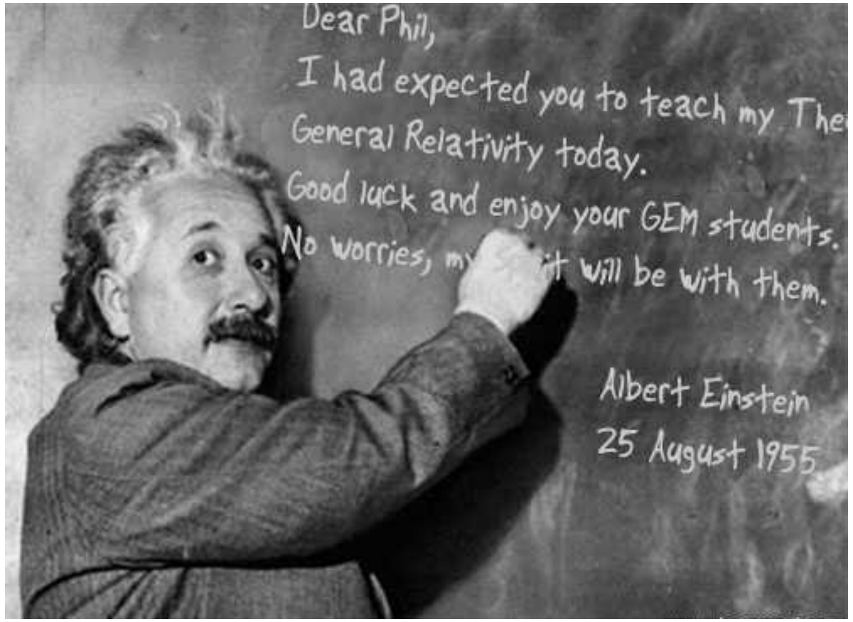
Einstein on History & Philosophy

Albert Einstein was extremely interested in the philosophical conclusions of his work. He writes: "I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today - and even professional scientists - seem to me like somebody who has seen thousands of trees but has never seen a forest. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is - in my opinion - the mark of distinction between a mere artisan or specialist and a real seeker after “truth”."

Einstein’s letter to Robert A. Thornton, 7 December 1944. *EA* 61-574.

Lecture 4



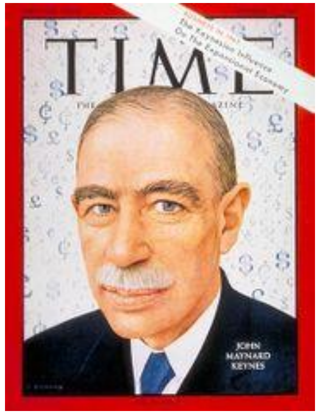
Einstein's Famous Pose
A Humorous Account

The difficulty !

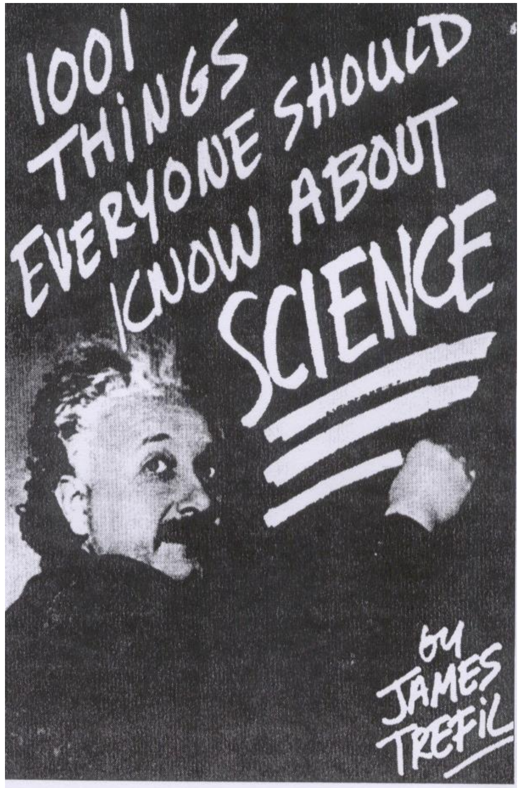
The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds.

J.M. Keynes

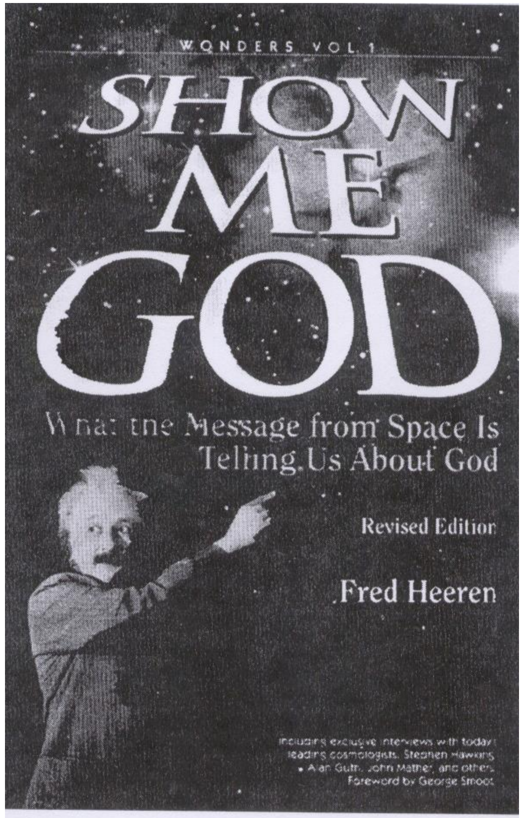
(1883-1946)



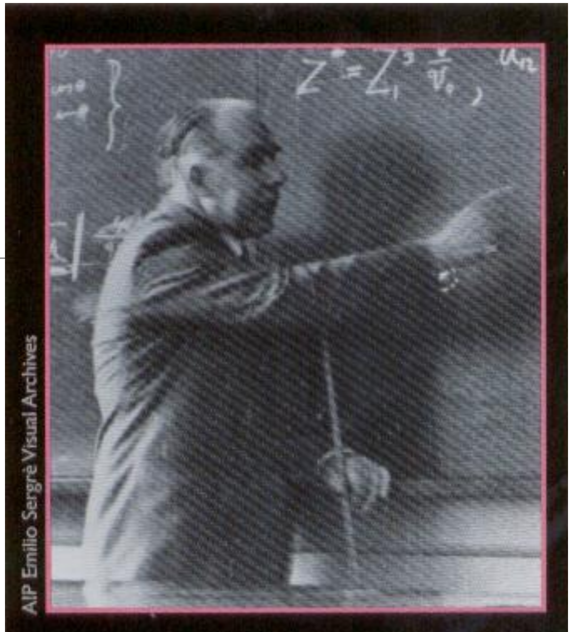
Other Similar Poses



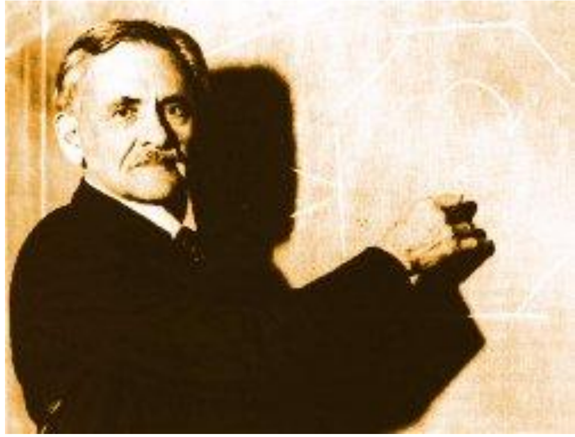
ig. 2. Jacket cover of James Trefil's *1001 Things Everyone hould Know About Science* (Doubleday, New York 1992). *Reproduced with permission of Doubleday, a division of Bantam Doubleday Dell Publishing Group, Inc.*



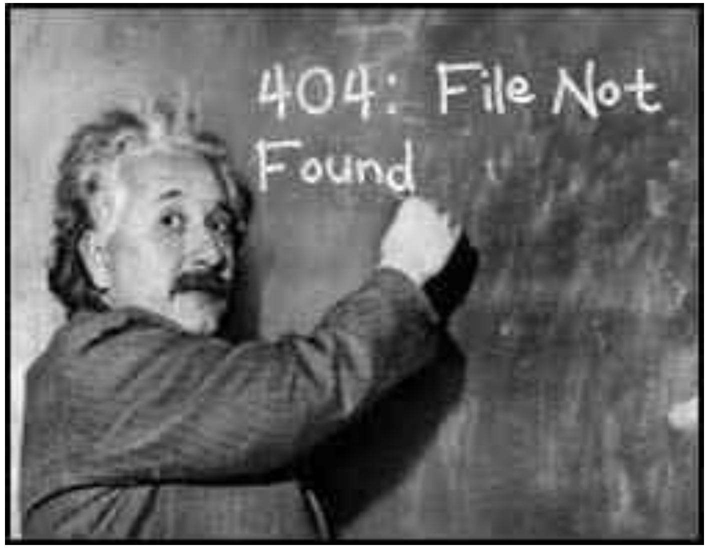
j. 3. Jacket cover of Fred Heeren's *Show Me God: What th essage from Space Is Telling Us About God*, rev. ed. heeling, Ill., Day Star, 1997). *Reproduced with permission of Fred Heer*

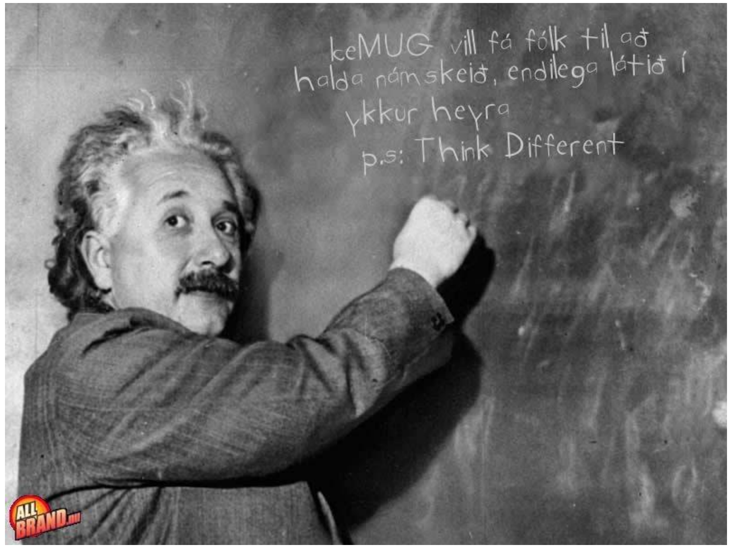


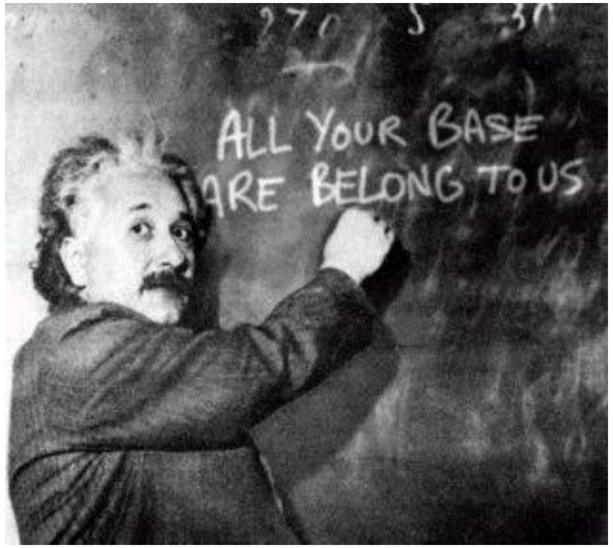
Niels Bohr (1885–1962) made essential contributions to our understanding of atomic structure.



