MTW 50

Kip Thorne

3 May 2023
Zoom Event Sponsored by
International Society of General Relativity and Gravitation

The Historical Context

- 1940 -1950s: GR - largely mathematical explorations
  - Astrophysicists' attitude - Jesse Greenstein
- 1954: **John Wheeler** (Princeton) turned from nuclear physics to GR … injected new viewpoints and very physical approach
  - **Charles Misner**: 1954-57 PhD student ; 56-63 faculty. 63 ➡ U Maryland professor
  - **Kip Thorne:** 1962-65 PhD student ; 65-66 postdoc 66 ➡ Caltech professor

GR Texts that I Studied or Browsed

- **Landau & Lifshitz - Classical Theory of Fields (1962)**
- **1963 Les Houches Lectures:** Relativity Groups & Topology
- Tolman - Relativity, Thermodynamics & Cosmology (1934)
- Bergman - Introduction to the Theory of Relativity (1942)
- Synge - Relativity the General Theory (1960)
- Weber - General Relativity & Gravitational Waves (1961)

Motivations for New GR Textbook

- New astrophysical/cosmological applications
  - 1963 Quasars; 64-65 CMB; 67 Pulsars
- Tie to modern differential geometry (a la Cartan)
- Focus on physical interpretation; physical intuition
- Geometric interpretation of GR; physics as geometry

John, Charlie and Kip
Agreement & Planning to Write MTW

- June 1967: Paris, France - Discussions. Agreement.
- November 1967: NYC - Chinese Restaurant Treaty
  - When two authors declare we are finished, we finish.
  - Book will be concise.
    - Ernst Schmutzer Relativistische Physik (1968) 968 pp
    - ?Sadly?: MTW 1279 pp

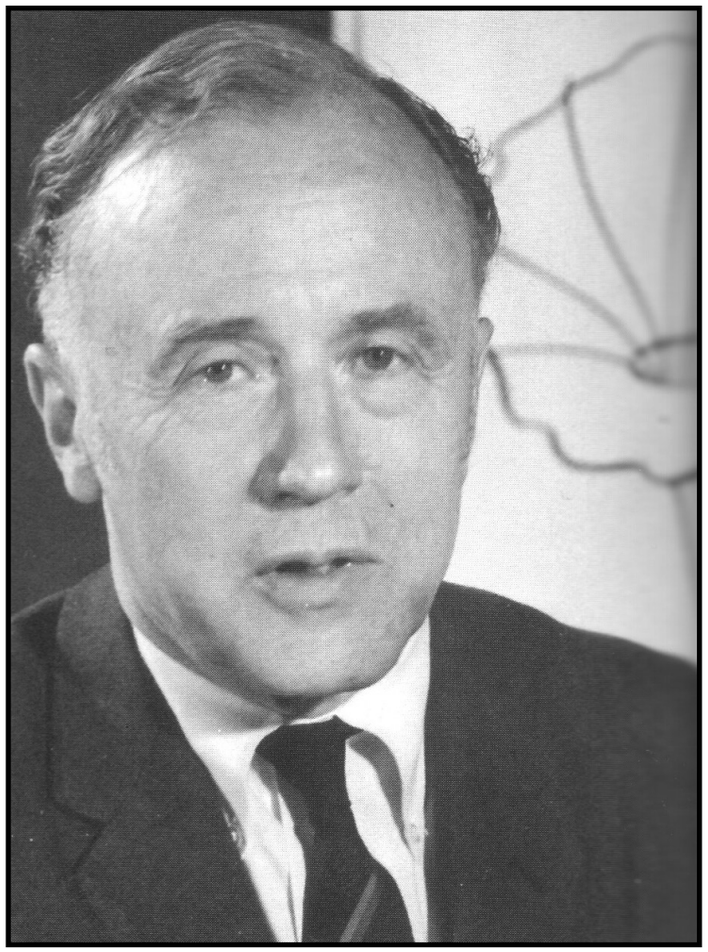
We Worked on MTW for 5 Years: 1967-72

- A period of intense change in GR & Relativistic Astrophysics
  - compact X-ray sources - Cygnus X-1 black hole
  - BH accretion disks; quasars powered by massive BHs
  - Uniqueness of BHs (“no hair”)
  - Laws of BH mechanics
  - Global methods & singularity theorems. Mixmaster & BKL
  - Cosmic censorship
  - BHs as dynamical objects; pulsations
  - Gravitational wave geometric optics; energy/momentum
  - PPN
  - …

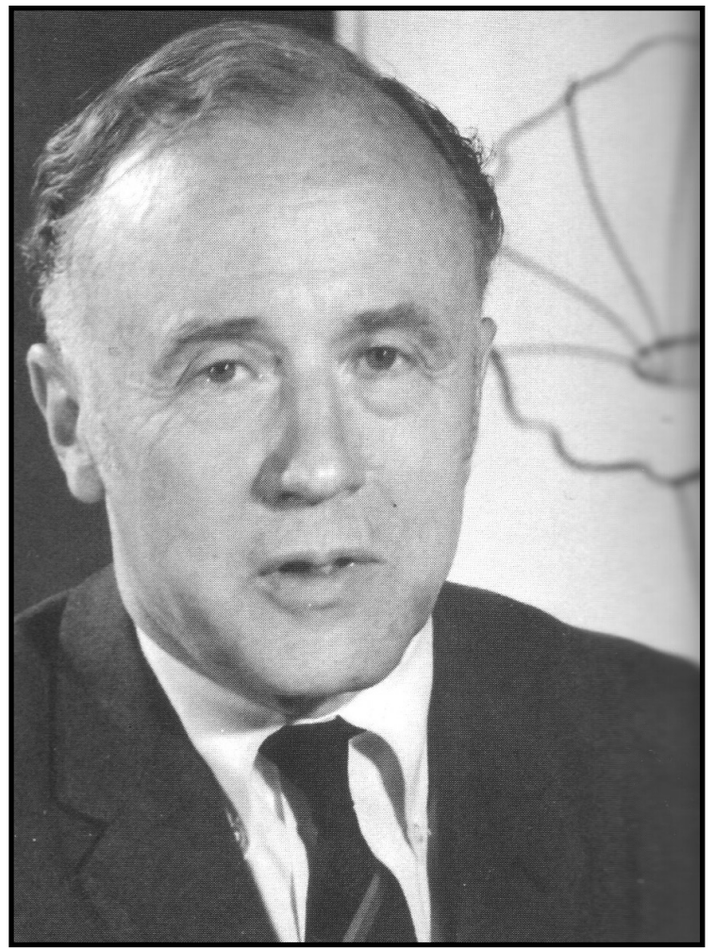
Some Remarks About the Authors

John Wheeler

- **Conservative politics & demeanor**
- **Colorful physics style**

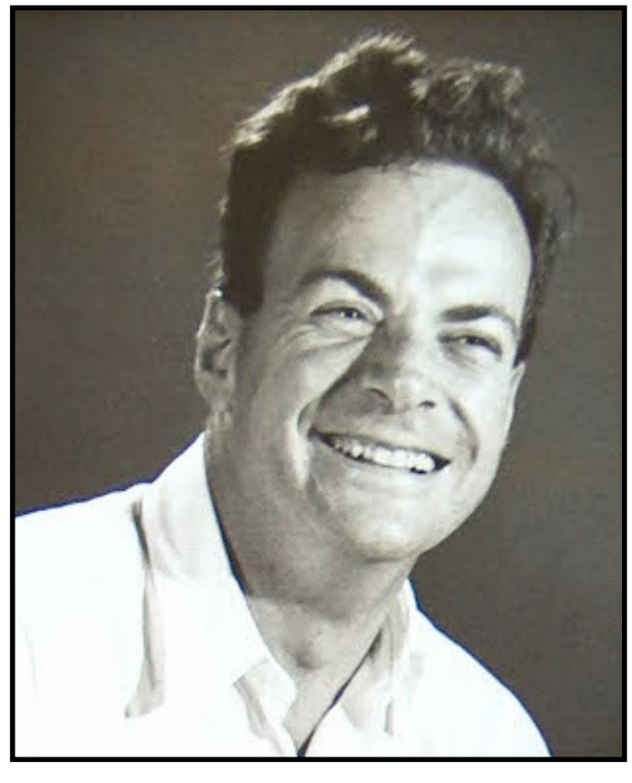


John Wheeler



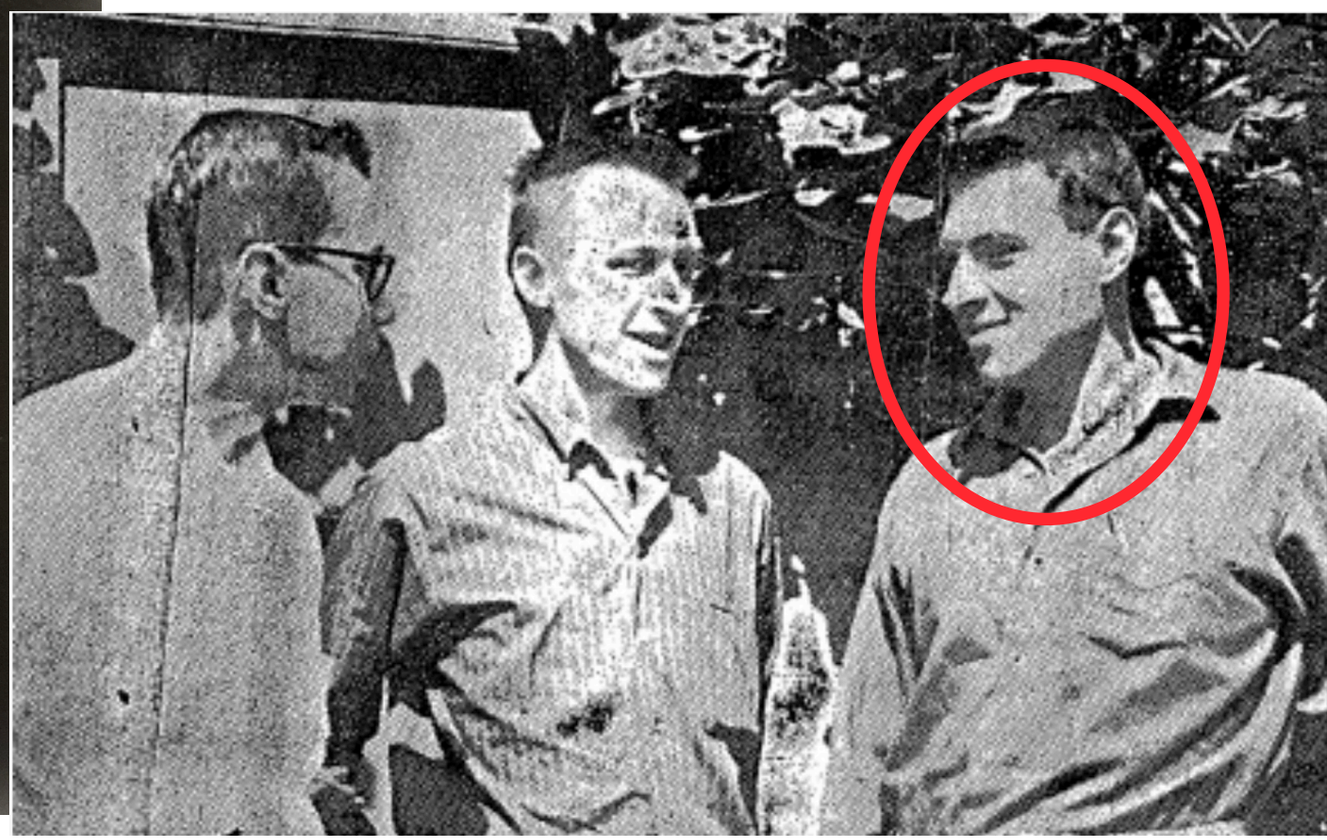
- **Conservative politics & demeanor**
- **Colorful physics style**
- **Deep physical intuition & willingness to speculate**
- **Mathematically strong**

