer sides protruded with respect to the bricks resting on the conic surface. This arrangement, known as a herring-bone, displays a spiral profile. Bricks were laid in one complete course, or layer, of bricks at a time. This way, the weight of the current layer being laid would be supported by the previous layer.

Each layer was stepped slightly inward so that as the Dome rose, it tapered toward the center. The horizontal layers will make it stable and not require timber centering. Finally, a system of measuring wires were fixed at the centres of curvature. Wooden machines were designed elaborately to move the needed building materials both horizontally and vertically as towards the end of the project, the Dome was almost 375 feet above the ground. Its springing point is 177 feet above ground level, while its height from the drum base to the top is about 108 feet.

The final structure that he elaborated and completed consisted of a double cupola of brick, laid herring-bone fashion, 91 metres high, completely self-supporting and based on an unusual system of flying rather than fixed centerings (which would of course have been impossible because of the size). The distance between two opposite edges of the
exterior octagonal base is about 176 feet. The exterior of the cupola, with domical vaults and stone ribs at the corners, appeared much larger and "blown up" than the interior, however it reproduced the same pointed arch profile to perfection. The dome weighs an estimated 37,000 metric tons, with 4 million bricks used.

**The Finishing Touches…**

The "Cupolone" or great cupola (as the Florentines have called it ever since) was completed in 1434. Two years later the lantern was placed in position (taking it from 91 to 114,5 metres in total height), while the four tribunes occupying the spaces created by the projections in the octagon of the apse were carried out in 1438. The decorations in the lantern were finished by 1446, when the great architect was on his deathbed. In 1461, decorations were applied to the lantern and a great copper sphere was positioned on the top in 1474).

**The Lantern**

**The Artistic Images on the Cupola’s Fresco…**

The pictorial cycle of the Cupola of Santa Maria del Fiore in Florence is the known wider mural cycle with an holy subject. It has a surface of 3.600 square meters realized with a lot of difficulties, due to the height from the ground.
The Cupola decoration is characterized by the close comparison between "Florentine manner", represented by Giorgio Vasari (that worked at the Cupola from 1572 to 1574) and "Roman manner", represented by Federico Zuccari (that completed the pictorial cycle in the years from 1576 to 1579). It was termed, “The 5 paths”.

Every sector of the Cupola represents a region of Inferno, dominated by a Deadly Sin. The area immediately over Inferno is painted with a triad of personifications, representing a Gift of Holy Spirit, a Virtue and a Beatitude. A category of Saints and Chosen is represented in every sector of the Cupola, over the personified triad. The 24 Seniori of Saint John's Apocalypse, with lyres, lilies and crowns, are placed at the top of the Cupola, inside a false architecture that represents the biblical "Tabernaculum". The sector number five, located at East, over the altar, stands out from the others. Christ, surrounding by Virgin Mary, Saint John, Adam, Eve and Patrons of Florence, intercedes with the Father showing Him the plagues that redeemed the umanity. It’s known as The Divine Judgement.

( As the description of the images are too spritual, only a brief mention is given.)

Interesting Happenings…

- During the competition, Brunelleschi asked the members of the committee to demonstrate to him how they would stand an egg on the table when he was asked to explain his construction of the dome. No one could. With that, Brunelleschi banged an egg on the table breaking its shell at the end and proceeded to stand this egg on the table. When the members of the committee protested that any one of them could have done that, Brunelleschi explained that this was exactly his point. If he told the committee how he planned to complete the task of the dome, all would claim that they could have done it.
- The competition for the construction of the Dome, held in 1418, was won by Brunelleschi but the directors of the Opera del Duomo stipulated that Lorenzo Ghiberti (who had already managed to snatch the commission from him for the north door of the Baptistery ) should collaborate as overseer for the work. The artist was so offended that he nearly destroyed his model (the same one that we can see today in the Museum of the Opera del Duomo );
his friends Donatello and Luca della Robbia instead advised him to pretend he was ill and leave all the responsibility to Ghiberti. He followed their advice and Ghiberti soon came to a standstill and had to admit that he was incapable of understanding the project and going ahead with the work.

- After the completion of the cupola, the copper sphere on top of the lantern fell off after being struck by lightning on July 17th 1600 and was replaced two years later by a larger one and a marble plaque commemorating the event is paved in the square behind the Cathedral.

- The decoration of the gallery around the drum was never finished: the balustrade designed by Baccio d'Agnolo and carried out on only one side of the octagon, did not meet with the approval of Michelangelo who, defining it "a cage for crickets", decreed its final condemnation.

Footnotes:
♥ Gothic: An architectural style of the 12th-16th centuries, with pointed arches.

