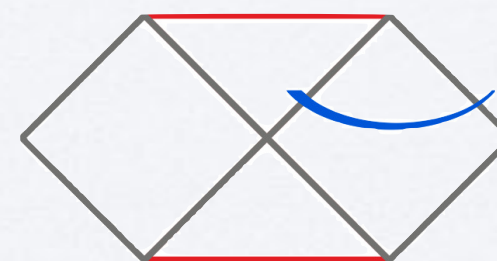


THE CENTER OF GRAVITY

# RELATIVITY AND CURVED SPACETIME

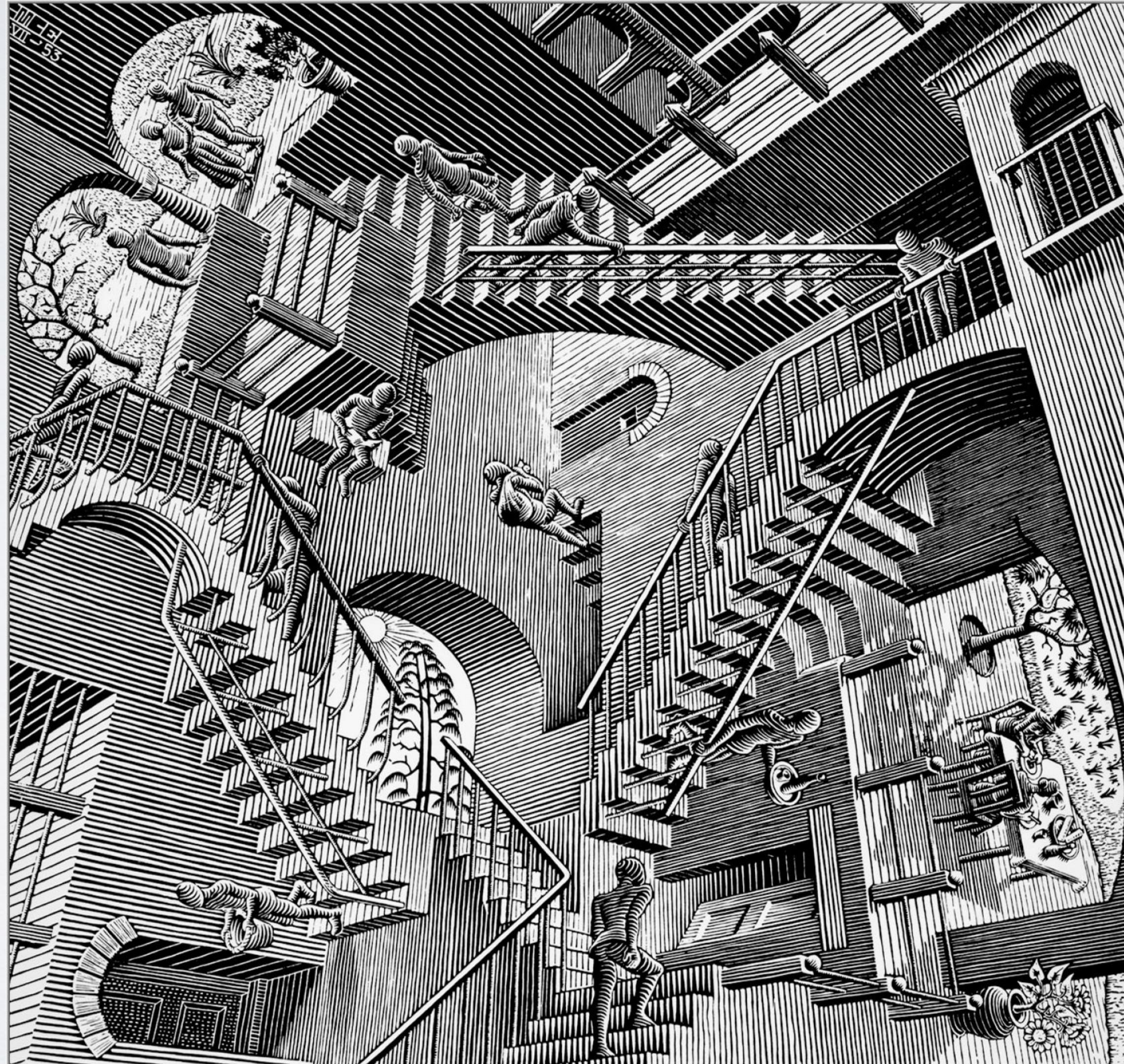
Rodrigo Panosso Macedo



<https://hyperboloid.al>



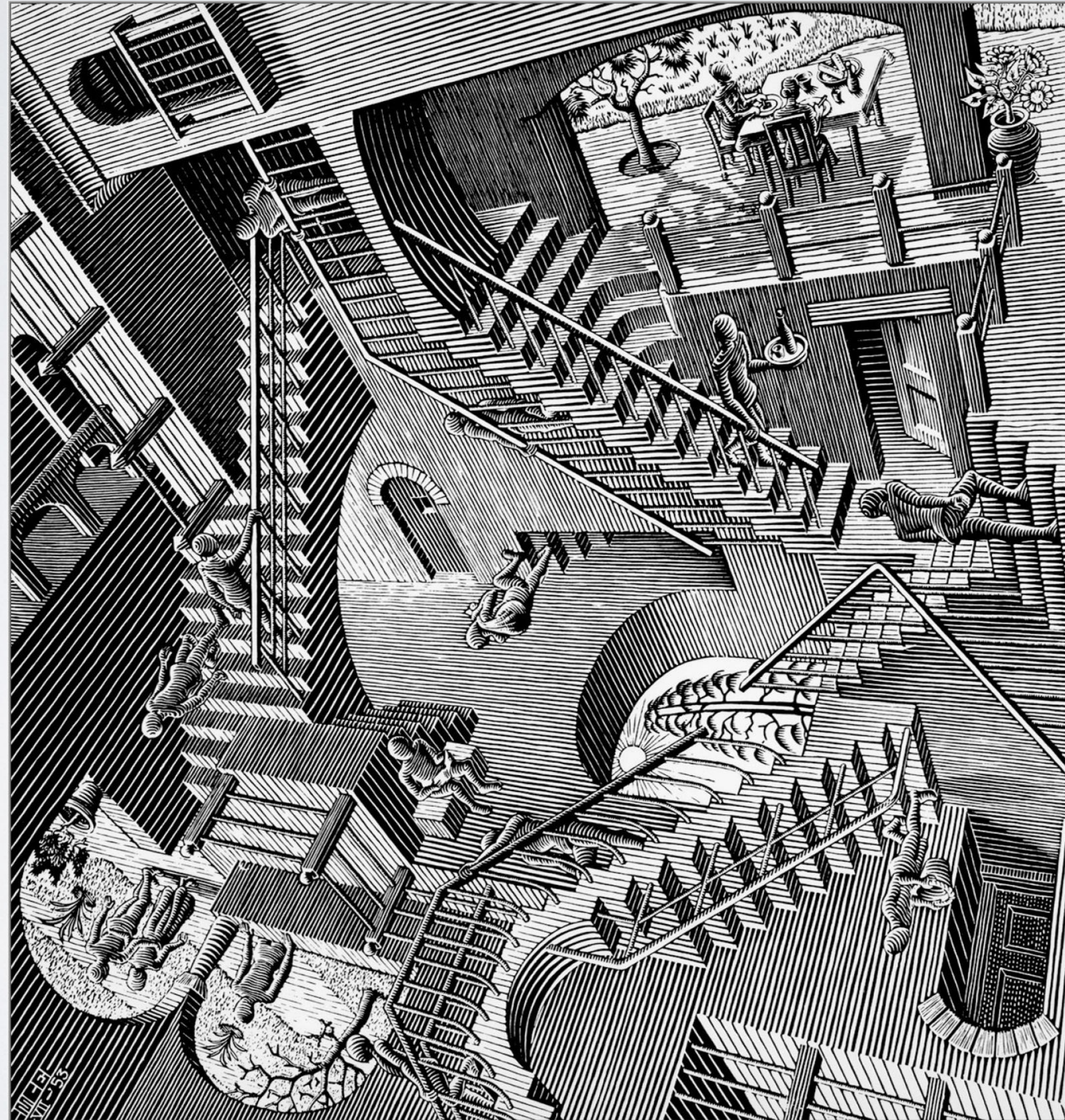
# EVERYTHING IS RELATIVE !



*Relativity, by M. C. Escher*



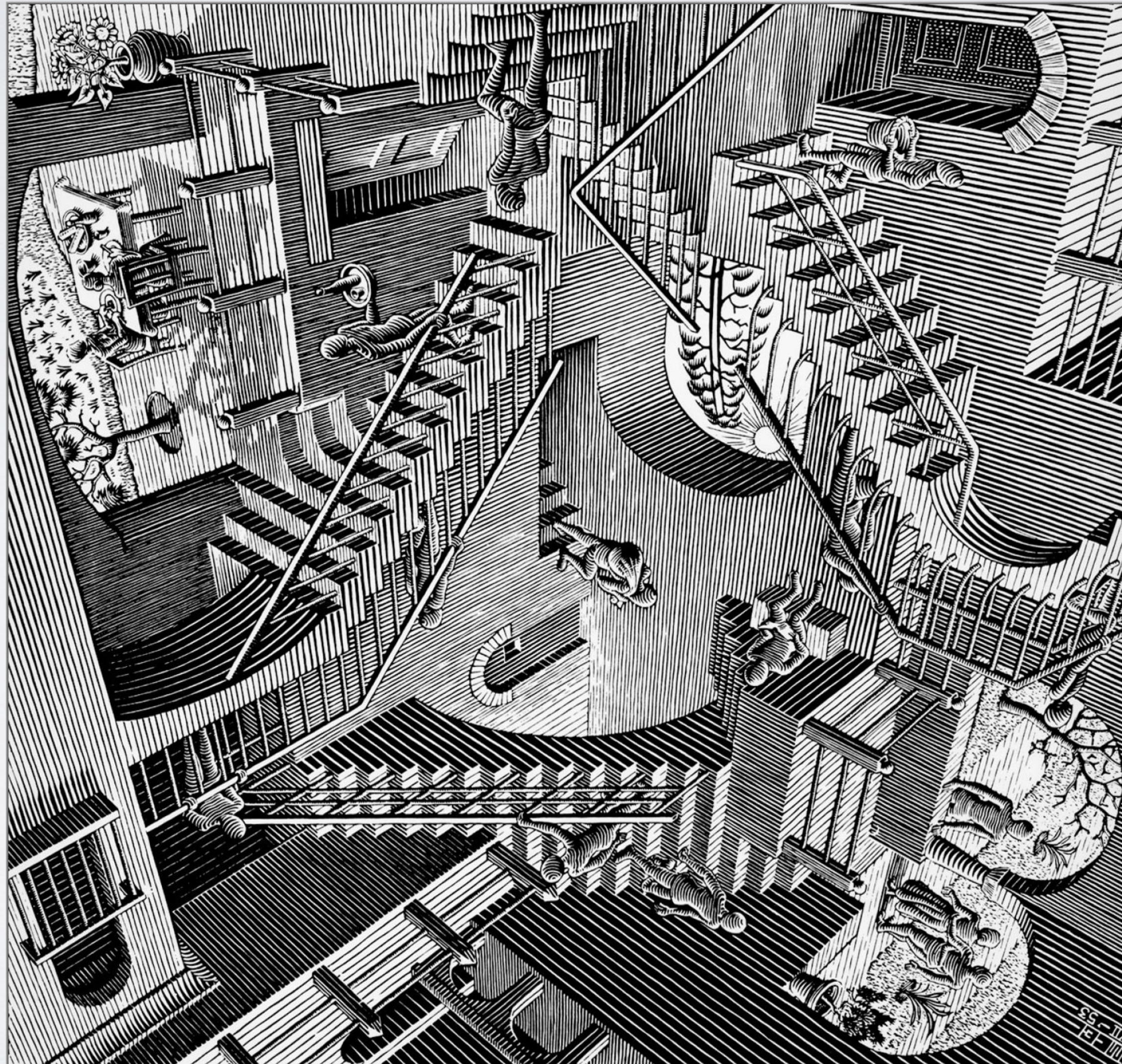
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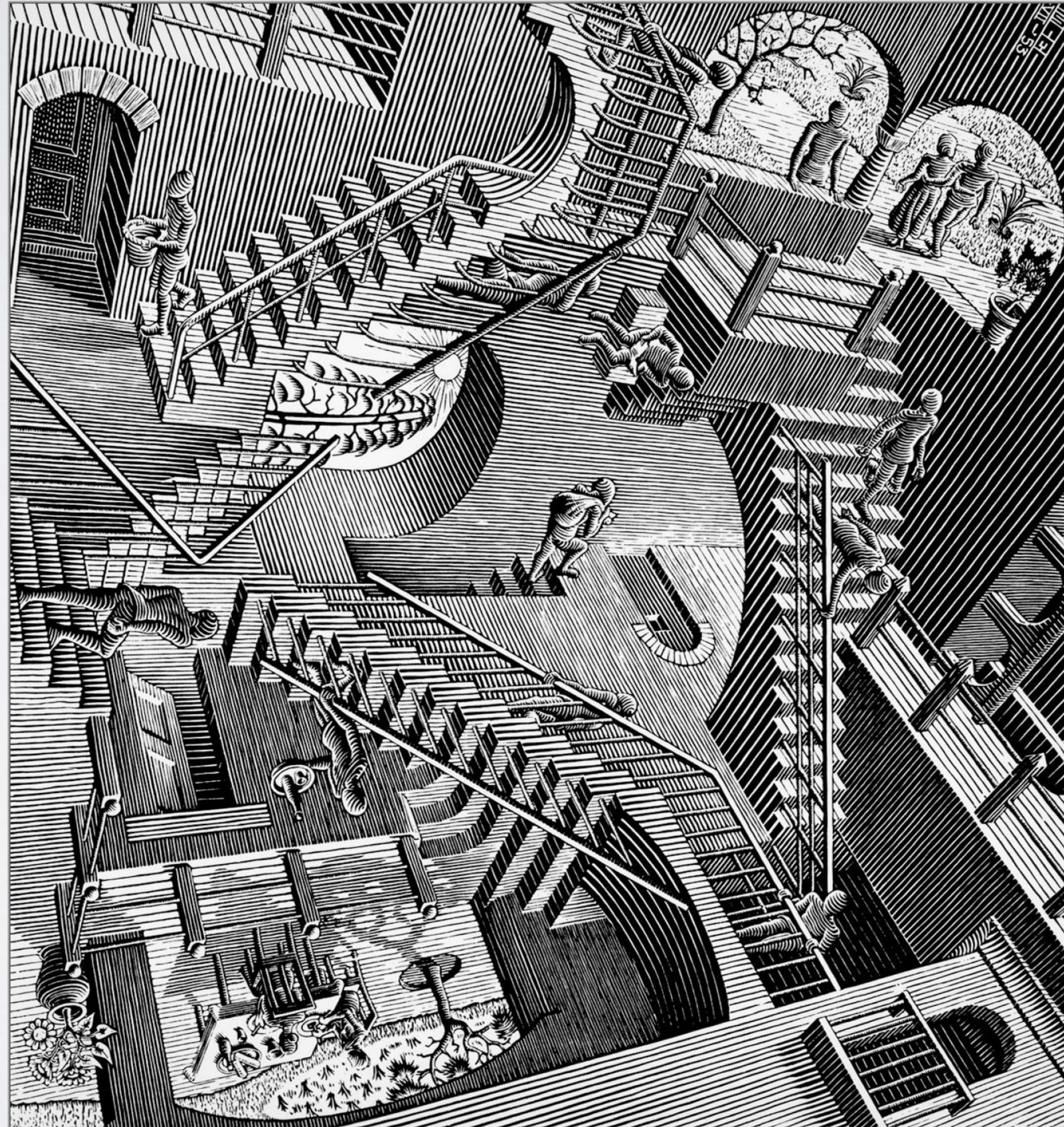
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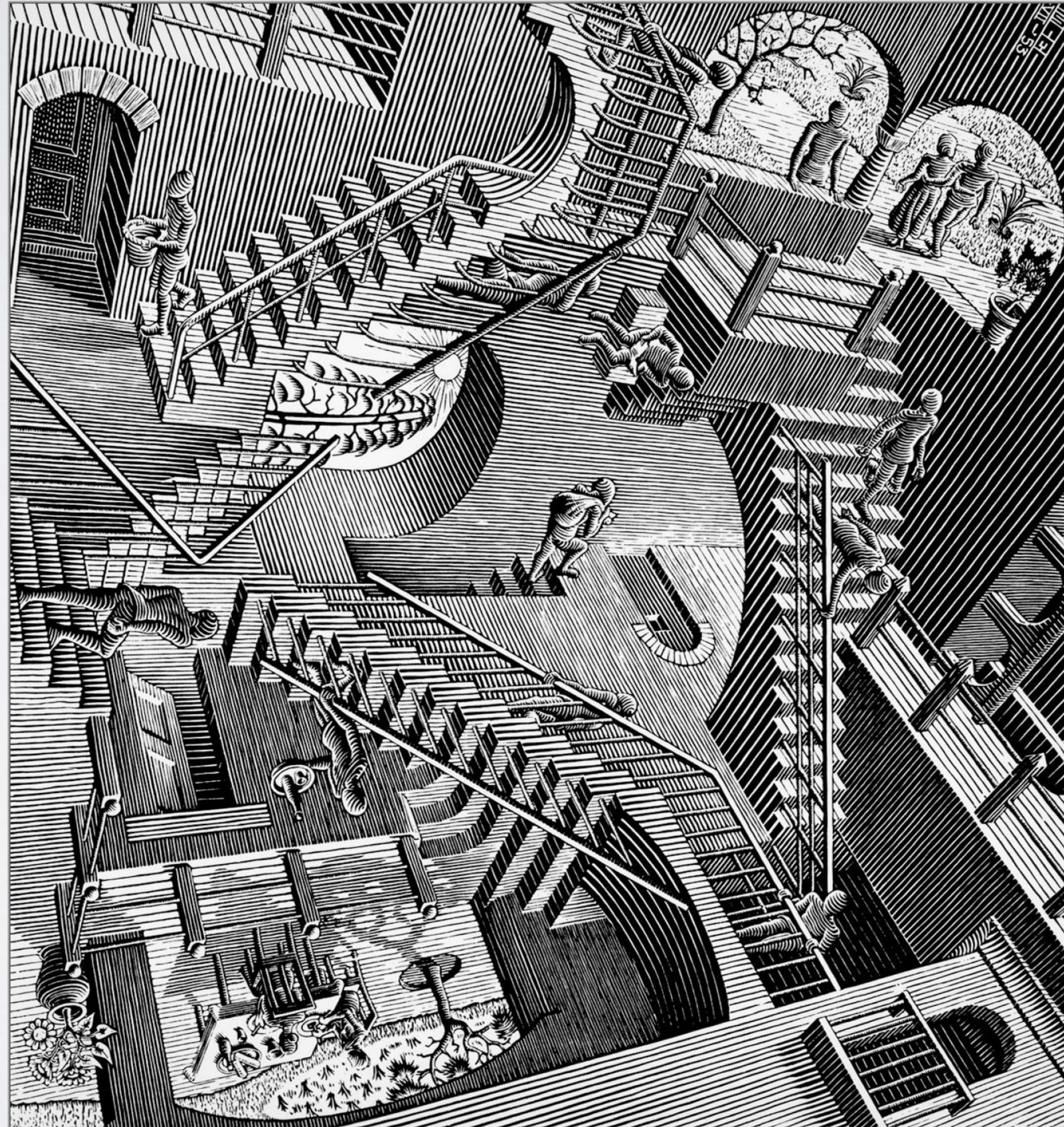
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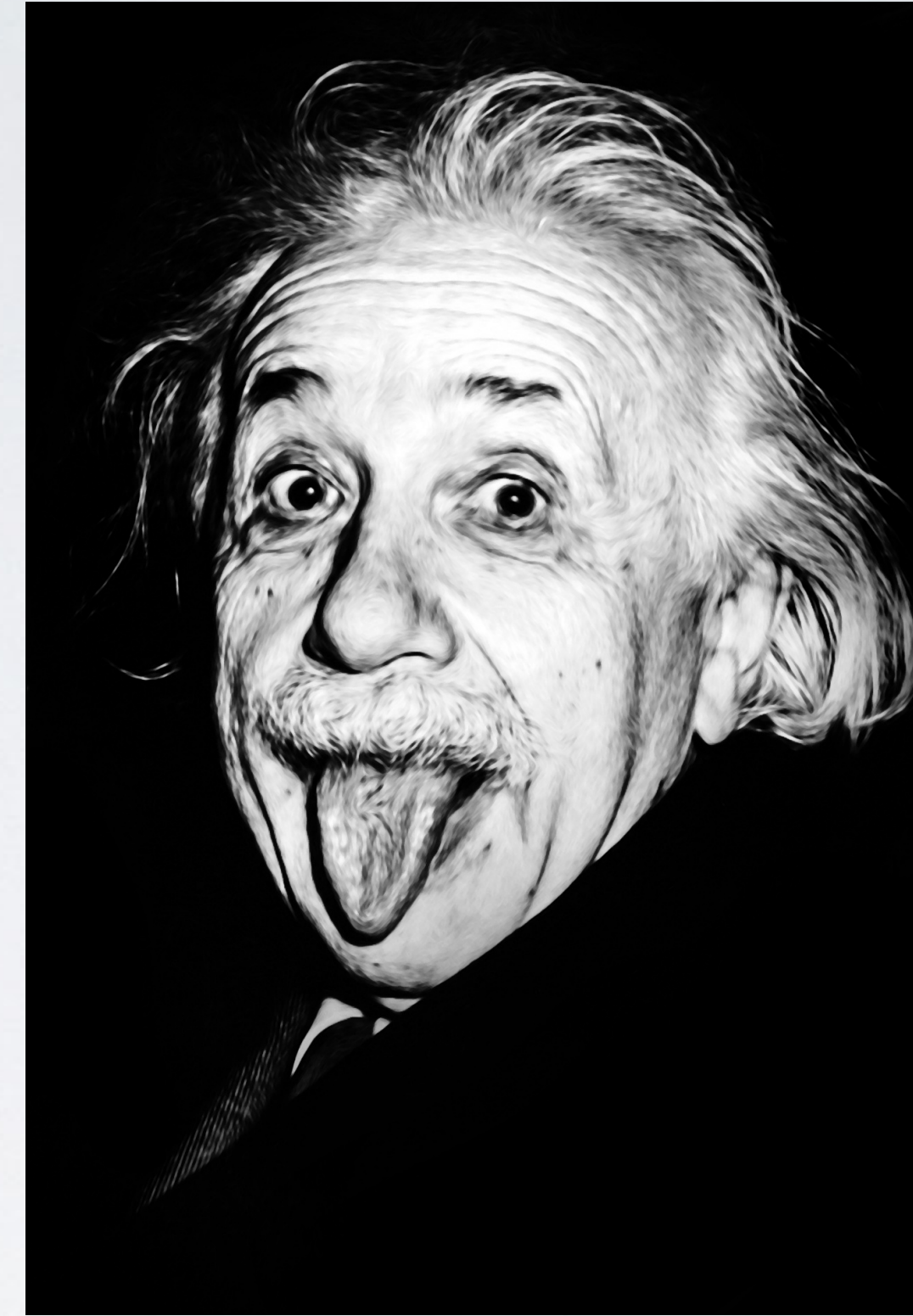