Richard Feynman



Charles Misner

- **Mathematically the deepest**
- **ADM [Arnowitt Deser Misner]**
  3+1 Hamiltonian formulation of GR



Kip

- **Closest to astrophysics & experiment**

1967-68 Preparing to Write MTW

- Misner and Wheeler teaching GR courses at Maryland and Princeton; Kip at U Chicago with Chandrasekhar

Misner Lecture Notes

p. 37

Phys. 236
Dr. Misner
Feb. 21, 1968

In this lecture we begin by discussing red shifts in accelerated frames. This topic is important enough that we will discuss it several times, that is:

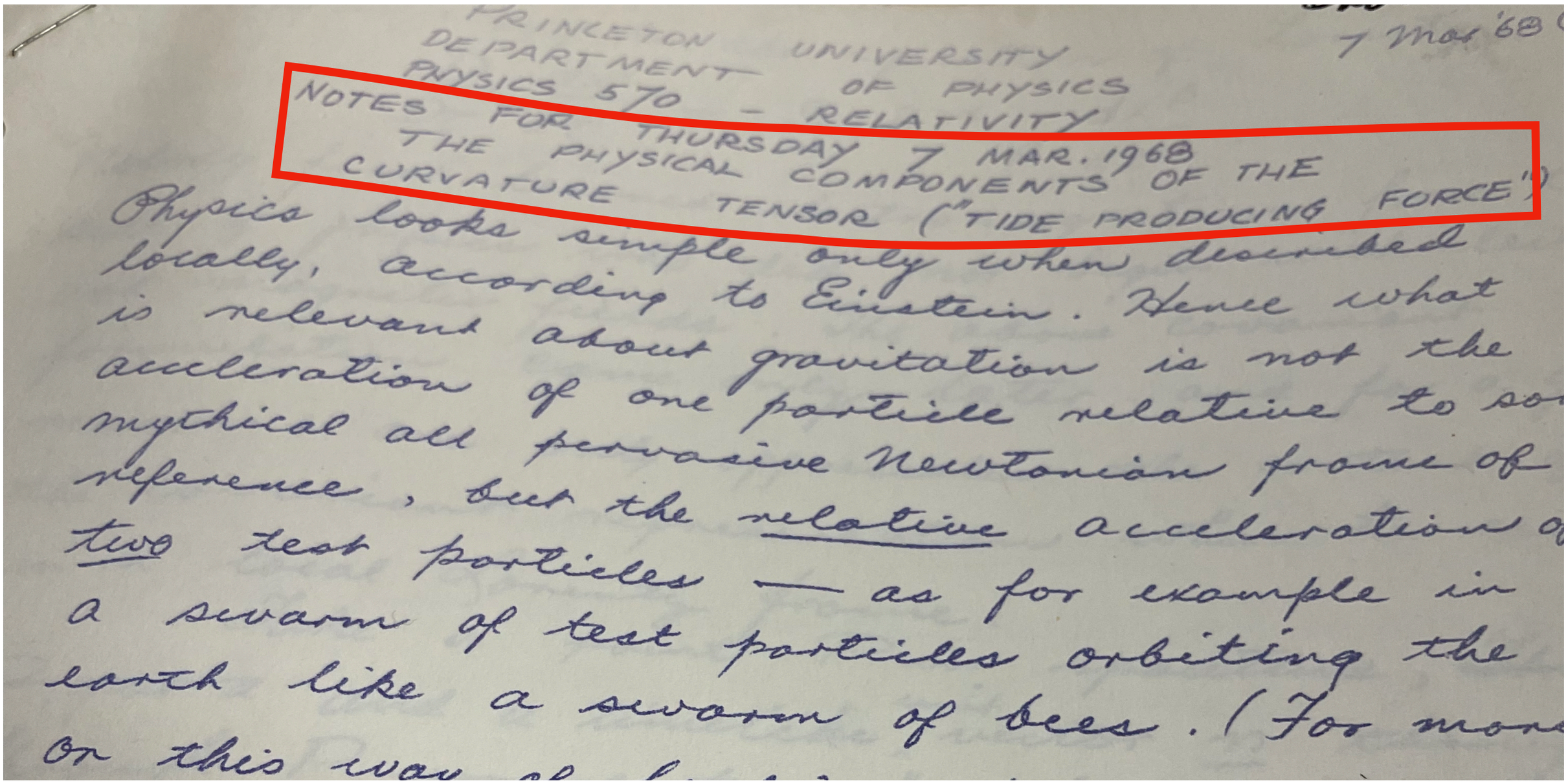
1) From the "Newtonian" viewpoint with more knowledge of the behavior of light than Newtonian mechanics assumes.

2) From the viewpoint

1967-68 Preparing to Write MTW

- Misner and Wheeler teaching GR courses at Maryland and Princeton; Kip at U Chicago with Chandrasekhar

Wheeler Lecture Notes


PRINCETON UNIVERSITY
DEPARTMENT OF PHYSICS
PHYSICS 570 - RELATIVITY
NOTES FOR THURSDAY 7 MAR. 1968
THE PHYSICAL COMPONENTS OF THE
CURVATURE TENSOR ("TIDE PRODUCING FORCE")

7 Mar 68

Physics looks simple only when described locally, according to Einstein. Hence what is relevant about gravitation is not the acceleration of one particle relative to some mythical all pervasive Newtonian frame of reference, but the relative acceleration of two test particles — as for example in a swarm of test particles orbiting the earth like a swarm of bees. (For more

Kip - December 1967 - Proposed MTW Outline

Part I A 10 week course on fundamentals of GR

- Chapter 1: Special Relativistic Preliminarieszz inertial frames, fundamentals of SR, Stress-energy tensor, accelerated reference frames
- Chapter 2: Intro to Differential Geometry
- Chapter 3: Einstein Field Equations
- Chapter 4: Relativistic Stellar Structure
- Chapter 5: Intro to Cosmology
- Chapter 6: Schwarzschild-Kruskal
- Chapter 7: Elementary Theory of Gravitational Waves
- Chapter 8: Experimental tests of GR

Part II A deeper, more detailed treatment of the most important special topics.

- Chapter 1: Modern Differential Geometry
- Chapter 2: Problems with Spherical Symmetry
- Chapter 3: Electromagnetic Theory
- Chapter 4: Exact Solutions (RN, Kerr Taub-NUT, charged Kerr-NUT, Weyl, Methods of generating new solutions)
- Chapter 6. Gravitational Radiation Theory
- Chapter 7: Equations of Motion
- Chapter 8 Post Newtonian Approximation
- Chapter 9 Cosmology
- Chapter 10 Singularities
- Chapter 11 Initial Value Formulation
- Chapter 12 Kinetic Theory
- Chapter 13: Rotation
- Chapter 14: Geometrodynamics
- Chapter 15: Alternative Relativistic Rheories of Gravitation

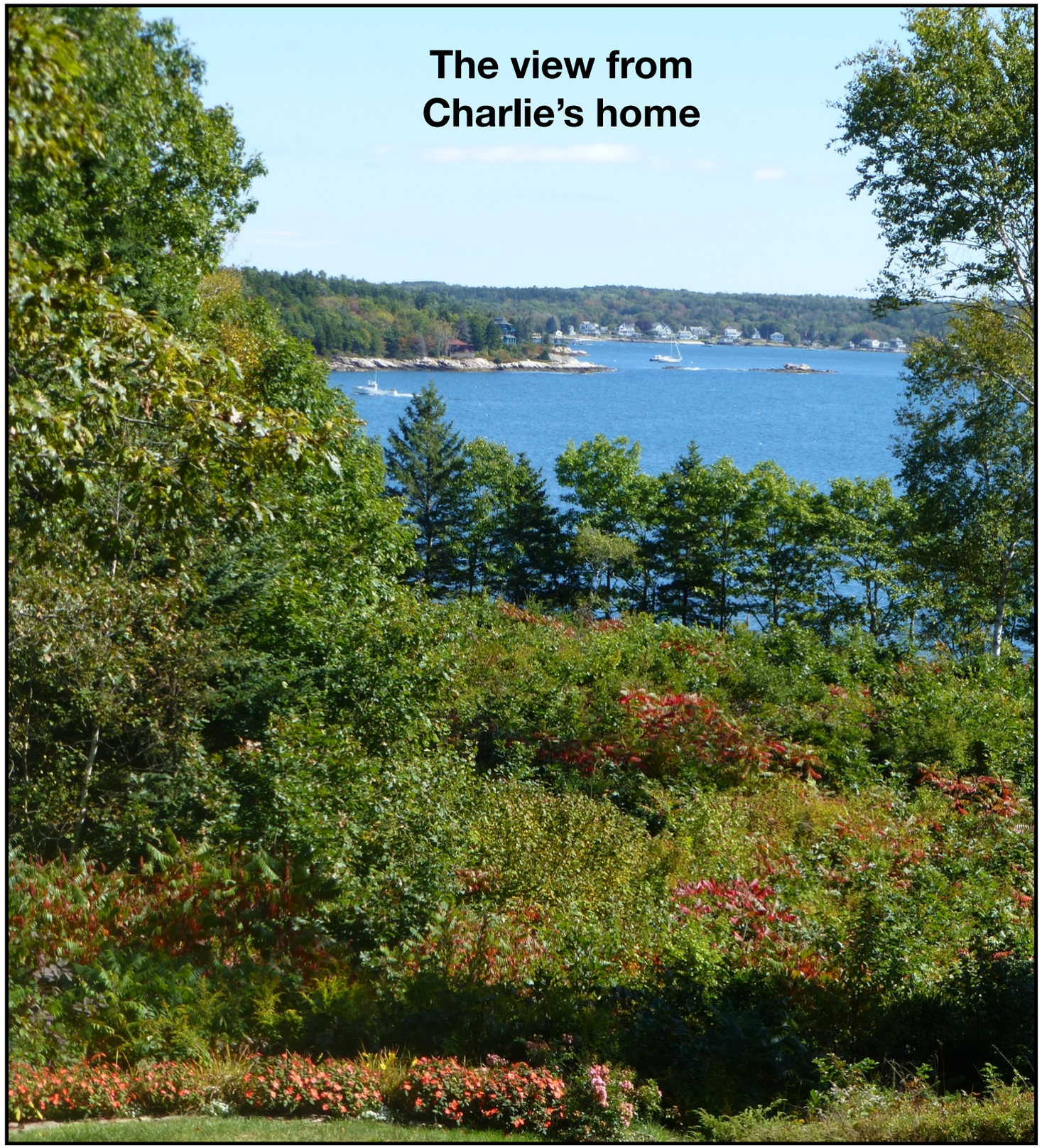
Summer 68 - Spring 69

- Many long discussions / planning
- Low level of work on book
- Drafts of chapters & pieces of chapters
- Reorganization: Track 1 & 2 mingled
- Boxes introduced