♥ Renaissance: The historic period between the late 14th century and the second half of the 16th century, which was characterized by the rebirth of the cultural and artistic life. It meant a complete release of thought and action from the strict theological and very limited dogmas of the Middle Ages. From the philosophical point of view, the Renaissance meant naturalism, i.e., the study of man and the universe without the
use of metaphysics. Man is the centre and measure of all things, a chosen creator who echoes the deep harmony between the microcosm and the macrocosm.)

♥ Basilica: An oblong hall or church with an apse at one end

♥ Naves: Main parts of a church.

♥ Opera del Duomo: The large number of administrators, artists and craftsmen (stone cutters, marble workers, carpenters...) who were employed in the construction of the new cathedral of Santa Maria del Fiore.

♥ Fresco: Picture painted on a wall or ceiling before the plaster is dry.

♥ Vault: Arch roof
The Hagia Sophia

*Introduction and significance*

The Hagia Sophia is famous for its ground-breaking structure, the scale of its construction and well as the lavish materials used for its creation. Due to its structure and magnificence, it stands unique throughout the ages and is constantly being set as a model of many other churches and great Turkish mosques. It is also well known for the art it houses, within its walls are precious artifacts and Byzantine art that had survived the test of time, history and natural disasters. Today, it is fourth largest cathedrals in the world, one of Turkey's most popular museums as well as a favourite for tourists.

*The history:*

The first Hagia Sophia was built by the emperor Constantius and first opened for services in 360 AD. It was originally named the great church, due to its size compared with other churches at that time. The name later changed to “Hagia Sophia”, which means holy wisdom in Christian context. This original church was destroyed by mobs in 404
AD and was rebuilt in 415 AD by the emperor Theodosius, only to be brought to the ground again by the revolting crowds of the Nike Revolt. After resorting to bloodshed, Emperor Justinian succeeded in saving his throne. As a act of celebration, he decided to rebuild the Great church. He ambitioned to make this new church more unique and magnificent than any other church ever known as a celebration of his rule. The church was to be built on plans well ahead of its time, under the expertise of Anthemius of Tralles and Isidorus of Miletus, whom Justinian enlisted to realise his vision. The finest and rarest materials were brought to Justinian from all four corners of his empire. It took five years, ten months and four days, from February 23rd 532 to December 27th 537. Hence the church was completed in an unbelievable short span of time, considering its massive size.

As magnificent as the church was, it still could not withstand the forces of nature and was repeated damaged by earthquakes and fires and had to be repaired and reinforced countless times in order to prevent and eventual collapse. For example:
- in 1204, it was sacked by the four crusaders and had to be repaired by the architect Ruchas
- in 1348, the eastern half of the dome collapsed and was described as being in a state of disrepair.

A new phase of Hagia Sophia’s history began when the Turks conquered Constantinople in 1453 and it was converted into a mosque. As a result of stringent islamic code, most of the beautiful Christian mosaics and frescos which it was famous for had to be covered up in plaster (very very unfortunate indeed). A few islamic structures were built (e.g. Sultan Mehmed built an altar and a brick minaret, (the tall thin tower of a mosque))

Finally in 1926, Hagia Sophia was converted into a museum in which it remains today. Some plasters covering the Christian mosaics was removed and the mosaics and frescos restored. Thus the Hagia Sophia is the embodiment of both Christian and Islamic art, two
religions which recently have been seem to be at odds with each other. The long and eventful history makes the Hagia Sophia one of the most precious buildings around the world, as it illustrated strength and ever lasting nature of art and culture that was able to survive through time and disaster.

**The structure:**

Hagia Sophia was built by the mathematician Anthemius of Tralles and the architect Isidorus of Miletus, whom was able to combine scientific accuracy as well as vivid imagination in the construction of this great monument. Hagia sophia’s structure came about as a result of a groundbreaking innovation of Byzantine architecture at that time. Its structure was one of the domed basilica (a type of dome which was similar to the St Peter’s basilica) It presented to many the architectural phenomenon of how to raise a circular dome over a square base. The revolutionary solution to this architectural question was presented in the following ways.

At the square base, Anthemius built four large columns (each measuring approximately 100 sq feet at the base) at the corner of each square. On top of each column rests an arch and four large arcs swing across, linked by pendentives (curved triangular shapes that adopted the circular ring of the dome) made out of masonry (building material such as stone, which could resist compression). The arcs are furthered strengthened and supported by 2 half domes opening east and west. Thus a firm base and support structure for the magnificent main dome is constructed.

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*This picture shows clearly the four arcs as mentioned above as well as the four large piers. (how the circular dome is supported by a square base)*
Exterior view: The thrust of the huge dome is countered by the two half-domes and the smaller domes, to the east and west, and the massive buttresses to the north and south.

