

# GRAVITATION

## Universal Law of Gravitation

According to Newton's universal law of gravitation, every object in the universe attracts every other object with a force, which is

- (i) Directly proportional to the product of the masses of the objects and
- (ii) Inversely proportional to the square of the distance between their centres.

$$G = \frac{F \times d^2}{M \times m}$$

The SI unit of  $G$  can be obtained by substituting the unit of force, distance and mass in equation (iii).

$$G = \frac{Nm^2}{kg \times kg}$$

$$G = Nm^2 / kg^2 \text{ or } G = Nm^2 kg^{-2}$$

Newton's third law of motion (i.e., action and reaction are always equal and opposite) applies to gravitational force as well.

## Kepler's Laws of Planetary Motion

**1<sup>st</sup> Law:** Every planet revolves around the Sun in an elliptical orbit, with the Sun situated at any one of the foci of the ellipse.

**2<sup>nd</sup> Law:** In the elliptical orbit of the planet, the line joining the centre of the planet to the centre of Sun sweeps out equal areas in equal intervals of time.

**3<sup>rd</sup> Law:** The Square of time period of revolution of a planet around the Sun is directly proportional to the cube of the semi-major axis or the elliptical orbit.

• Newton guessed the inverse square rule  $\left( \text{i.e., } F \propto \frac{1}{r^2} \right)$  using Kepler's third law of planetary motion, and assuming that orbits of planets around the Sun are circular.

**Gravity is the phenomenon of attraction between Earth and any other body.** Force of gravity,

$$F = \frac{GmM}{r^2}$$

where  $M$  is mass of Earth and  $m$  is mass of the body at a distance  $r$  from the centre of Earth.

## Relation between $g$ and $G$

The relation between  $g$  and  $G$  is  $g = \frac{GM}{R^2}$  where  $M$  is mass of Earth and  $R$  is radius of Earth.

The value of  $g$  does not depend on mass of the body.

## Three Equations of Motion under Gravity

$$v = u + gt$$

# Physics Notes 12 Science Gravitation Chapter

**Anthony Zee**



## Physics Notes 12 Science Gravitation Chapter :

*Epistemology of Experimental Gravity - Scientific Rationality* Nicolae Sfetcu, 2019 The evolution of gravitational tests from an epistemological perspective framed in the concept of rational reconstruction of Imre Lakatos based on his methodology of research programmes Unlike other works on the same subject the evaluated period is very extensive starting with Newton's natural philosophy and up to the quantum gravity theories of today In order to explain in a more rational way the complex evolution of the gravity concept of the last century I propose a natural extension of the methodology of the research programmes of Lakatos that I then use during the paper I believe that this approach offers a new perspective on how evolved over time the concept of gravity and the methods of testing each theory of gravity through observations and experiments I argue based on the methodology of the research programmes and the studies of scientists and philosophers that the current theories of quantum gravity are degenerative due to the lack of experimental evidence over a long period of time and of self immunization against the possibility of falsification Moreover a methodological current is being developed that assigns a secondary unimportant role to verification through observations and or experiments For this reason it will not be possible to have a complete theory of quantum gravity in its current form which to include to the limit the general relativity since physical theories have always been adjusted during their evolution based on observational or experimental tests and verified by the predictions made Also contrary to a widespread opinion and current active programs regarding the unification of all the fundamental forces of physics in a single final theory based on string theory I argue that this unification is generally unlikely and it is not possible anyway for a unification to be developed based on current theories of quantum gravity including string theory In addition I support the views of some scientists and philosophers that currently too much resources are being consumed on the idea of developing quantum gravity theories and in particular string theory to include general relativity and to unify gravity with other forces as long as science does not impose such research programs