More Advertisements

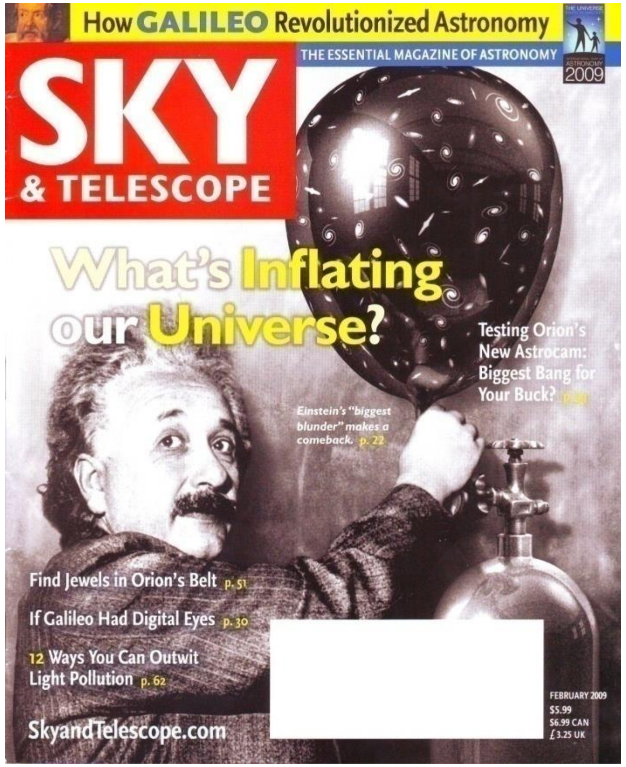




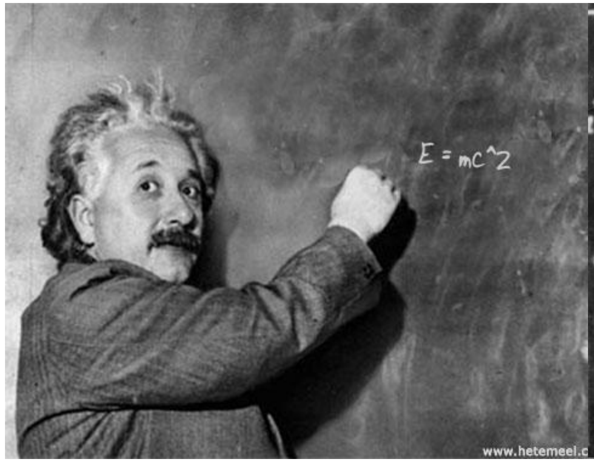


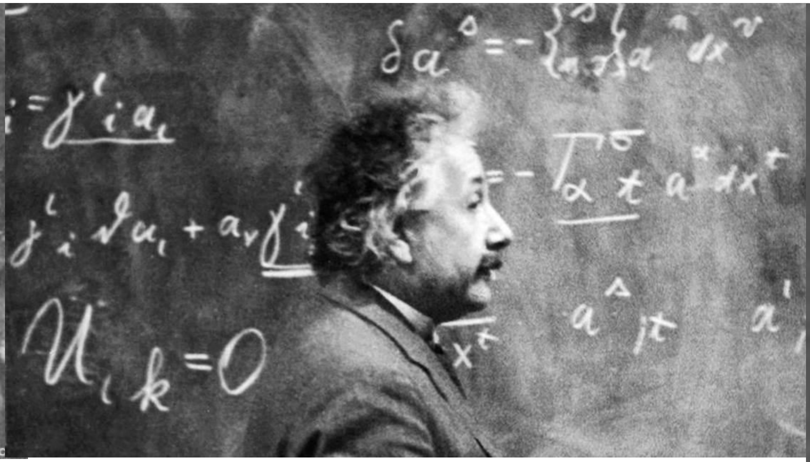
Some More Advertisements

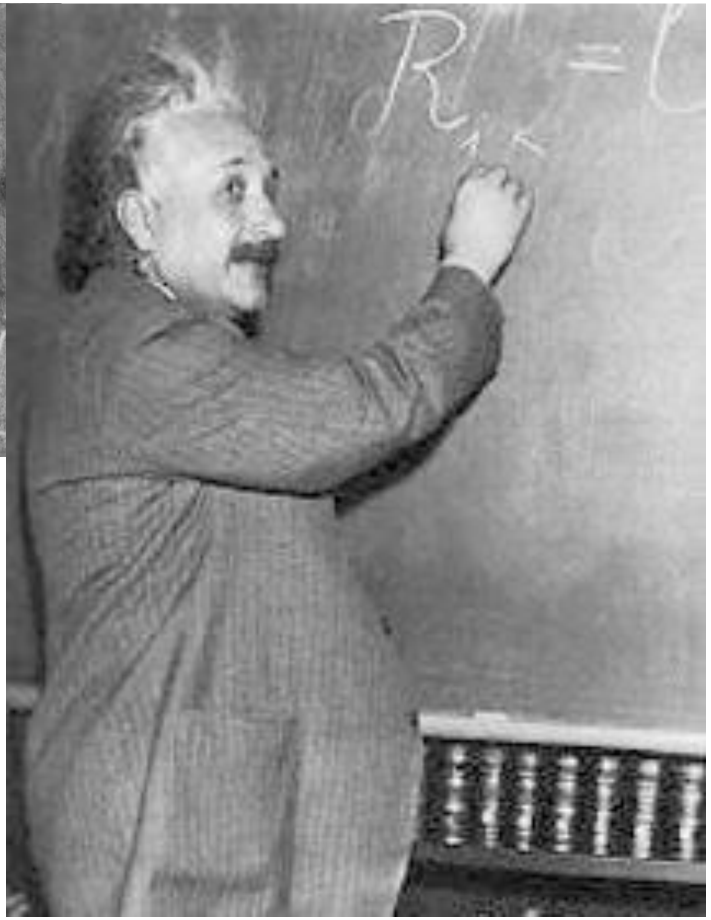
Fig. 4. Billboard advertising Apple Computers. Photo, taken by *Sylvia Topper* in Toronto, August 1998 includes author D.T.

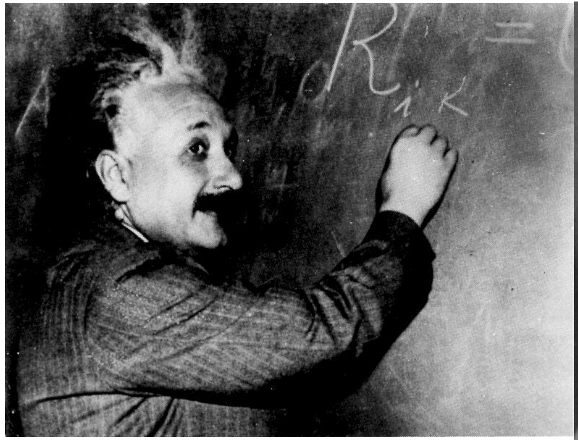


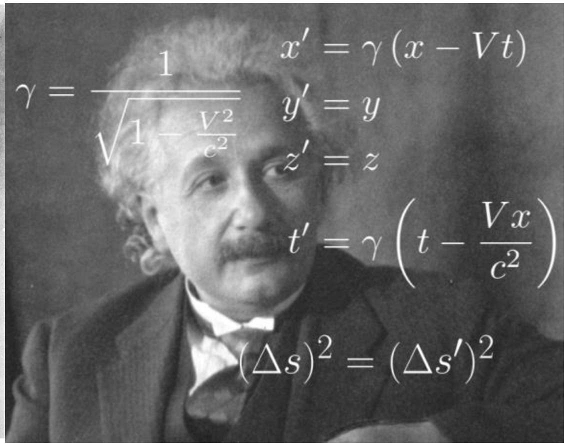
So what exactly did Einstein write ?