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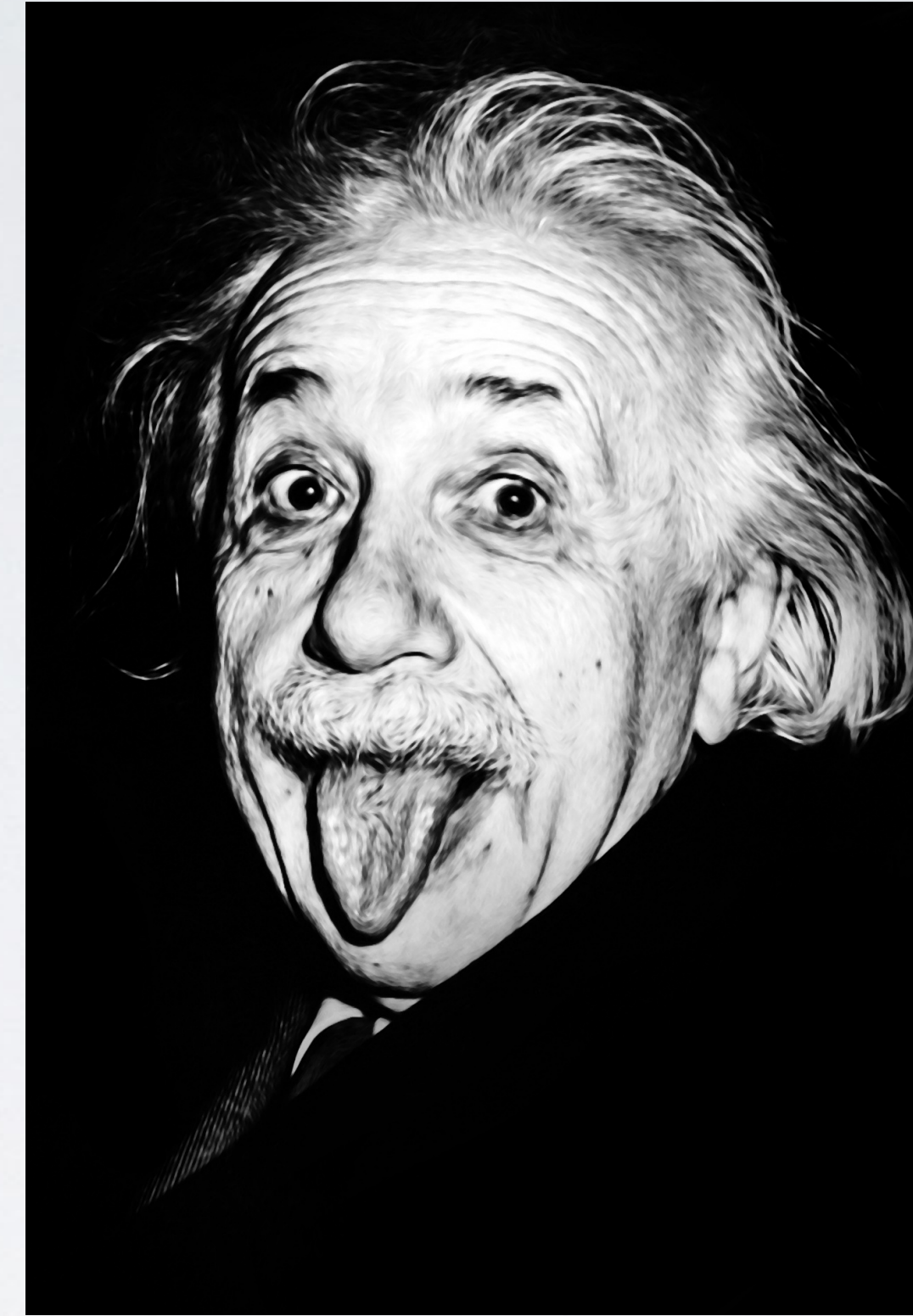
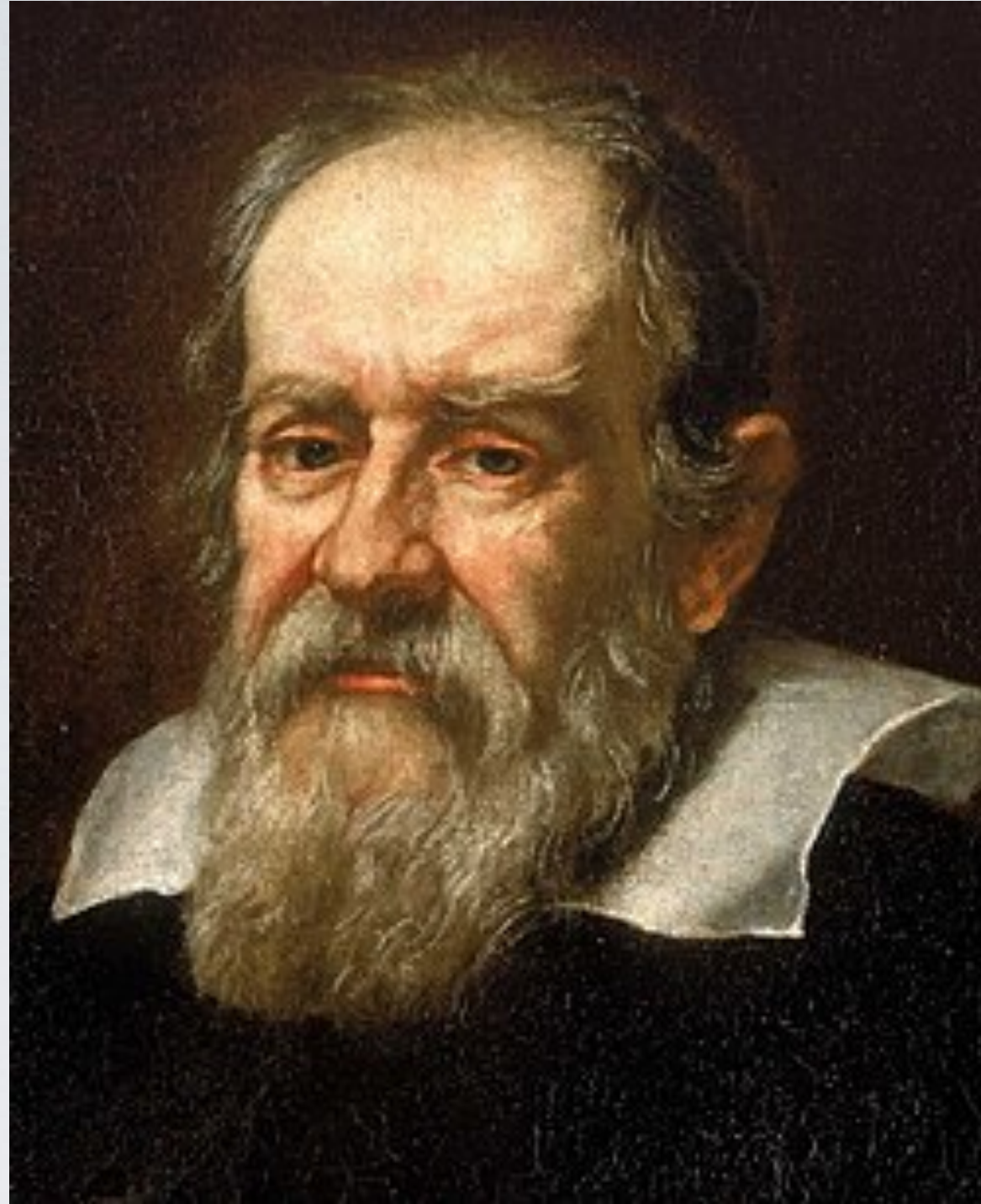
# WHAT IS RELATIVITY ?

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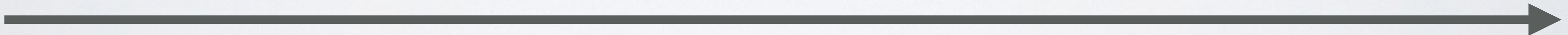
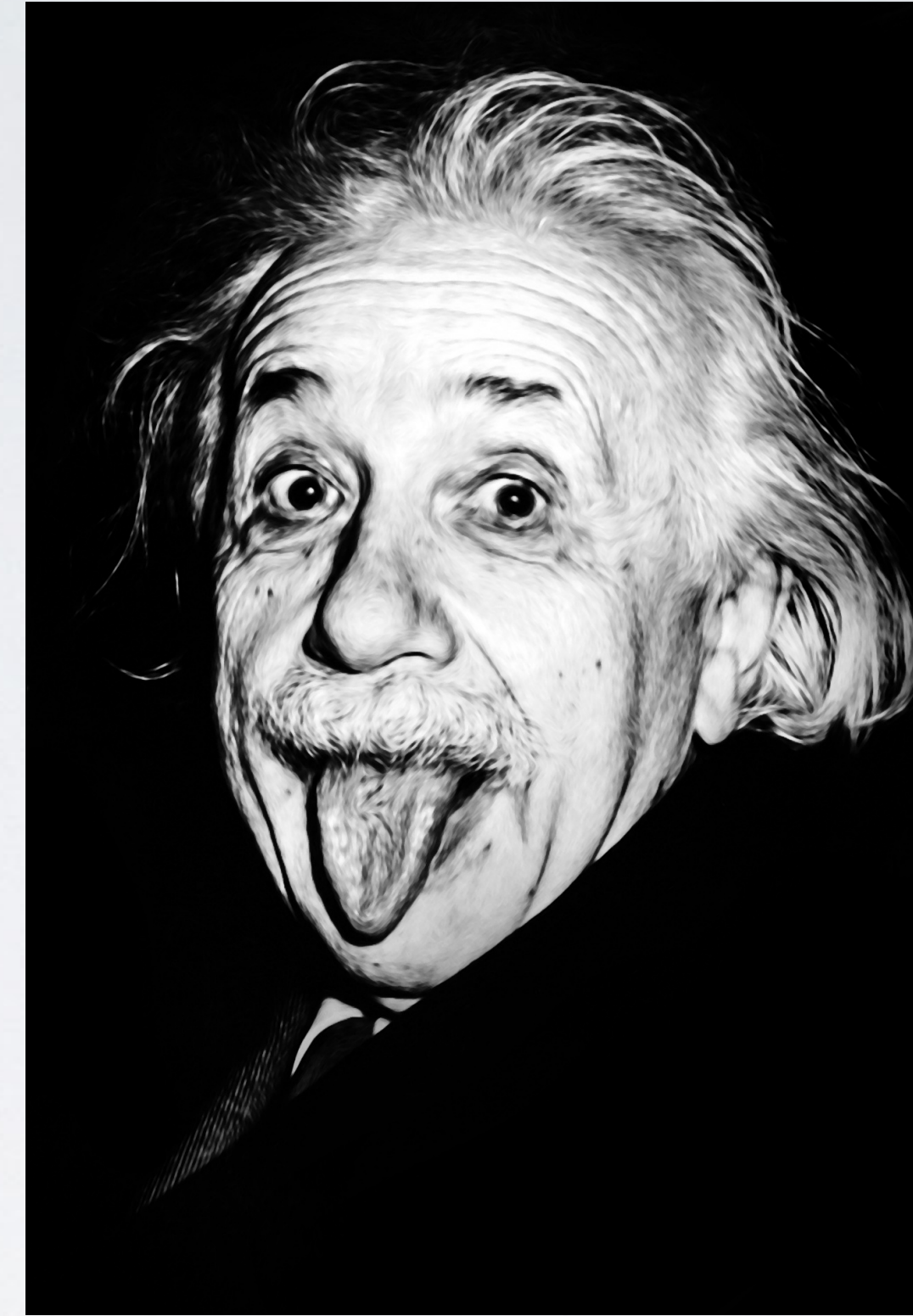
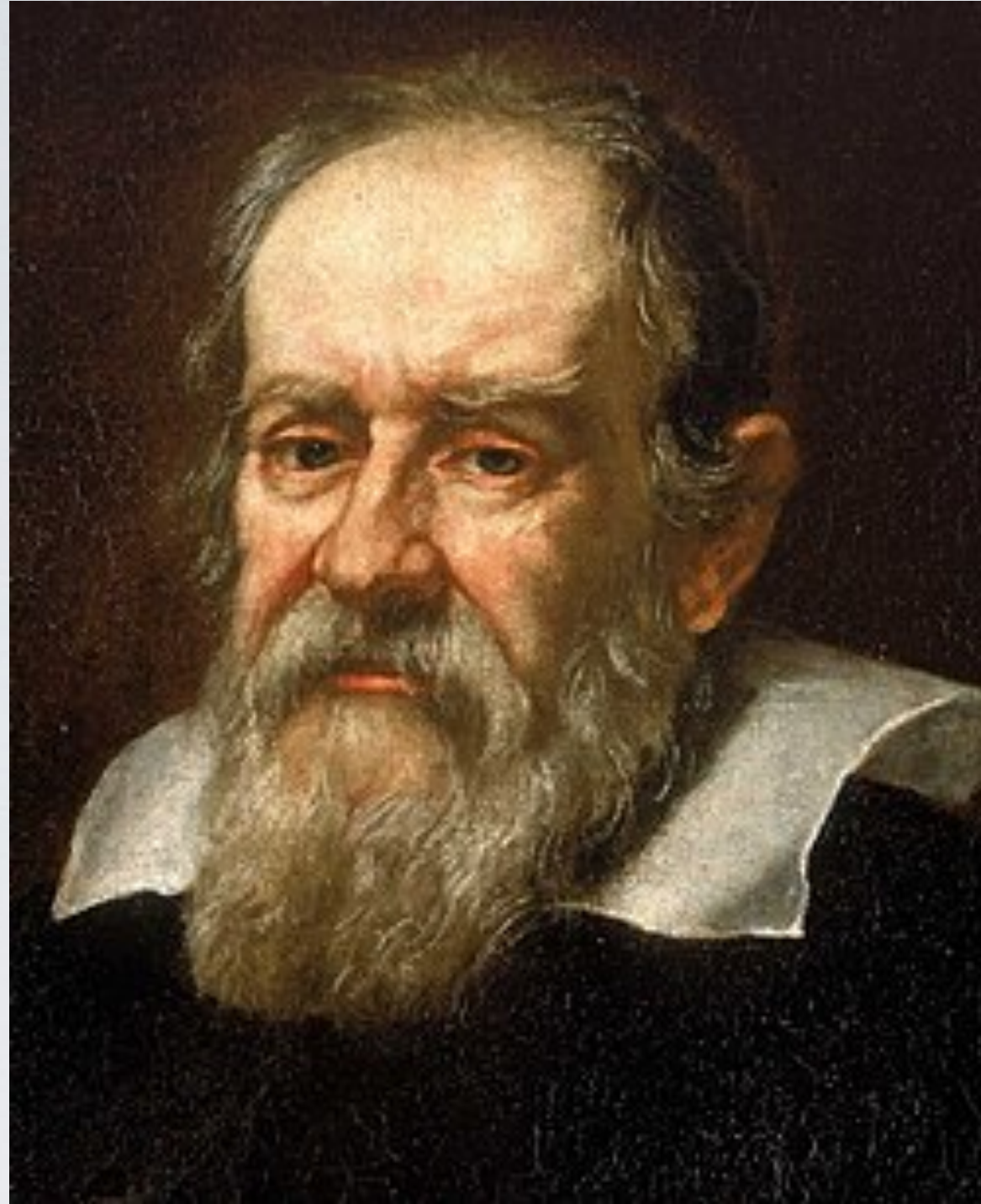


