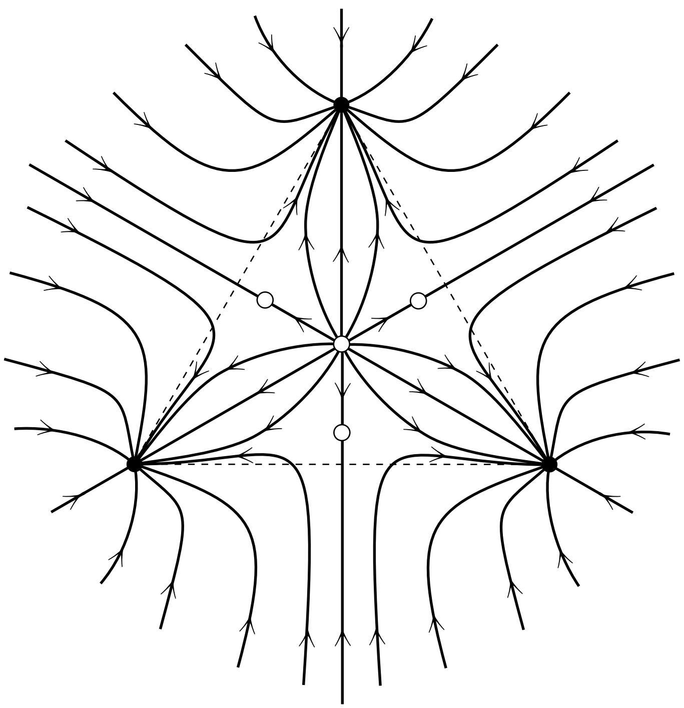
PHYSNET

MISN-0-108

THE GRAVITATIONAL FIELD



Project PHYSNET Physics Bldg. Michigan State University East Lansing, MI

THE GRAVITATIONAL FIELD

by

Peter Signell and Michael Brandl

Title: **The Gravitational Field**

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Input Skills:

1. Given a vector's components in two dimensions, determine the magnitude of the vector and the angle it makes with the two coordinate axes, and conversely (MISN-0-2).
2. Add vectors in two dimensions by addition of cartesian components (MISN-0-2).
3. Use Newton's Law of Gravitation to find the force on one mass due to a given configuration of other masses (MISN-0-101).

Output Skills (Knowledge):

K1. Define operationally the concept of the gravitational field, explaining how its spatio-temporal description differs from that of a particle or other massive object.

Output Skills (Problem Solving):

S1. Given a configuration of masses, calculate the gravitational field at a specified space-point.

S2. Given a configuration of masses, draw gravitational field lines and indicate all nulls.

External Resources (Required):

1. M. Alonso and E. J. Finn, *Physics*, Addison-Wesley (1970). For availability, see this module's *Local Guide*.

THIS IS A DEVELOPMENTAL-STAGE PUBLICATION
OF PROJECT PHYSNET

The goal of our project is to assist a network of educators and scientists in transferring physics from one person to another. We support manuscript processing and distribution, along with communication and information systems. We also work with employers to identify basic scientific skills as well as physics topics that are needed in science and technology. A number of our publications are aimed at assisting users in acquiring such skills.

Our publications are designed: (i) to be updated quickly in response to field tests and new scientific developments; (ii) to be used in both classroom and professional settings; (iii) to show the prerequisite dependencies existing among the various chunks of physics knowledge and skill, as a guide both to mental organization and to use of the materials; and (iv) to be adapted quickly to specific user needs ranging from single-skill instruction to complete custom textbooks.

New authors, reviewers and field testers are welcome.

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1. Introduction

A problem which bothered Newton, one to which he could find no satisfactory answer, was this: Suppose we suddenly move a mass to a position farther away from the center of the earth. Does the gravitational force on the moved-mass and on the earth each instantly decrease? If so, how could the object and the earth have instantly received the knowledge of each other's new distance to put into the Law of Universal Gravitation?

All information-carrying signals mankind has discovered have finite (non-infinite) speeds. In fact, there is strong reason to believe that no information-carrying signal can travel faster than the speed of light. Then is some constant-velocity signal constantly being emitted by each of the masses, reflected off the other mass, and received back with the transit time being measured in order to determine the distance? If so, what powers this communication process? Can we intercept the signal and measure its properties? The answers to these questions are still being developed, but the picture which has emerged so far in this century is a strange and wondrous one. It has provided a glimpse into the basic workings of nature which has seemed so un-human to many physicists, including the great Albert Einstein, that they have refused to accept it at face value. In this module we begin the investigation into the fundamentals of gravitation, picking up the vital concept of "field." A culmination of sorts occurs in Elementary Particle Physics, but a full understanding of the subtleties of the current picture in that area requires years of further study.