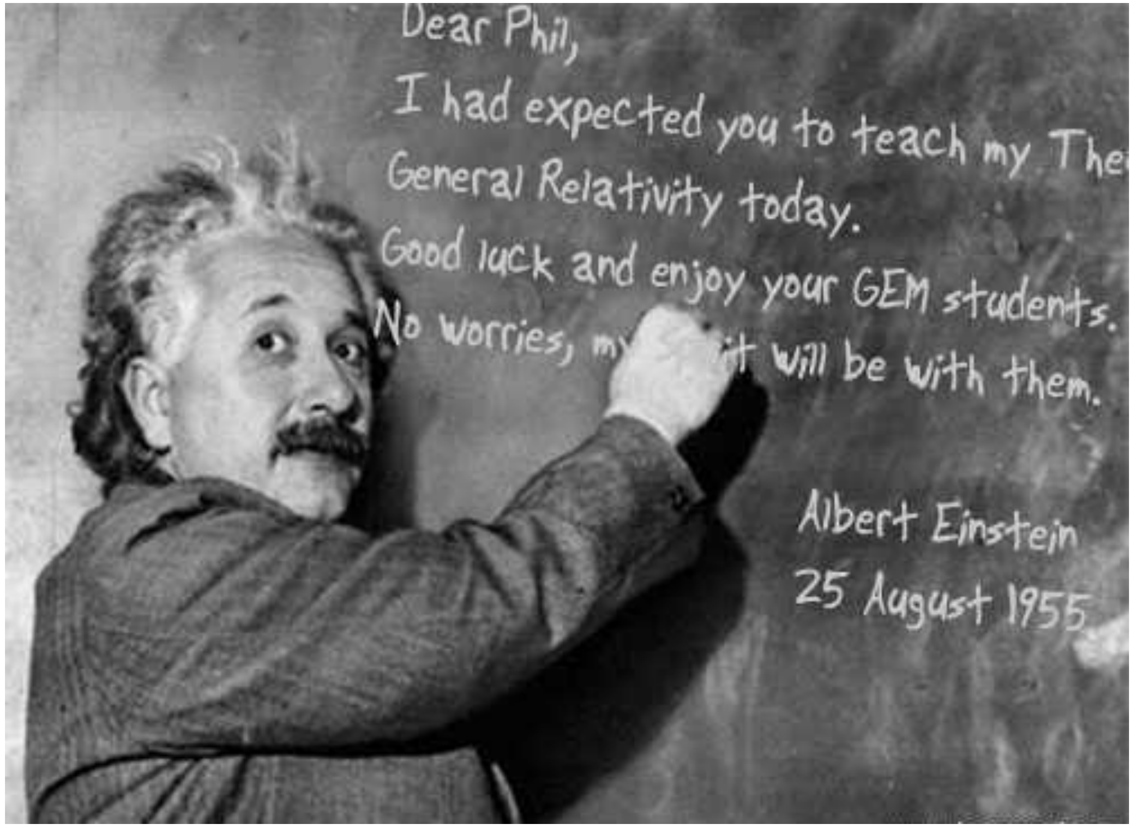








Do it yourself … souvenir



Born on the Π day

http://www.hetemeel.com/einsteinform.php

At Mount Wilson Observatory

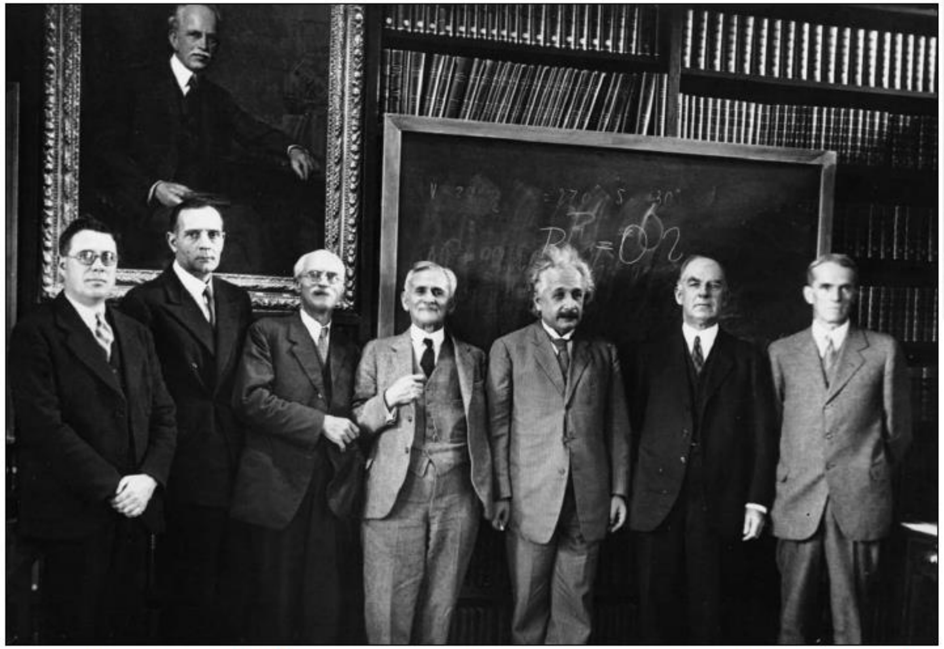
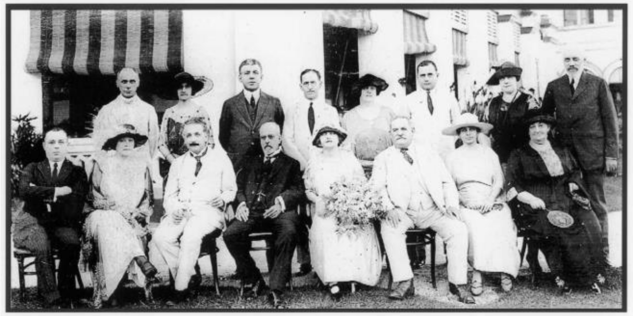
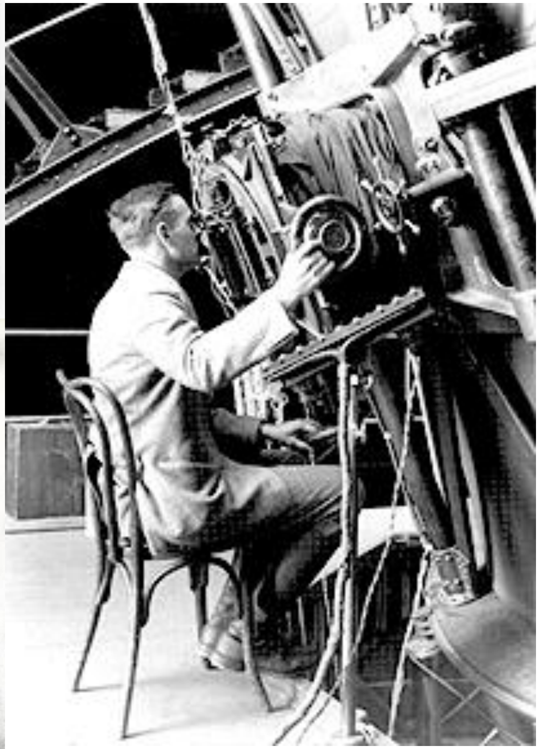


Fig. 6. Group picture at the Mount Wilson Observatory Library, January or early February 1931. From the left: Milton L. Humason, Edwin P. Hubble, Charles E. St. John, Albert A. Michelson, Einstein, William W. Campbell, and Walter S. Adams. The portrait is of George Ellery Hale, founder of the Mount Wilson Observatory. *Reproduced with permission of the Observatories of the Carnegie Institution of Washington.*



Albert Einstein with prominent members of Singapore's Jewish community.
Photo includes, seated from left to right: the Einsteins' hosts, Alfred Montor and his wife;
Meyer, whom Einstein refers to as 'Croesus'; and Einstein's wife Elsa, Meyer's daughter Mo

Met Charlie Chaplin and Upton Sinclair



Hubble ... expansion of the Universe

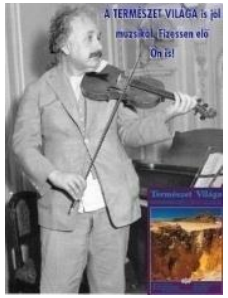
Einstein met The 2 % Speech ...
hosted by R. Millikan, Nobel Prize 1923

Host: R. Millikan

... he did experiments to disprove the photon ... even after his own experimental confirmation he did not believe in the theory.

“Experiment has outrun theory, or better, guided by erroneous theory, it has discovered relationships which seem to be of the greatest interest and importance, but the reasons for them are as yet not at all understood”

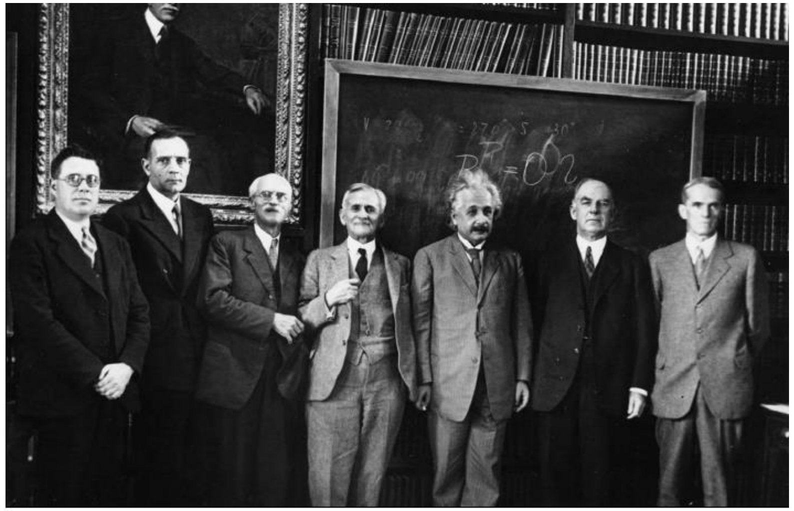
... perhaps they were deflected by the refraction of gases in the solar atmosphere, an explanation that was “plausible” ... he said he hoped to be true.



Mt. Wilson Observatory 1931

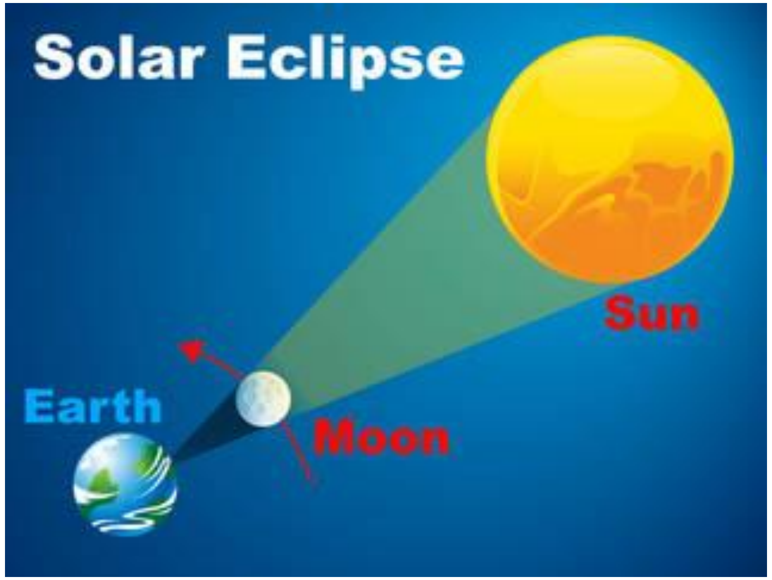
From left, Walters S. Adams succeeded George Ellery Hale, as Director of Mt. Wilson Observatory.

Studied gravitational red-shift of burnt-out stars Sirius B, the companion star of Sirius. In 1915, he found that Sirius B is 50,000 times as dense as water hence a good candidate to test Einstein's General Relativity.



Mt. Wilson Observatory 1931

William Campbell, President of the U. of California and Director of Lick Observatory. He worked on gravitational bending of light. 1922 Solar Eclipse, he found full agreement with Einstein's prediction. But in 1918 Eclipse, he got a negative result.



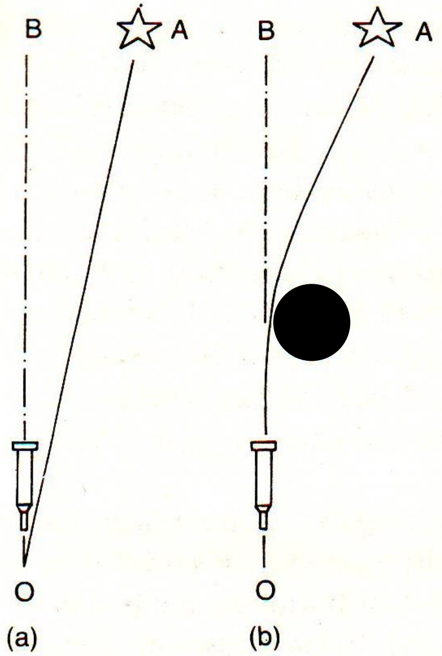
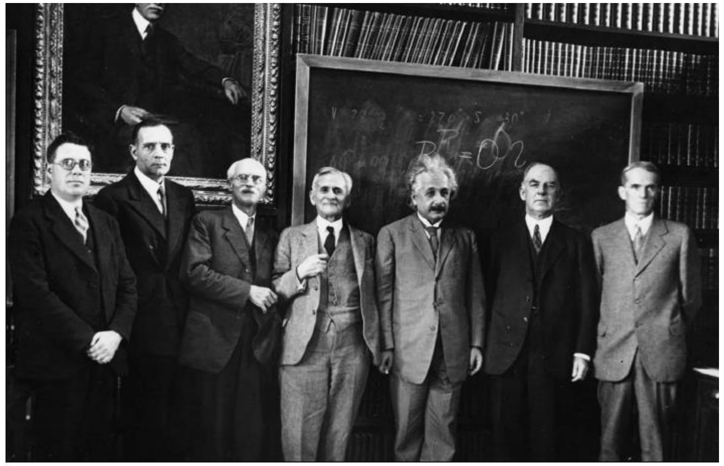


Fig. 10.4 The principle of the light-bending experiment that provided a sensational verification of the general theory is illustrated here. Consider the star A in (a). If the telescope is directed along some other direction like OB, then light from the star would obviously not reach the observer looking through the telescope. However, if there is a massive object (like our Sun) in between, then the light could bend while travelling from the star to the Earth, and the star become visible as illustrated in (b). Such experiments can only be performed during a total solar eclipse for it is only then that the brightness of the Sun does not obscure the star. Much before the expeditions to observe the stars during the eclipse (of 1919), Einstein wrote to his friend Besso, "I do not doubt the correctness of the whole system [i.e., the general theory], whether the observation of the solar eclipse succeeds or not."

Mt. Wilson Observatory 1931

Albert Michelson, did the famous Michelson and Morley “no Aether experiment”, Case Institute of Technology in Cleveland, Ohio 1887.

But he continued to believe to the end of his life in the existence of aether !



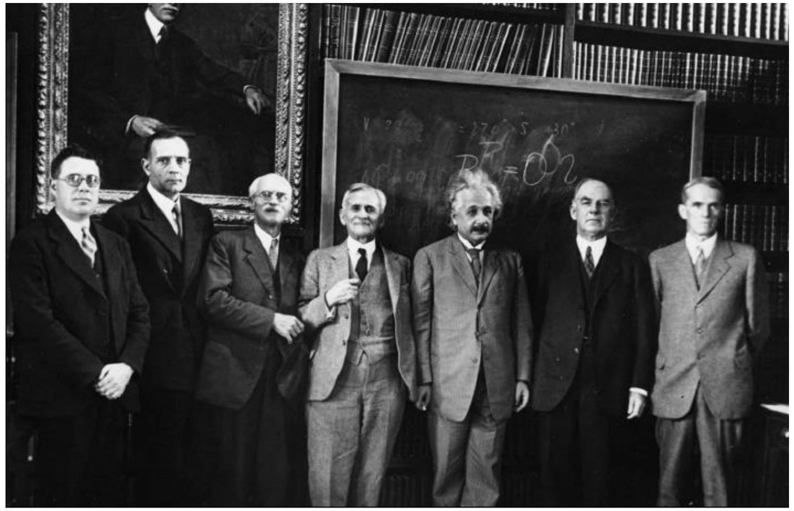
Mt. Wilson Observatory 1931

Charles St. John, collaborator of Hale at Mt. Wilson.

He performed a series of experiments to detect the gravitational redshift in the solar light that bombards earth.

1917 negative result

1923 positive; confirming GR.

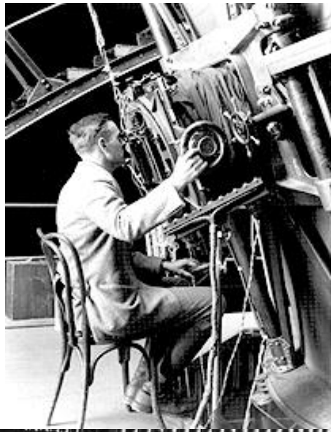


The Most Unlikely Pair !