Summer 1969 - Summer 1970

- Intense, near 100% effort on book - leading to First Preliminary Edition in September 1970
- Whenever two of us expected to be together, the third was obligated to try to join, at least for a few days
- We met, and wrote and revised in — among others —
  - Princeton U. , Princeton Institute for Advanced Study, U. of Maryland, Caltech, U. Texas Austin, National Airport Washington DC, Dublin Ireland, Kyoto (Japan), USSR (Moscow, Kiev, Leningrad), … and Maine
  - Particularly memorable: Summer 1970 in Main

Maine - July & August 1970

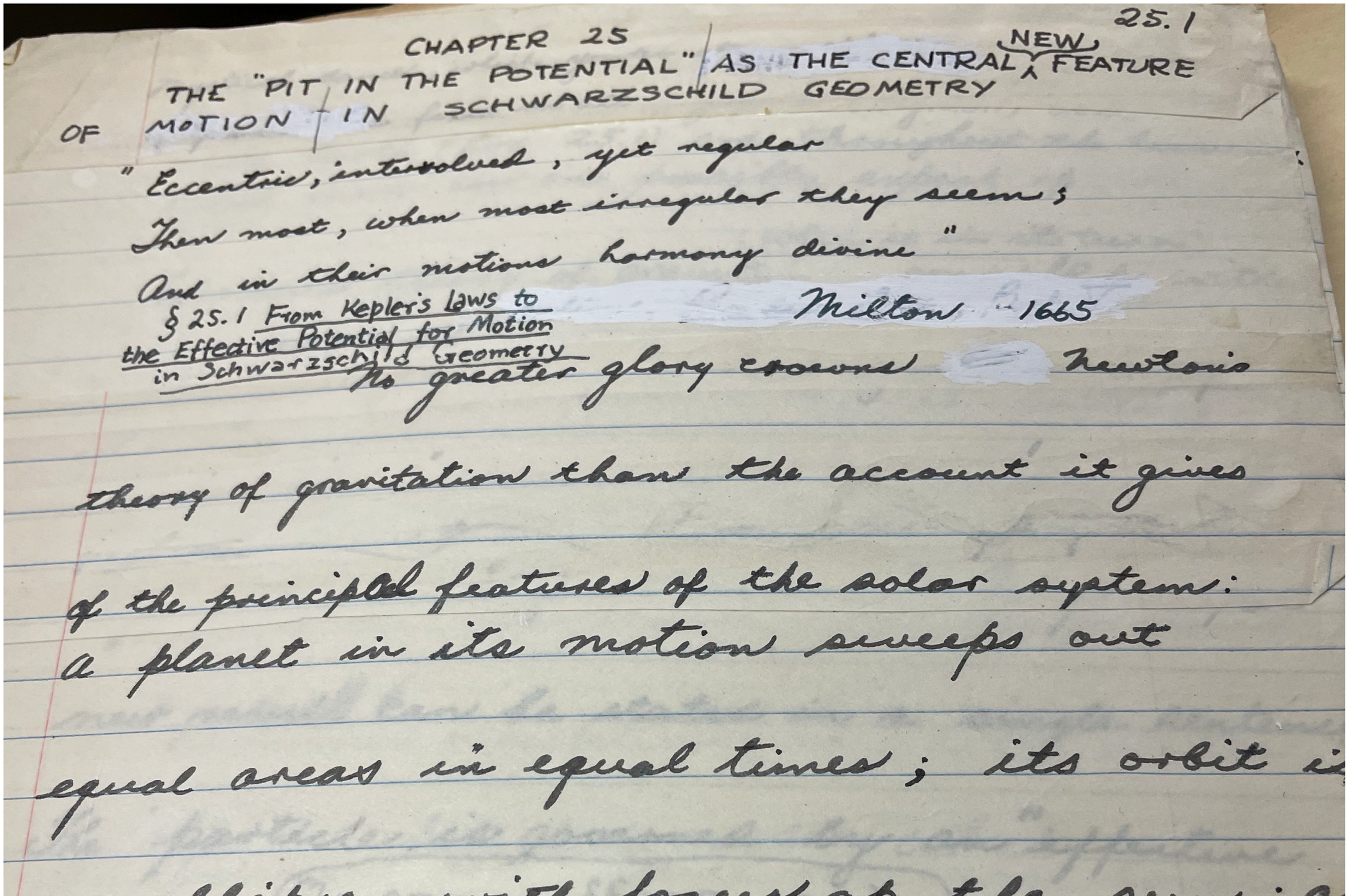


1 km

Summer 1969 - Summer 1970

- For each chapter:
  - One of us wrote first draft.
  - Circulated to other authors … at least three times around (nine revisions) … until converged.
  - Sent out for typing whenever the manuscript got too messy.

John - First Draft of a Chapter on Orbits in Schwarzschild



25.1

CHAPTER 25

NEW FEATURE

THE "PIT IN THE POTENTIAL" AS THE CENTRAL

OF MOTION IN SCHWARZSCHILD GEOMETRY

"Eccentric, interwolved, yet regular
Then most, when most irregular they seem;
And in their motions harmony divine"

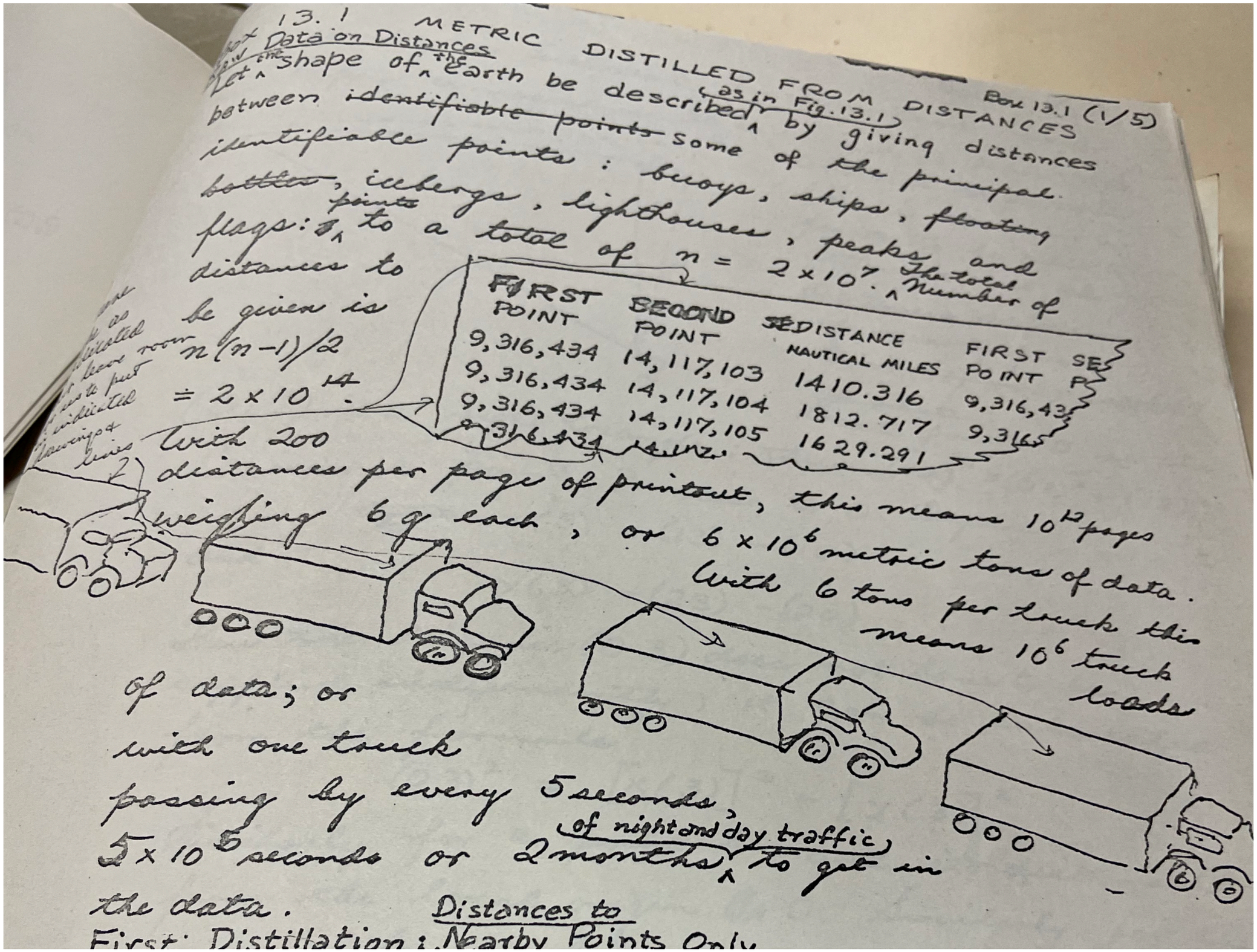
Milton 1665

§ 25.1 From Kepler's laws to the Effective Potential for Motion in Schwarzschild Geometry