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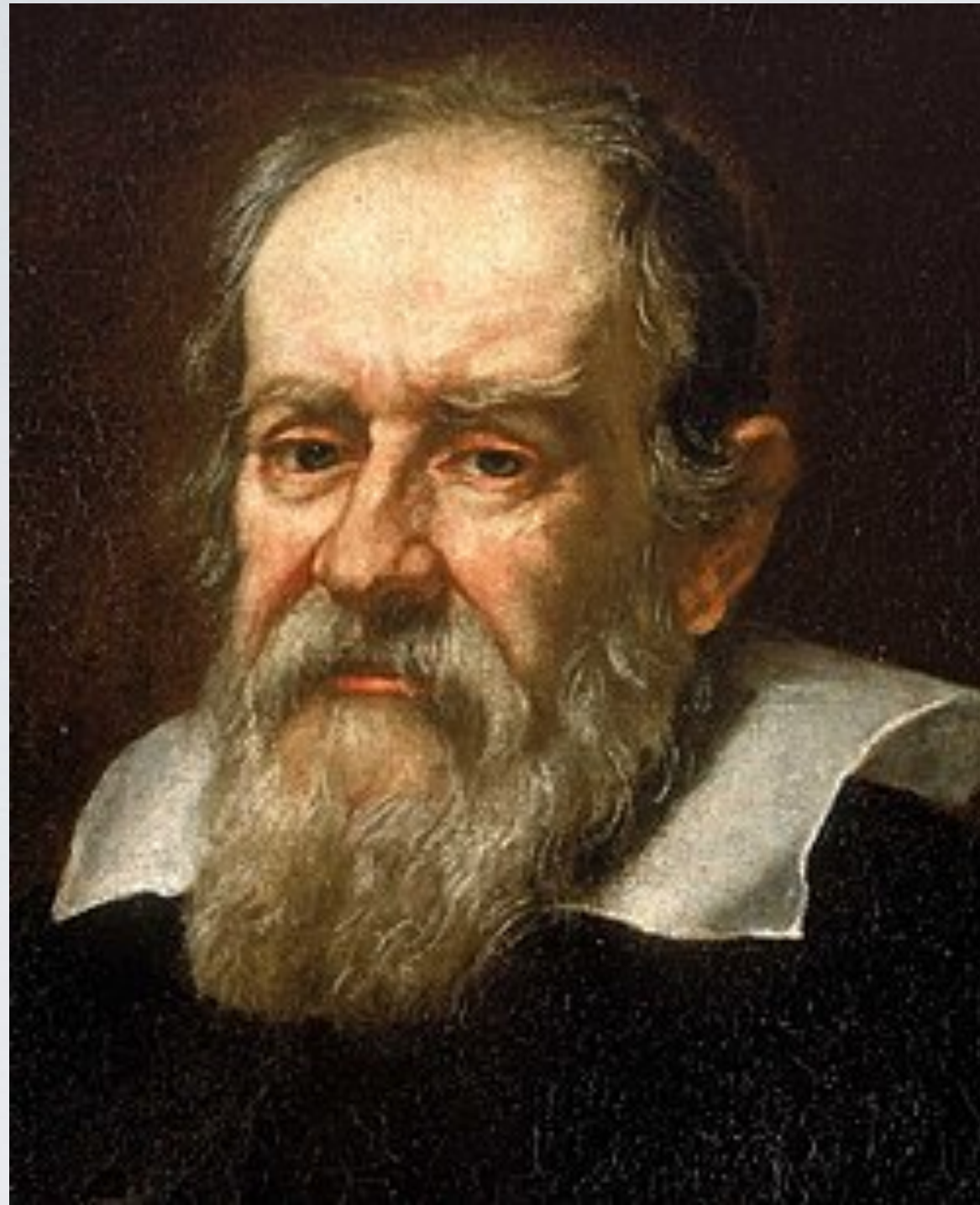


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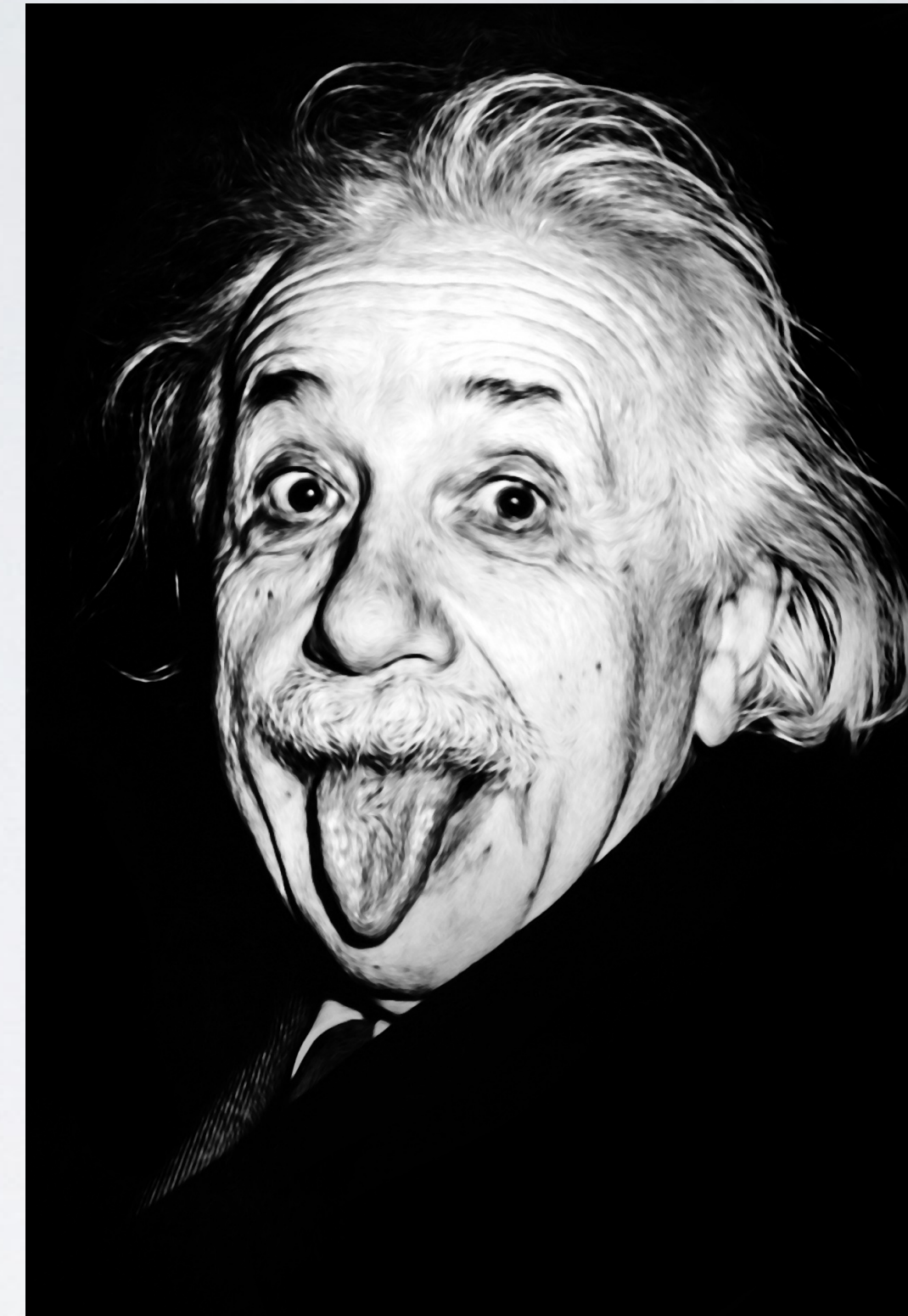


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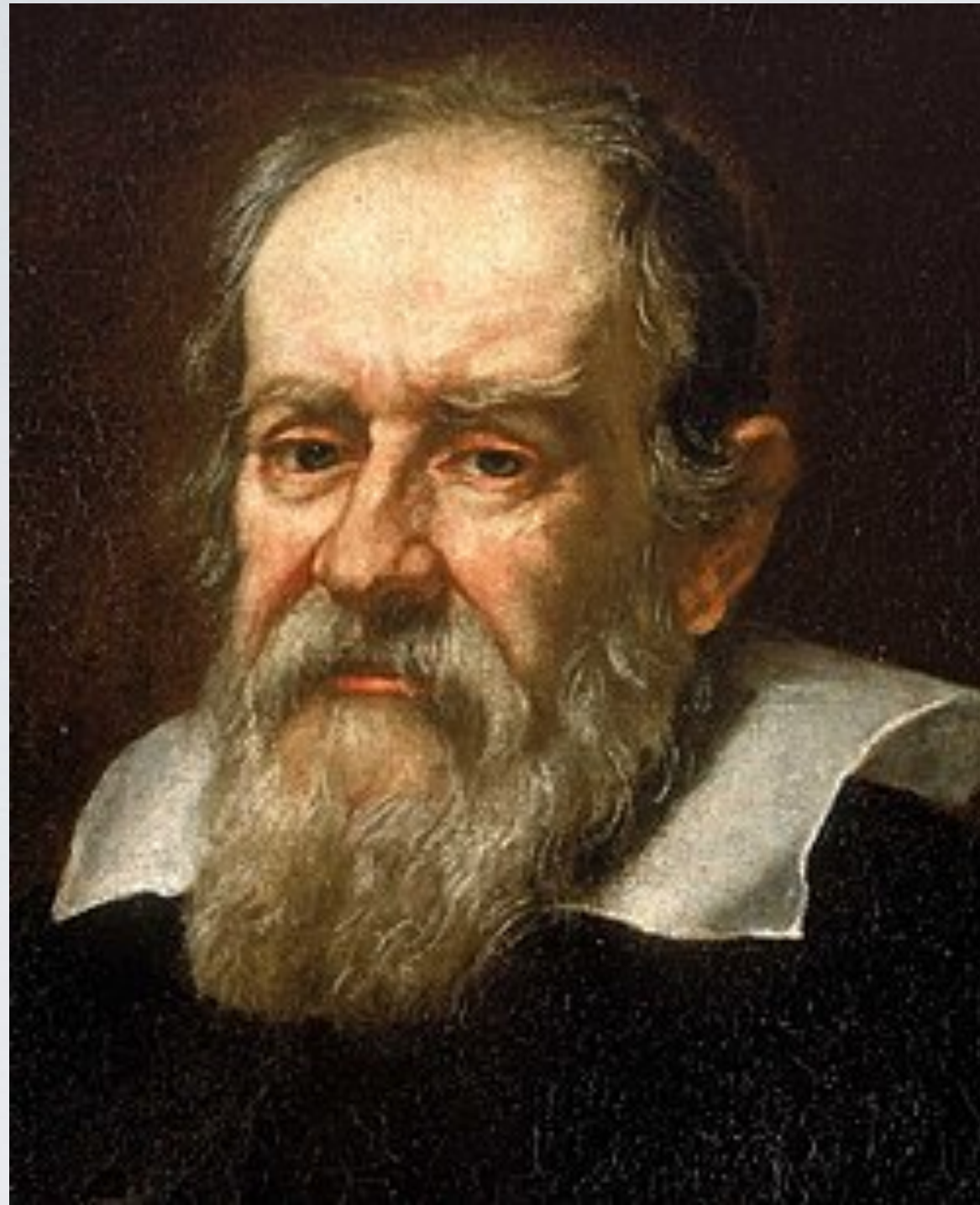
1632

Principle of Relativity  
(velocities)



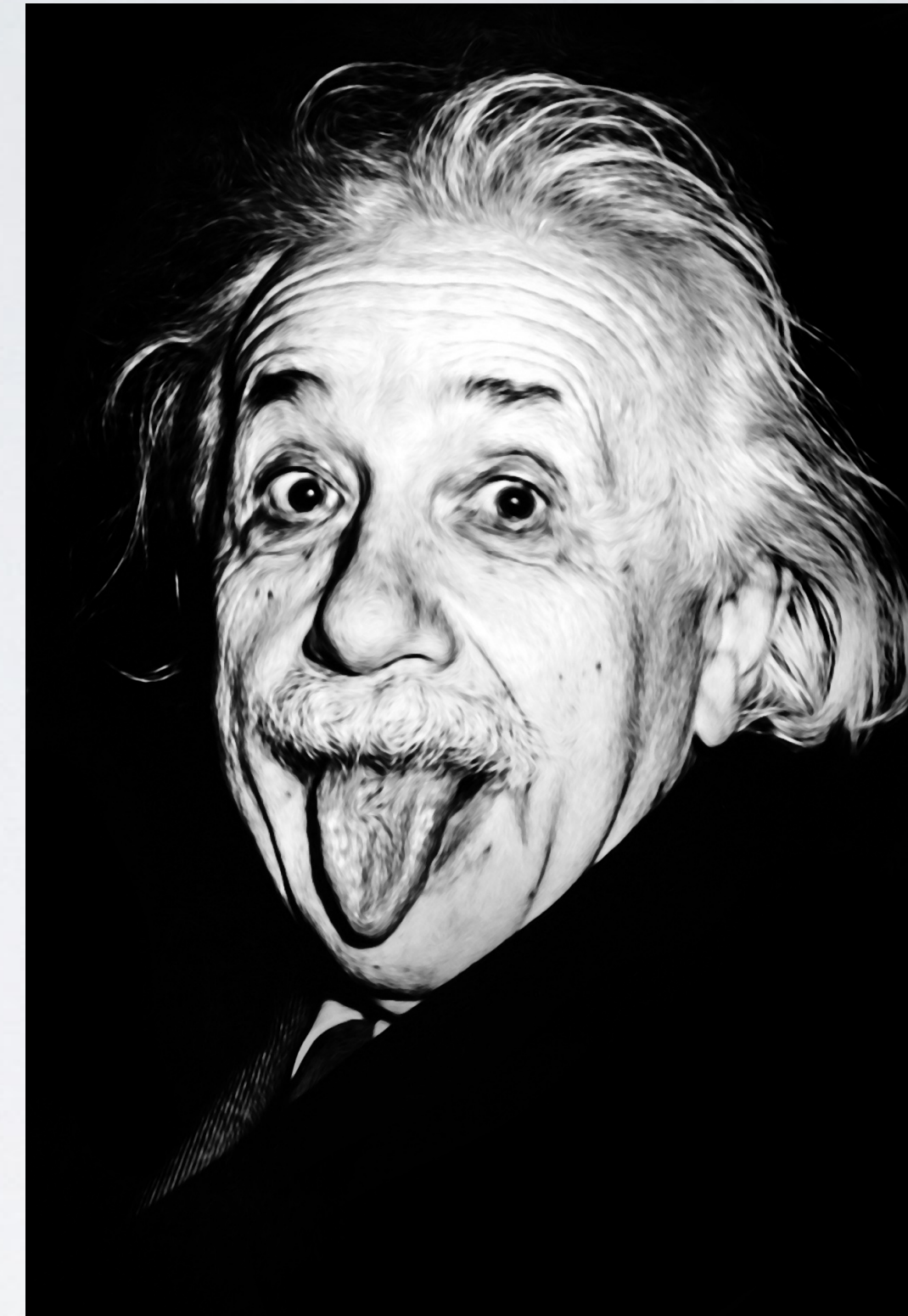


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1632

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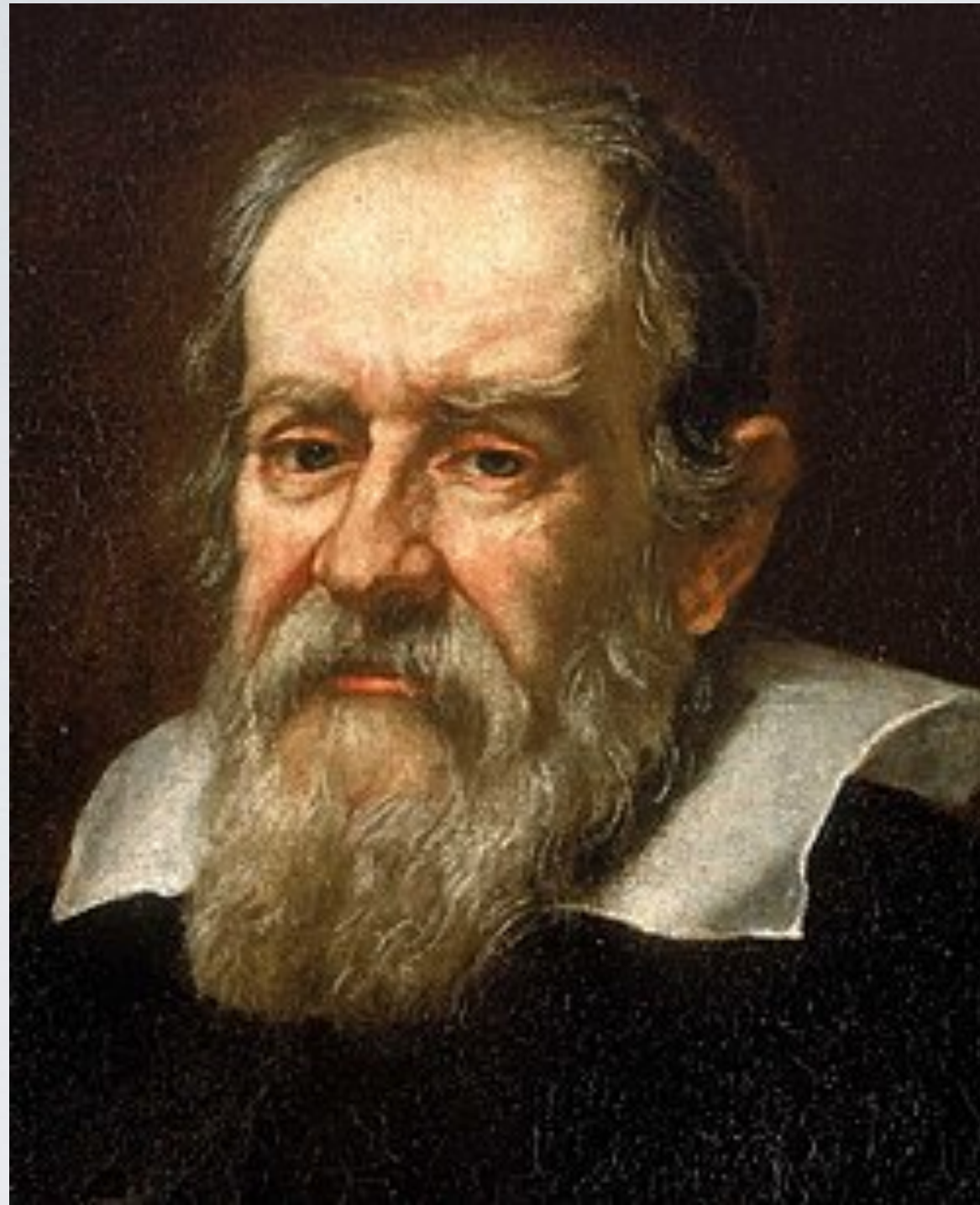


1905

Special Relativity  
(Galileo+light)

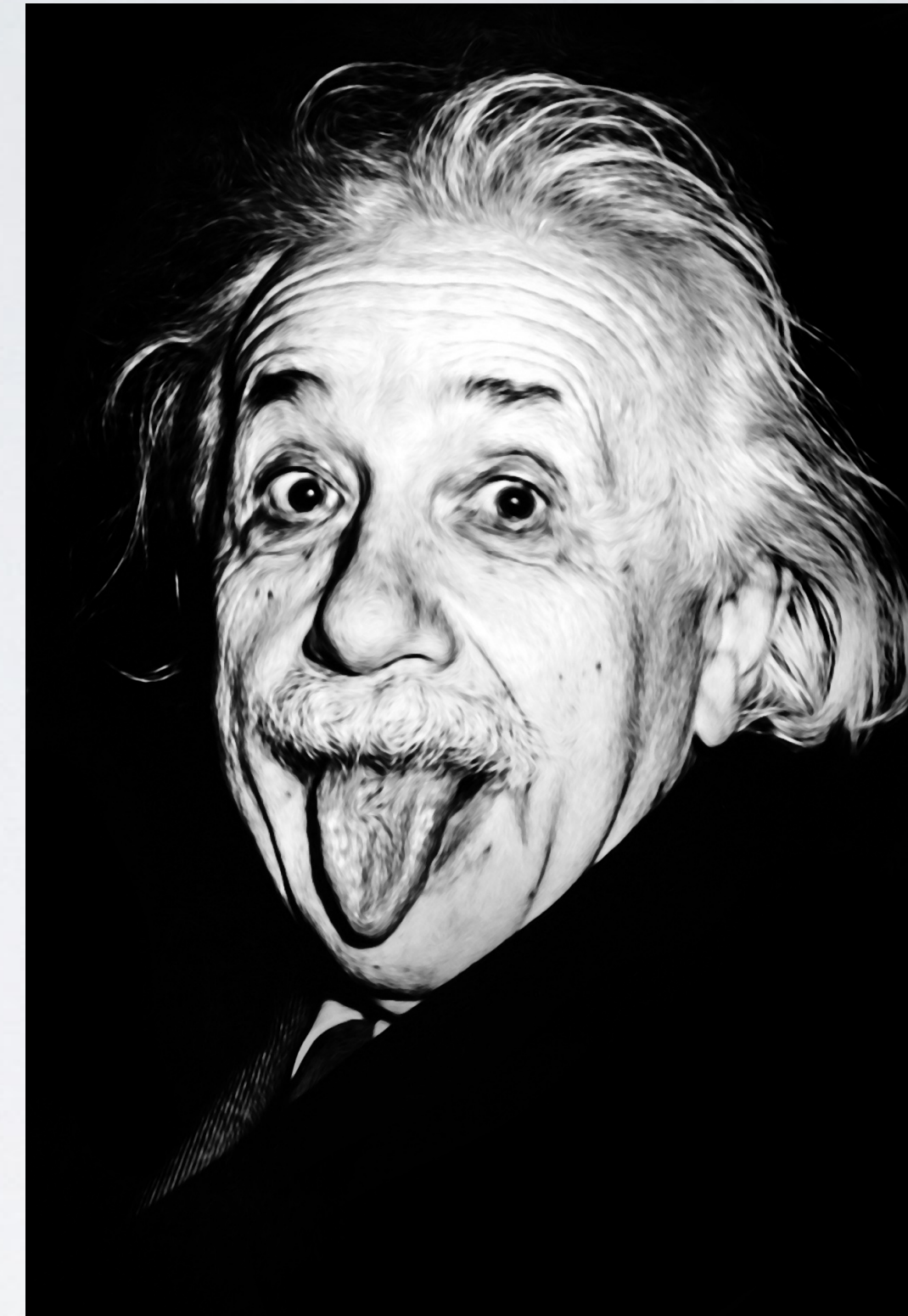


# WHAT IS RELATIVITY ?



1632

Principle of Relativity  
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1905