Edwin Hubble, the lawyer, heavy weight boxer, high school teacher, soldier, Oxford Rhodes Scholar

Discovered the Universe is expanding : The Hubble's Law

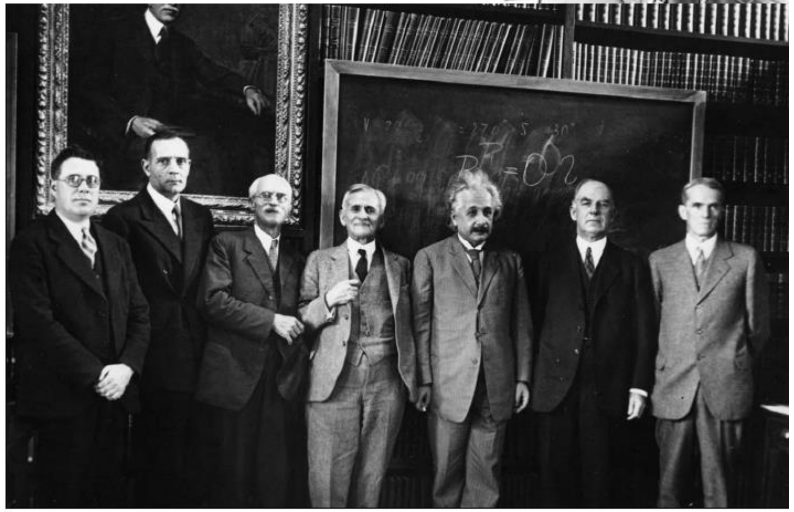
Why was he not awarded The Nobel Prize?



Milton Humason, self taught astronomer, mule-train driver, janitor at Mount Wilson Observatory.

Discovered that the receding velocities of galaxies and the increasing distances to the same galaxies were directly related.

This is later known as Hubble's Law.



Allan Sandage

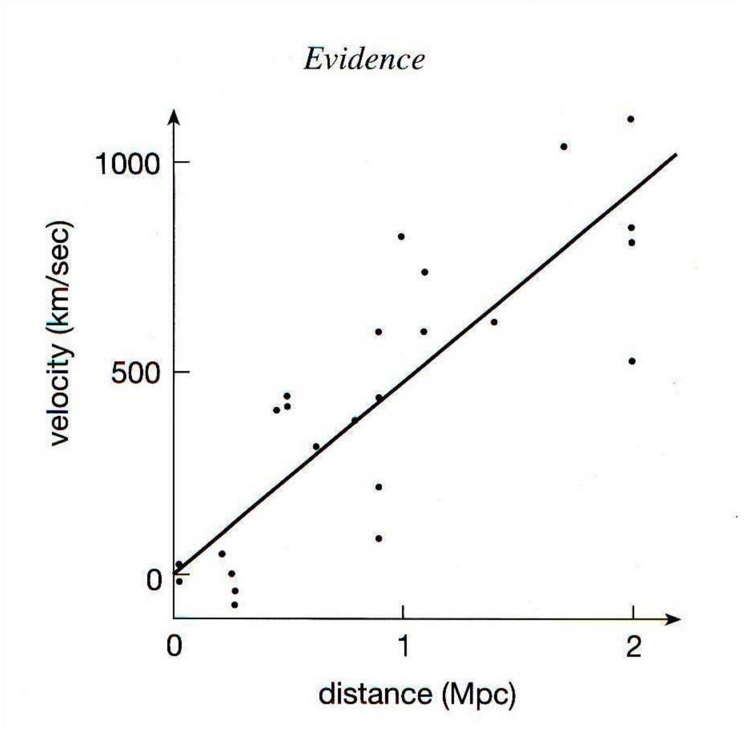
A famed astronomer at Mt. Wilson.

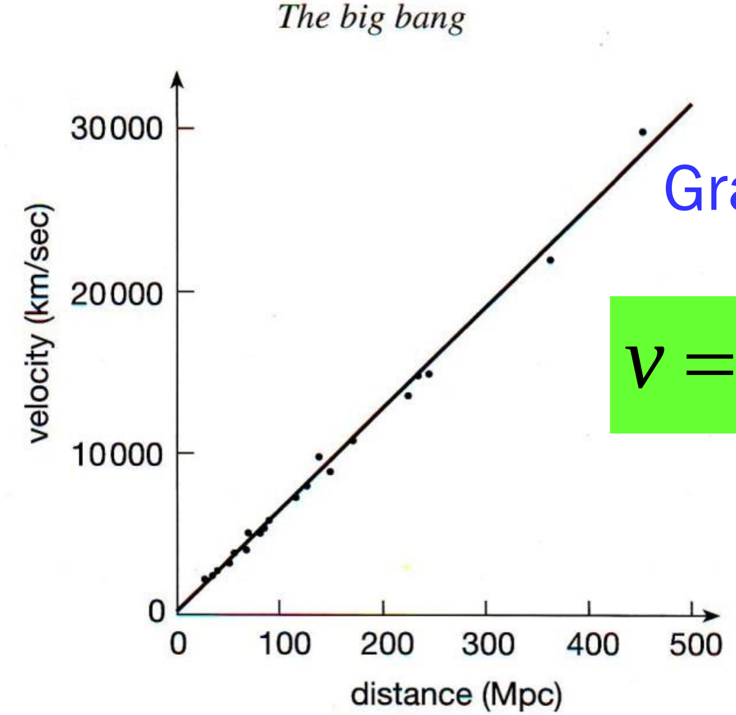
“Hubble never accepted the real expansion of the Universe.”

“I expect all this was over the astronomer’s head since they were all observers, not theoreticians.”

The Hubble's (Humason) Law

The Hubble's Law, $H_0 = 71$ km/s/Mpc



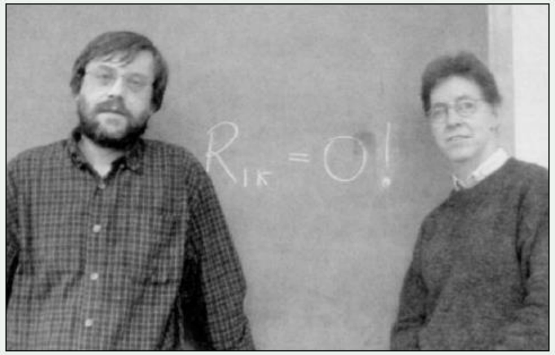


Gradient

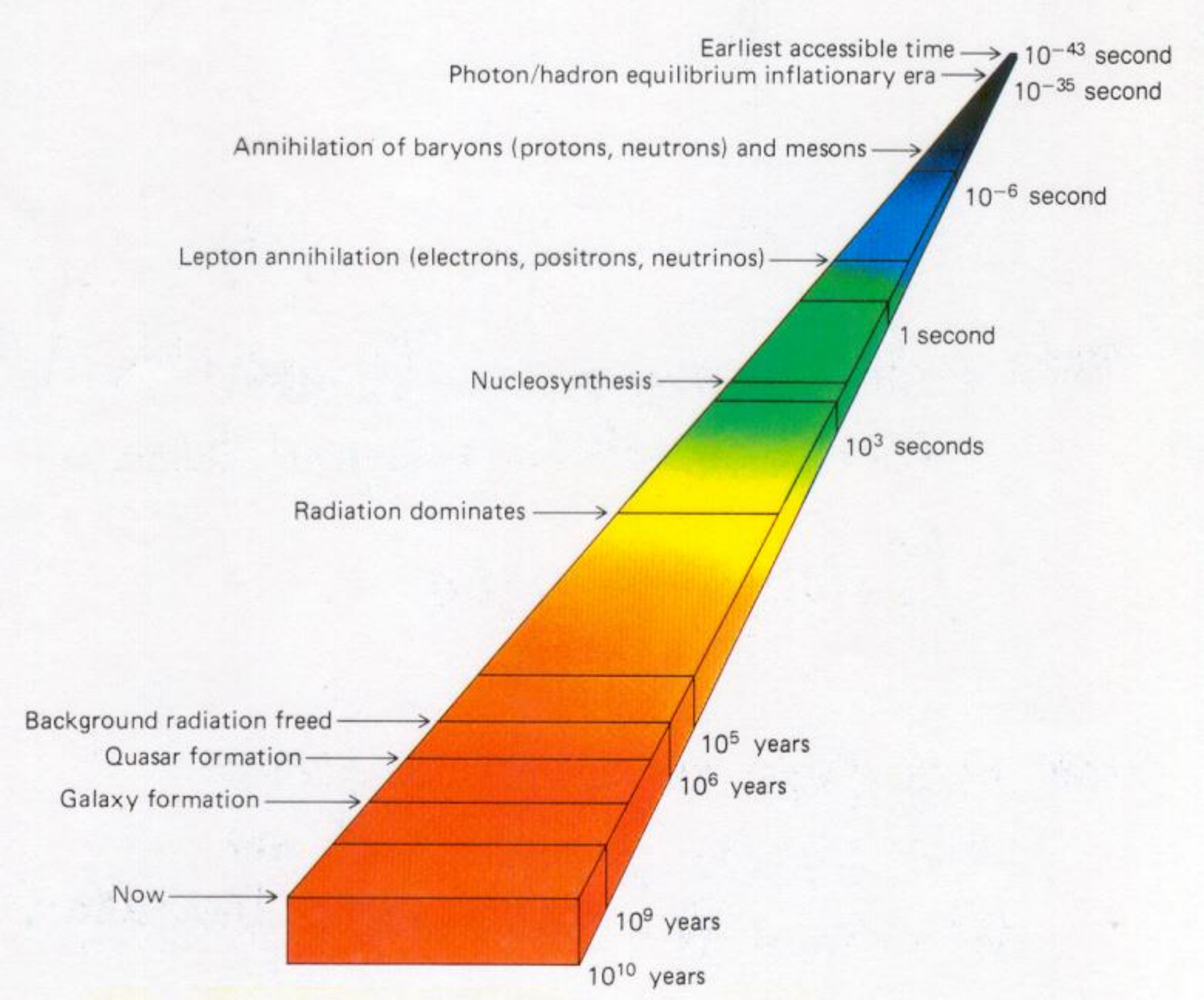
$$\boxed{v = H_0 r}$$

Distance from the earth

1 pc = 3.26 light years, 1 ly = 9.46 x 10^{15} m (distance for light to travel in one year)



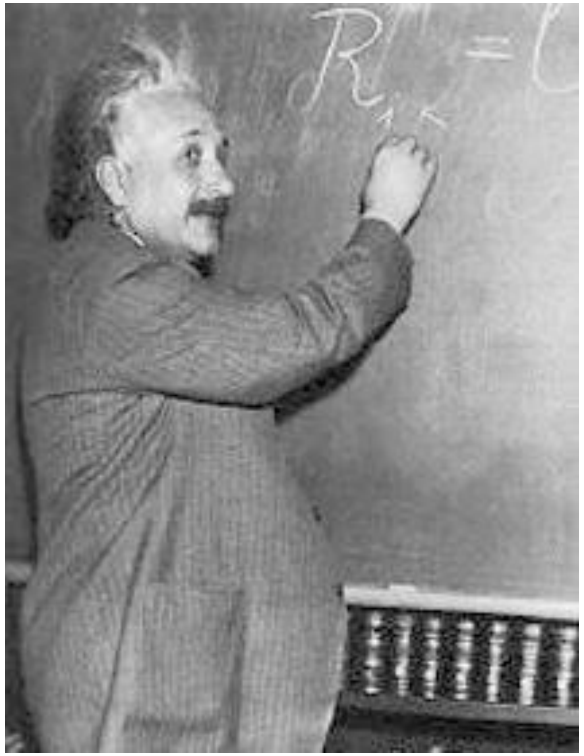
Authors Dwight Vincent, left, and David Topper.



A Cosmologist &
A Historian of Science

David Topper and Dwight E. Vincent, *Posing Einstein's Question: Questioning Einstein's Pose*, THE PHYSICS TEACHER Vol. 38, May 2000

At last you see it, Voilà ?



$$R_{ik} = 0 \quad ?$$

How can one understand ?