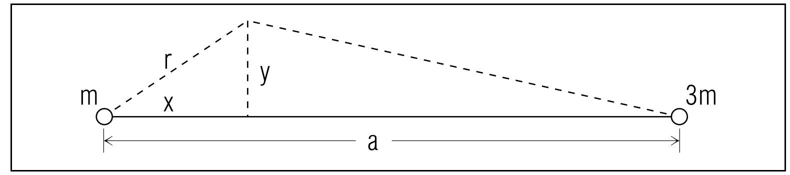
2. The Gravitational Field of a Spherical Body

Study Material: In AF[1] read Sections 15.6 and 15.8. The relevant text Questions, (p. 326) are: 10, 12 (force only), and 13 (field only, near the middle). Relevant Problems are: 15.27a, 15.28 a, b (field only), and 15.30 (field only).

Brief Answers:

[1] *Physics*, Alonso and Finn, Addison-Wesley (1970). For availability, see this module's *Local Guide*.

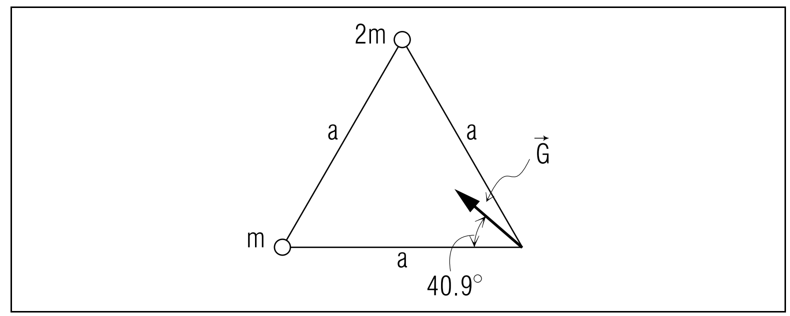
15.27 a. the point given by $x = 0.366a$, $y = z = 0$.



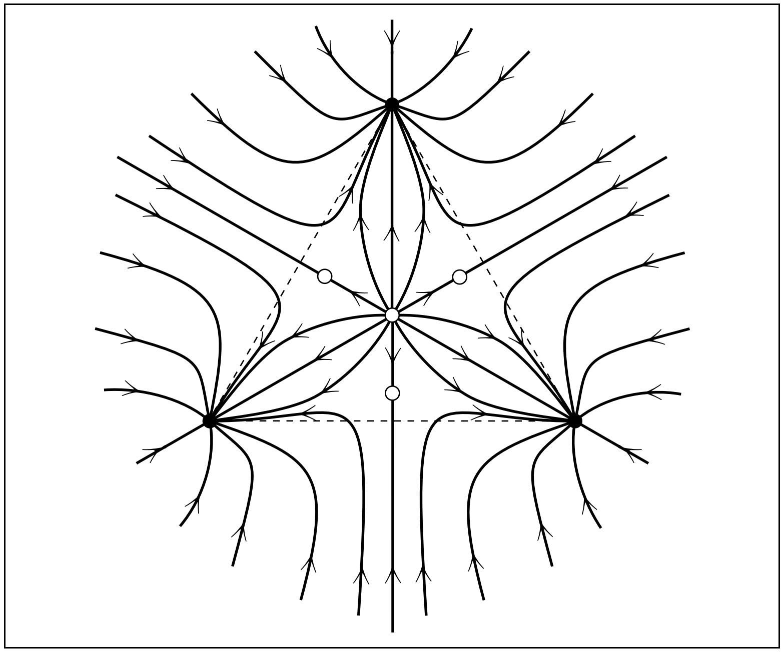
b. the point given by $x = -1.366a$ (negative sign means to left of m).

15.28 a. $4\gamma m/a^2$, toward $2m$.

b. $2.65\gamma m/a^2$, $40.9°$.



15.30 o = points where field is zero.



3. Operational Definition

An operational definition of the gravitational field[2] is given by specifying how you would measure its value at any specified point at any specified time. Note the difference from the specification of a particle's three position coordinates, each of which is a function of time. Finally, remember that when you measure the gravitational field at a space time point you must use a test mass which is very much smaller than the masses producing the gravitational field, so you don't cause the other masses to shift, thereby altering the field.

You are strongly urged to read, "Action at a Distance," pages 181-183 in Victor Guillemin's beautifully written book, *The Story of Quantum Mechanics*, Charles Scribner's Sons, N.Y. (1968).

[2]The word "field" is used to mean something that has a value at every point in space at any time. This is in contrast to a "particle," which exists at only one point in space at any particular time.

Acknowledgments

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LOCAL GUIDE

The readings for this unit are on reserve for you in the Physics-Astronomy Library, Room 230 in the Physics-Astronomy Building. Ask for them as "The readings for CBI Unit 108." Do **not** ask for them by book title.