CONTENTS Introduction Gravity Gravitational tests Methodology of Lakatos Scientific rationality The natural extension of the Lakatos methodology Bifurcated programs Unifying programs 1 Newtonian gravity 1 1 Heuristics of Newtonian gravity 1 2 Proliferation of post Newtonian theories 1 3 Tests of post Newtonian theories 1 3 1 Newton's proposed tests 1 3 2 Tests of post Newtonian theories 1 4 Newtonian gravity anomalies 1 5 Saturation point in Newtonian gravity 2 General relativity 2 1 Heuristics of the general relativity 2 2 Proliferation of post Einsteinian gravitational theories 2 3 Post Newtonian parameterized formalism PPN 2 4 Tests of general relativity and post Einsteinian theories 2 4 1 Tests proposed by Einstein 2 4 2 Tests of post Einsteinian theories 2 4 3 Classic tests 2 4 3 1 Precision of Mercury's perihelion 2 4 3 2 Light deflection 2 4 3 3 Gravitational redshift 2 4 4 Modern tests 2 4 4 1 Shapiro Delay 2 4 4 2 Gravitational dilation of time 2 4 4 3 Frame dragging and geodetic effect 2 4 4 4 Testing of the principle of equivalence 2 4 4 5 Solar system tests 2 4 5 Strong field gravitational tests 2 4 5 1 Gravitational lenses 2 4 5 2 Gravitational waves 2 4 5 3 Synchronization binary pulsars 2 4 5 4

Extreme environments 2 4 6 Cosmological tests 2 4 6 1 The expanding universe 2 4 6 2 Cosmological observations 2 4 6 3  
 Monitoring of weak gravitational lenses 2 5 Anomalies of general relativity 2 6 The saturation point of general relativity 3  
 Quantum gravity 3 1 Heuristics of quantum gravity 3 2 The tests of quantum gravity 3 3 Canonical quantum gravity 3 3 1  
 Tests proposed for the CQG 3 3 2 Loop quantum gravity 3 4 String theory 3 4 1 Heuristics of string theory 3 4 2 Anomalies of  
 string theory 3 5 Other theories of quantum gravity 3 6 Unification The Final Theory 4 Cosmology Conclusions Notes  
 Bibliography DOI 10.13140/RG.2.2.35350.70724      **On Gravity** Anthony Zee, 2020-03-10 Of the four fundamental forces of  
 nature gravity might be the least understood and yet the one with which we are most intimate From the months each of us  
 spent suspended in the womb anticipating birth to the moments when we wait for sleep to transport us to other realities we  
 are always aware of gravity In *On Gravity* physicist A Zee combines profound depth with incisive accessibility to take us on  
 an original and compelling tour of Einstein's general theory of relativity Inspired by Einstein's audacious suggestion that  
 spacetime could ripple Zee begins with the stunning discovery of gravity waves He goes on to explain how gravity can be  
 understood in comparison to other classical field theories presents the idea of curved spacetime and the action principle and  
 explores cutting edge topics including black holes and Hawking radiation Zee travels as far as the theory reaches leaving us  
 with tantalizing hints of the utterly unknown from the intransigence of quantum gravity to the mysteries of dark matter and  
 energy Concise and precise and infused with Zee's signature warmth and freshness of style *On Gravity* opens a unique  
 pathway to comprehending relativity and gaining deep insight into gravity spacetime and the workings of the universe  
 Publisher's website      [Gravitation and Inertia](#) Ignazio Ciufolini, John Archibald Wheeler, 2018-06-26 Einstein's standard and  
 battle tested geometric theory of gravity spacetime tells mass how to move and mass tells spacetime how to curve is  
 expounded in this book by Ignazio Ciufolini and John Wheeler They give special attention to the theory's observational checks  
 and to two of its consequences the predicted existence of gravitomagnetism and the origin of inertia local inertial frames in  
 Einstein's general relativity inertia here arises from mass there The authors explain the modern understanding of the link  
 between gravitation and inertia in Einstein's theory from the origin of inertia in some cosmological models of the universe to  
 the interpretation of the initial value formulation of Einstein's standard geometrodynamics and from the devices and the  
 methods used to determine the local inertial frames of reference to the experiments used to detect and measure the dragging  
 of inertial frames of reference In this book Ciufolini and Wheeler emphasize present past and proposed tests of gravitational  
 interaction metric theories and general relativity They describe the numerous confirmations of the foundations of  
 geometrodynamics and some proposed experiments including space missions to test some of its fundamental predictions in  
 particular gravitomagnetic field or dragging of inertial frames and gravitational waves      [The Gravity of Math](#) Steve  
 Nadis, Shing-Tung Yau, 2024-04-16 A must read Avi Loeb New York Times bestselling author of *Extraterrestrial* One of the  
 preeminent mathematicians of the past half century shows how physics and math were combined to give us the theory of