In full glory …
Wah Lau ! … this time … Voi la'

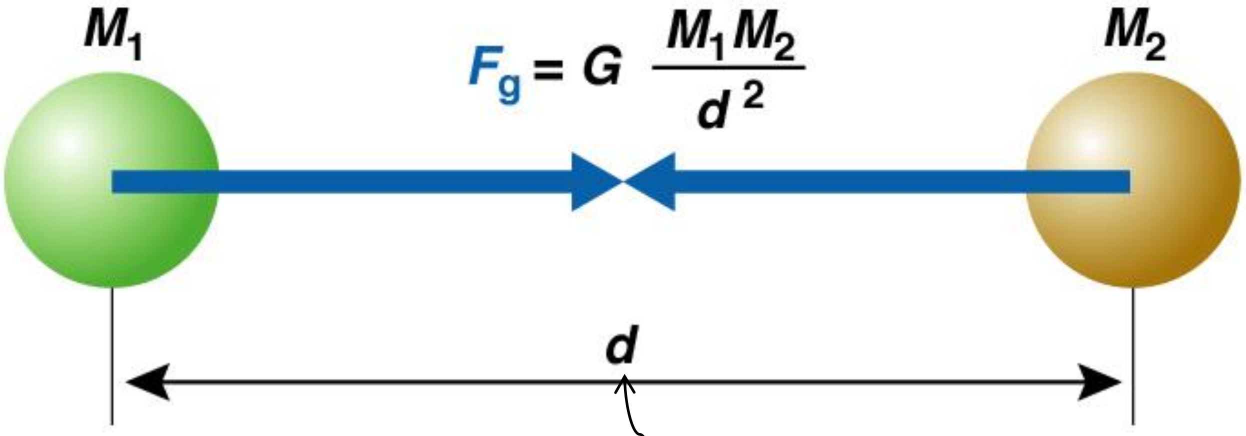
A Brief Revision

On Newton’s Law of Gravity

What determines the strength of gravity?

The **Universal Law of Gravitation** (“*action at a distance*”) **:**

1. Every mass attracts every other mass.
2. Attraction is *directly* proportional to the product of their masses.
3. Attraction is *inversely* proportional to the *square* of the distance between their centers.



Notation : r

Newtonian Gravitational Potential

$$F(r) = G\frac{Mm}{r^2}$$

$$V(r) = -G\frac{Mm}{r}$$

Inverse Square Law

Some books
Notation : U (r)

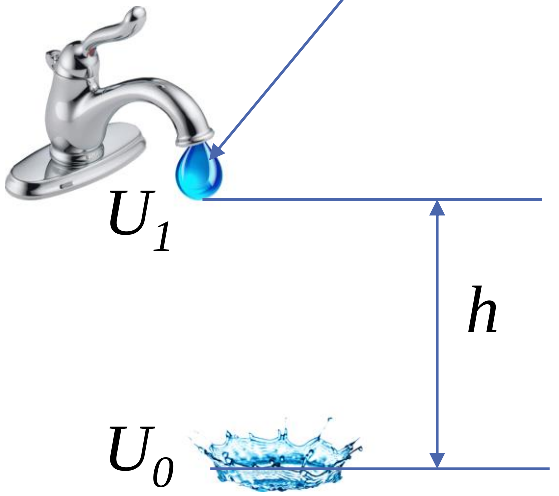
M is the mass of the source.
G is the gravitational constant.
r is the distance between the location of the source of the gravitational field and the point where the field is being evaluated.

High School Text

Recall for school

Potential

Energy = mgh



9.12 Gravitational Potential Energy Close to the Earth's Surface

In Chapter 6, we found that the gravitational potential energy of a mass m at a height h above the ground is greater than when it is on the ground by mgh. This can be deduced from the formula for gravitational potential energy, i.e.,

$$U = -\frac{GMm}{r}.$$

For a mass m on the earth's surface, its gravitational potential energy

$$U_0 = -\frac{GMm}{R} \qquad (r = R, \text{ radius of earth})$$

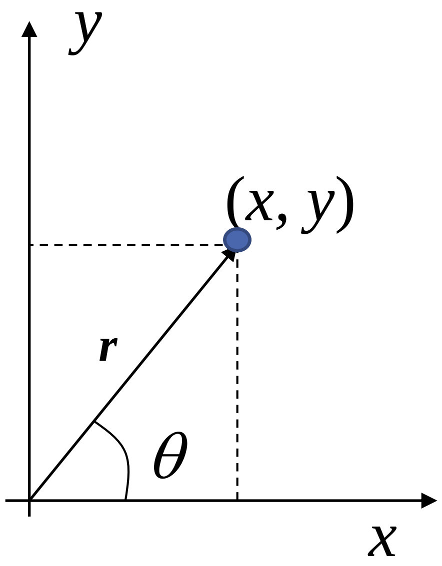
When the mass m is at a height h above the earth's surface, its gravitational potential energy

$$U_1 = -\frac{GMm}{(R+h)} \qquad r = (R+h)$$

Therefore, the increase in gravitational potential energy is

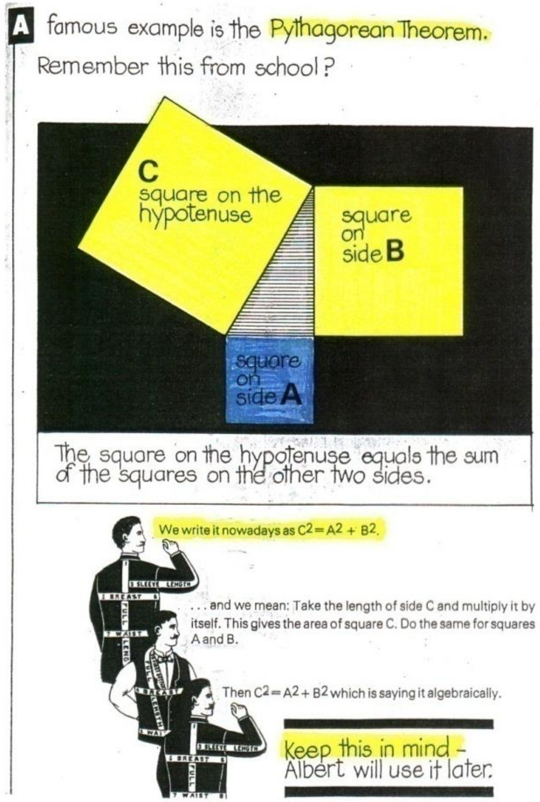
$$\begin{aligned}
U_1 - U_0 &= -\frac{GMm}{(R+h)} - \left(-\frac{GMm}{R}\right) \\
&= \frac{GMm}{R} - \frac{GMm}{R\left(1+\frac{h}{R}\right)} \\
&= \frac{GMm}{R}\left[1 - \frac{1}{1+\frac{h}{R}}\right] \\
&= \frac{GMm}{R}\left[1 - \left(1+\frac{h}{R}\right)^{-1}\right] \\
&= \frac{GMm}{R}\left[1 - \left(1-\frac{h}{R}+\dots\right)\right] \quad \text{neglecting terms in } \frac{h^2}{R^2} \text{ and higher, if } h \ll R. \\
&= \frac{GMmh}{R^2} \qquad \left(\frac{GMm}{R^2} = mg\right) \\
&= mgh
\end{aligned}$$

Revision : Vectors and Pythagoras



2 Dimensional Cartesian (or sometimes called Euclidean co-ordinate.

$$r^2 = x^2 + y^2 = (r\cos\theta)^2 + (r\sin\theta)^2$$



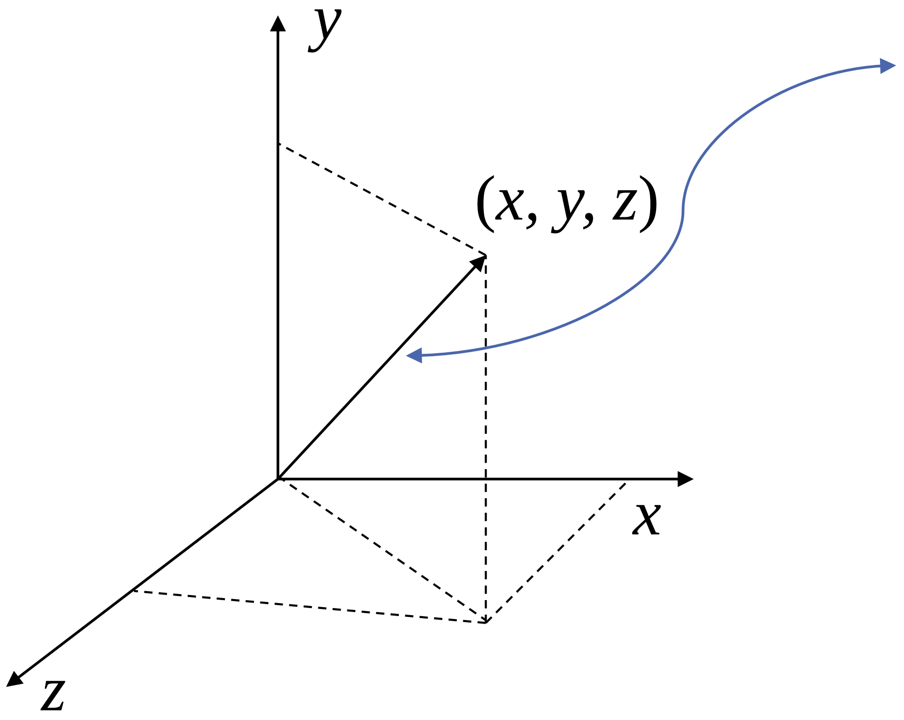
r is called the magnitude, invariant quantity.

In short: it is a Vector :

What is a scalar object then ? *It is* x or y by itself

3 Dimensional Vectors

3 Dimensional Cartesian Co-ordinate



$$r = \sqrt{x^2 + y^2 + z^2}$$

But

Einstein Relativity: (t, x, y, z) or (x, y, z, t)

4 Dimension Co-ordinate

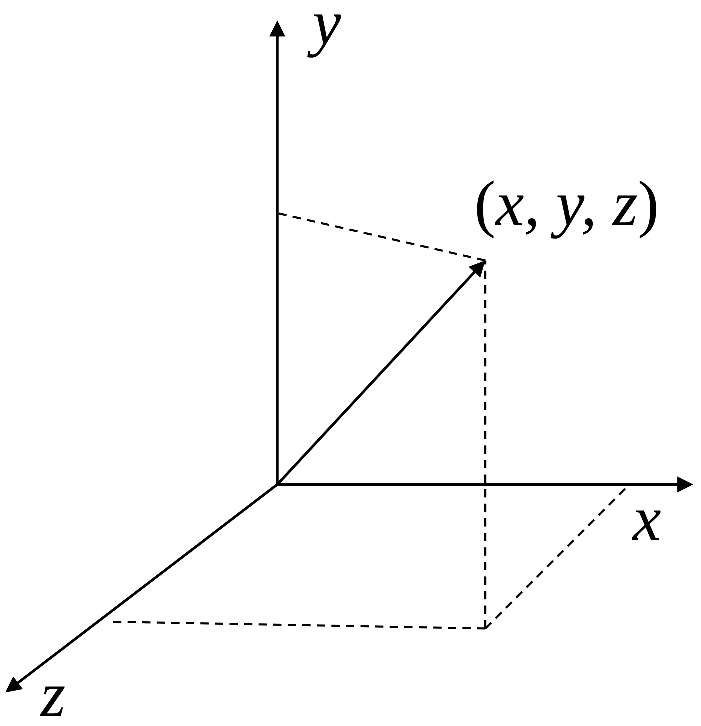
Reminder: Special Relativity: (ct, x, y, z), c is set to one for simplicity

Notice that "time, t is treated as equal footing" as x, y, z.

3 Dimensional Cartesian Co-ordinate

3 dimensional Cartesian Co-ordinates

$$r = \sqrt{x^2 + y^2 + z^2}$$



Infinitesimal changes in the co-ordinates

$$dr^2 = dx^2 + dy^2 + dz^2$$

4 Dimensional Vectors

4 Dimensional Cartesian Co-ordinate

We expect to write down this $$r = \sqrt{(ct)^2 + x^2 + y^2 + z^2}$$

And Infinitesimal changes $$dr^2 = d(ct)^2 + dx^2 + dy^2 + dz^2$$

But it should be according to Einstein (note the negative sign) $$dr^2 = -d(ct)^2 + dx^2 + dy^2 + dz^2$$

?