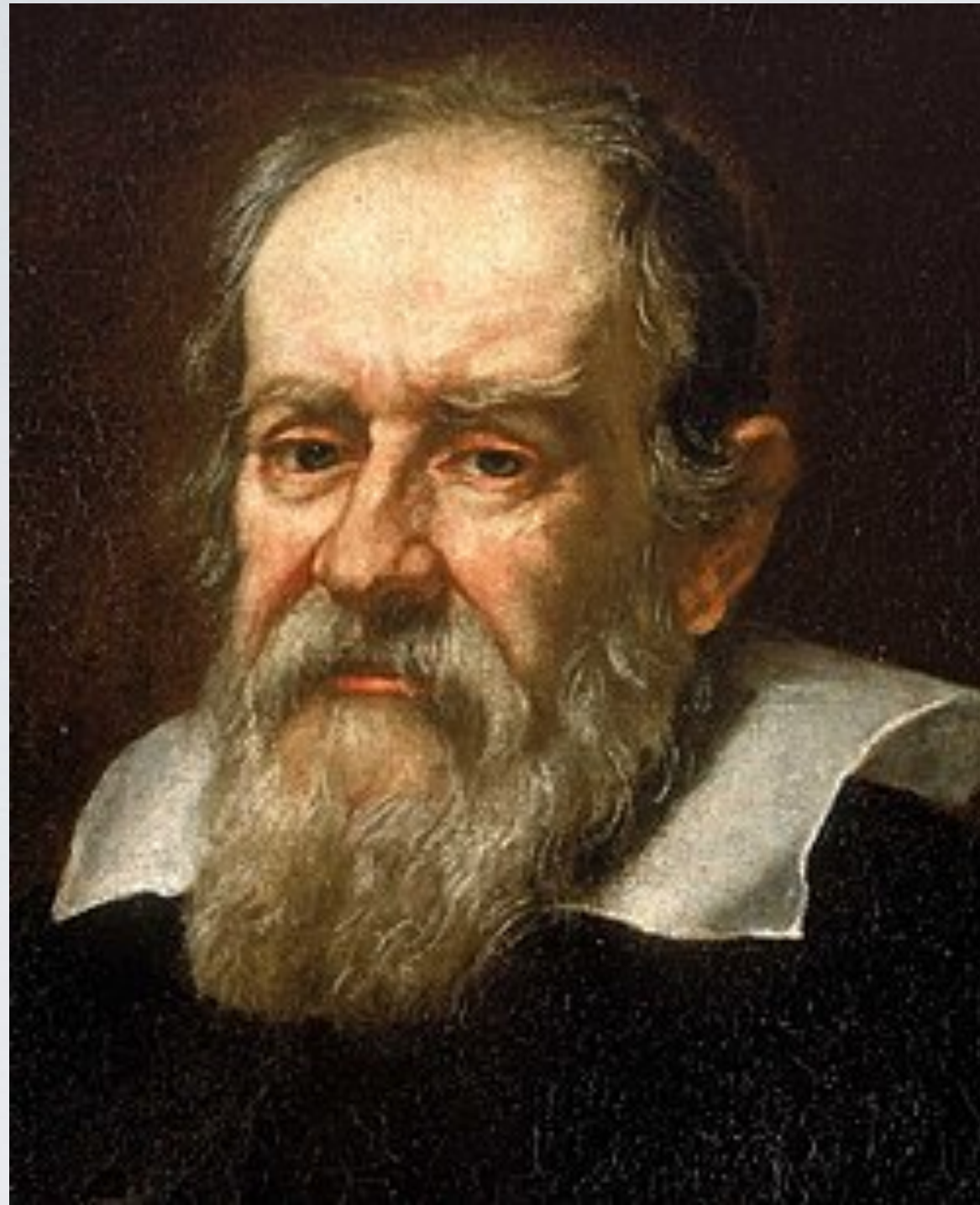
Special Relativity  
(Galileo+light)

1907

Equivalence Principle  
(acceleration=gravity)



# WHAT IS RELATIVITY ?



1632

Principle of Relativity  
(velocities)

1905

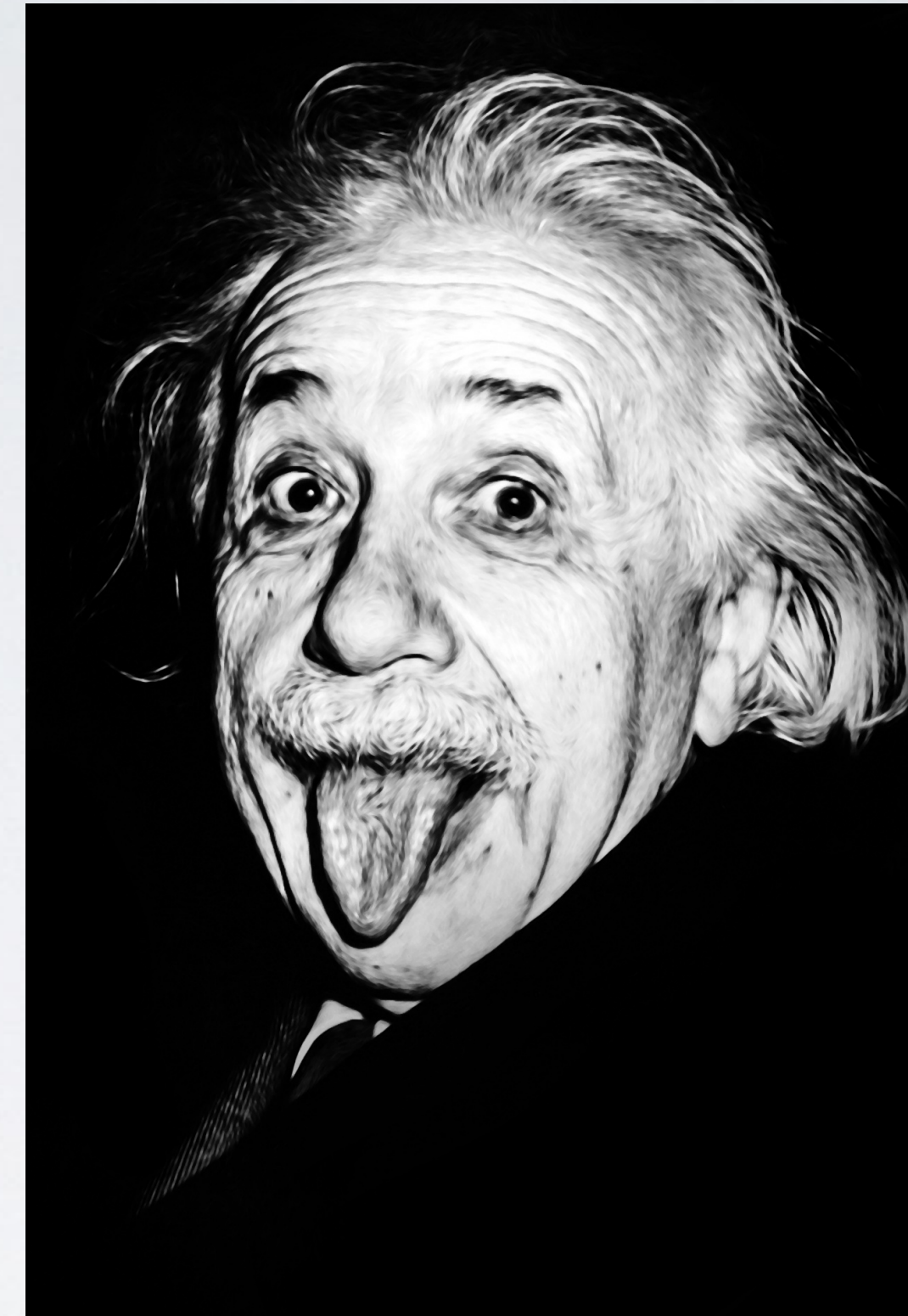
Special Relativity  
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1907

Equivalence Principle  
(acceleration=gravity)

1915

General Relativity Theory  
(Special Relativity  
+gravity)

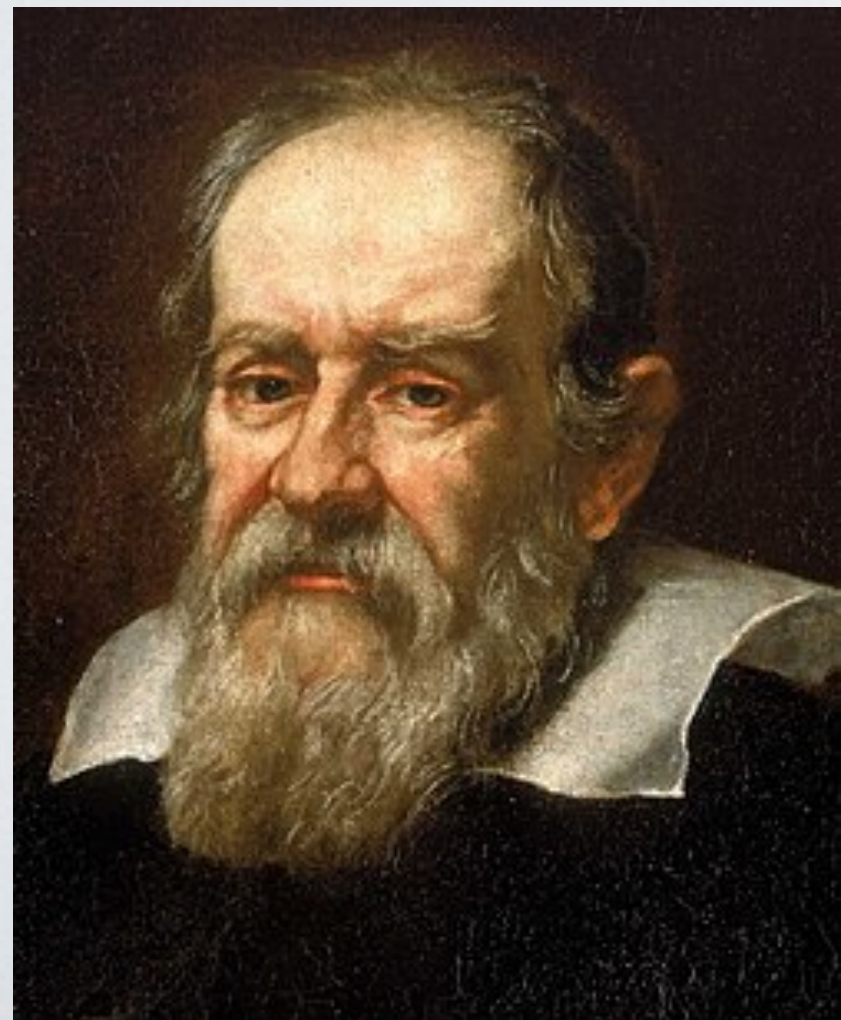




# GALILEO'S PRINCIPLE OF RELATIVITY

Velocity is relative !

Who is motion and who is at rest?

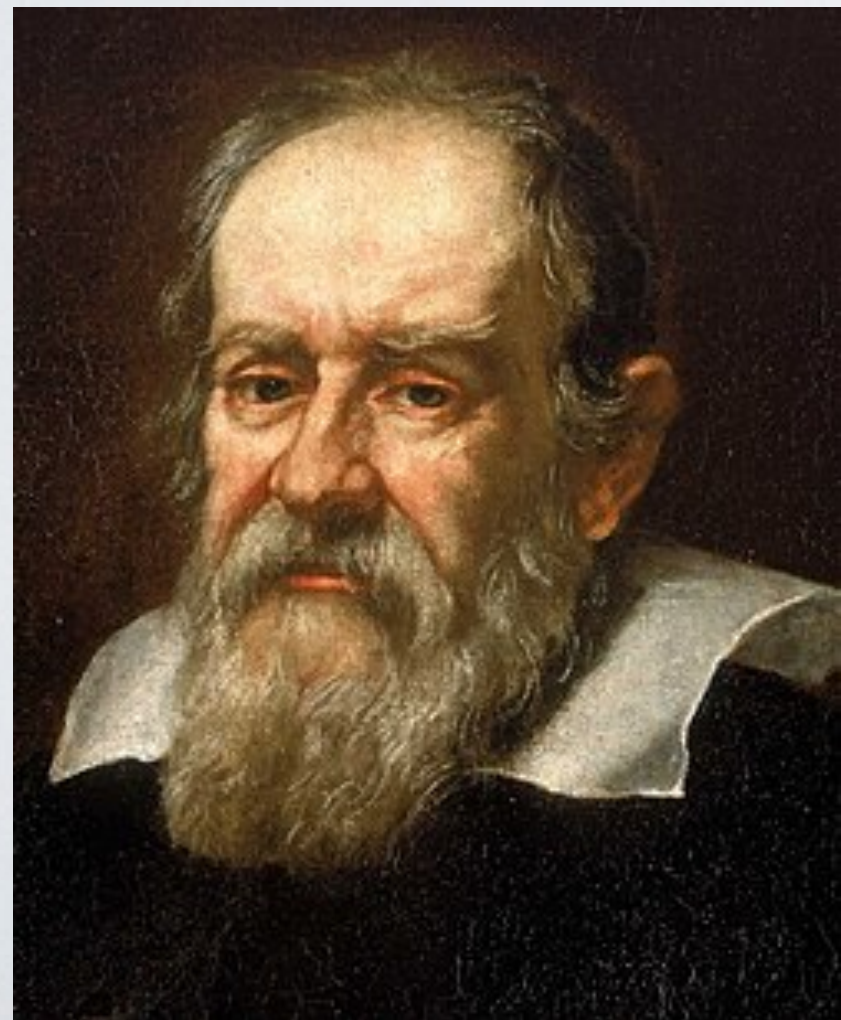


1632



# **GALILEO'S PRINCIPLE OF RELATIVITY**

The laws of physics are the  
same for all inertial  
observers !

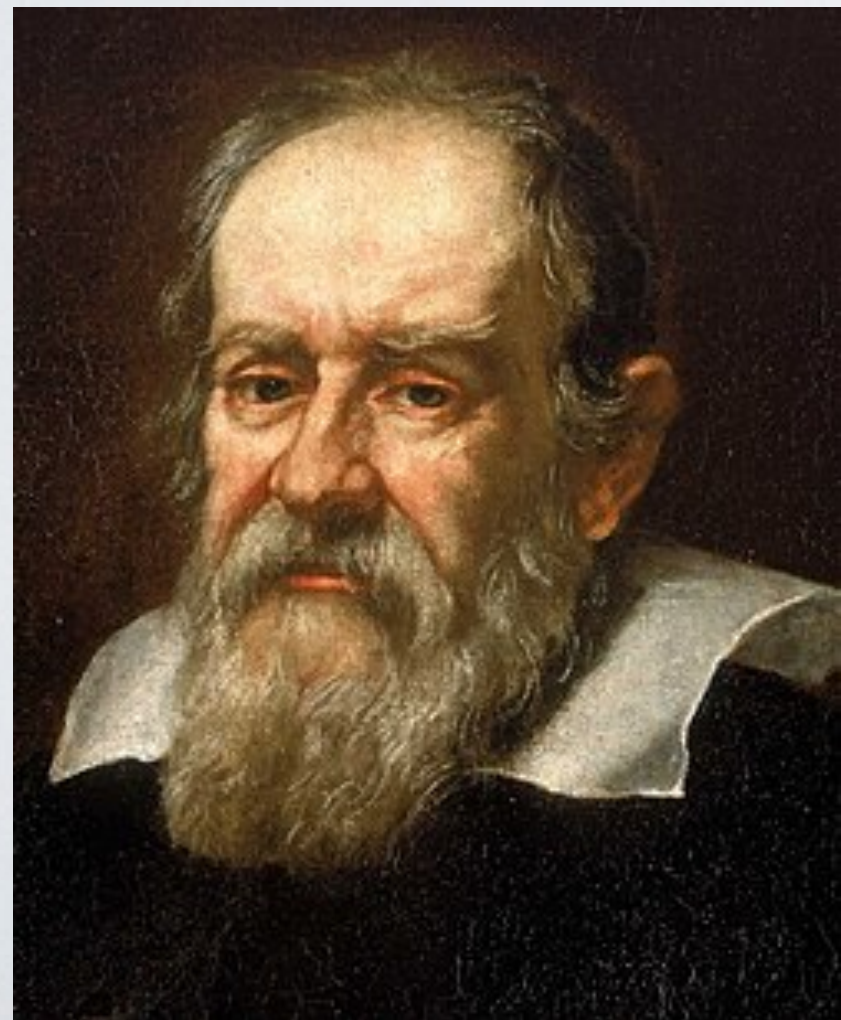


1632



# GALILEO'S PRINCIPLE OF RELATIVITY

Nothing (*absolute nothing*)  
can tell if we are at rest, or  
with a constant velocity