However, it was the dome itself that was the most impressive piece of architecture. The shallow golden dome was made from forty equally spaced ribs. It soars 62m above the floor and has a diameter of 33m. It is pierced by forty windows, each of them bringing a passage of light inside, illuminating the vast interior and creating an illusion of infinite space.(!)
Another point worth a mention is the clever arrangements of the piers and the columns supporting the dome (all 106 of them). The mass of the bearing structures are pushed aside into the aisles and galleries, away from sight and voila! the vast interior is thus wholly free of any suggestion of load or support. To the average observer, it generates the illusion that the gigantic golden dome is a weightless and miraculously stable golden shell floating in the air.

interior view: bearing structures were hidden from view, creating an illusion that the dome was a weightless floating golden shell. (!!!)

All in all, the structure of the Hagia Sophia is the epitome of roman methods of construction which is enriched by new theories as well as strikingly colourful and lavish materials and ornaments in which we will take a look at in the next section.

The art

When Justinian begun with the construction of Hagia Sophia, he summoned the finest and rarest materials from all four corners of his empire. A few examples are the the prophyry columns taken from an Egyptian temple in Heliopolis, gold icons and ornaments from ancient temples in Ephesus, Kizikos and Baalbek which were all summoned for the construction of the church. One other example of the lavishness of the materials were in the marble chosen to decorate the walls of the main nave and inner narthex. These colourful marbles were
taken from different regions of Justinian’s empire. The white marble was from the Island of Marmara, the green from mount Tagetus near Isparta, the pink from Synada, the yellow from Africa and the red from north Africa. These exotic materials became pieces of breathtaking art under the hands of many specialized craftsmen, technicians, masons, marble carvers and many others. Now, we would take you through a brief walk though of the artwork in different sections of the Hagia Sophia.

*The inner narthex*

The ceiling of the inner narthex is completely covered by colourful mosaics of floral and geometric motifs on a gold background. What was particularly interesting about the art of the inner narthex was that it displayed forms of art that was not known to have existed then! (!!)Sources have indicated that during emperor Justinian’s era, figural mosaics did not exist, and yet the imperial gate of the inner narthex was decorated with a figural mosaic of Jesus sitting on a magnificent celestial throne. Another interesting fact about this controversial imperial gate was that according to legend, it was made form the wood of Noah’s ark. (!!!)

*The dome*

![Image of The Dome](image-url)
The mosaics on the ceiling of the dome is covered by Koran inscriptions due to strict Islamic codes.

The interior of the dome is completely covered in mosaic, from the crown to the base. However, today, these are replaced by Islamic art. (Inscriptions in Koran)
The 40 windows of the dome are all covered in mosaics as well. The eastern pendentives bears mosaics of four winged cherubims on the east when the pendentives in the west bears frescoes.

A mosaic found on the ceiling. Is there symmetry?

The walls
Mosaics on the walls were covered with plaster when the church became a mosque but were now restored to their previous glory.

The walls of the Hagia Sophia were completely covered in marbles, but these are not ordinary marble. They are a exotic selection of marble delivered from all four corners of Justinian’s empire. (see above description of marble source.) They were then cut symmetrically to create symmetrical patterns to decorate the walls.

Another example of Islamic art was the gold medallions (measuring 7.5 ft) hanging from the four large piers, inscribed with Islamic teachings.

The Apse

The Apse contain one of the most important and famous art pieces present in the Hagia Sophia, The mosaic of the Virgin Mary holding the Christ child on her lap. Other figures around her were permanently destroyed by earthquakes and plastering but she remains in good condition.
The picture on the left shows the mosaic of the virgin mary when the one on the right shows the same location, when plaster over the mosaic had not been removed. Other than mosaic, frieze patterns extends all along the apse.

Columns
The column heads are carved meticulously in exquisite lace like designs. The column capitals contained monograms of Emperor Justinian and his wife. The most important of Hagia Sophia’s 107 columns were in the ground floor, and these are column transferred to the church from other exotic locations (from the Temple of the Sun and Heliopolis, from monuments in Rome and Baalheik e.g.)

The column heads are carved in a lace like design.

The southern nave
The ceiling of the southern nave is covered with 6th century gold mosaics, and the vaults and arches are decorated with multi-coloured geometric and floral designs. Decorative panels embellish the marble vaults. The two panels facing each other on the eastern side are decorated with Poseidon's trident and dolphins, which were a coat of arms in Byzantine times.

LOOK!: At the southeastern part of the church stands a rectangular column with a handprint rumoured to be the very one of the Virgin Mary. (would have been a “!!!!!” but unfortunately, we could not locate the picture)
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