Strange indeed, why ?

Cheat a bit (some books) !

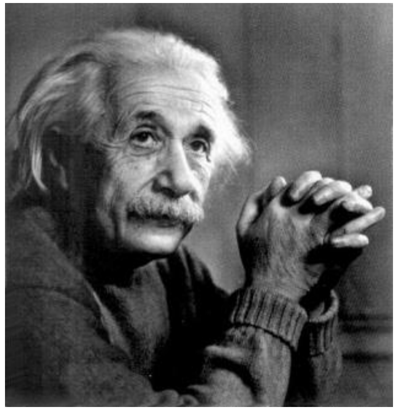
$$dr^2 = d(c\tau)^2 + dx^2 + dy^2 + dz^2$$

$$where\ c\tau = ict$$

So can one visualize 4 dimensional Space-Time ? … called Minkowski space

I rarely think … in words at all.

A. Einstein (*1879 - 1955*)



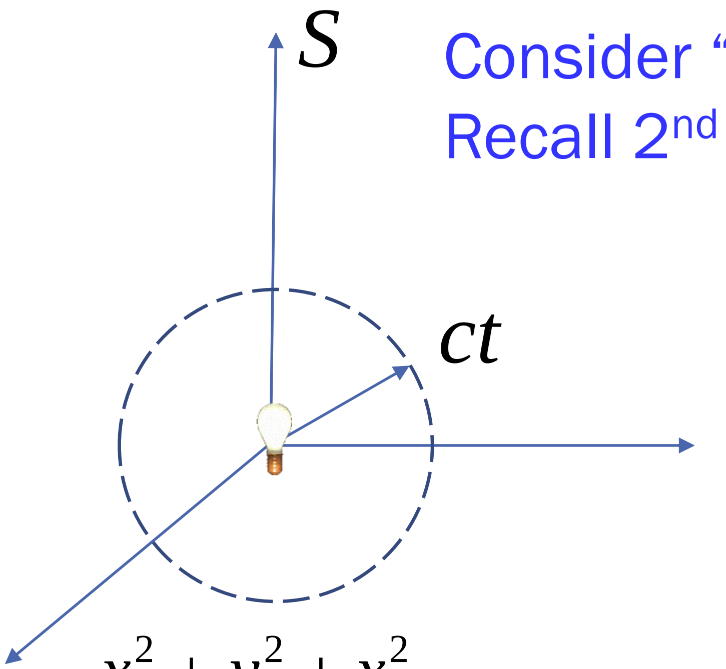
Note: $\left(\sqrt{-1}\right)^2 = -1$

or $i^2 = -1$

How to understand the negative sign ?

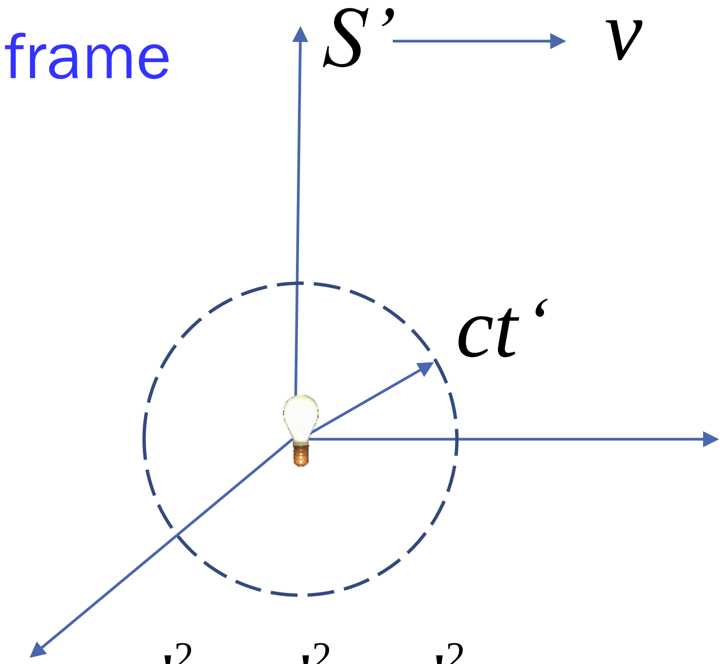
Consider “Light” in 2 reference frame

Recall 2nd Postulate



$$c^2 = \frac{x^2 + y^2 + x^2}{t^2}$$

$$= -c^2t^2 + x^2 + y^2 + z^2 = 0$$



$$c^2 = \frac{x'^2 + y'^2 + x'^2}{t'^2}$$

$$= -c^2t'^2\, x'^2 + y'^2 + z'^2 = 0$$

In fact, the glory of Mathematics is that we do not have to say what we are talking about. R. Feynman

In Mathematics, you don't understand things, you just get used to them. Von Neumann

Let us look at the generalization of the 3 dimensional distance relation to 4 dimensions

$$
\begin{aligned}
dr^2 = \\
&+ g_{tt}d(ct)d(ct) && + g_{tx}d(ct)dx && + g_{ty}d(ct)dy && + g_{tz}d(ct)dz \\
&+ g_{xt}dxd(ct) && + g_{xx}dxdx && + g_{xy}dxdy && + g_{xz}dxdz \\
&+ g_{yt}dyd(ct) && + g_{yx}dydx && + g_{yy}dydy && + g_{yz}dydz \\
&+ g_{zt}dzd(ct) && + g_{zx}dzdx && + g_{zy}dzdy && + g_{zz}dzdz
\end{aligned}
$$

What Einstein was saying is the general Pythagorean expression is not just 1) 3 or 4 terms and also the 2) the co-efficients can be –ve or a function called g terms … notice the matrix formation.

Minkowski space

How to take care of the negative / positive signs & coefficients ?

Einstein's summation convention (or Invention !)

$$dr^2 = \sum_{\mu=0}^{3} \sum_{\nu=0}^{3} g_{\mu\nu} dx^\mu dx^\nu$$

Not exponentials & not powers)

$$(ct, x, y, z) \longrightarrow (x^0, x^1, x^2, x^3)$$

Note 1 (in the literature) $ds^2 = g_{\mu\nu} dx^\mu dx^\nu$

Note 2 Summation signs disappeared

Note 3 can you see all gs forms a matrix

g_{uv} is a matrix you've learned in school

$$ds^2 = \sum_{\mu=0}^{3}\sum_{\nu=0}^{3} g_{\mu\nu} dx^\mu dx^\nu$$

$$\begin{pmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{pmatrix}$$

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

$$\begin{pmatrix} g_{tt} & g_{tx} & g_{ty} & g_{tz} \\ g_{xt} & g_{xx} & g_{xy} & g_{xz} \\ g_{yt} & g_{yx} & g_{yy} & g_{yz} \\ g_{zt} & g_{zx} & g_{zy} & g_{zz} \end{pmatrix}$$

The g_{uv} has a name, called Metric Tensor which is a Matrix. Recall the elements in the Matrix are the co-efficients of the Pythagorean expression.

In General Relativity the array in the Matrix … are potential functions

$$\begin{pmatrix} g_{tt} & g_{tx} & g_{ty} & g_{tz} \\ g_{xt} & g_{xx} & g_{xy} & g_{xz} \\ g_{yt} & g_{yx} & g_{yy} & g_{yz} \\ g_{zt} & g_{zx} & g_{zy} & g_{zz} \end{pmatrix} \qquad ds^2 = V_{\mu\nu} dx^\mu dx^\nu \qquad \begin{pmatrix} V_{tt} & V_{tx} & V_{ty} & V_{tz} \\ V_{xt} & V_{xx} & V_{xy} & V_{xz} \\ V_{yt} & V_{yx} & V_{yy} & V_{yz} \\ V_{zt} & V_{zx} & V_{zy} & V_{zz} \end{pmatrix}$$

The Metric Tensor is a Matrix.

Dual roles : g (what is this role ?) or V (potential)

How do we know g and V are related ?

a) If motion of any body not travelling at the speeds close to c,

b) and in the vicinity of low intensity gravitational field

The Metric reduces to

$$V_{tt} = 1 + \frac{2V(r)}{c^2}$$

$$\begin{pmatrix} V_{tt} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

Recall : Correspondence Principle

Newtonian Gravitational Potential

$$F(r) = G\frac{Mm}{r^2}$$

$$V(r) = -G\frac{Mm}{r}$$

Inverse Square Law

Some books Notation : U (r)

Attractive force

M is the mass of the source.
G is the gravitational constant.
r is the distance between the location of the source of the gravitational field and the point where the field is being evaluated.

This somewhat complicated looking expression is a generalization of the 3 dimensional distance relation to 4 dimensions. Let us rewrite.

$$ds^2 =$$

$$\begin{array}{llll}
V_{tt}d(ct)\bullet d(ct) & +V_{tx}d(ct)dx & +V_{ty}d(ct)dy & +V_{tz}d(ct)dz \\
V_{xt}dxd(ct) & +V_{xx}dxdx & +V_{xy}dxdy & +V_{xz}dxdz \\
V_{yt}dyd(ct) & +V_{yx}dydx & +V_{yy}dydy & +V_{yz}dydz \\
V_{zt}dzd(ct) & +V_{zx}dzdx & +V_{zy}dzdy & +V_{zz}dzdz
\end{array}$$

Hard work; to be beneficial, it must be regular, rigorous and rewarding.

J.E. Anderson, The Reader's Digest

After Einstein has obtained the equation at the end of 1915 … after what he referred to as a period of unremitting labour.

Foster and Nightingale

The Price to pay … for new ideas

It is not until we attempt to bring the theoretical part of our training into contact with the practical that we begin to experience the full effect of what Faraday has called "mental inertia" … not only the difficulty of recognizing among the objects before us, the abstract relations which we have learned from books, but ***the distracting pain of wrenching the mind away from the symbols to the objects, and from the objects back to symbols***. This, however, is the price we have to pay for new ideas.

J.C. Maxwell

Intro. lecture at Cavendish Lab. 1871

In Pure Riemannian Geometry

Einstein continued to play …

$$V_{tx} = V_{xt} \qquad V_{ty} = V_{yt} \qquad V_{tz} = V_{zt}$$

$$V_{xy} = V_{yx} \qquad V_{xz} = V_{zx} \qquad V_{yz} = V_{zy}$$

With these conditions in effect, we see that the gravitational array contains only 10 independent functions. Why ?

In Pure Riemannian Geometry

Einstein continued to play … with symmetric matrix

General Relativity requires an array of potential functions.

$$\begin{pmatrix} V_{tt} & V_{tx} & V_{ty} & V_{tz} \\ V_{xt} & V_{xx} & V_{xy} & V_{xz} \\ V_{yt} & V_{yx} & V_{yy} & V_{yz} \\ V_{zt} & V_{zx} & V_{zy} & V_{zz} \end{pmatrix}$$

Only 10 independent terms left.

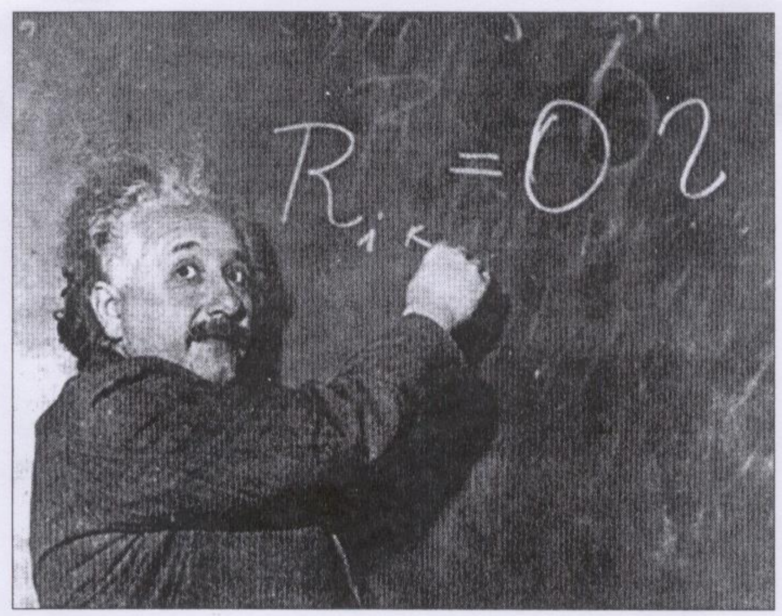


Fig. 1. Einstein at the blackboard of the Mount Wilson Observatory Library, January or early February 1931. In light of one of the themes of this paper, we must point out that our Fig. 1 is cut horizontally below Einstein's right arm. Compare with Fig. 5.