1632



# EINSTEIN'S PRINCIPLE OF RELATIVITY (EQUIVALENCE PRINCIPLE)

The effects of gravity are  
indistinguishable from an  
accelerated observer



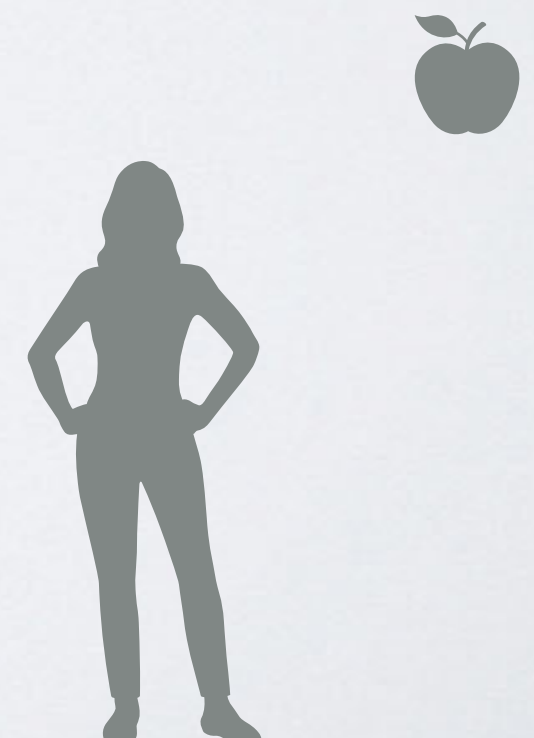


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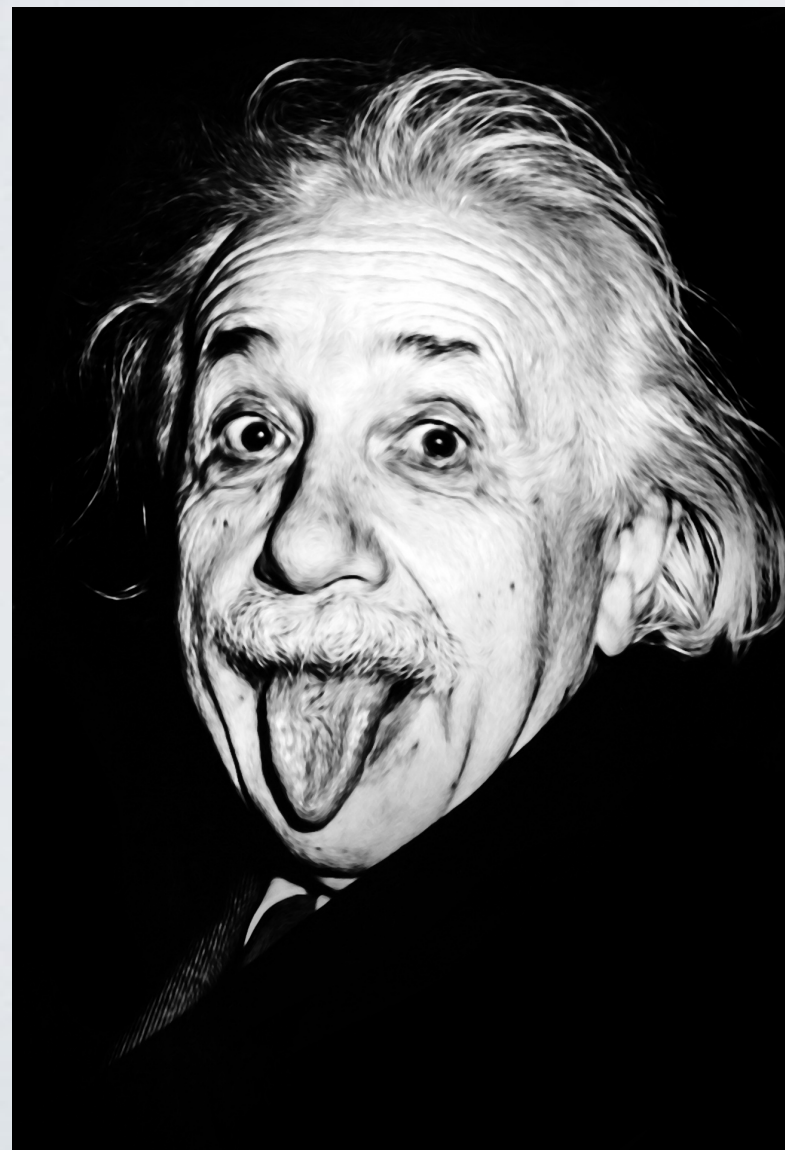
1907





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1907

$\vec{g}$



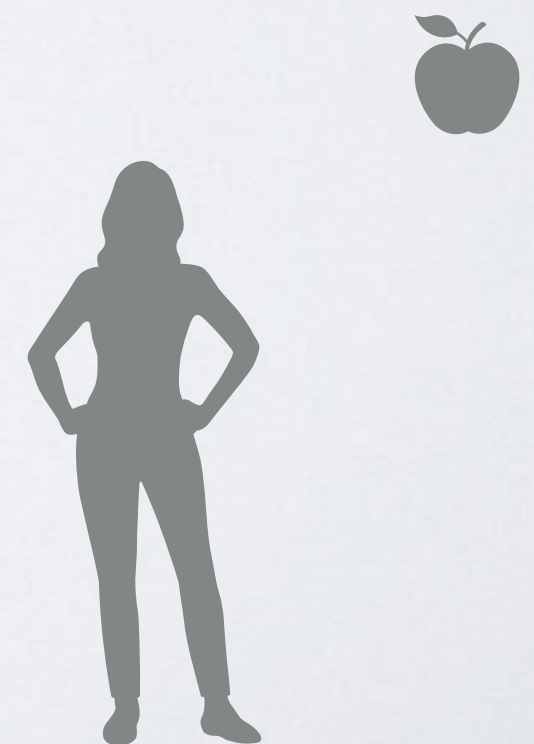


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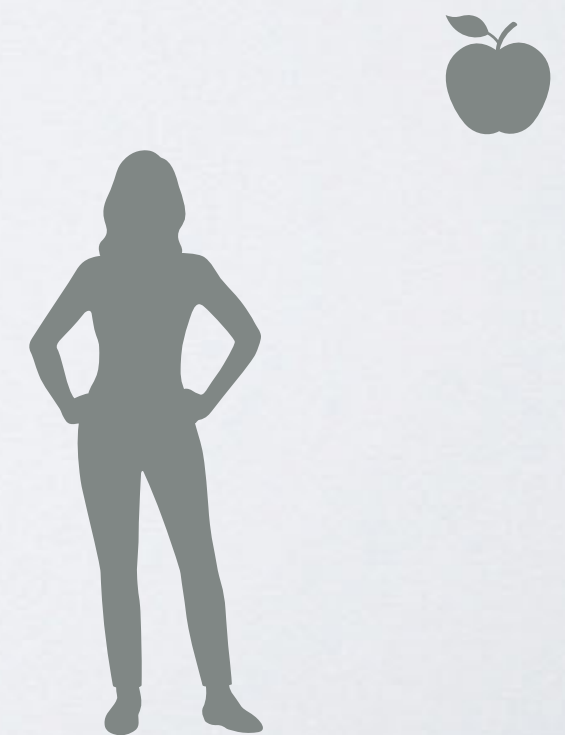


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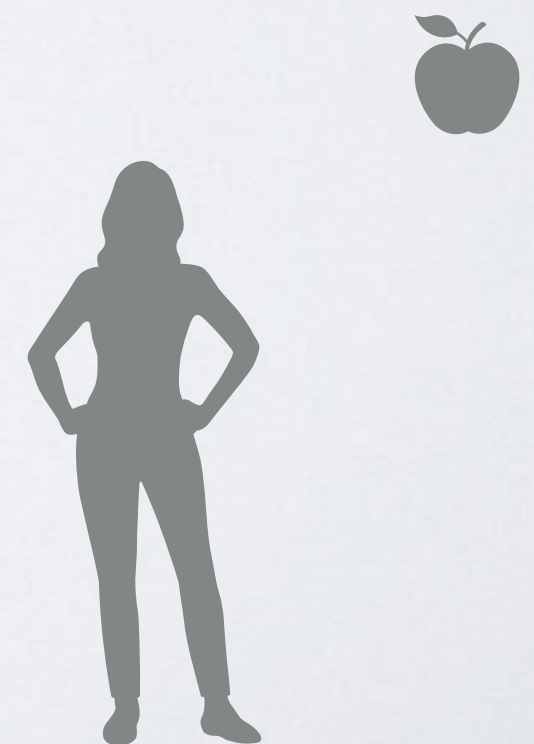


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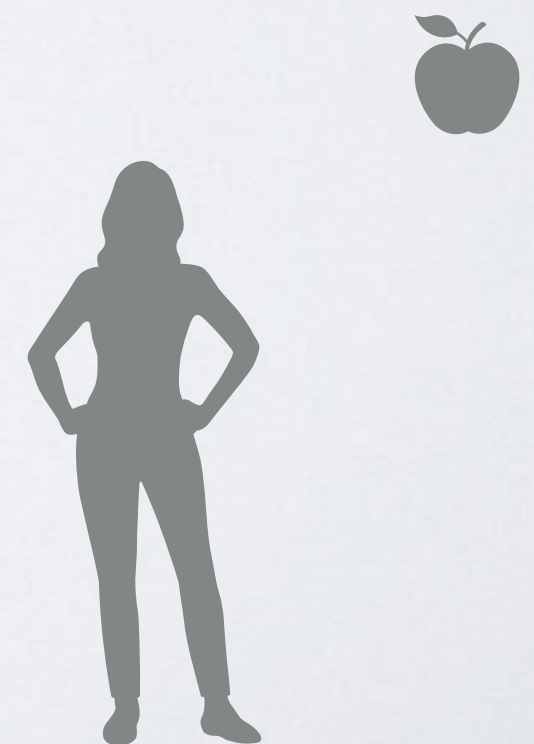


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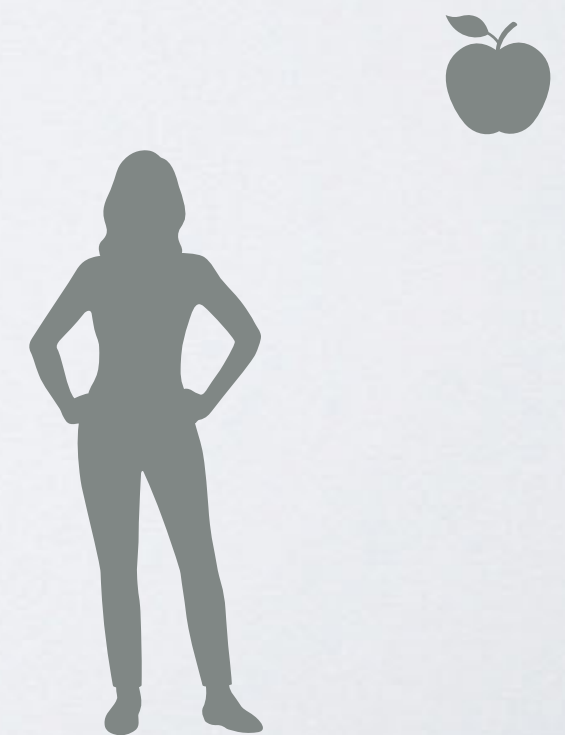


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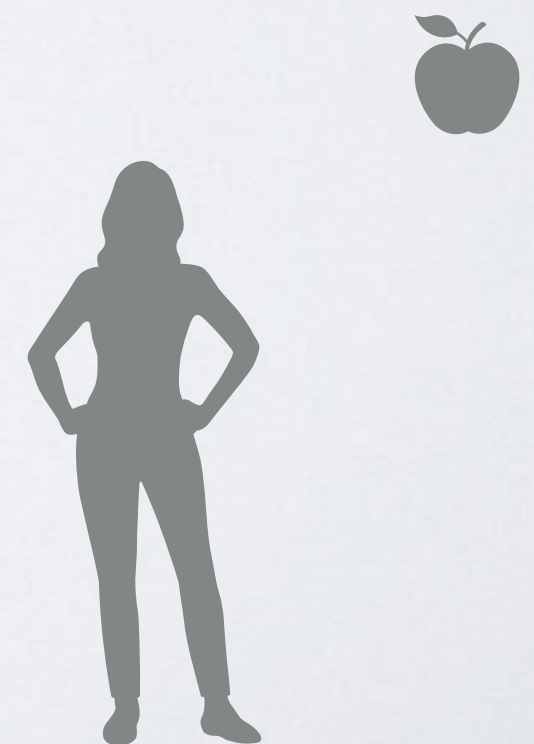


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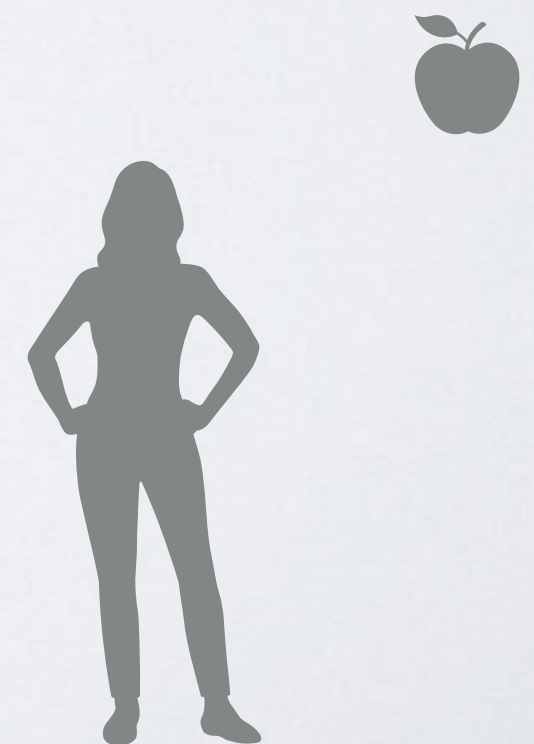


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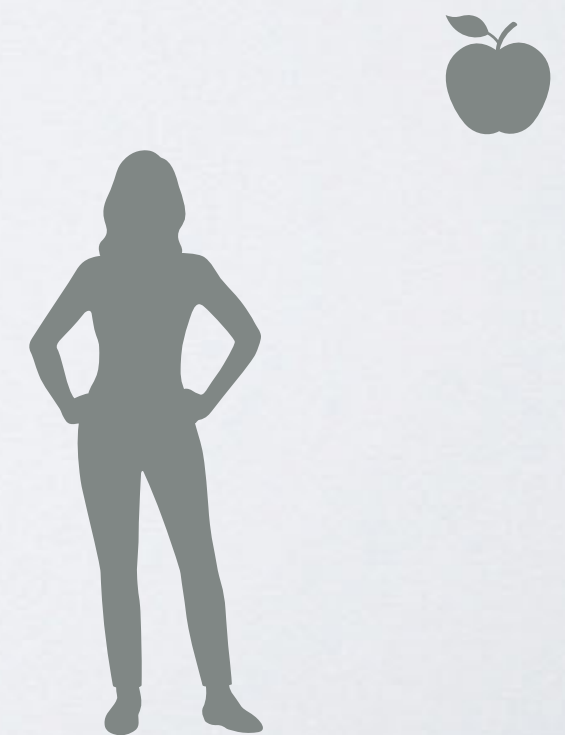


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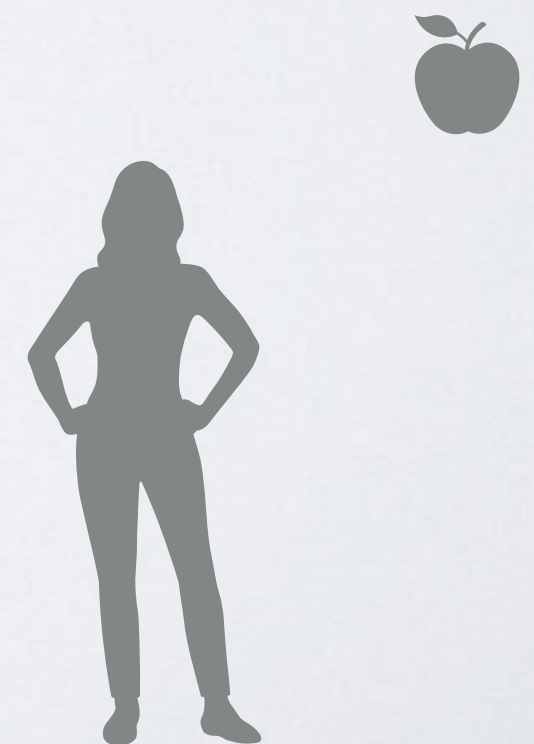


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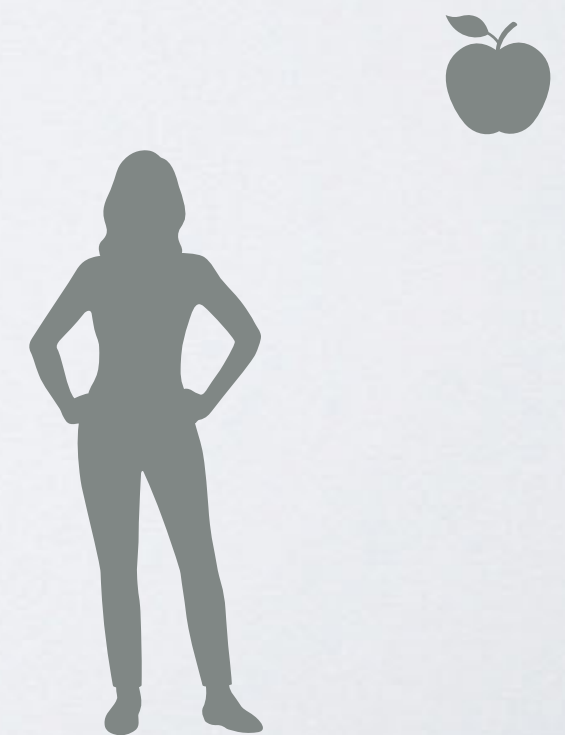


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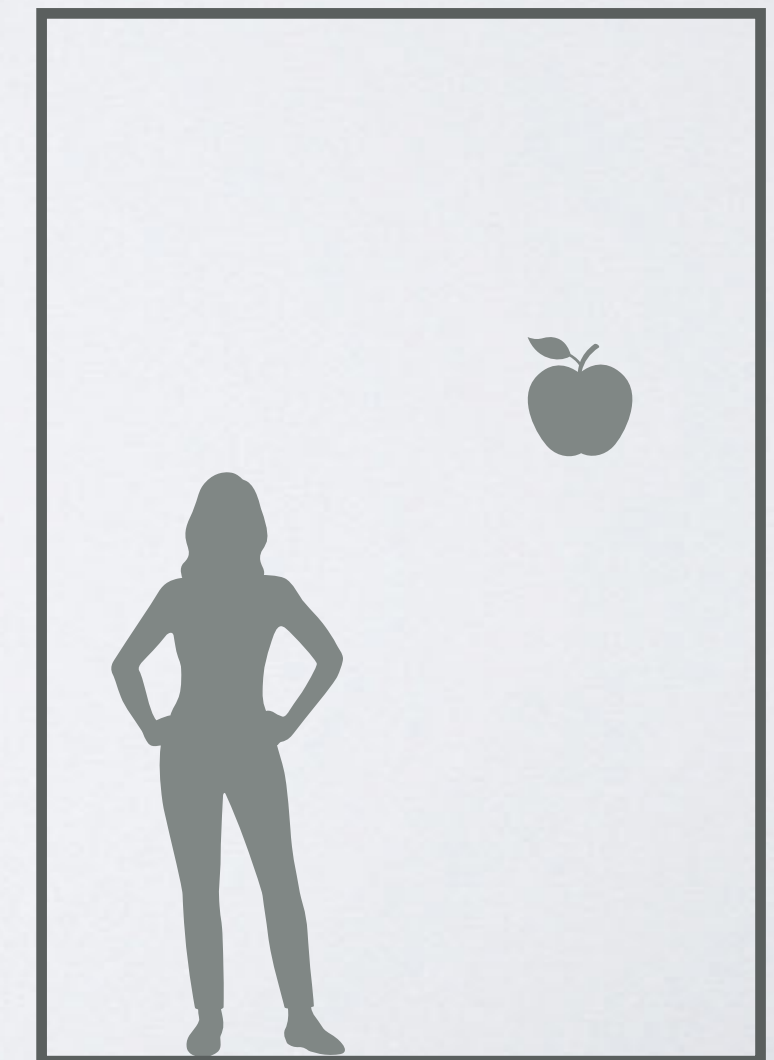
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1907