gravity and the dizzying array of ideas and insights that has come from it Mathematics is far more than just the language of science It is a critical underpinning of nature The famed physicist Albert Einstein demonstrated this in 1915 when he showed that gravity long considered an attractive force between massive objects was actually a manifestation of the curvature or geometry of space and time But in making this towering intellectual leap Einstein needed the help of several mathematicians including Marcel Grossmann who introduced him to the geometrical framework upon which his theory rest In The Gravity of Math Steve Nadis and Shing Tung Yau consider how math can drive and sometimes even anticipate discoveries in physics Examining phenomena like black holes gravitational waves and the Big Bang Nadis and Yau ask Why do mathematical statements derived solely from logic provide the best descriptions of our physical world The Gravity of Math offers an insightful and compelling look into the power of mathematics whose reach like that of gravity can extend to the edge of the universe

Advanced Interferometers and the Search for Gravitational Waves Massimo Bassan,2014-07-08 The search for gravitational radiation with optical interferometers is gaining momentum worldwide Beside the VIRGO and GEO gravitational wave observatories in Europe and the two LIGOs in the United States which have operated successfully during the past decade further observatories are being completed KAGRA in Japan or planned ILIGO in India The sensitivity of the current observatories although spectacular has not allowed direct discovery of gravitational waves The advanced detectors Advanced LIGO and Advanced Virgo at present in the development phase will improve sensitivity by a factor of 10 probing the universe up to 200 Mpc for signal from inspiraling binary compact stars This book covers all experimental aspects of the search for gravitational radiation with optical interferometers Every facet of the technological development underlying the evolution of advanced interferometers is thoroughly described from configuration to optics and coatings and from thermal compensation to suspensions and controls All key ingredients of an advanced detector are covered including the solutions implemented in first generation detectors their limitations and how to overcome them Each issue is addressed with special reference to the solution adopted for Advanced VIRGO but constant attention is also paid to other strategies in particular those chosen for Advanced LIGO

**Science Between Myth and History** José G. Perillán,2021 Science Between Myth and History explores scientific storytelling and its implications on the teaching practice and public perception of science In communicating their science scientists tend to use historical narratives for important rhetorical purposes This text explores the implications of doing this

**Literature 1988, Part 2** Astronomisches Rechen-Institut,2013-06-29 From the reviews Astronomy and Astrophysics Abstracts has appeared in semi annual volumes since 1969 and it has already become one of the fundamental publications in the fields of astronomy astrophysics and neighbouring sciences It is the most important English language abstracting journal in the mentioned branches The abstracts are classified under more than a hundred subject categories thus permitting a quick survey of the whole extended material The AAA is a valuable and important publication for all students and scientists working in the fields of astronomy and related sciences As such it represents a necessary ingredient