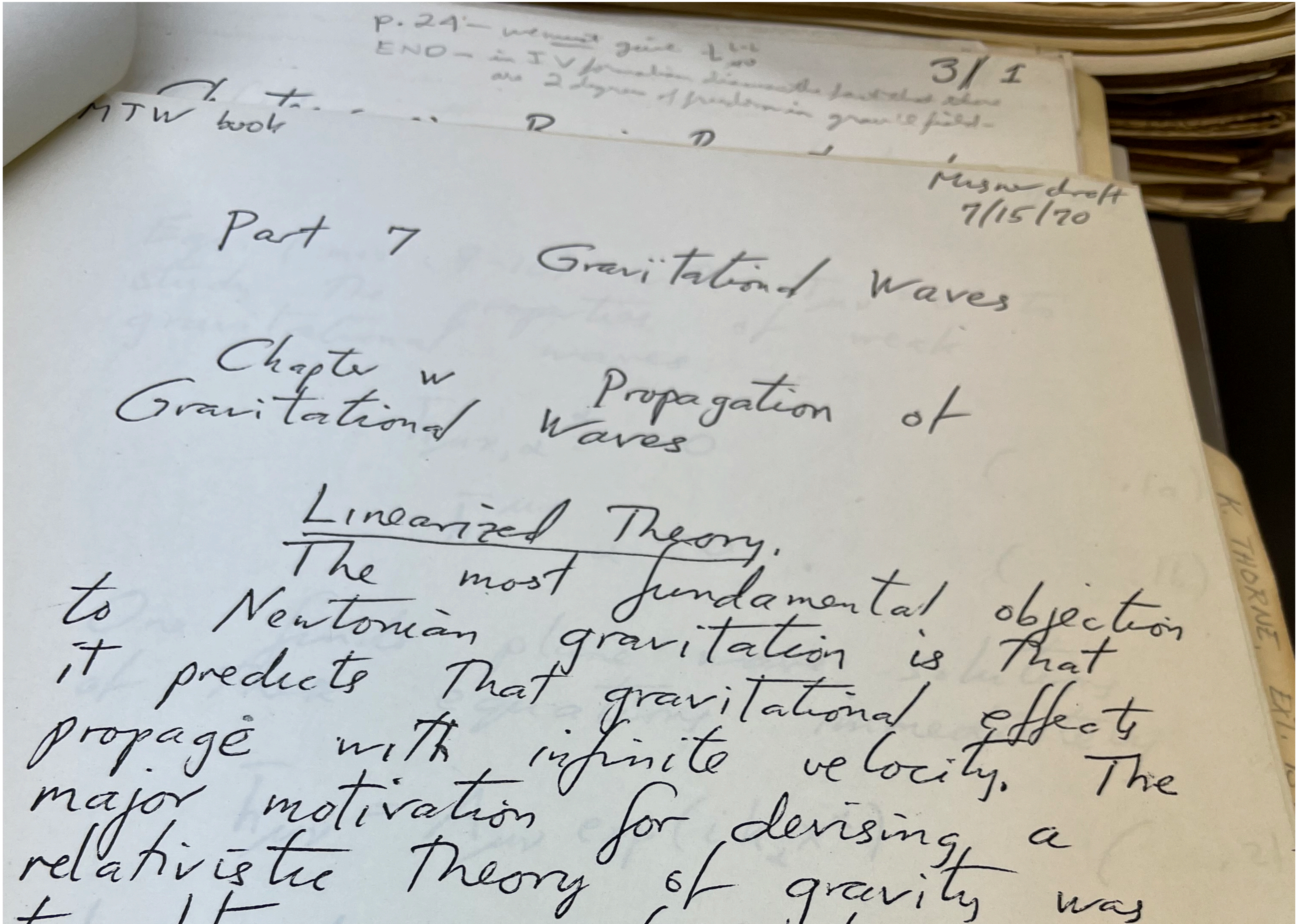
No greater glory crowns Newton's

theory of gravitation than the account it gives of the principal features of the solar system: a planet in its motion sweeps out equal areas in equal times; its orbit is an ellipse with focus at the sun; a

John - Typical First Draft of a Box



Charlie First Draft of a Chapter on Gravitational Waves



p. 24 — we must give the
END — in IV formulation discuss the fact that there are 2 degrees of freedom in grav'l field —

3/1

MTW book

Misner draft
7/15/70

Part 7 Gravitational Waves

Chapter w Propagation of Gravitational Waves

Linearized Theory.

The most fundamental objection to Newtonian gravitation is that it predicts that gravitational effects propagė with infinite velocity. The major motivation for devising a relativistic theory of gravity was

Kip First Draft of a Chapter on Global Methods

CHAPTER 34

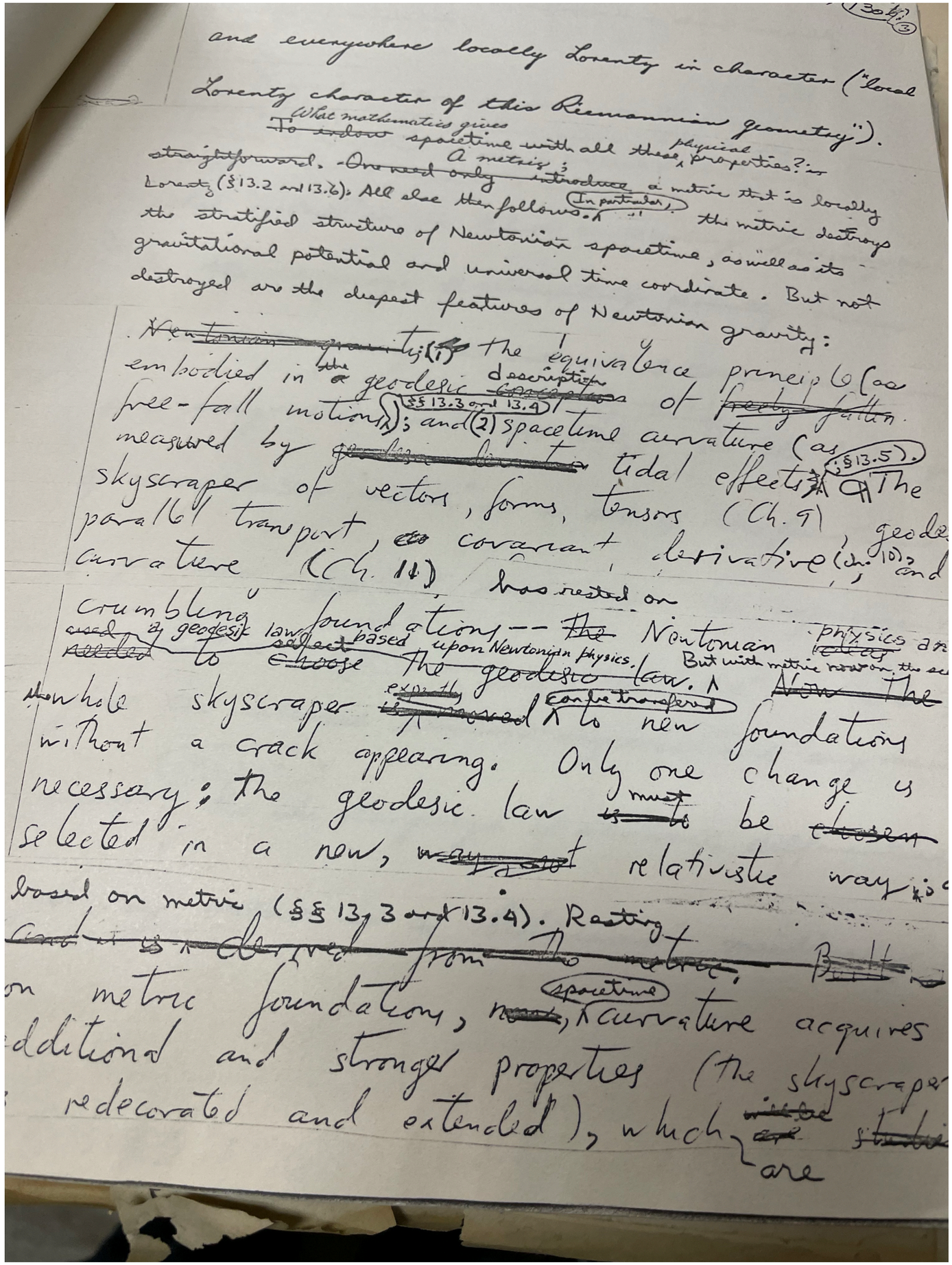
GLOBAL TECHNIQUES, HORIZONS, AND SINGULARITY THEOREMS

34.1 Global Techniques

Until the 1960's, computations in gravitation theory used local techniques almost exclusively: The Einstein field equation describes how the stress-energy T at a given event generates curvature G at that same event. When reduced to differential equations for the metric, $G = 8\pi T$ relates $g_{\alpha\beta}$, $\partial g_{\alpha\beta}/\partial x^\mu$, and $\partial g_{\alpha\beta}/\partial x^\mu \partial x^\nu$ at each given event to $T_{\gamma\delta}$ at that same event. The solution of these differential equations is effected, on a computer or in any initial-value type analysis, by integrating forward in time from event to event to event. The nongravitational laws of physics are obtained by invoking the equivalence principle in a local Lorentz frame at each individual event in spacetime. To build up an understanding of the global structure of spacetime, one performs local computations near each event, and then patches the local results together to form a global picture.

Why this great reliance on local analyses? Because the laws of gravitation physics take on particularly simple forms when stated locally.

That gravitation physics is also subject to powerful and simple



and everywhere locally Lorentz in character ("local Lorentz character of this Riemannian geometry").

To endow What mathematics gives spacetime with all these physical properties?: A metric; straightforward. One need only introduce a metric that is locally Lorentz (§13.2 and 13.6); All else then follows. (In particular), the metric destroys the stratified structure of Newtonian spacetime, as well as its gravitational potential and universal time coordinate. But not destroyed are the deepest features of Newtonian gravity:

~~Newtonian gravity~~: (1) the equivalence principle (as embodied in the geodesic description of ~~free fall~~ (§§13.3 and 13.4); and (2) spacetime curvature (as measured by ~~geodesic deviation~~ tidal effects (§13.5). The skyscraper of vectors, forms, tensors (Ch. 9) parallel transport, ~~etc~~ covariant derivative (ch. 10), and curvature (Ch. 11), has rested on crumbling foundations -- ~~the~~ Newtonian physics as used ~~a~~ geodesic law based upon Newtonian physics. But with metric now on the scene ~~added~~ to select ~~choose~~ the geodesic law. ~~Now~~ The whole skyscraper ~~is moved~~ can be transferred to new foundations without a crack appearing. Only one change is necessary: the geodesic law ~~must~~ is to be ~~chosen~~ selected in a new, ~~way not~~ relativistic way: ~~is~~ based on metric (§§13.3 and 13.4). ~~Resting~~ ~~and it is derived from the metric.~~ But on metric foundations, ~~now~~ spacetime curvature acquires additional and stronger properties (the skyscraper redecorated and extended), which ~~are~~ ~~is~~ are

John

Kip

Charlie

John rewriting Charlie

Please capitalize only 1st letter of key words

Exercise ~~27.13~~ TURN-AROUNDS UNIVERSE MODEL NEGLECTING MATTER DENSITY.