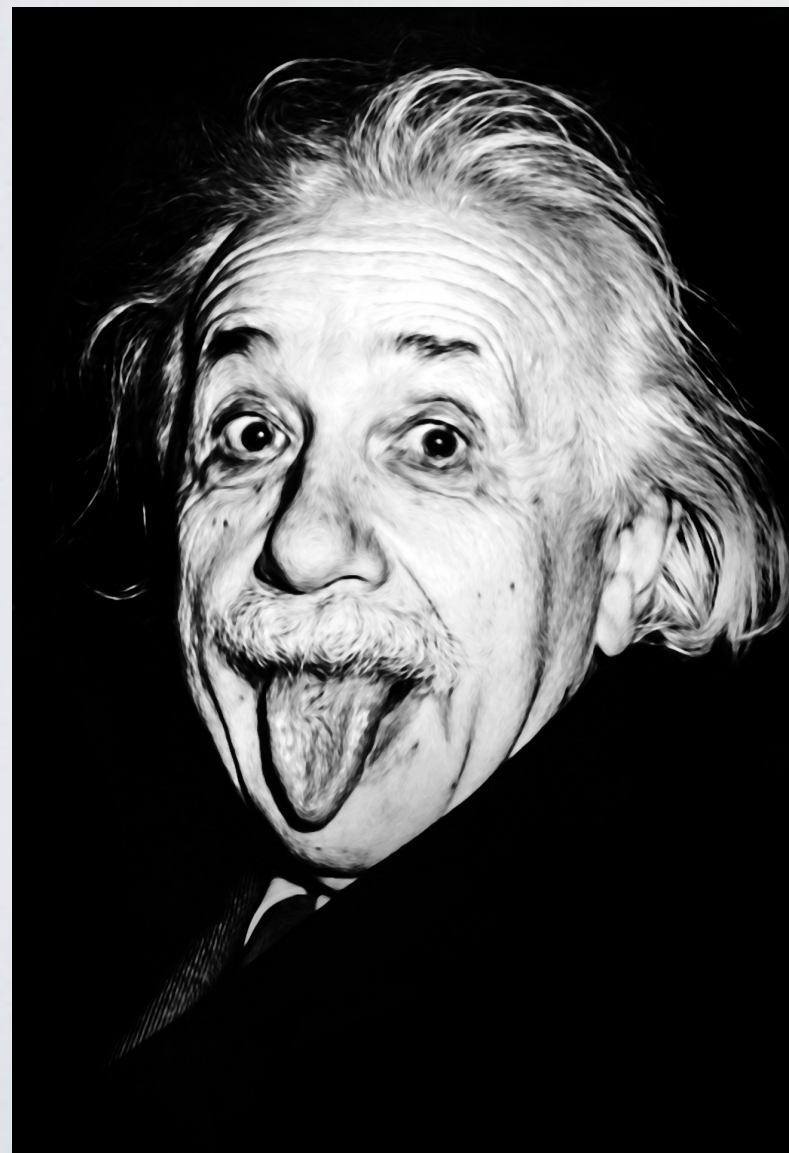
$\vec{g}$  ↑



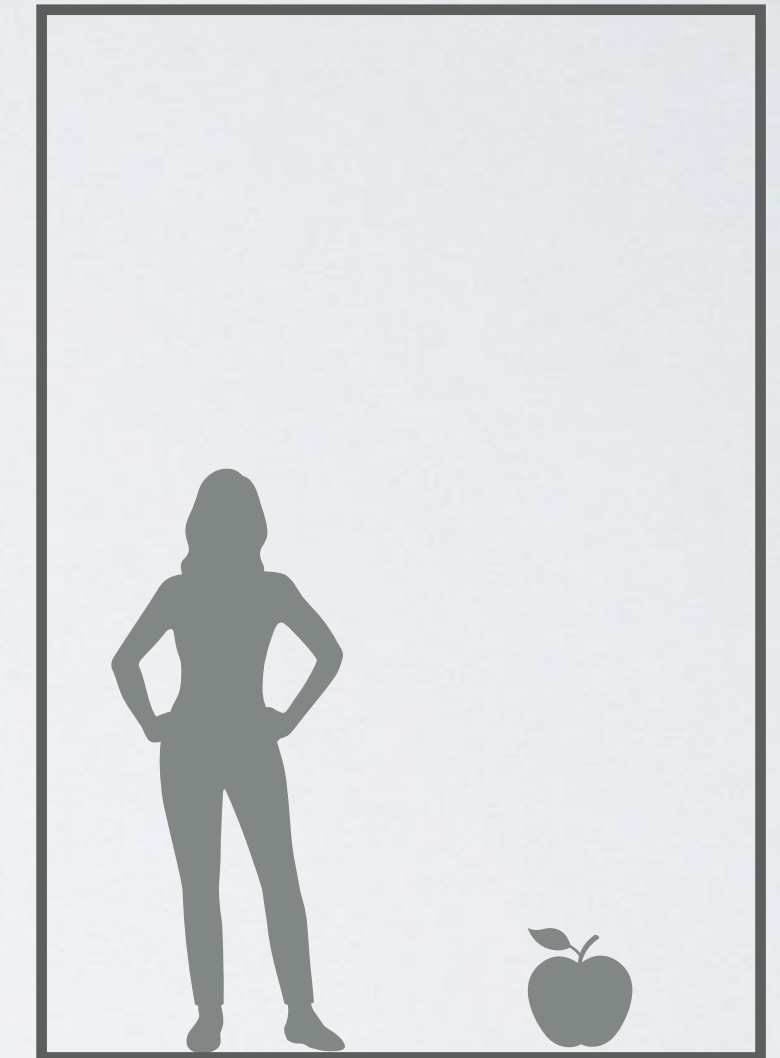
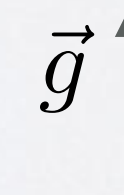


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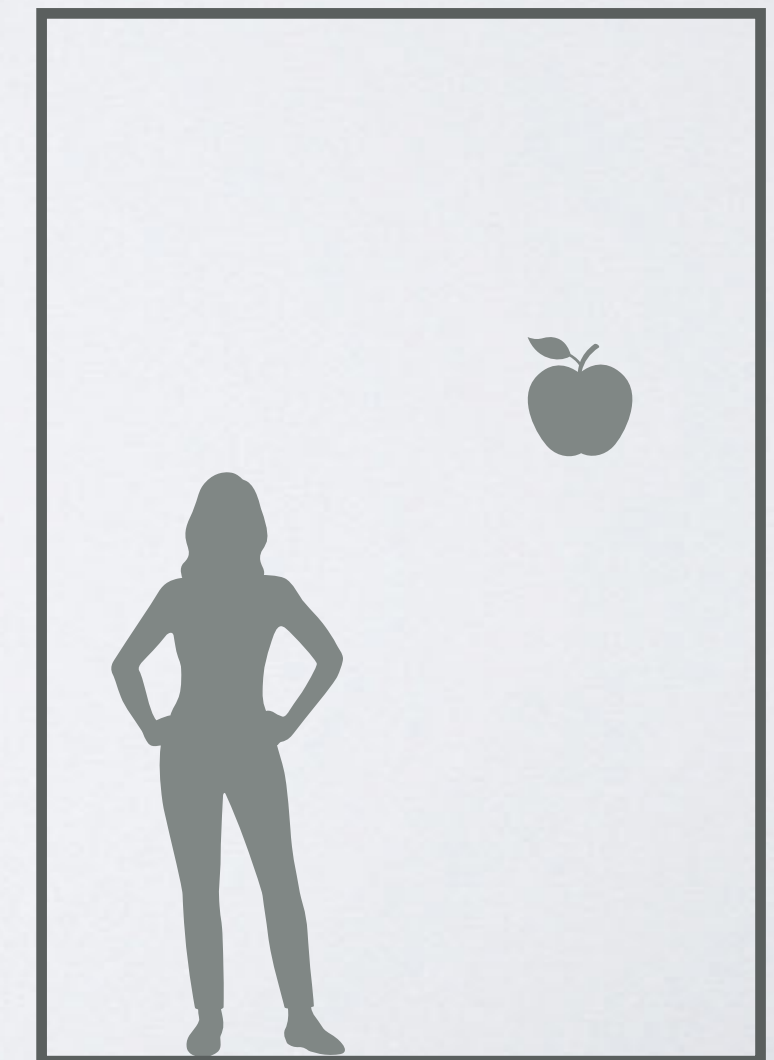
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1907

$\vec{g}$  ↑



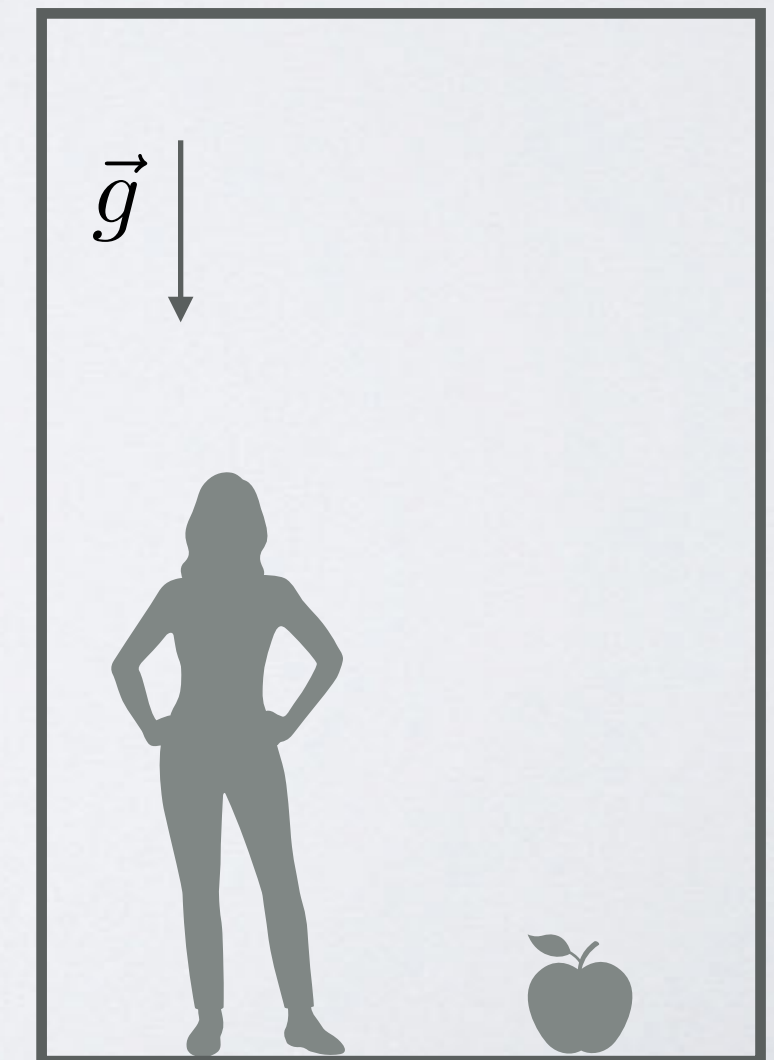


# EINSTEIN'S PRINCIPLE OF RELATIVITY (EQUIVALENCE PRINCIPLE)

The effects of gravity are  
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1907





# EINSTEIN'S PRINCIPLE OF RELATIVITY (EQUIVALENCE PRINCIPLE)

Nothing (*absolute nothing*)  
can tell if we are in a  
gravitational field, or in an  
accelerated “elevator”



1907



Gravity affects all  
bodies in the  
exact same way

**BECAUSE IT IS A RELATIVE EFFECT**



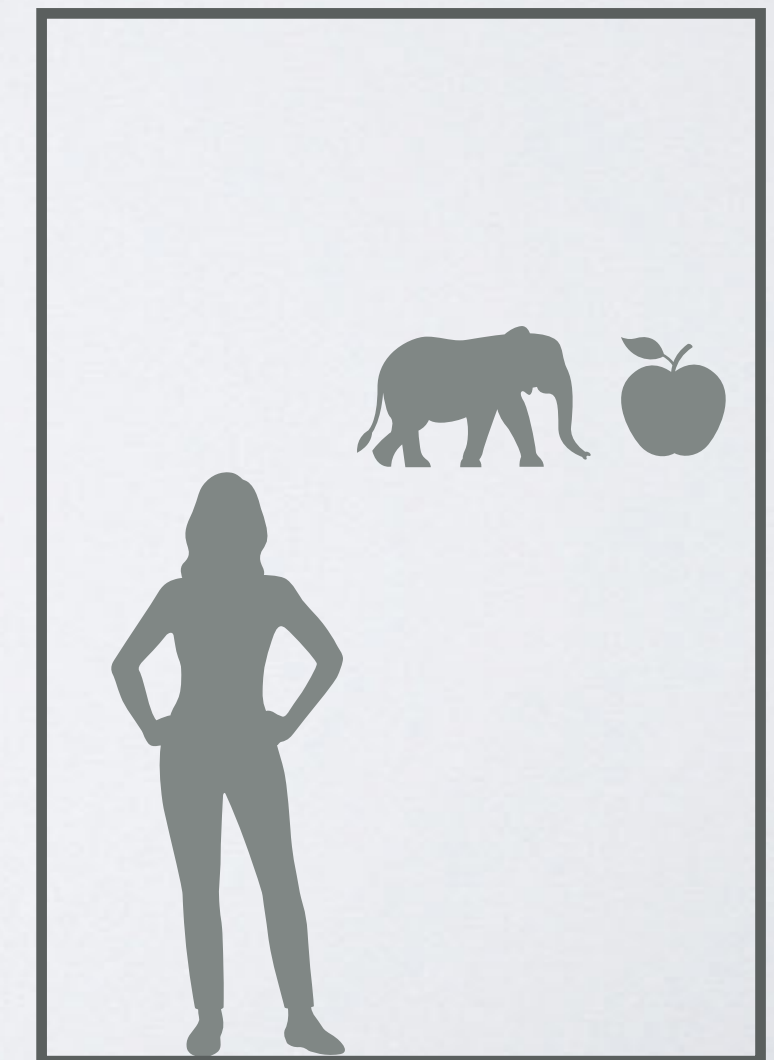
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1907

$\vec{g}$  ↑



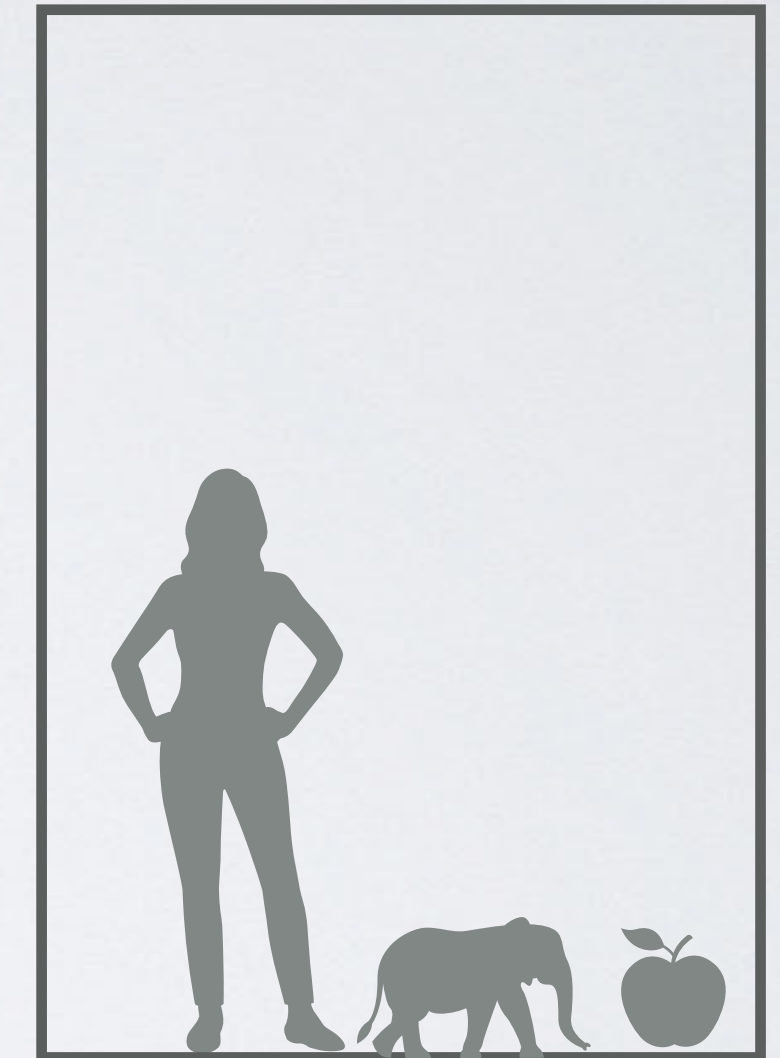
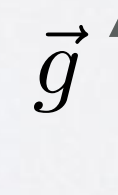


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1907





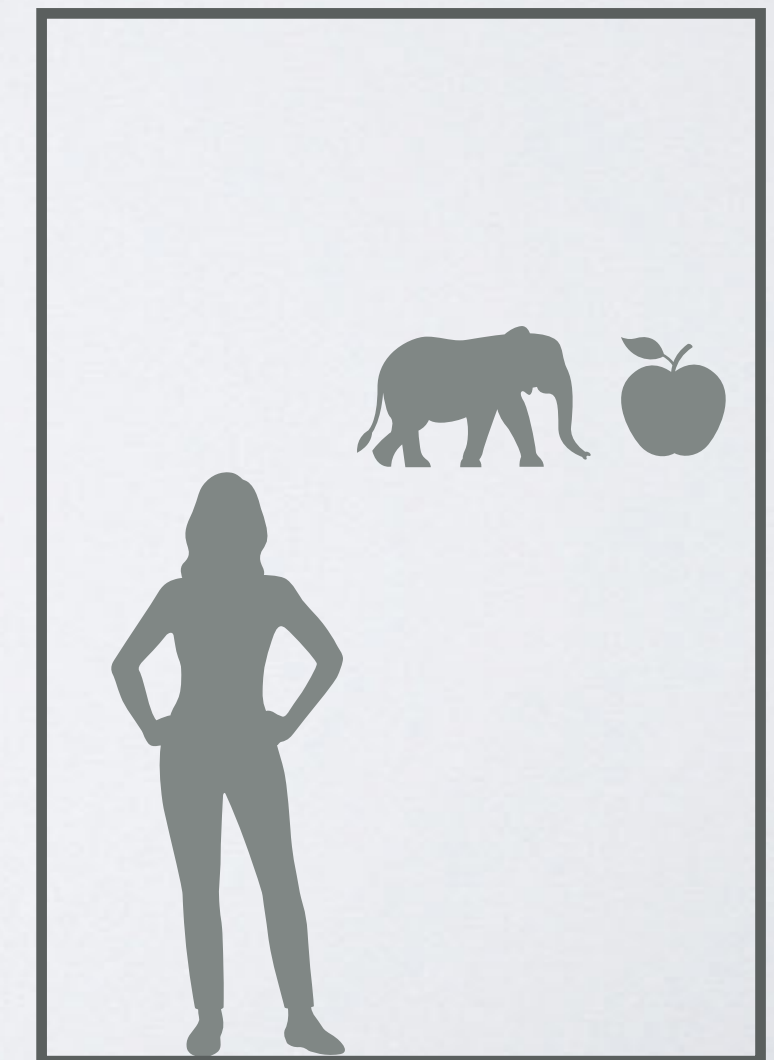
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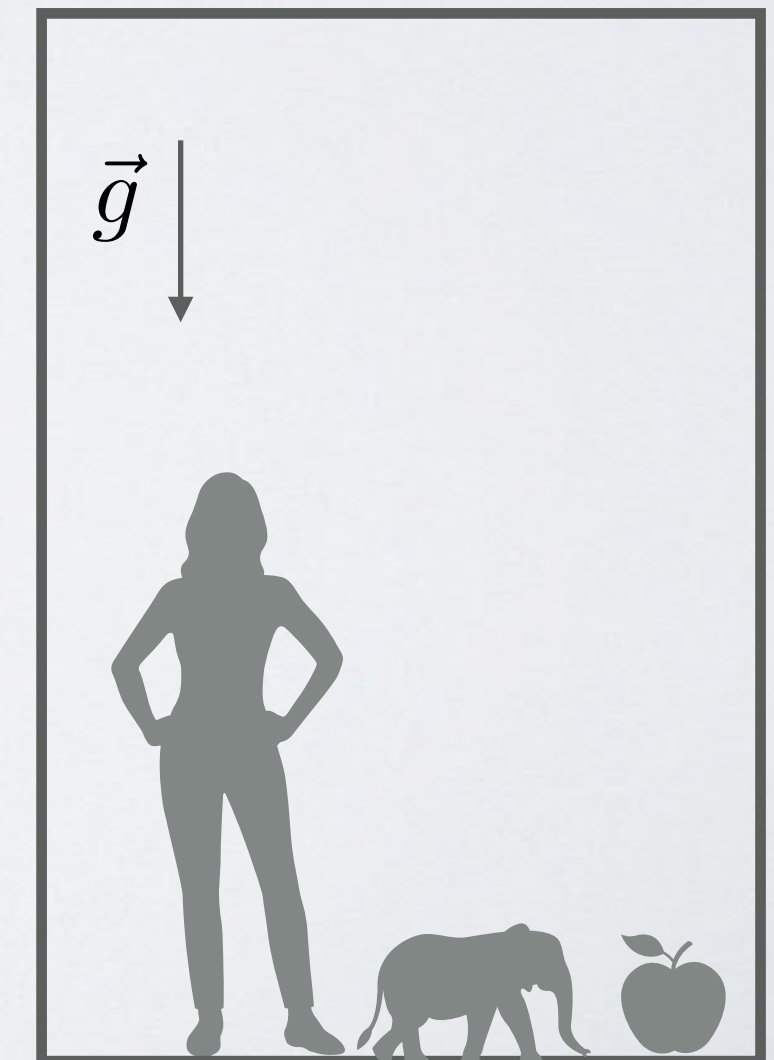