of any astronomical library all over the world Space Science Reviews 1 Dividing the whole field plus related subjects into 108 categories each work is numbered and most are accompanied by brief abstracts Fairly comprehensive cross referencing links relevant papers to more than one category and exhaustive author and subject indices are to be found at the back making the catalogues easy to use The series appears to be so complete in its coverage and always less than a year out of date that I shall certainly have to make a little more space on those shelves for future volumes The Observatory Magazine 2 *From Gravity to Thermal Gauge Theories: The AdS/CFT Correspondence* Eleftherios Papantonopoulos, 2011-03-26 The AdS CFT correspondence is a powerful tool in studying strongly coupled phenomena in gauge field theories using results from a weakly coupled gravity background studied in the realm of string theory AdS CFT was first successfully applied to the study of phenomena such as the quark gluon plasma produced in heavy ions collisions Soon it was realized that its applicability can be extended in a more phenomenological approach to condensed matter systems and to systems described by fluid dynamics The set of tutorial reviews in this volume is intended as an introduction to and survey of the principle of the AdS CFT correspondence in its field string theoretic formulation its applicability to holographic QCD and to heavy ions collisions and to give a first account of processes in fluid dynamics and condensed matter physics which can be studied with the use of this principle Written by leading researchers in the field and cast into the form of a high level but approachable multi author textbook this volume will be of benefit to all postgraduate students and newcomers from neighboring disciplines wishing to find a comprehensive guide for their future research *The American Mathematical Monthly*, 1920 Includes section Recent publications **Deep Space Flight and Communications** Claudio Maccone, 2009-06-09 The majority of books dealing with prospects for interstellar flight tackle the problem of the propulsion systems that will be needed to send a craft on an interstellar trajectory The proposed book looks at two other equally important aspects of such space missions and each forms half of this two part book Part 1 looks at the ways in which it is possible to exploit the focusing effect of the Sun as a gravitational lens for scientific missions to distances of 550 AU and beyond into interstellar space The author explains the mechanism of the Sun as a gravitational lens the scientific investigations which may be carried out along the way to a distance of 550 AU and at the 550 AU sphere itself the requirements for exiting the Solar System at the highest speed and a range of project ideas for missions entering interstellar space Part 2 of the book deals with the problems of communicating between an interstellar spaceship and the Earth especially at very high speeds Here the author assesses a range of mathematical tools relating to the Karhunen Lo ve Transform KLT for optimal telecommunications technical topics that may one day enable humans flying around the Galaxy to keep in contact with the Earth This part of the book opens with a summary of the author's 2003 Pe ek Lecture presented at the IAC in Bremen which introduces the concept of KLT for engineers and newcomers to the subject It is planned to include a DVD containing the full mathematical derivations of the KLT for those interested in this important mathematical tool whilst the text itself will contain the various results without

outlines of the mathematical proofs Astronautical engineers will thus be able to see the application of the results without getting bogged down in the mathematics

**Gravity: From Falling Apples to Supermassive Black Holes** Nicholas Mee, 2022-11-18 Includes exciting recent advances in studying gravity and its cosmic manifestations Lord Martin Rees Astronomer Royal former President of the Royal Society A fascinating historical account of how we have reached our current understanding of gravity There have been sensational developments in gravitational physics in recent years The detection of gravitational waves ripples in the fabric of space has opened a new window on the universe These waves are produced by the most cataclysmic events in the universe the collisions and mergers of black holes and neutron stars There have also been great strides in our understanding of supermassive black holes We now know that a black hole with a gargantuan mass lies at the heart of every galaxy and we even have an image of one such beast Gravity From Falling Apples to Supermassive Black Holes provides an engaging and accessible account of how we have reached our current understanding of gravity and places these amazing discoveries in their true context Gravity From Falling Apples to Supermassive Black Holes is written in a captivating historical style with stories about the researchers of the past and present that illuminate many key ideas in astronomy and physics The historical material leads from discussions of the early cosmologies to the great breakthroughs of Tycho and Kepler We then consider Galileo's contributions to astronomy and mechanics and the significance of Jeremiah Horrocks's ideas to the Newtonian revolution that would follow Newton's theories brought about a new scientific age and his description of gravity was unrivalled for over two centuries until it was superseded by Einstein's description in terms of curved spacetime The outlandish predictions of Einstein's theory have been confirmed again and again including black holes and gravitational waves Finally we move on to more speculative ideas including Hawking radiation and primordial black holes and attempts to find a quantum theory of gravity

3D Printed Science Projects Joan Horvath, Rich Cameron, 2016-05-11 Create 3D printable models that can help students from kindergarten through grad school learn math physics botany chemistry engineering and more This book shows parents and teachers how to use the models inside as starting points for 3D printable explorations Students can start with these models and vary them for their own explorations Unlike other sets of models that can just be scaled these models have the science built in to allow for more insight into the fundamental concepts Each of the eight topics is designed to be customized by you to create a wide range of projects suitable for science fairs extra credit or classroom demonstrations Science fair project suggestions and extensive where to learn more resources are included too You will add another dimension to your textbook understanding of science What You'll Learn Create and present the science behind 3D printed models Use a 3D printer to create those models as simply as possible Discover new science insights from designing 3D models Who This Book Is For Parents and teachers