If turn-around occurs far to the right (large a) of the maximum of the potential $V(a)$ in equation (27.~~44~~74), the matter terms will be negligible. Set $\rho_{m0} = \rho_{r0} = 0$ Then ~~what~~ (what signs of k, Λ are needed for turn-around ?) and solve to show that

$\Lambda = 3\,(a_{min})^{-2}$; $H = (a_{min})^{-1} \tanh\,(t/a_{min})$

and that the deceleration parameter $q \equiv -(1/H^2 a)(d^2a/dt^2)$ has the value

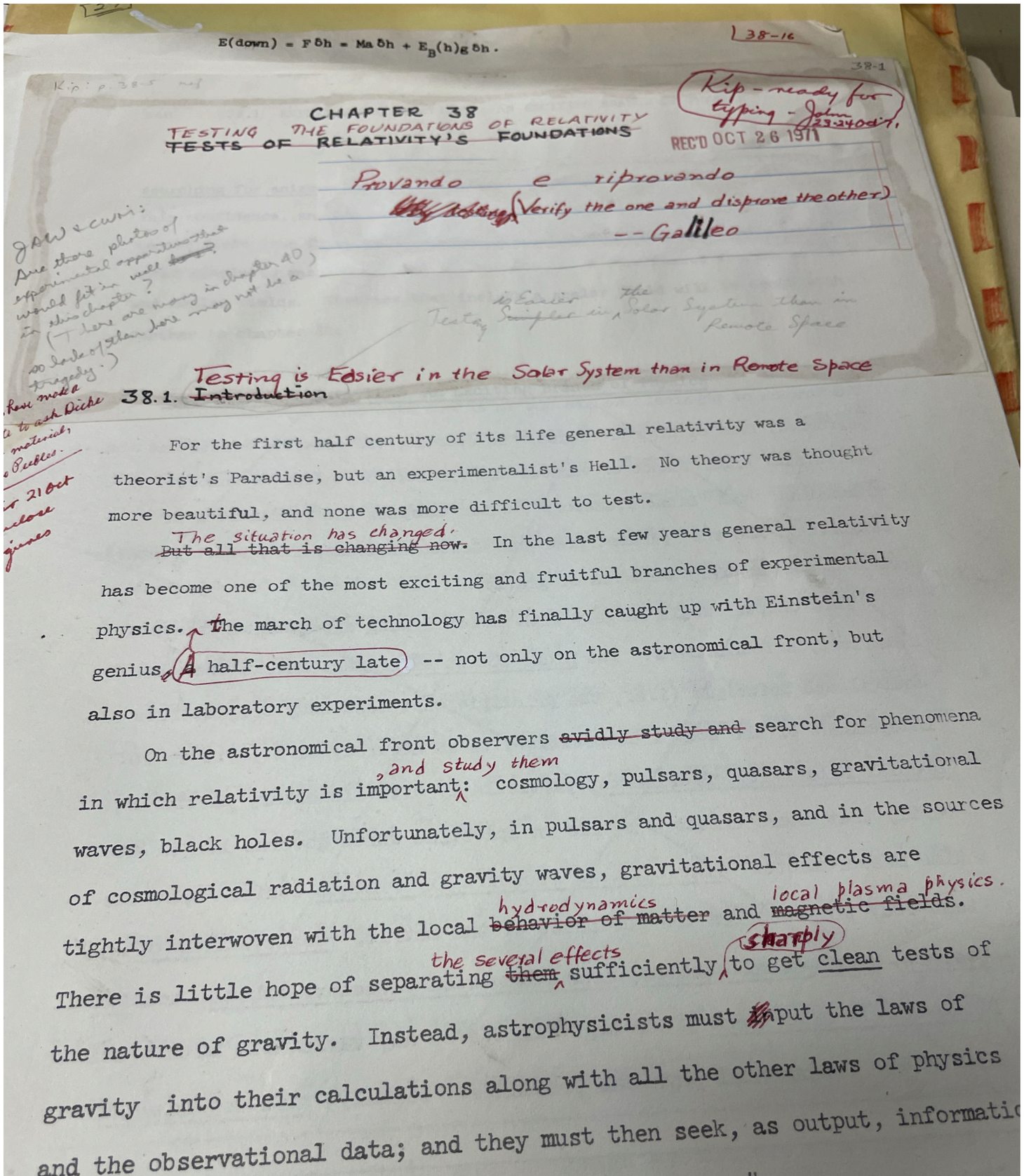
$$q = -a^2\,(a^2 - a_{min}^2)^{-1} < -1 .$$

pls. cap. only 1st letter of key words.

Exercise 27.~~14~~ "HESITATION" UNIVERSE

Neglect radiation in equation (27.~~44~~74) but assume K_0 and Λ chosen so that the universe spent a very long time with $a(t)$ near a_h (a_h measures location of highest point of the barrier, or the size

John rewriting a typescript - ready for retyping



$E(\text{down}) = F\delta h = Ma\,\delta h + E_B(h)g\,\delta h.$

38-16

38-1

Kip p. 38-5 ref

Kip - ready for typing - John 23 Oct 71

REC'D OCT 26 1971

CHAPTER 38

~~TESTS OF~~ TESTING THE FOUNDATIONS OF ~~RELATIVITY'S FOUNDATIONS~~ RELATIVITY

Provando e riprovando

(Verify the one and disprove the other)

--Galileo

JAW & CWM:
Are there photos of experimental apparatus that would fit in well ~~here~~ in this chapter? (There are many in chapter 40 so lots of selection here may not be a tragedy.)

Testing is Easier in the Solar System than in Remote Space

Testing is Easier in the Solar System than in Remote Space

38.1. ~~Introduction~~

For the first half century of its life general relativity was a theorist's Paradise, but an experimentalist's Hell. No theory was thought more beautiful, and none was more difficult to test.

The situation has changed.
~~But all that is changing now.~~ In the last few years general relativity has become one of the most exciting and fruitful branches of experimental physics. The march of technology has finally caught up with Einstein's genius, A half-century late -- not only on the astronomical front, but also in laboratory experiments.

On the astronomical front observers ~~avidly study and~~ search for phenomena in which relativity is important, and study them: cosmology, pulsars, quasars, gravitational waves, black holes. Unfortunately, in pulsars and quasars, and in the sources of cosmological radiation and gravity waves, gravitational effects are tightly interwoven with the local ~~behavior of matter~~ hydrodynamics and ~~magnetic fields~~ local plasma physics. There is little hope of separating ~~them~~ the several effects sufficiently sharply to get clean tests of the nature of gravity. Instead, astrophysicists must input the laws of gravity into their calculations along with all the other laws of physics and the observational data; and they must then seek, as output, informatio

Manuscript Mailed Princeton to Caltech

First Preliminary Edition September 1970

Kip S. Thorne

First Preliminary Edition
September 1970

GRAVITATION

Charles W. Misner
Department of Physics and Astronomy, University of Maryland

Kip S. Thorne
Kellogg Radiation Laboratory, California Institute of Technology

John Archibald Wheeler
Joseph Henry Laboratories, Princeton University

UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS AND ASTRONOMY
COLLEGE PARK, MARYLAND

TABLE OF CONTENTS

- 9 Parts
  vs 10 in final book
- 33 chapters
  vs 44 in final book

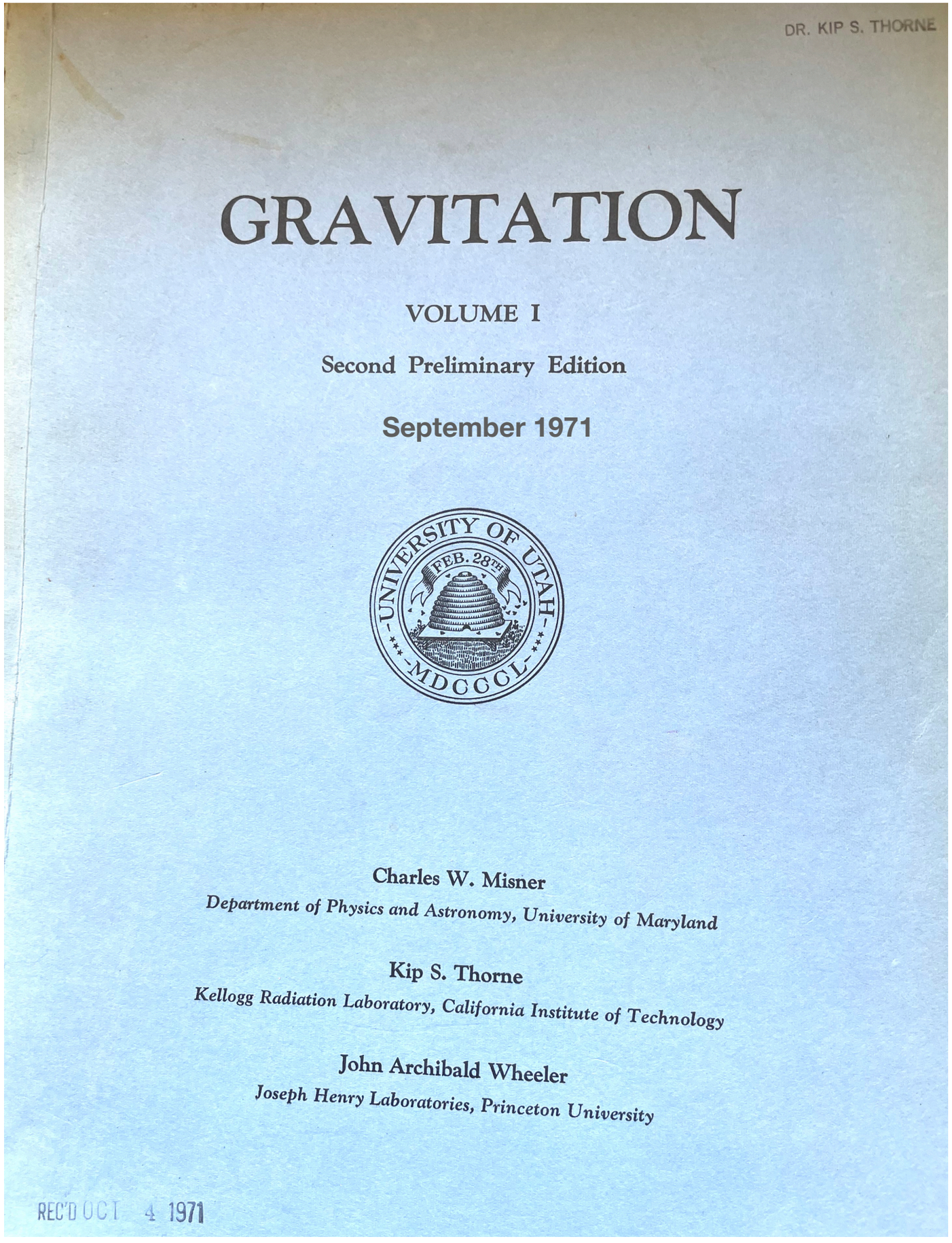
Summer 1970 - Summer 1971

- Extensive Revisions. Eleven Chapters and One Part Added. Converging
- Got together in Maine, Princeton U, Institute for Advanced Study, U Maryland, Caltech, San Felipe (by the sea) Mexico

Second Preliminary Edition September 1970

- Same 9 Parts as final book
- Same 44 Chapters as final book, but some titles a little different

Despite what I said in my talk, this edition in fact was printed at and distributed by the Physics Department of the University of Utah - under the auspices of Richard Price.
- Kip



Bill Press

- Dialog between Sagredus and Salvatius
- Patterned after Galileo's Dialogue Concerning the two Chief World Systems

CHAPTER 33

BLACK HOLES

A luminous star, of the same density as the Earth, and whose diameter should be two hundred and fifty times larger than that of the Sun, would not, in consequence of its attraction allow any of its rays to arrive at us; it is therefore possible that the largest luminous bodies in the universe may, through this cause, be invisible. P. S. Laplace (1798).