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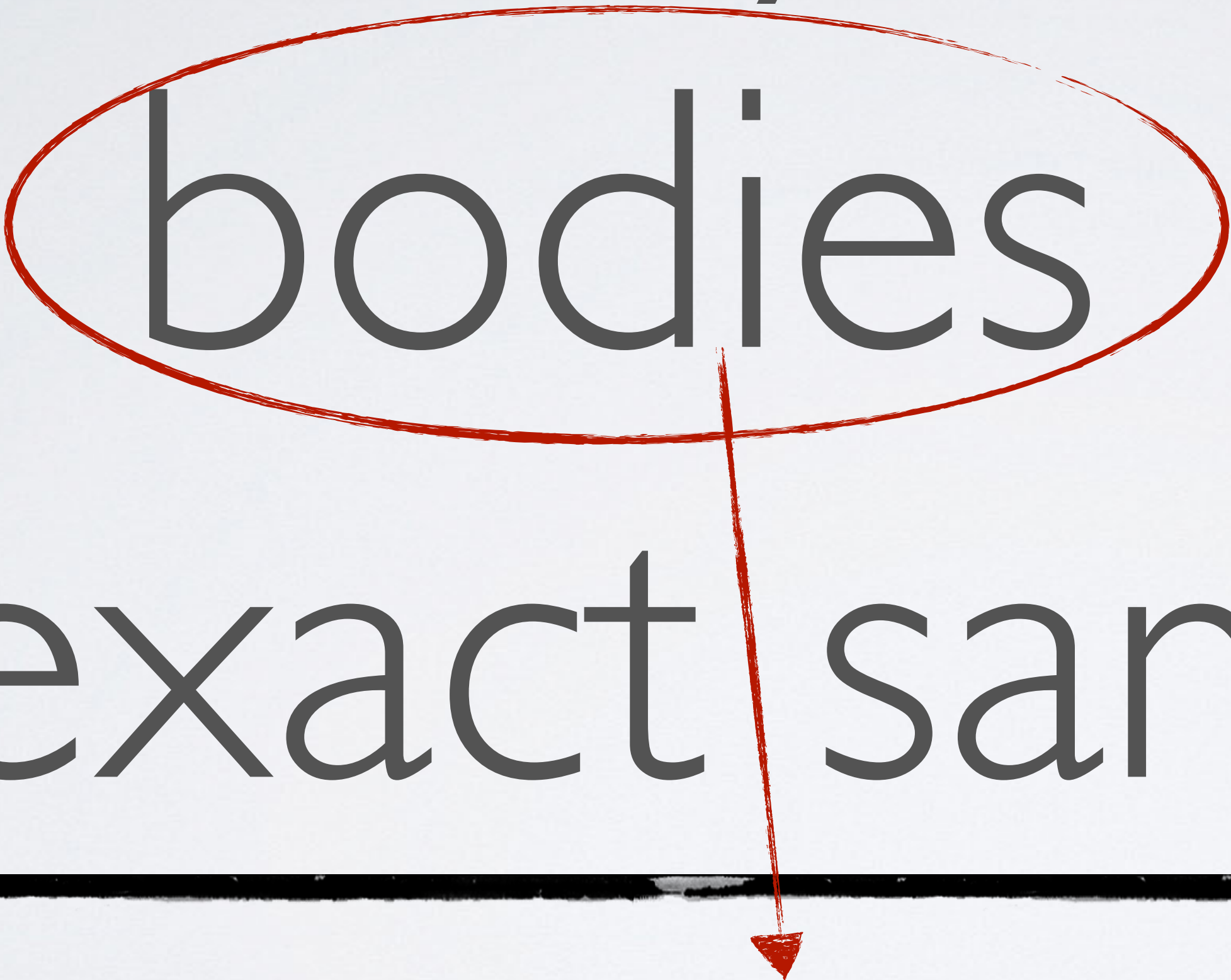
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1907





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**HOW ABOUT LIGHT?**

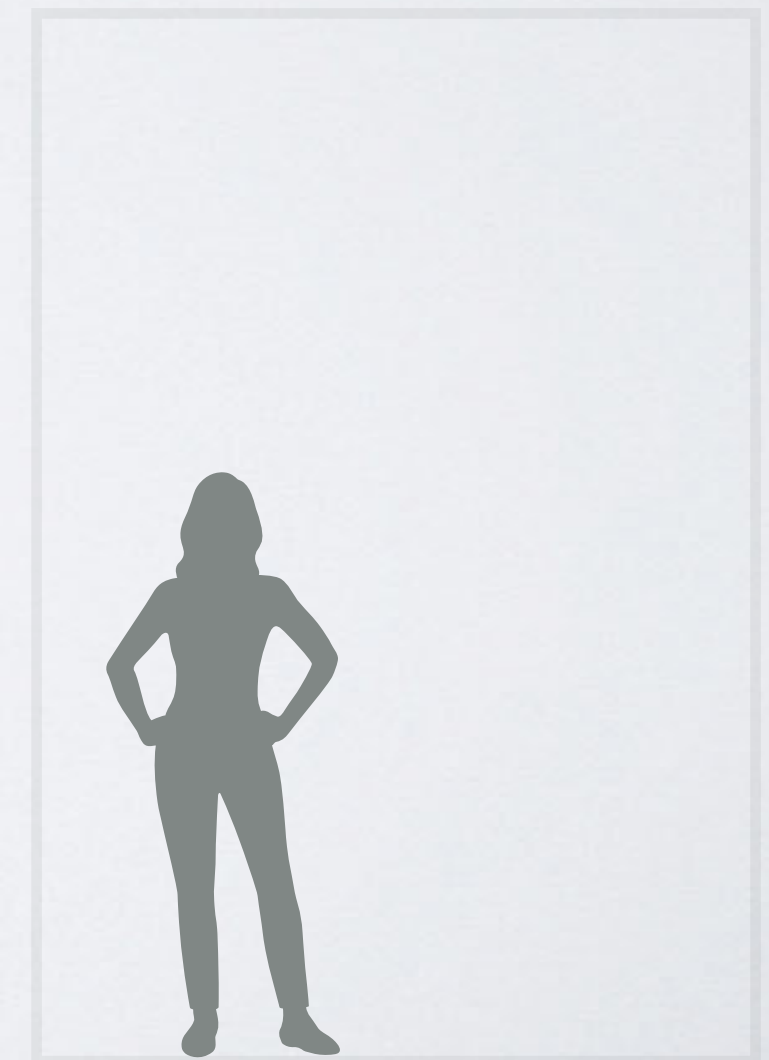


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1907



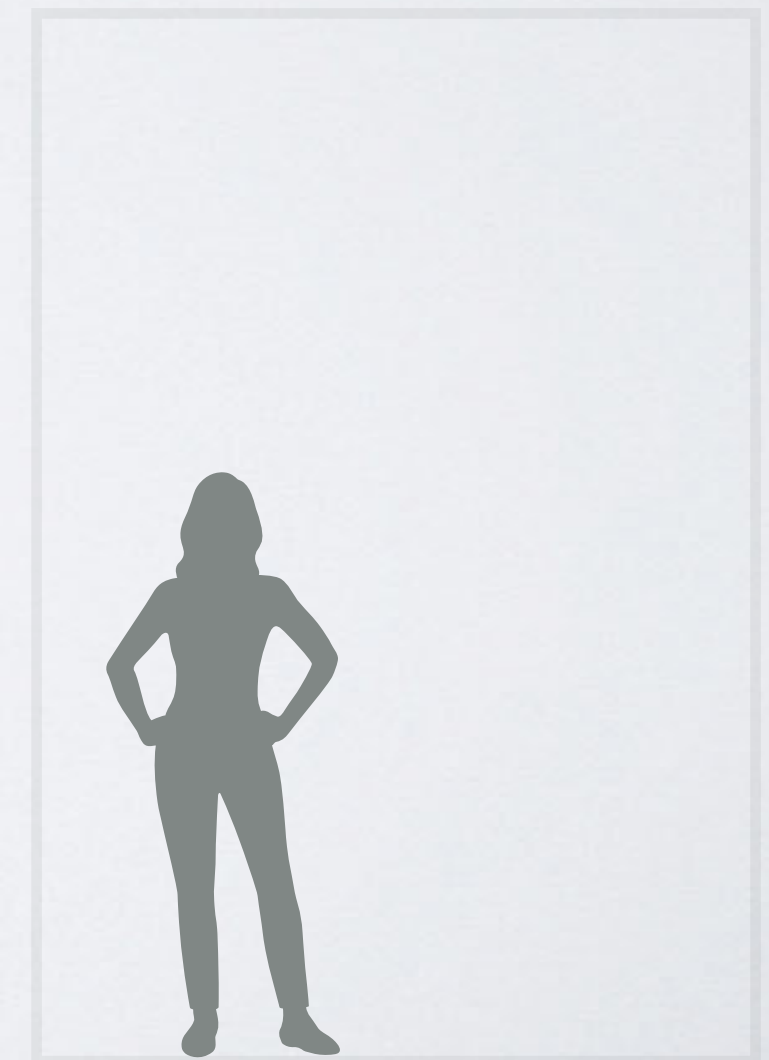


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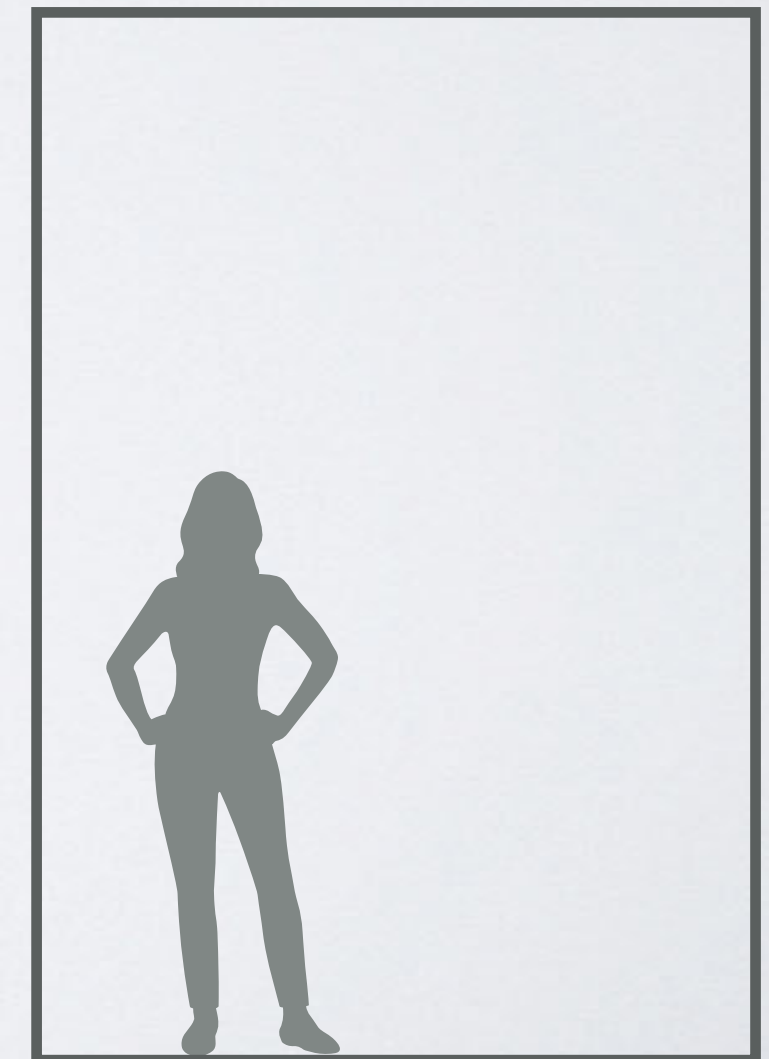
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1907

$\vec{g}$  ↑



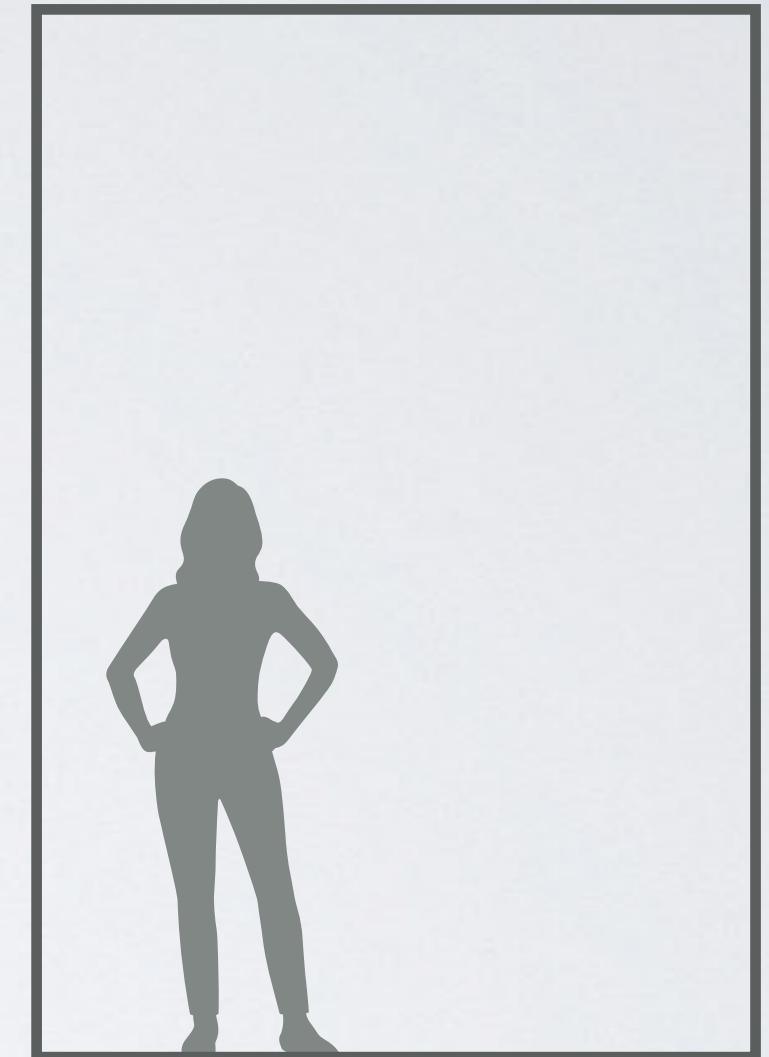
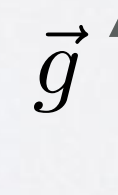


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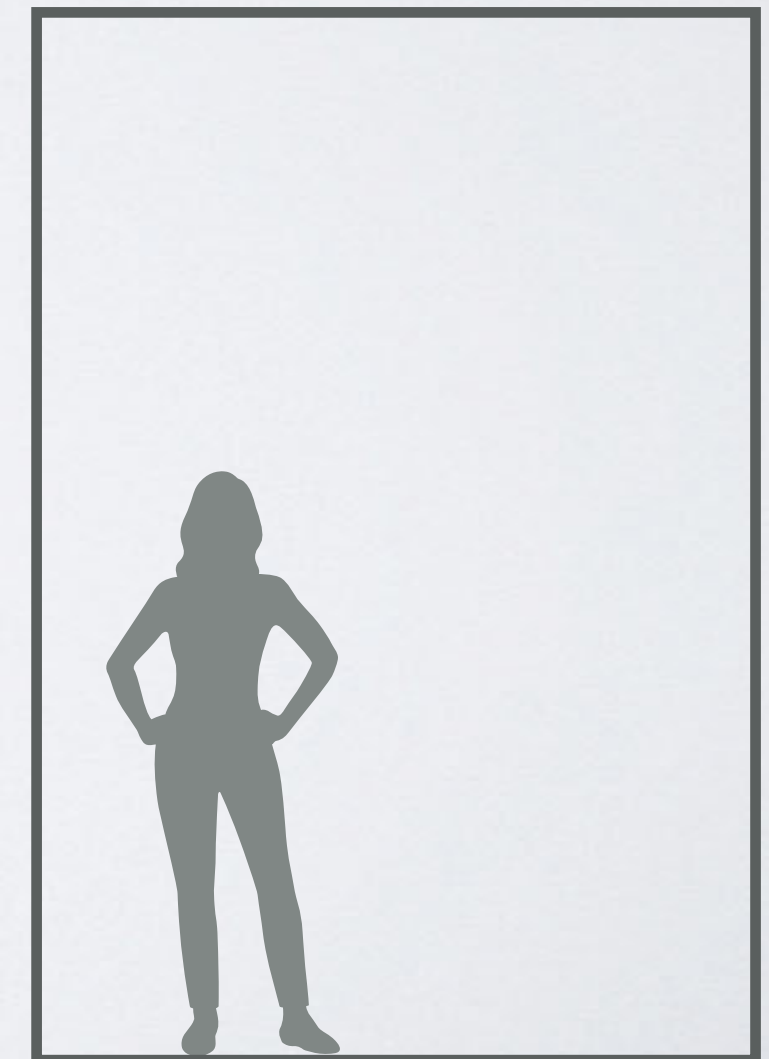
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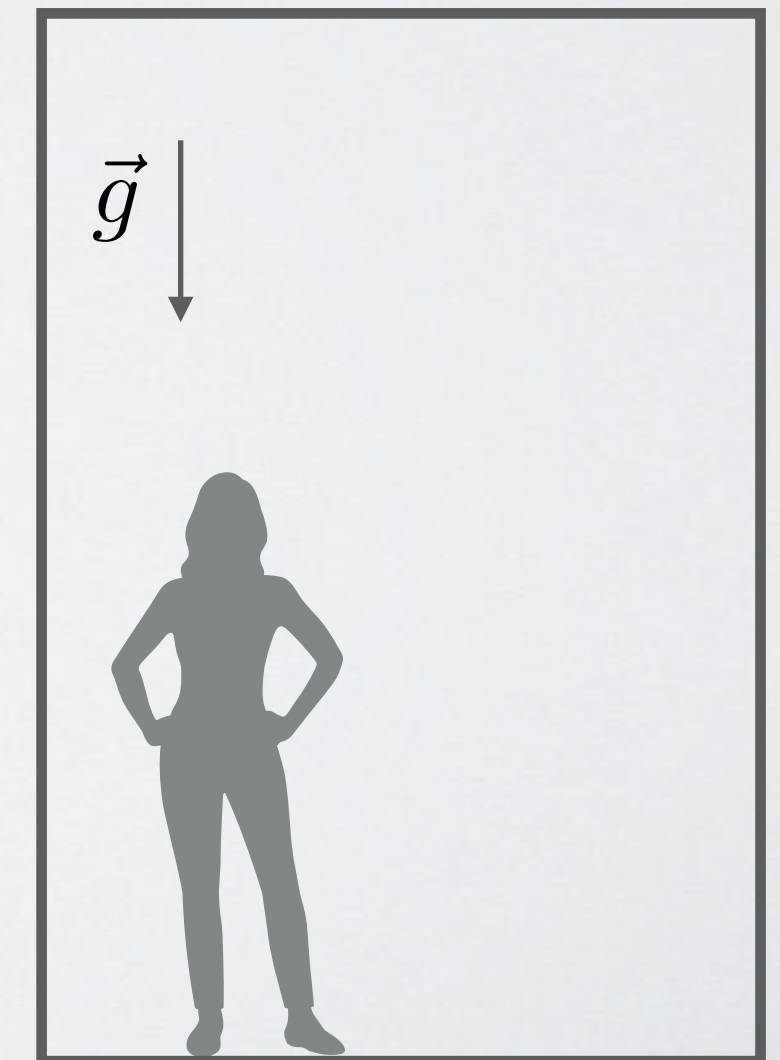