We are now in the position :

$$R_{ik} = 0 \quad ?$$

This is the famous Ricci Curvature Tensor

What is a Tensor ? ... Matrix

In full glory ... Wah Lau ! ... this time ...
'lee kong seem meade' Chim ya, ha !

Of course this is not French !

Voila !

Where did $R_{ik} = 0$ come from ?

The very famous Einstein Field's Equations !

For Vacuum $$R_{tt} = \frac{1}{r}\frac{\partial V_{tt}}{\partial r} + \frac{1}{2}\frac{\partial^2 V_{tt}}{\partial r^2} = 0$$

Non Vacuum $$R_{tt} = \frac{1}{r}\frac{\partial V_{tt}}{\partial r} + \frac{1}{2}\frac{\partial^2 V_{tt}}{\partial r^2} = \frac{4\pi G\rho}{c^2}$$

For Pundits $$R_{\alpha\beta} - \frac{1}{2} R g_{\alpha\beta} = \frac{8\pi G T_{\alpha\beta}}{c^4}$$

Einstein's Field Equation

$$R_{ij} - \frac{1}{2} R g_{ij} = \frac{8\pi G T_{ij}}{c^4}$$

$$\begin{pmatrix} R_{tt} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix} - \frac{1}{2} R \begin{pmatrix} g_{tt} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix} = \frac{8\pi G}{c^4} \begin{pmatrix} T_{tt} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

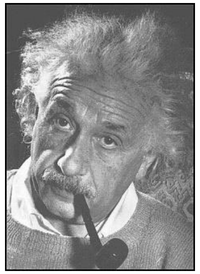
Let's re-write using the notations below

$(ct, x, y, z) \longrightarrow$

(x^0, x^1, x^2, x^3)

$$\begin{pmatrix} R_{00} & - & - & - \\ - & - & - & - \\ - & R_{21} & - & - \\ - & - & - & - \end{pmatrix} - \frac{1}{2} R \begin{pmatrix} g_{00} & - & - & - \\ - & - & - & - \\ - & g_{21} & - & - \\ - & - & - & - \end{pmatrix} = \frac{8\pi G}{c^4} \begin{pmatrix} T_{00} & - & - & - \\ - & - & - & - \\ - & T_{21} & - & - \\ - & - & - & - \end{pmatrix}$$

Einstein's Field Equation



$$R_{ij} - \frac{1}{2} R g_{ij} = \frac{8\pi G T_{ij}}{c^4}$$

Re-write

$$R_{ij} - \frac{1}{2} R g_{ij} = G_{ij}$$

$G_{ij} = \kappa T_{ij}$ where T_{ij} contains all forms of energy (mass) & momentum.

For example if there is electromagnetic radiation present, it must be included in T_{ij} . R is the Ricci scalar … just a constant

What is the meaning of $R_{ij} = 0$? Empty space time equations …
where no matter (and energy) is present.

Einstein continued to play …

Einstein continued to play …

He changed the metric tensor array by making potentials that are located off diagonal of the array, anti-symmetric.

$$V_{tx} = -V_{xt} \qquad V_{ty} = -V_{yt} \qquad V_{tz} = -V_{zt}$$

$$V_{xy} = -V_{yx} \qquad V_{xz} = -V_{zx} \qquad V_{yz} = -V_{zy}$$

$$\begin{pmatrix} V_{tt} & V_{tx} & V_{ty} & V_{tz} \\ V_{xt} & V_{xx} & V_{xy} & V_{xz} \\ V_{yt} & V_{yx} & V_{yy} & V_{yz} \\ V_{zt} & V_{zx} & V_{zy} & V_{zz} \end{pmatrix}$$

What was Einstein motive in this play ?

General Relativity requires an array of potential functions.

$$\begin{pmatrix} V_{tt} & V_{tx} & V_{ty} & V_{tz} \\ V_{xt} & V_{xx} & V_{xy} & V_{xz} \\ V_{yt} & V_{yx} & V_{yy} & V_{yz} \\ V_{zt} & V_{zx} & V_{zy} & V_{zz} \end{pmatrix}$$

Why did Einstein change the metric?

To unify Gravity and Electromagnetism.

He later used complex numbers … plays usual game again …

$$\mathrm{Re}(V_{tx}) = \mathrm{Re}(V_{xt}) \quad \mathrm{Re}(V_{ty}) = \mathrm{Re}(V_{yt}) \quad \mathrm{Re}(V_{tz}) = \mathrm{Re}(V_{zt})$$

$$\mathrm{Re}(V_{xy}) = \mathrm{Re}(V_{yx}) \quad \mathrm{Re}(V_{xz}) = \mathrm{Re}(V_{zx}) \quad \mathrm{Re}(V_{yz}) = \mathrm{Re}(V_{zy})$$

$$\mathrm{Im}(V_{tx}) = -\mathrm{Im}(V_{xt}) \quad \mathrm{Im}(V_{ty}) = -\mathrm{Im}(V_{yt}) \quad \mathrm{Im}(V_{tz}) = -\mathrm{Im}(V_{zt})$$

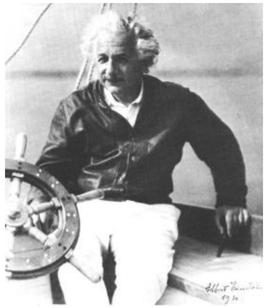
$$\mathrm{Im}(V_{xy}) = -\mathrm{Im}(V_{yx}) \quad \mathrm{Im}(V_{xz}) = -\mathrm{Im}(V_{zx}) \quad \mathrm{Im}(V_{yz}) = -\mathrm{Im}(V_{zy})$$

complex numbers

$z = x + iy$ **or** $z = \mathrm{Re}(z) + i\,\mathrm{Im}(z)$ **(QED)**

One major problem !

Einstein's Field Equation



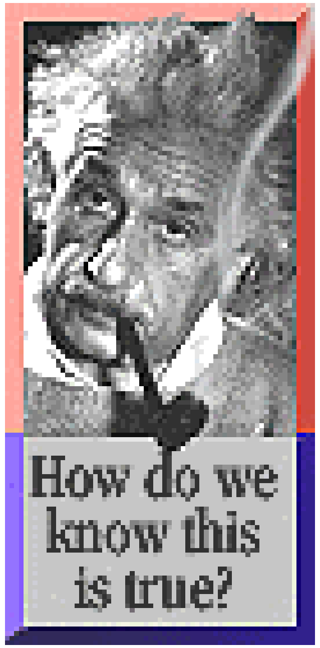
$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$$

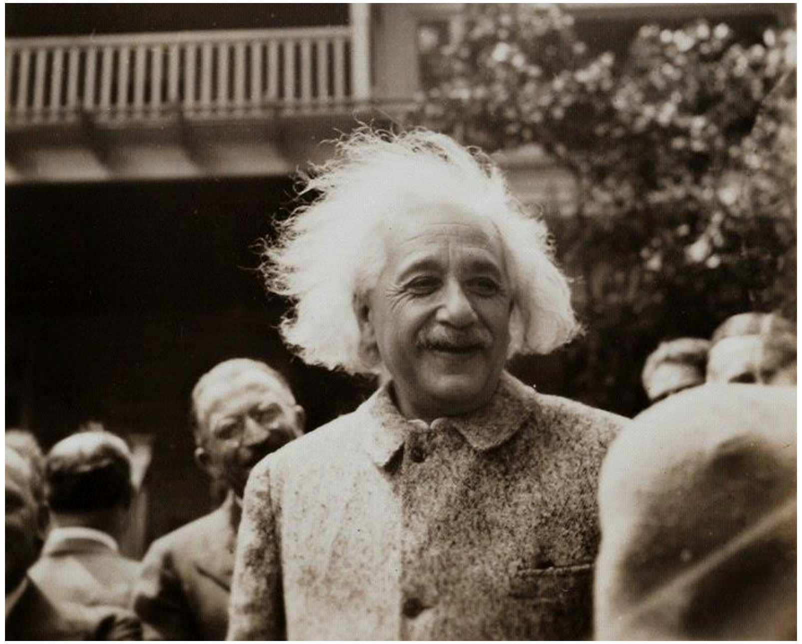
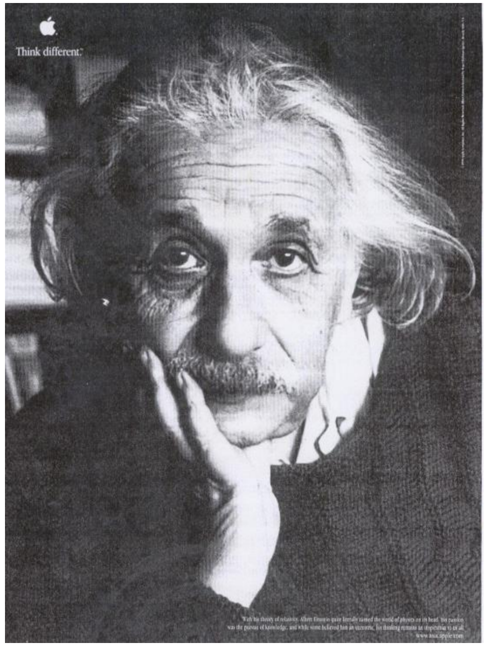
$$v = H_0 r$$

Λ is the famous Einstein's cosmological constant.

Called the biggest blunder ? 1917 paper

When Einstein applied his equation (above) to calculate the behaviour of the Universe on the large scale it was apparent that it favoured an expanding Universe. But due to prejudice of the time, he favoured a static Universe, hence he added Λ to suppress this expansion.

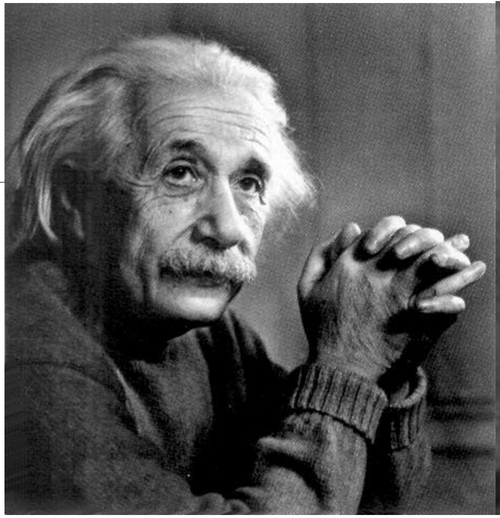
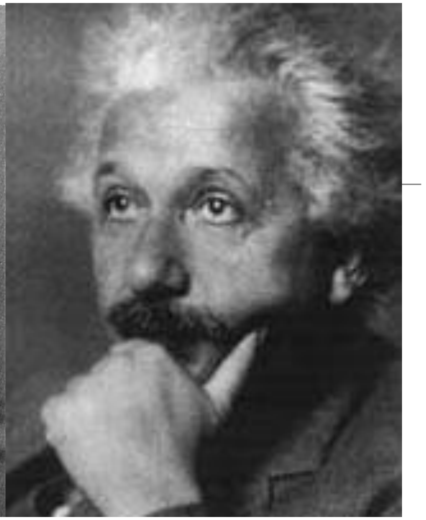