§33.1. Why "Black Hole"?

SAGREDUS: What is all this talk about "black holes"? When an external observer watches a star collapse, he sees it implode with ever increasing speed, until the relativistic stage is reached. Then it appears to slow down and become "frozen", just outside its horizon (gravitational radius). However long the observer waits, he never sees the star proceed further. How can one reasonably give the name "black hole" to such a frozen object, which never disappears from sight?

SALVATIUS: Let us take the name "black hole" apart. Consider first the blackness. Surely nothing can be blacker than a black hole. The very redshift which makes the collapsing star appear to freeze also makes it darken and become black. In the continuum approximation, where one ignores the discreteness of photons, the intensity of the radiation received by distant observers decreases exponentially as time passes, $L \propto \exp(-t/3\sqrt{3}\,M)$, with an exceedingly short e-folding time

In Meantime: May 1971 Chose Publisher Negotiated Contract

WH Freeman & Company
San Francisco
owned by Scientific American

I took responsibility for interactions with publisher

Agreement for Publication

THIS AGREEMENT, made this Third day of May, 1971, by and between

CHARLES W. MISNER, KIP S. THORNE, and JOHN ARCHIBALD WHEELER

hereinafter called the AUTHOR, and W. H. FREEMAN AND COMPANY, a California corporation, San Francisco, California, hereinafter called the PUBLISHER:

Witnesseth:

I The author agrees to deliver to the publisher a manuscript in duplicate for a **book on general relativity.**

The manuscript shall be legible and suitable in form as copy for editing and typesetting. It shall be of such content as the author and publisher are willing to have published.

II The publisher agrees to publish, manufacture, and distribute this work and to pay all of the expenses of publication, manufacture, and distribution, except as provided in Paragraph V of this agreement. The publisher shall have the right of final decision on all matters relating to publication, manufacture, and distribution.

III The author hereby grants to the publisher, for the period of the copyright and renewal of the copyright, the sole and exclusive right to publish, manufacture, and distribute this work, including the exclusive right to publish revisions, abridgements, and translations, and the right to take out copyright in the name of the publisher, or in the name of the author, if the author so desires. The author agrees to apply for the renewal of the copyright at least six months prior to its expiration.

IV The publisher agrees to pay royalties to the author at the following terms:

A. On domestic sale of bound books:

15% of list price.

B. On foreign sale of bound books: **Sales in Canada: 15% of list price.**
Other foreign sales: 7-1/2% of list pri

C. On sale of translation or other rights: **50% of net receipts.**

D. On sale of printed sheets: **10% of net receipts.**

E. No royalty shall be paid on sales made at or below manufacturing cost nor shall royalties be paid on gratuitous copies.

F. In the event a trade edition—that is, a long discount edition—is published in addition to the text edition, the royalty on the sales of the trade edition shall be computed on the list price of the text edition.

G. An accounting of sales and royalties due the author shall be made as of June 30 of each year and shall be reported to the author as soon thereafter as is possible. Royalties shall be paid to the author within three months after June 30.

H. The authors shall notify the publisher before publication

Fall 1971 - Summer 1972

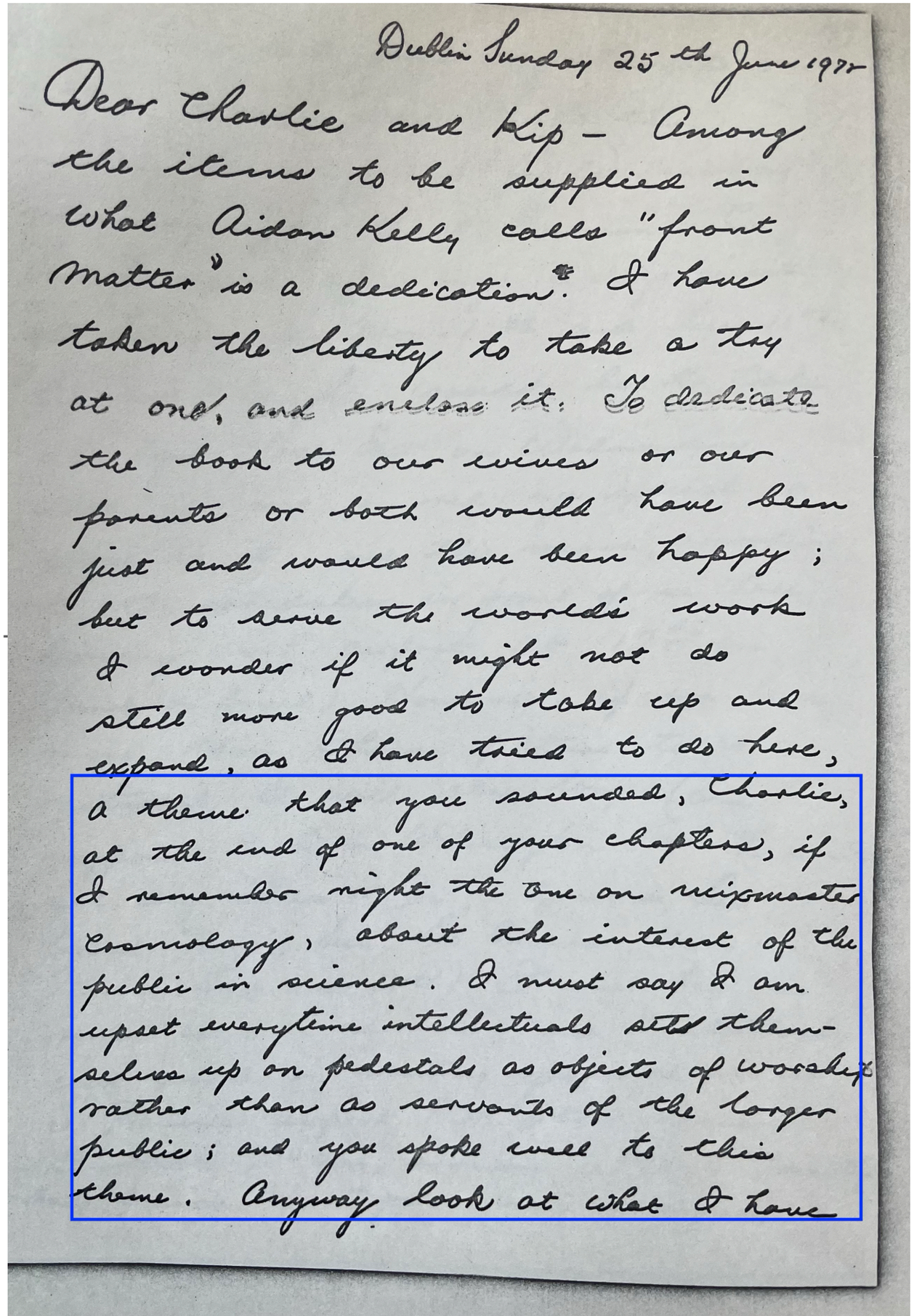
- Massaged manuscript.
  - added a dedication

Motivation for Dedication

Letter from John - 25 January 1972

I would like to "… take up and expand on … a theme that you sounded, Charlie, at the end of your chapter on … Mixmaster cosmology, about the interest of the public in science. I must say I am upset every time intellectuals set themselves up on pedestals as objects of worship rather than as servants of the larger public…"

In that vein he proposed this dedication



Dublin Sunday 25th June 1972

Dear Charlie and Kip – Among the items to be supplied in what Aidan Kelly calls "front matter" is a dedication. I have taken the liberty to take a try at one, and enclose it. To dedicate the book to our wives or our parents or both would have been just and would have been happy; but to serve the world's work I wonder if it might not do still more good to take up and expand, as I have tried to do here, a theme that you sounded, Charlie, at the end of one of your chapters, if I remember right the one on mixmaster cosmology, about the interest of the public in science. I must say I am upset everytime intellectuals set themselves up on pedestals as objects of worship rather than as servants of the larger public; and you spoke well to this theme. Anyway look at what I have

This book is dedicated

To the humble old lady

Sweeping the walk with her broom

The eager child,

And all who with their love of truth

Take from their own wants

By taxes and gifts,

And now and then send forth

A dedicated servant out of their number,

To forward the search

Into the mysteries and marvelous simplicities

of this strange and beautiful Universe

Our home.