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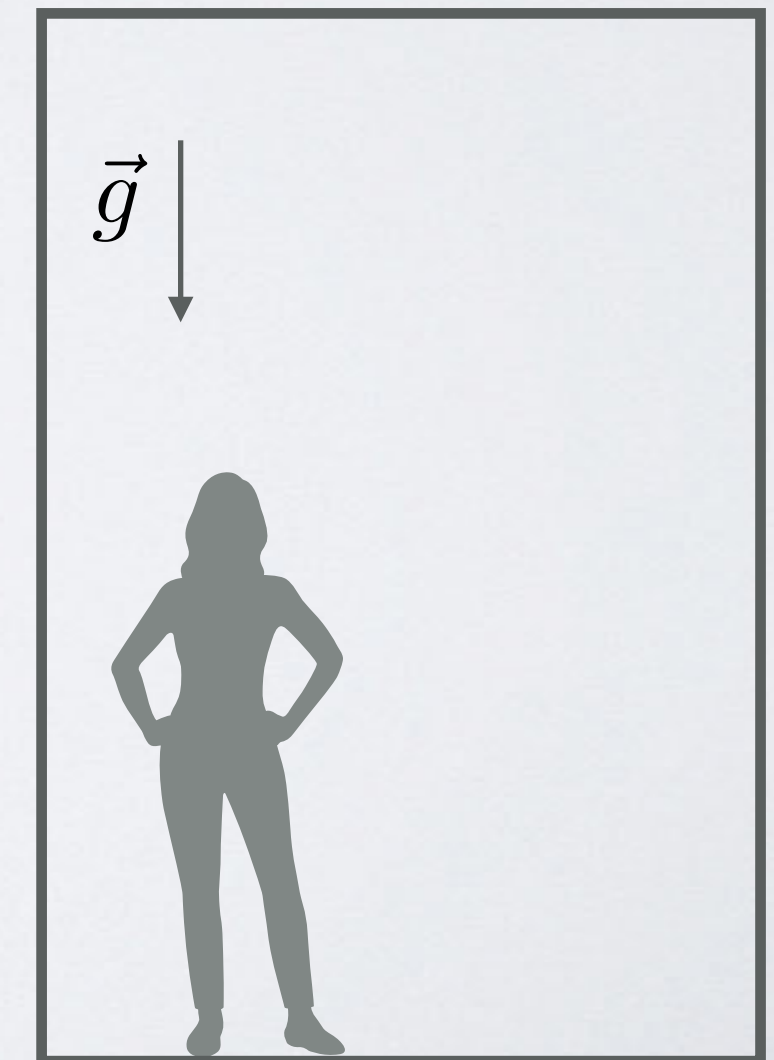


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The effects of gravity are  
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1907





Gravity affects all  
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**THUS, GRAVITY BENDS LIGHT!**

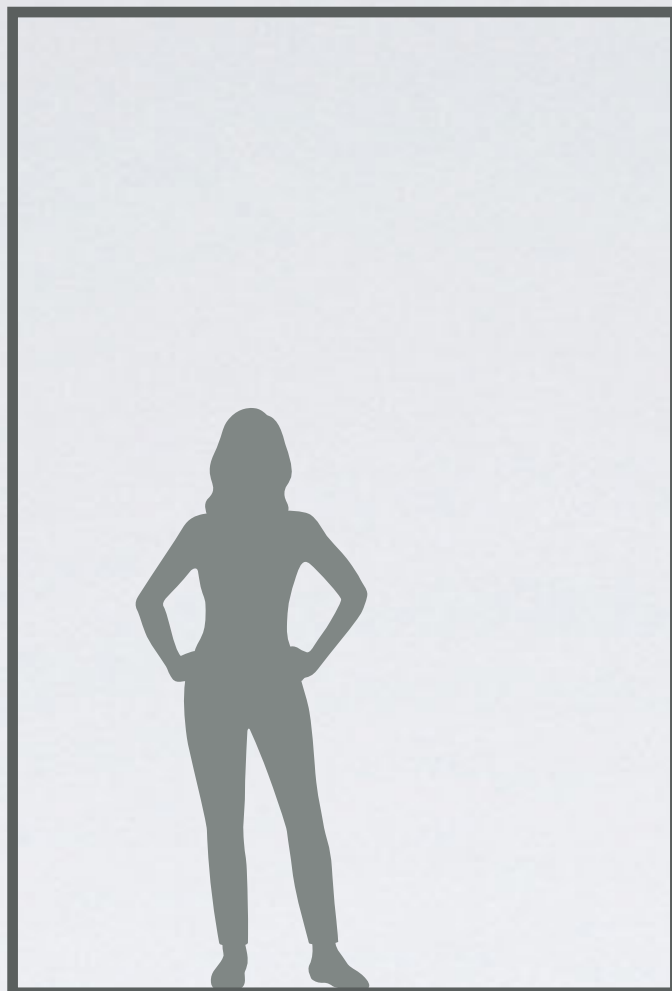


$\vec{g}$





$\vec{g}$

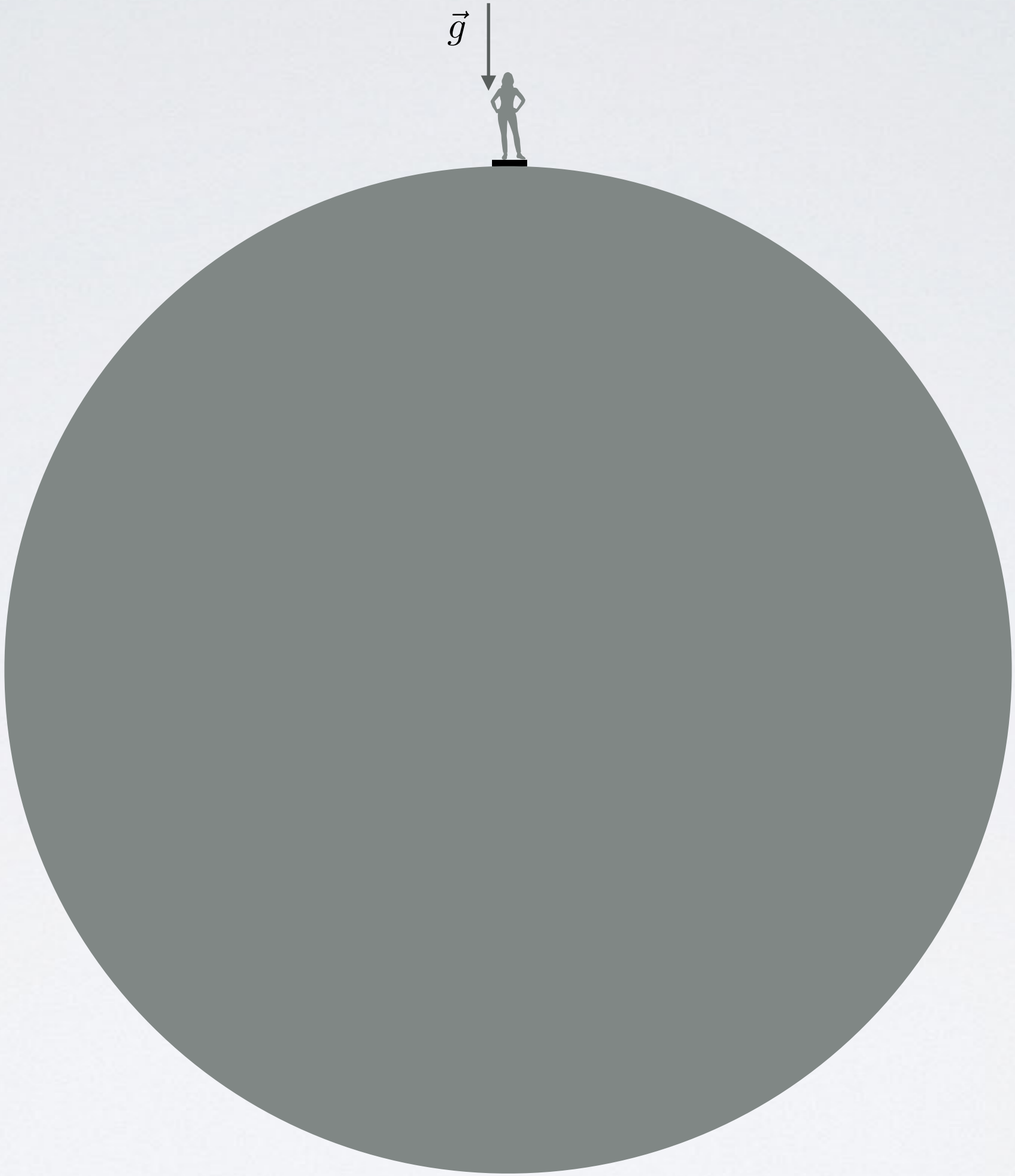




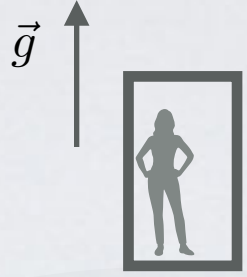
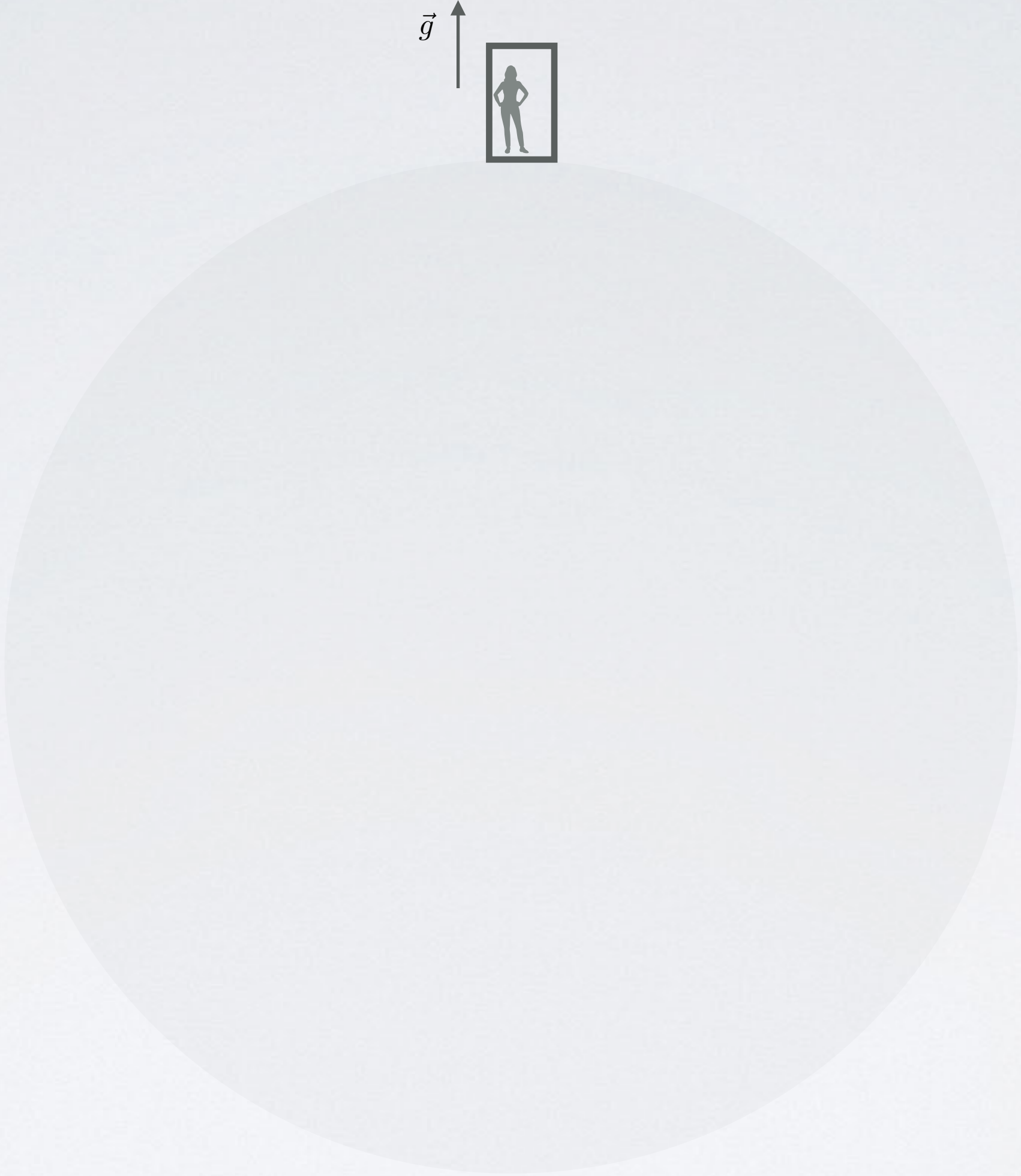
$\vec{g}$



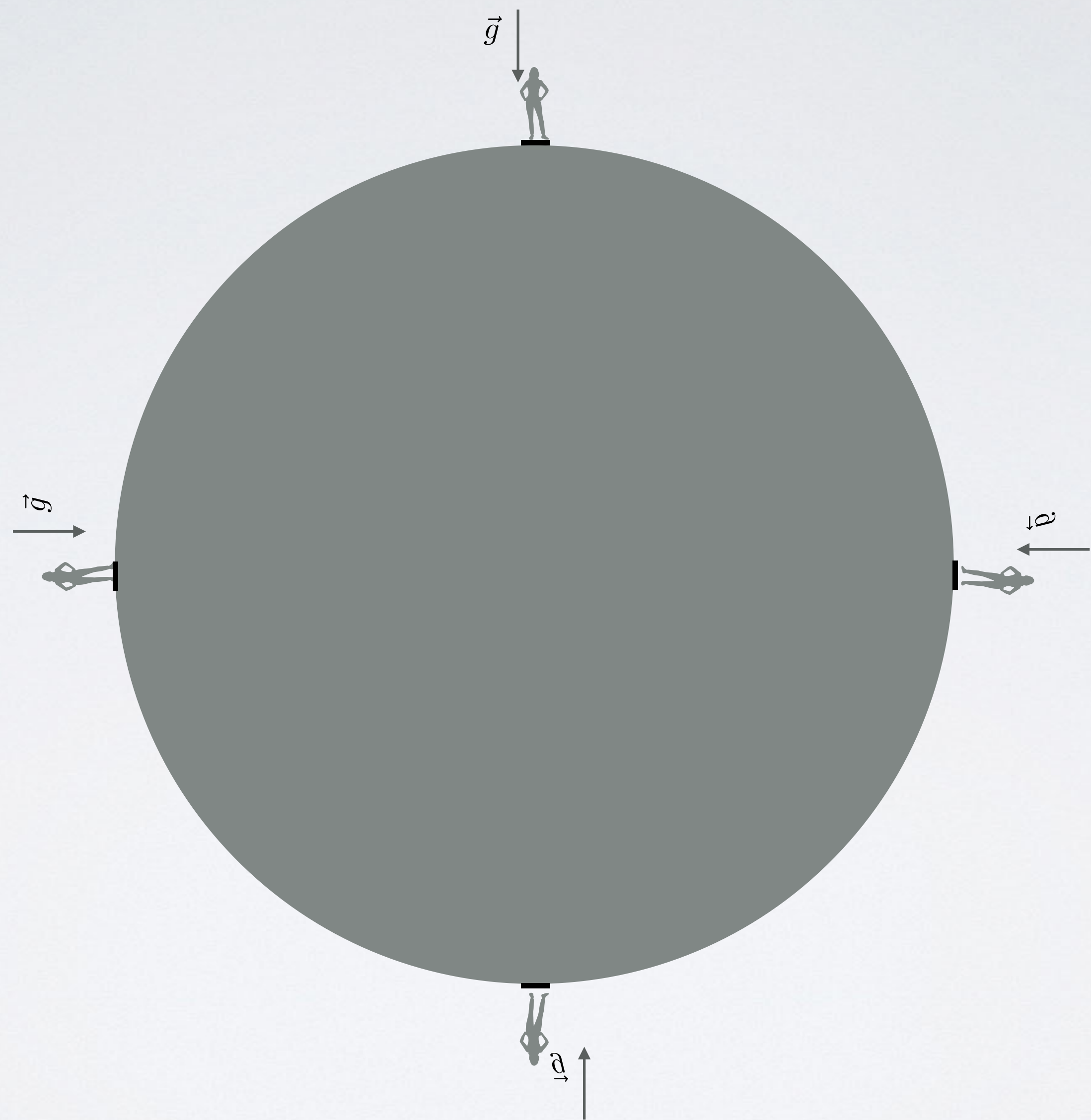




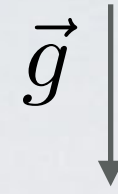








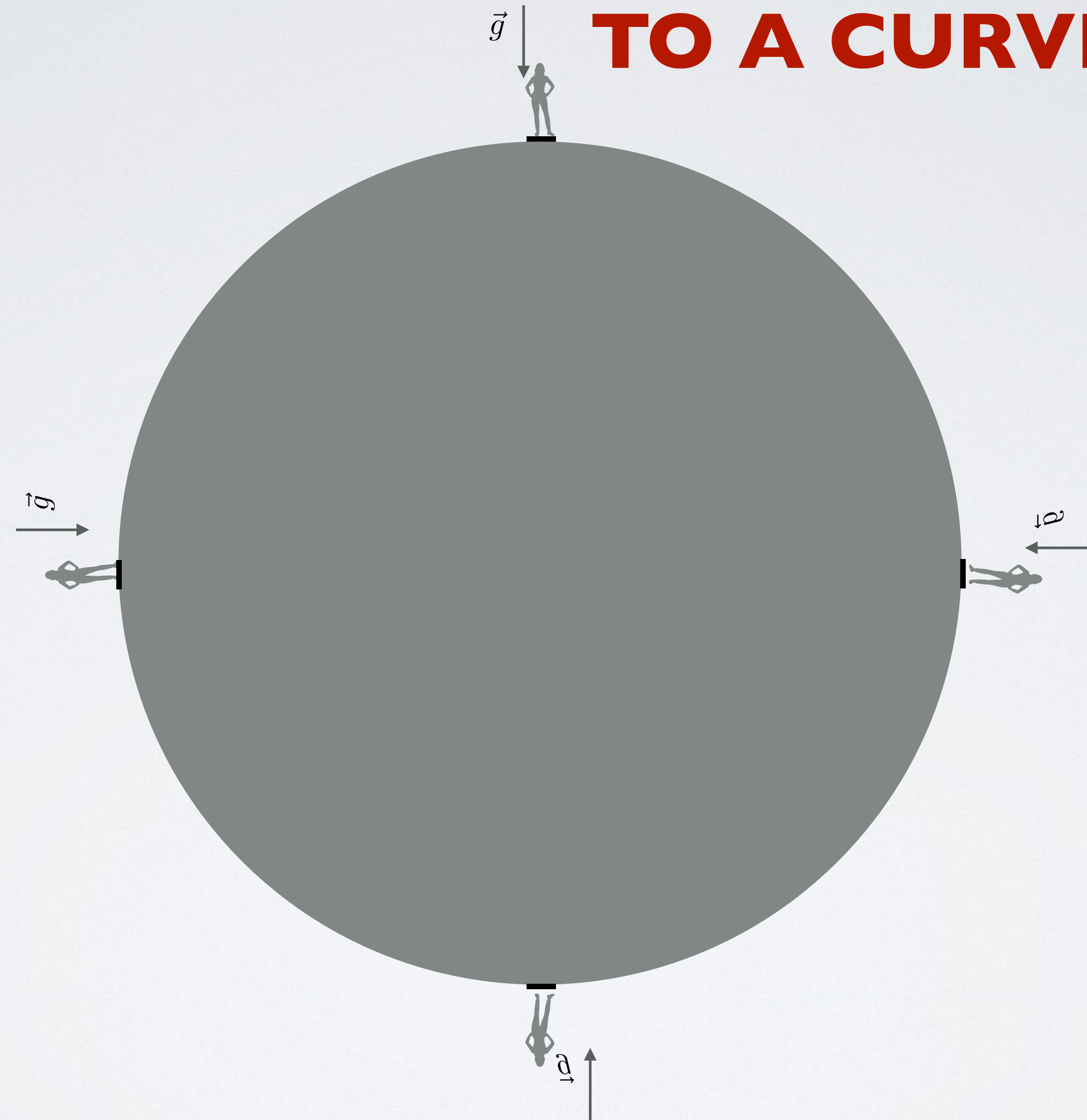




**FROM A FLAT “ELEVATOR”**



**TO A CURVED “ELEVATOR”**





**FROM A FLAT SPACE**

**TO A CURVED SPACE**



**FROM A FLAT SPACE-TIME**

**TO A CURVED SPACE-TIME**