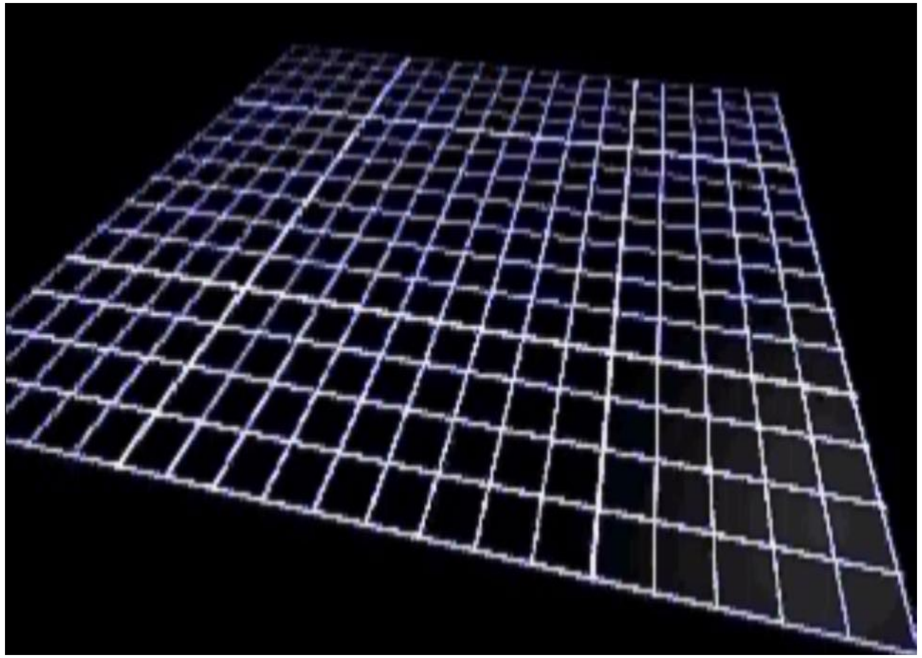



Einstein Poses

Permanent head Damage

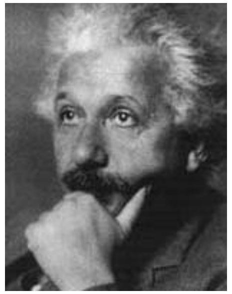
Sometimes called PhD



$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \kappa T_{\mu\nu}$$

$$\boxed{R_{ik} = 0} \;?$$



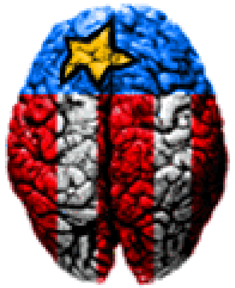
So what good is the Field Equation ?

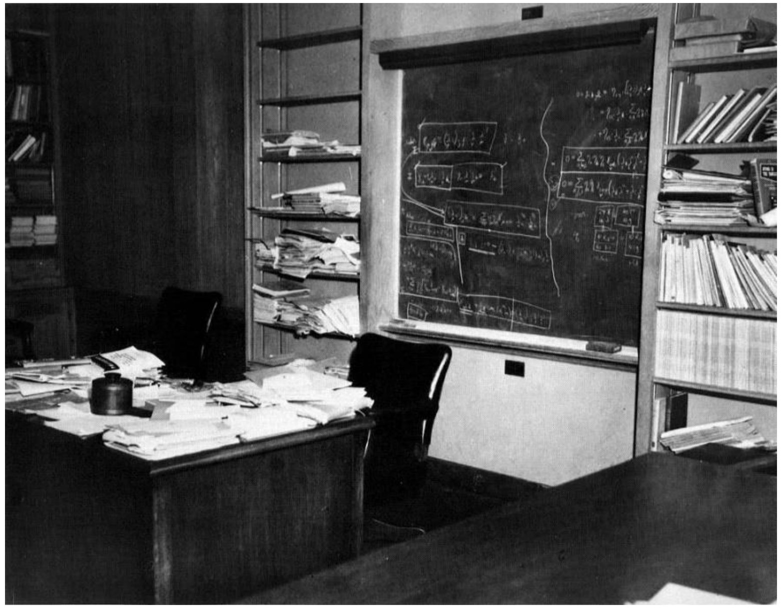
$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \cancel{\Lambda g_{\mu\nu}} = \kappa T_{\mu\nu}$$

Unified Geometry and Matter
Energy and Mass
Space and Time

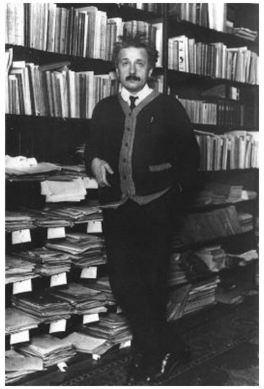
Einstein removed $\Lambda g_{\mu\nu}$

Grey Matter





Einstein’s last office, Princeton 1955



Brain Work

http://www.youtube.com/watch?v=JNOKT-xv7Dw

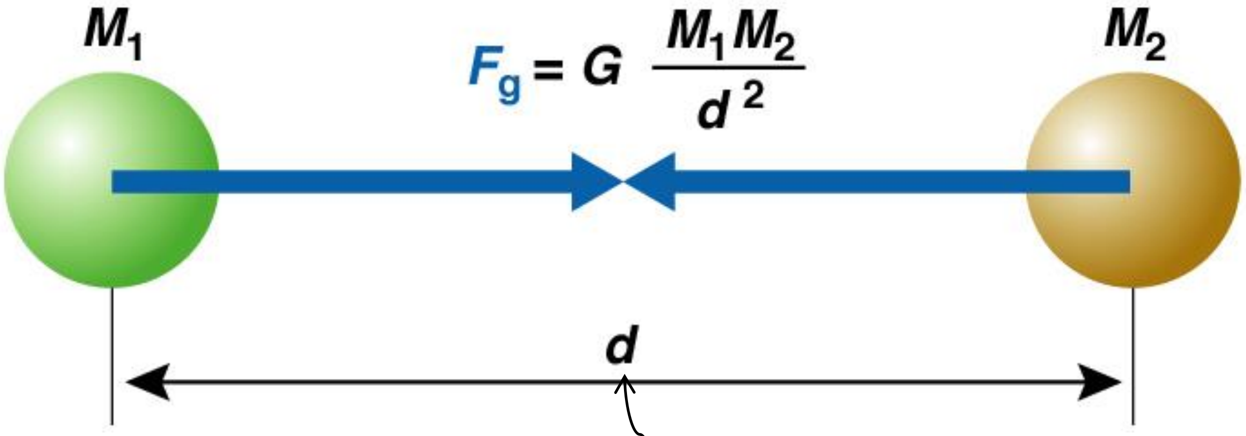
Summary of new ideas !

Where is the “Force” in Gravity ?

What determines the strength of gravity?

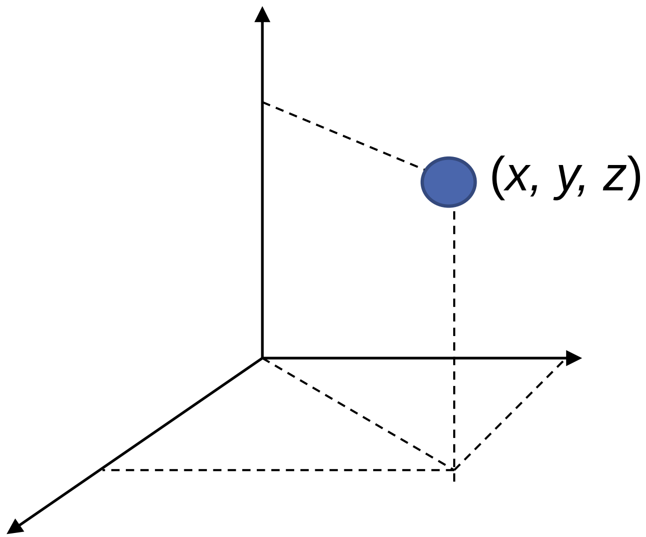
The **Universal Law of Gravitation** (**"*action at a distance*"**) **:**

1. Every mass attracts every other mass.
2. Attraction is *directly* proportional to the product of their masses.
3. Attraction is *inversely* proportional to the *square* of the distance between their centers.



Notation : r

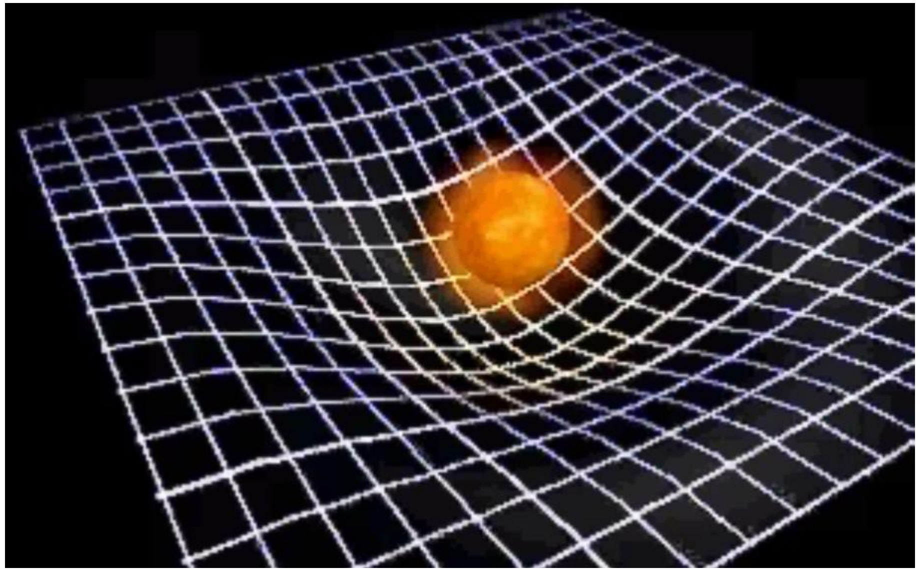
Space Time (some new ideas !)



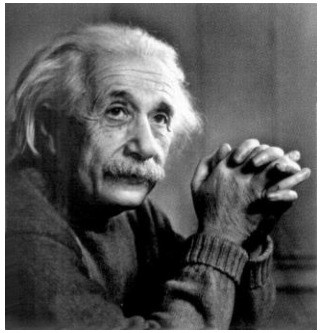
$$\frac{SPACE}{TIME} = \frac{SPACE}{TIME} = c$$

Note: (x, y, z, ct) or (ct, x, y, z)

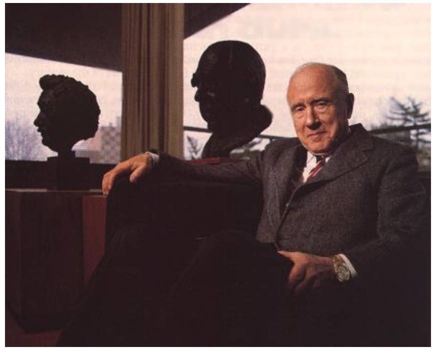
There is no force concept in Einstein's General Relativity



Space determines how **Mass** should move.
Mass determines how **Space** should curve.



John. A. Wheeler



Is there an Analogy ?

$$R_{ik} = 0 \ ?$$

Once a upon a time in school …

$R_{ik} = 0$? vacuum ← $a = 0$?

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \kappa T_{\mu\nu}$$ non vacuum

$$a = \frac{F}{m}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$$

$$F = ma$$

What do you mean by solve ?
Einstein's Field equation ?

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$
$$dr^2 = dx^2 + dy^2 + dz^2$$

The difficulty !

The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds.

J.M. Keynes, (1883-1946)

Some thoughts

Education is not the filling of a pail,

but the lighting of a fire.

William Butler Yeats 20th century poet and writer

"For everything that's lovely is/But a brief, dreamy, kind delight." - 'Never Give All the Heart', W. B. Yeats

An educated mind is never certain. K.P. Mohanan, NUS

Education's purpose is to replace an empty mind with an open one.

Charles Sturt University

We really hope to have opened your minds and rubbed onto you all some of the strong passions we feel about all these weird but wonderful things that mother nature offers.

Einstein on History & Philosophy

Albert Einstein was extremely interested in the philosophical conclusions of his work. He writes:

"I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today - and even professional scientists - seem to me like somebody who has seen thousands of trees but has never seen a forest. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is - in my opinion - the mark of distinction between a mere artisan or specialist and a real seeker after truth." **Einstein. letter to Robert A. Thornton, 7 December 1944. *EA* 61-574.**

Mathematics is not Physics

Physics is also not Mathematics …

… physics is closer to philosophy

… natural