This book is dedicated

~~To the humble old lady~~

~~Sweeping the walk with her broom~~

~~The eager child,~~

To

~~And~~ all who with their love of truth

Take from their own wants

By taxes and gifts,

And now and then send for

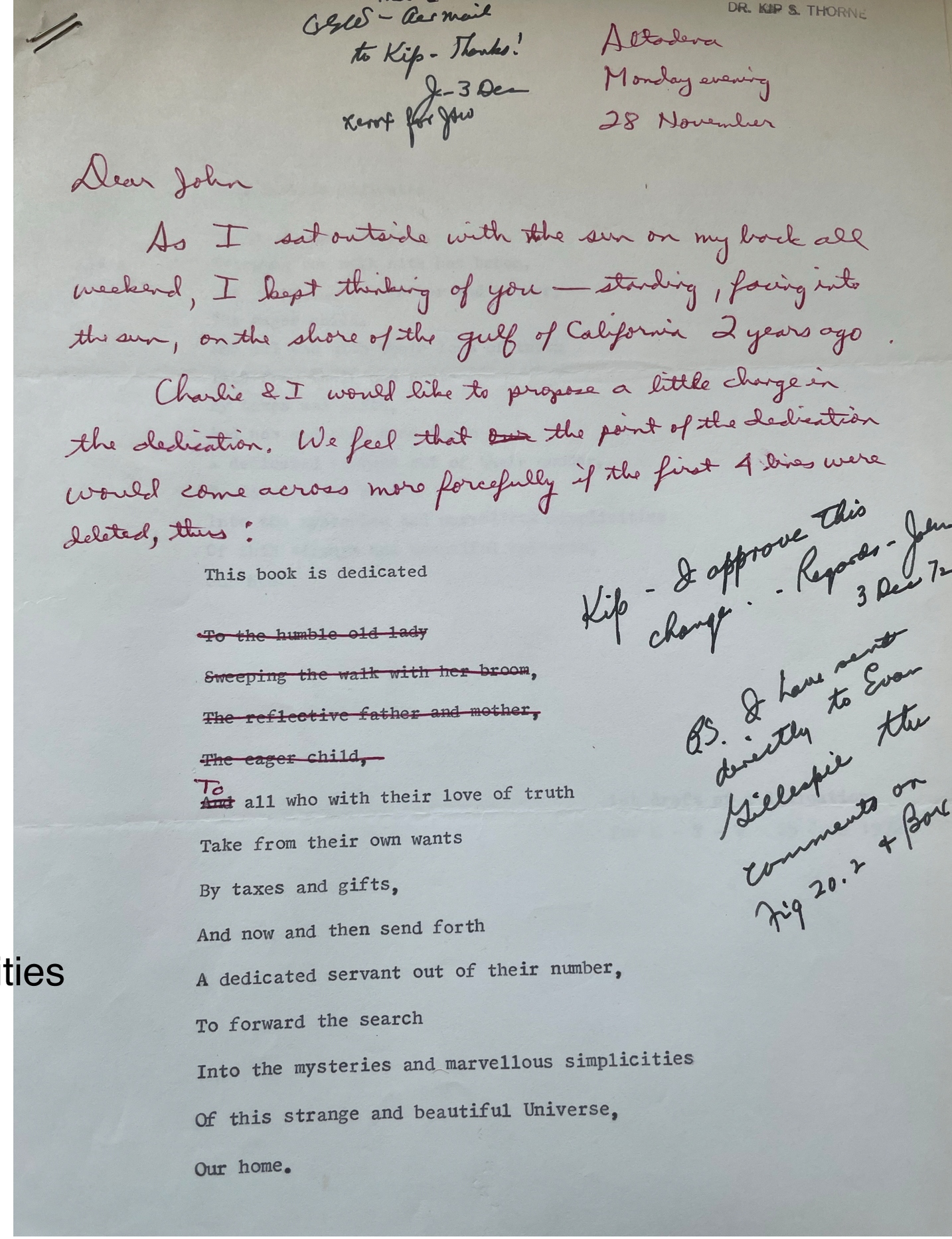
A dedicated servant out of their number,

To forward the search

Into the mysteries and marvelous simplicities

of this strange and beautiful Universe

Our home.



DR. KIP S. THORNE

Altadena
Monday evening
28 November

Dear John

As I sat outside with the sun on my back all weekend, I kept thinking of you — standing, facing into the sun, on the shore of the gulf of California 2 years ago.

Charlie & I would like to propose a little change in the dedication. We feel that ~~our~~ the point of the dedication would come across more forcefully if the first 4 lines were deleted, thus:

This book is dedicated

~~To the humble old lady~~

~~Sweeping the walk with her broom~~,

~~The reflective father and mother,~~

~~The eager child,~~

To
~~And~~ all who with their love of truth

Take from their own wants

By taxes and gifts,

And now and then send forth

A dedicated servant out of their number,

To forward the search

Into the mysteries and marvellous simplicities

Of this strange and beautiful Universe,

Our home.

Kip - I approve this change. - Regards - John
3 Dec 7-

P.S. I have sent directly to Evan Gillespie the comments on Fig 20.2 + Box

Fall 1971 - Summer 1972

- Massaged manuscript.
  - added a dedication
- Added and checked references.
  - John took responsibility; maintained bibliography
- Checked equations in manuscript & searched for errata
  - Goal: NO errors in equations - if readers find errors they quickly lose faith.
    - (I'm aware of about 10 errors in the first printing of the entire book.)
  - We each took responsibility for 1/3 of chapters, and hired a student to help. - Mine was Carlton Caves

Chapter Assignments for Equation Checking

edited manuscript will be back at Freeman within a week or so.

There remains the crucial problem of getting the errors out of our equations. Let me remind you that we have each agreed to recheck every equation in the following sets of chapters:

Charles	Kip	John
3	5	1
7	8	2
9	13	4
10	16	6
11	19	17
12	22	21
14	24	25
15	26	27
18	29	28
20	32	31
23	33	37
30	36	41
34	38	42
35	39	43
	40	44

I have already hired a student to help me with my rechecking. I hope that you are both proceeding in one manner or another. Of course, the recheck must be completed by galley-proof time. And that is not far off. I gather we can expect to start receiving galleys on the early

Errata from Readers

⇒ Carl Caves:
Here is a rather thorough error list.
-Kip

I have incorporated the errors listed except those for C.'s 14-15, since I am not familiar with those chapters. C.C.

August 4, 1972
5206 Newton St. Apt T2
Bladensburg, Md. 20710

Kip S. Thorne
Kellogg Radiation Laboratory
California Institute of Technology
Pasadena, California 91109

Dear Dr. Thorne,

Last semester I took Dr. Brill's relativity course at Maryland using your "Second Preliminary Edition" of your book Gravitation. I circled the errors I found but never wrote them down to send to you. Enclosed, you will find my corrections for volume I. I don't have time to do the same for volumes II and III because I must study for my qualifier, on Aug 23-24. After that I will gladly write up my corrections if you can still make use of them. Please notify me of the latest date at which you would still want them. If possible could you

PART I, II, III, IV
YOUR CRITICAL COMMENTS

A major reason for our producing this preliminary version of our tex book is to get feedback from you that will improve the final version. We seek, particularly, critical remarks, not complementary ones! We would b grateful if, as you work through the book, you would fill out this sheet others like it at the end of each Part. After you have finished each Part please tear its sheet from the book, fold it in thirds, staple it, and ma it. The address is on the back. Thank you! — CWM, KST, and JAW

Please list here all errors and serious deficiencies which you found in the text:

Errors

X Box 1.3, page 5/5, line 6, "length of SAB",
X Chapt 2, p.46, line 3 from below, "even the components (2.
X Chapt. 2, some references are incomplete.
X Chapt. 5, p.124, l.4, "(Figure 5-3 a)"
X Chapt 5, p.125, l.5 from below, "in Figure 5-3"
X Box 8.3, p. 313, l.17, "$[u,v] = (u^\beta v^\alpha_{;\beta} - v^\beta u^\alpha_{;\beta})(d/dx$
X Chapt 10, p. 231, last line, "gradient of a $\binom{1}{0}$ tensor"
X Chapt 10, p. 233, l.4 from below, "at the event P_0 is"
X Box 10.2, page 4/6, line 12, "derivative of b along u" der
X Chap. 11, p. 254, l.5, "to (11.12)"
X Chapt 11, p. 255, eqn. (11.14) δA + Riemann (..., u Δa, v
eqn. (11.14") Similar change: Riemann (...,
X Box 12.1, p. 2/2, first eqn, "$\frac{D^2 x^\alpha}{d\lambda^2} =$"
X Chapt 13, p. 295, last eqn, $X^{\alpha'} = \Lambda^{\alpha'}_{\ \mu} X^\mu + \frac{1}{2} N^{\alpha'}_{\mu\nu} X^\mu$
X Chapt 13, p. 309, l.2 from below, "(Fig. 13.4a)"
X Figure 13.4, {Notation on the figure is inconsistent with where $P = \omega[\tau, n, s)$, but on the diag
$P = \omega[\tau, s, n)$
X Chapt. 17, page 17.7, l.2, "and (iv) vanishes"
X Chapt. 17, p. 17.16, l.6, "$\frac{d^2 x^i}{dt^2} = \frac{d^2 x^i}{dz^2}$"
X Chapt 17, Box 17.2, p. 4/20, l.7, "Box 17.2 is part"

February 1972 - SHOCK from Publisher

with it. [...] Freeman had not been expecting to pick up the textbook market with this book" at all, but rather to prepare an expensive hardcover edition for sale to libraries.

Kip Thorne to John Wheeler and Charles Misner, February 17, 1972

We negotiated a reduction in royalties, in return for which a paperback edition would be priced below or same as Weinberg's book.

Publisher did a market survey.
Estimated lifetime sales of 8000 copies
(I was told in extreme confidence)

~ September 1972? - Another Shock

- We were beginning to submit chapters for copy editing. Publisher told me: Production much more complex than they had anticipated. ***No way book could be out in time for classes in autumn 1973!***

- I went to San Francisco and discussed with editorial and production staff. A recently hired young woman named ***Beth Eddy*** asserted that, if they put her in charge of production, she could make that deadline.

- She was given the job, succeeded, made a great reputation for herself, and after our book came out, left Freeman for greener pastures.

from my memory - I can't find paper documentation

Beth's Production Schedule

	Begin	End
MS. TO PROD.	(11/15)	12/20
MS. TO COMP.	10/27	1/8
GG IN	12/4	2/14
GG TO AU.	12/8	2/19
DUMMYING	12/18	2/28
GG FROM AU.	1/5	3/12
DUMMY TO. AU.	1/5	3/12
DUMMY FROM AU.	1/26	4/2
GG/DUMMY TO COMP.	2/2	4/9
F.M. TO COMP.	2/2	
PP IN	3/16	5/7
PP TO AU.	3/21	5/11
PP FROM AU.	4/12	6/4
PP TO COMP.	4/19	6/11
INDEX TO COMP.	6/11	
BLUES IN	7/16	7/17
B.BOOKS	9/14/73	

galleys to authors
rechecked equations
once again

page proofs to authors

I indexed in San Francisco

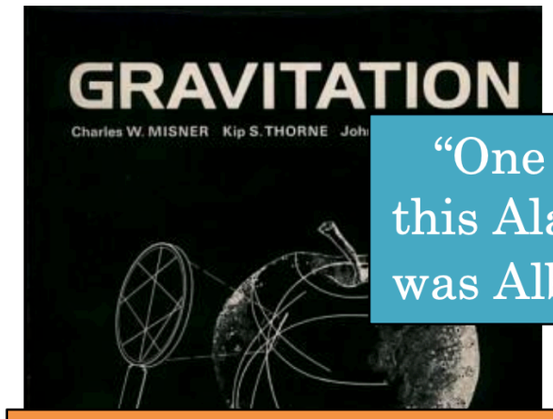
Book Published

Colleagues' and Reviewers' Reactions to MTW

What Kind of Book is MTW?