General Relativity and Gravitation, 1989 Neil Ashby, David F. Bartlett, Walter Wyss, 1990-10-26 This volume contains the proceedings of the twelfth triannual International Conference on General Relativity and Gravitation the premier conference for presentation and

discussion of new ideas in relativity and cosmology The volume will contain the invited talks as well as short reports on the parallel workshops that took place at the meeting It will be essential reading for all research workers in relativity cosmology and astrophysics

The Singularity Uziel Awret, 2016-11-23 This volume represents the combination of two special issues of the Journal of Consciousness Studies on the topic of the technological singularity Could artificial intelligence really out think us and what would be the likely repercussions if it could Leading authors contribute to the debate which takes the form of a target chapter by philosopher David Chalmers plus commentaries from the likes of Daniel Dennett Nick Bostrom Ray Kurzweil Ben Goertzel Frank Tipler among many others Chalmers then responds to the commentators to round off the discussion

**The Quantization of Gravity** Claus Gerhardt, 2018-04-14 A unified quantum theory incorporating the four fundamental forces of nature is one of the major open problems in physics The Standard Model combines electro magnetism the strong force and the weak force but ignores gravity The quantization of gravity is therefore a necessary first step to achieve a unified quantum theory In this monograph a canonical quantization of gravity has been achieved by quantizing a geometric evolution equation resulting in a gravitational wave equation in a globally hyperbolic spacetime Applying the technique of separation of variables we obtain eigenvalue problems for temporal and spatial self adjoint operators where the temporal operator has a pure point spectrum with eigenvalues  $\lambda_i$  and related eigenfunctions while for the spatial operator it is possible to find corresponding eigendistributions for each of the eigenvalues  $\lambda_i$  if the Cauchy hypersurface is asymptotically Euclidean or if the quantized spacetime is a black hole with a negative cosmological constant The hyperbolic equation then has a sequence of smooth solutions which are products of temporal eigenfunctions and spatial eigendistributions Due to this spectral resolution of the wave equation quantum statistics can also be applied to the quantized systems These quantum statistical results could help to explain the nature of dark matter and dark energy

*Einstein Gravity in a Nutshell* A. Zee, 2013-05-05 An ideal introduction to Einstein's general theory of relativity This unique textbook provides an accessible introduction to Einstein's general theory of relativity a subject of breathtaking beauty and supreme importance in physics With his trademark blend of wit and incisiveness A Zee guides readers from the fundamentals of Newtonian mechanics to the most exciting frontiers of research today including de Sitter and anti de Sitter spacetimes Kaluza Klein theory and brane worlds Unlike other books on Einstein gravity this book emphasizes the action principle and group theory as guides in constructing physical theories Zee treats various topics in a spiral style that is easy on beginners and includes anecdotes from the history of physics that will appeal to students and experts alike He takes a friendly approach to the required mathematics yet does not shy away from more advanced mathematical topics such as differential forms The extensive discussion of black holes includes rotating and extremal black holes and Hawking radiation The ideal textbook for undergraduate and graduate students *Einstein Gravity in a Nutshell* also provides an essential resource for professional physicists and is accessible to anyone familiar with classical mechanics and electromagnetism It



features numerous exercises as well as detailed appendices covering a multitude of topics not readily found elsewhere  
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Ideal for students physicists and scientifically minded lay readers Solutions manual available only to teachers

Gravitational Field Khalid S. Essa, 2022-12-14 This book presents a comprehensive overview of gravity and gravitational fields The eight chapters are presented in two sections Chapters in the first section address such topics as the theory of gravity transient gravitational forces the nature of our temporal universe and photo-gravitational celestial mechanics Chapters in the second section discuss how to create a gravity survey analyze data collected by satellites and on the ground and present visualizations of several field cases around the world

**An Introduction to General Relativity and Cosmology** Jerzy Plebanski, Andrzej Krasinski, 2006-08-14 General relativity is a cornerstone of modern physics and is of major importance in its applications to cosmology Plebanski and Krasinski are experts in the field and in this book they provide a thorough introduction to general relativity guiding the reader through complete derivations of the most important results Providing coverage from a unique viewpoint geometrical physical and astrophysical properties of inhomogeneous cosmological models are all systematically and clearly presented allowing the reader to follow and verify all derivations For advanced undergraduates and graduates in physics and astronomy this textbook will enable students to develop expertise in the mathematical techniques necessary to study general relativity

Matter & Gravity in Newton's Physical Philosophy Adolph Judah Snow, 1926

*100 Years of Gravity and Accelerated Frames* Jong-Ping Hsu, Dana Fine, 2005 This collection of papers presents ideas and problems arising over the past 100 years regarding classical and quantum gravity gauge theories of gravity and spacetime transformations of accelerated frames Both Einstein's theory of gravity and the Yang-Mills theory are gauge invariant The invariance principles in physics have transcended both kinetic and dynamic properties and are at the very heart of our understanding of the physical world In this spirit this book attempts to survey the development of various formulations for gravitational and Yang-Mills fields and spacetime transformations of accelerated frames and to reveal their associated problems and limitations The aim is to present some of the leading ideas and problems discussed by physicists and mathematicians We highlight three aspects formulations of gravity as a Yang-Mills field first discussed by Utiyama problems of gravitational theory discussed by Feynman Dyson and others spacetime properties and the physics of fields and particles in accelerated frames of reference These unfulfilled aspects of Einstein and Yang-Mills profound thoughts present a great challenge to physicists and mathematicians in the 21st century

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### **Table of Contents Physics Notes 12 Science Gravitation Chapter**

1. Understanding the eBook Physics Notes 12 Science Gravitation Chapter
  - The Rise of Digital Reading Physics Notes 12 Science Gravitation Chapter
  - Advantages of eBooks Over Traditional Books
2. Identifying Physics Notes 12 Science Gravitation Chapter
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Physics Notes 12 Science Gravitation Chapter
  - User-Friendly Interface
4. Exploring eBook Recommendations from Physics Notes 12 Science Gravitation Chapter
  - Personalized Recommendations
  - Physics Notes 12 Science Gravitation Chapter User Reviews and Ratings

- Physics Notes 12 Science Gravitation Chapter and Bestseller Lists
- 5. Accessing Physics Notes 12 Science Gravitation Chapter Free and Paid eBooks
  - Physics Notes 12 Science Gravitation Chapter Public Domain eBooks
  - Physics Notes 12 Science Gravitation Chapter eBook Subscription Services
  - Physics Notes 12 Science Gravitation Chapter Budget-Friendly Options
- 6. Navigating Physics Notes 12 Science Gravitation Chapter eBook Formats
  - ePub, PDF, MOBI, and More
  - Physics Notes 12 Science Gravitation Chapter Compatibility with Devices
  - Physics Notes 12 Science Gravitation Chapter Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Physics Notes 12 Science Gravitation Chapter
  - Highlighting and Note-Taking Physics Notes 12 Science Gravitation Chapter
  - Interactive Elements Physics Notes 12 Science Gravitation Chapter
- 8. Staying Engaged with Physics Notes 12 Science Gravitation Chapter
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Physics Notes 12 Science Gravitation Chapter
- 9. Balancing eBooks and Physical Books Physics Notes 12 Science Gravitation Chapter
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Physics Notes 12 Science Gravitation Chapter
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Physics Notes 12 Science Gravitation Chapter
  - Setting Reading Goals Physics Notes 12 Science Gravitation Chapter
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Physics Notes 12 Science Gravitation Chapter
  - Fact-Checking eBook Content of Physics Notes 12 Science Gravitation Chapter
  - Distinguishing Credible Sources

- 
13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
  14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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