"A pedagogic masterpiece."

Dennis Sciama, *Science* (March 22, 1974)

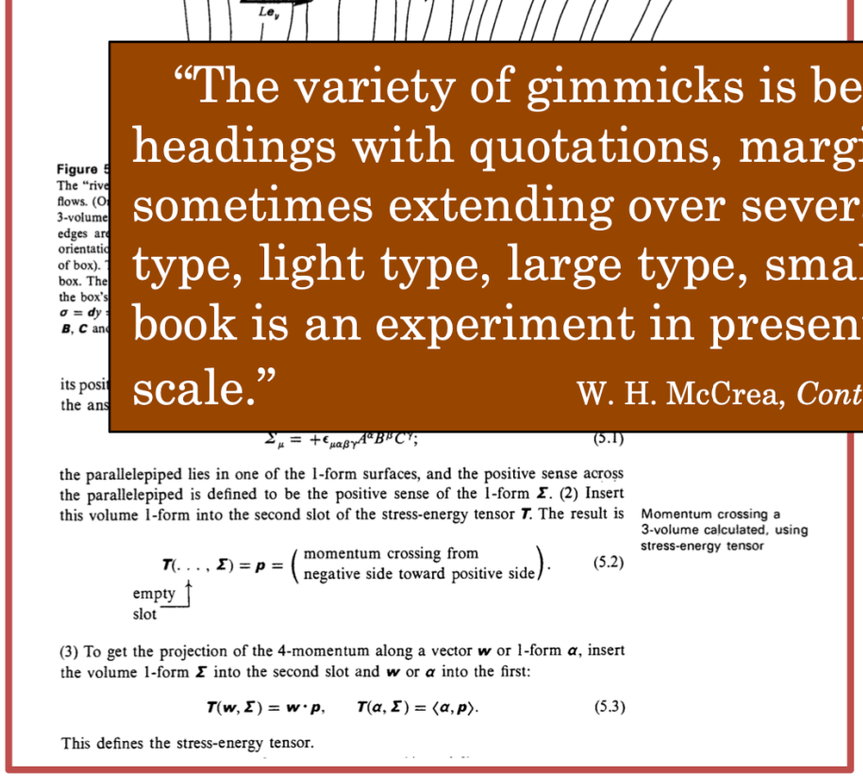


"One of the great books of science, a lamp to illuminate this Aladdin's cave of theoretical physics whose genie was Albert Einstein."

Michael Berry, *Science Progress* (1975)

"This is a difficult book to read in a linear, progressive fashion. [...] There is a commendable attempt at informality, but this reviewer found the breeziness irritating at times."

L. Resnick, *Physics in Canada* (June 1975)

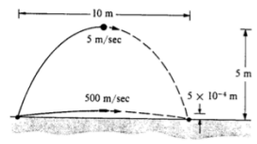


Box 1.6 CURVATURE OF WHAT?

Nothing seems more attractive at first glance than the idea that gravitation is a manifestation of the curvature of space (A), and nothing more ridicu-

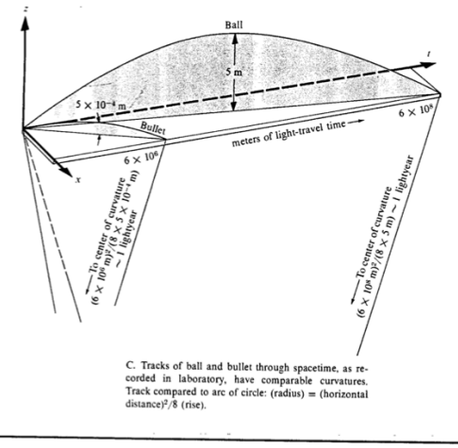
of spacetime and the curvature of spacetime. To make that forward step took the forty years to special relativity (1905: time on the same footing as space) and then another ten years (1915: gen-

ratory. The earth-bound laboratory has no simple status whatsoever in a proper discussion. First, it is no Lorentz frame. Second, even to mention the earth makes one think of an action at a distance



B. Tracks of ball and bullet through space as seen in laboratory have very different curvatures.

Photograph of stars when sun (eclipsed by moon) lies as indicated



C. Tracks of ball and bullet through spacetime, as recorded in laboratory, have comparable curvatures. Track compared to arc of circle: (radius) = (horizontal distance)²/8 (rise).

light pursues geodesic, but geometry in which it travels is curved (actual travel takes place in spacetime rather than space; correct deflection is twice that given by above elementary picture). Deflection inversely proportional to angular separation between star and center of

"The variety of gimmicks is bewildering—framed headings with quotations, marginal titles, 'boxes' sometimes extending over several pages, heavy type, light type, large type, small type. Clearly the book is an experiment in presentation on a grand scale."

W. H. McCrea, *Contemporary Physics* (July 1974)

Figure 5

The "rive
flows. (O
3-volume
edges ar
orientatio
of box).
box. The
the box's
$\sigma = dy$
B, C an

its posit
the ans

$$\Sigma_\mu = +\epsilon_{\mu\alpha\beta\gamma} A^\alpha B^\beta C^\gamma; \qquad (5.1)$$

the parallelepiped lies in one of the 1-form surfaces, and the positive sense across the parallelepiped is defined to be the positive sense of the 1-form $\boldsymbol{\Sigma}$. (2) Insert this volume 1-form into the second slot of the stress-energy tensor $\boldsymbol{T}$. The result is

Momentum crossing a 3-volume calculated, using stress-energy tensor

$$\boldsymbol{T}(\ldots, \boldsymbol{\Sigma}) = \boldsymbol{p} = \begin{pmatrix} \text{momentum crossing from} \\ \text{negative side toward positive side} \end{pmatrix}. \qquad (5.2)$$

empty slot ↑

(3) To get the projection of the 4-momentum along a vector $\boldsymbol{w}$ or 1-form $\boldsymbol{\alpha}$, insert the volume 1-form $\boldsymbol{\Sigma}$ into the second slot and $\boldsymbol{w}$ or $\boldsymbol{\alpha}$ into the first:

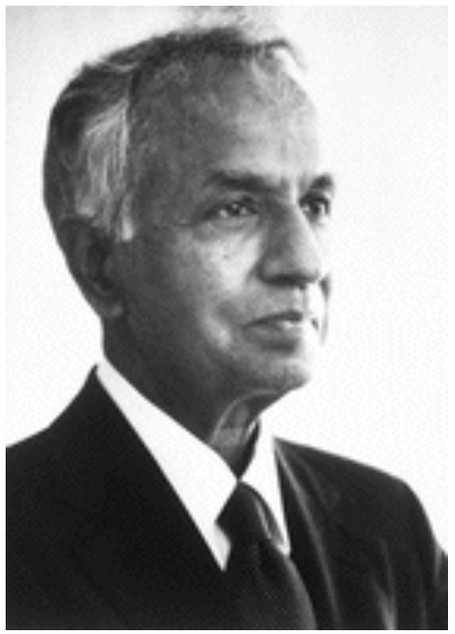
$$\boldsymbol{T}(\boldsymbol{w}, \boldsymbol{\Sigma}) = \boldsymbol{w} \cdot \boldsymbol{p}, \qquad \boldsymbol{T}(\boldsymbol{\alpha}, \boldsymbol{\Sigma}) = \langle \boldsymbol{\alpha}, \boldsymbol{p} \rangle. \qquad (5.3)$$

This defines the stress-energy tensor.

A reader would be most comfortable with *MTW* "if he is a regular subscriber to *Time* magazine—the writing of these authors has much in common with its breathless style."

Ian Roxburgh, *New Scientist* (September 26, 1974)

Colleagues' and Reviewers' Reactions



- S. Chandrasekhar (Chandra), a close personal friend of mine, wrote a review for *Physics Today*

MTW - reviews

Kip: If you are disappointed with the review, you may take consolation in T. Huxley's remark, "A man of science past sixty does more harm than good."

Chandra

There is one over-riding impression this book leaves: "It is written with the zeal of a missionary preaching to cannibals" … But this reviewer (probably for historical reasons) has always been allergic to missionaries."

The last paragraph of the review left me chuckling for about ten minutes.

- Differences in style between Chandra and John Wheeler.

MTW as a “Cult” Book

- Street People in Berkeley ~ 1973 - 1975
- U Texas Austin Physics Department

Are thoughts of the ‘Why’ keeping you up at night?

Us too, and we have coffee.

UT Physics

Demise of MTW

- WH Freeman was purchased by Scientific American in 1964 (before our 1971 signing with them)
- In 1986 Scientific American sold WH Freeman to Holtzbrink publishing group
- In 1999 McMillan Publishers was sold to the Holtzbrinck, and in 2007 Holtzbrinck in the U.S. changed its name to Macmillan. After that Freeman became an imprint of Macmillan.
- In 2008 John died. - Huge loss!
- Around 2014 Macmillan classified MTW as *Chemistry* and moved it into its Chemistry Catalog and appears to have stopped marketing it on Amazon. Sales dropped precipitously, and in 2015 Macmillan took MTW out of print without notifying the authors.
- I got a few emails from people having trouble buying the book, and the next royalty statement from Macmillan showed zero sales in the U.S.

Resurrection

- After consulting with Charlie and with John Wheeler's children Jamie, Letitia, and Alison, I arranged for Joan Winstein (who was experienced in dealing with Macmillan on similar matters) to negotiate with Macmillan.

- A few days after LIGO announced discovery of gravitational waves, Joan began trying, via emails and phone calls, to get Macmillan to either put MTW back into print, or return rights to the authors. Macmillan showed no interest in doing either, despite pleadings that the discovery of gravitational waves would trigger increased sales.

- After two months of total inaction by Macmillan, Joan had an attorney write a letter demanding the return of rights to the authors, on grounds that Macmillan had failed to put the book back in print or even say they would do so. Macmillan quickly responded, returning us all rights to the book

Resurrection

- With rights in hand, we explored republishing with Dover and Princeton University Press - and chose Princeton.
- Sales with Princeton, in five years (2017-2022) have been 25,000: 5,000 a year on average.
    - for ebook at list price $44.
    - in hardback at list price $60. — which deflates to about $10. in 1973
        - compared to list price about $20. for paperback in 1973, when first published.
- Lifetime Sales have been about 110,000 - compared to WH Freeman & Company's 1972 Market estimate of 8,000.

John and Janette Wheeler

"It looks strange and it looks strange, and it looks very strange, and then suddenly it does not look strange at all, and you cannot understand what made it look strange in the first place." - Gertrude Stein