PHYSICS 107 FALL 1994 — Prof. B. Durand

INFORMATION ABOUT PHYSICS 107

The Ideas of Modern Physics

Professor Bernice Durand, 4205 Chamberlin Hall, 262-3827, mailbox on 2nd floor of Chamberlin, email address: bdurand@wishep.physics.wisc.edu. Do not call me at home except for an emergency. Mailing address: Prof. Bernice Durand, Dept. of Physics, 1150 University Ave., Madison, WI 53706. I am a theoretical particle physicist.

Teaching Assistants Jonathan Hessler, 4250 Chamberlin Hall, 265-3430, mailbox on 2nd floor of Chamberlin. Jonathan can also be reached at 262-0011, his office in 418 Van Vleck (Math). Jonathan is a math graduate student.

Chris Greiveldinger, 3514 Sterling Hall, 262-7555, mailbox on 2nd floor of Chamberlin. Chris's email address is: greivel@astrog.physics.wisc.edu. Chris is an astrophysics graduate student.

Text *Physics for Poets, 3rd Ed.*, R.H. March, McGraw-Hill, 1992.

Goals "Physics for Poets" is a concepts course designed to acquaint you with

- the vocabulary of physics
- the personalities and methods of some great physicists
- the two great ideas of twentieth century physics, relativity and quantum mechanics
- the physics subjects you will most likely be reading about in the future.

My aim is for you to understand the concepts and how to apply them in a very simple way, not to become an expert problem solver. I will not ask you to be creative in physics!

Description There are three units. **Unit I** sweeps from Aristotle through Maxwell, covering more than 2000 years in four weeks. While partly historical, and heavily descriptive, this unit does include the simple mathematical formulation of a few specific physics accomplishments by Galileo, Kepler, Descartes, and Newton. In Unit I you will learn much of the necessary vocabulary and methodology for the course.

Unit II is the longest unit, and it starts with a "breather" on waves and chaos. Then it centers on Einstein's theory of special relativity, published in 1905 and one of the two great concepts of modern physics. During these three weeks you will not only grasp the logic behind the relativistic distortion of space and time, but also learn to calculate the magnitude of that distortion. We close the unit with general relativity, also Einstein's theory, and modern cosmology, how the whole universe evolves. This is a difficult and rewarding unit, which has cured most students of math anxiety.

Unit III first races through quantum mechanics, the second great concept of twentieth century physics, in less than three weeks. Since Planck introduced the "quantum" in 1900, physics has exploded, as has the number of physicists. We will become familiar with the work of many Nobel Physics laureates. In our final three weeks we come up to date with a crash course in 1990's physics vocabulary and a review of recent accomplishments and outstanding problems.

Lectures MWF 9:55, 1300 Sterling Hall.

Attendance at lectures is essential to learning the subjects covered on exams. The lectures include **demonstrations** (experiments performed live, with unpredictable success!) and my commentary on the concepts and physicists we are studying. You should master the textbook; but if reading a book is all you want out of a course, save your tuition! My lecture notes will be on reserve in the Physics Library after class. Videos of the TV version of the course are on reserve in the College Library and Physics Library. They cover the same subjects but were recorded in past semesters. Some of them have slightly different titles or numbers from this year. Follow this year's syllabus! *A considerable amount of the material is not in the text.* In many lectures, you will answer questions on small cards and hand them in (not to be graded), so I'll know if you weren't there!

Schedule See the gray schedule sheet. Please become familiar with it.

To Get Help Read this sheet for course information. Go to discussions for lecture and homework help. See your TA for help beyond discussion section. See me for special problems. ASK ONE OF US—WE'LL BE HAPPY TO ANSWER!

Discussion Sections DISCUSSION SECTIONS START MONDAY, SEPTEMBER 12. These are really HOMEWORK HELP SESSIONS, a way of MINIMIZING OUR INDIVIDUAL OFFICE HOURS, and they are OPTIONAL but *very useful*. If you make an appointment with one of us to get help just before homework is due, and you *haven't* been to discussion sections, we won't be happy. They are all on Monday or Tuesday, since homework is due on Wednesdays and exams are Tuesday nights. We will start each discussion by answering questions about lectures or text material, then *we will go systematically through the homework which is related to the lectures since the previous discussion*. We will do similar math problems, discuss essay questions, and answer all questions except "what exact words should I use?"

Discussions meet Monday at
12:05 in 3331 Sterling (Prof. Durand)
2:25 in 3331 Sterling (Chris Greiveldinger)
7:30 pm in 3331 Sterling (Durand)

Tuesday at
11:00 in 3331 Sterling (Jonathan Hessler)
12:05 in 3331 Sterling (Hessler)
1:20 in 3331 Sterling (Greiveldinger)
4:35 in 3331 Sterling (Greiveldinger)
7:30 pm in 3331 Sterling (Hessler)

OVER

Office Hours Jonathan, Chris, and I prefer that you make an appointment, since if you need to see us beyond discussion sections it is probably for something pretty serious. We don't want to sit at our desks for some fixed time each week with no students showing up, when we might need to be doing something elsewhere. All of us have pretty flexible schedules. I answer messages on my answering machine or email as soon as I get them. The best policy is this:

Before lectures, ask Jonathan or Chris but please leave me alone then because I'll be setting up demonstrations for the lecture.

After lectures, 10:45 MWF, we will all three head for the hall outside 1300 Sterling—to get out of the way of the next class—and you can catch us there to make an appointment or get a question answered on the spot. I have that whole hour after lecture open on my schedule, until 11:30 or 11:45.

Leave a note on the "Leave Messages Here" pink sheet at the front of the lecture hall if you want something and can't manage to speak to us after class.

Before exams and if necessary before homework is due we will hold "open house" office hours, to be announced. I also have a **review session the evening before** every **exam.**

Grade **60%** from *three hour exams*, **40%** from *three homework sets*.. There will be no *comprehensive final exam*, but the *third hour exam will be given at the assigned final examination time*. **The three hour exams will be performance weighted**: your best exam counts the most and your poorest exam counts the least. The weights will be *25% – 20% – 15%*. My curve is likely to be A 90–100, AB 87-89, B 75–86, BC 72-74, C 60–71, D 50–59.

Homework 40% of your grade will be based on 41 required homework questions, one from each lecture, with two of them worth 1/2% each. Homework assignments are on blue paper. You should do each question right after the lecture on that question, so if you don't understand it you can get help in discussion section. Much of the homework will be paragraphs, and some will be math problems. Don't be lulled—writing a paragraph about a concept is not easy! For help, come to discussion sections. For serious math or physics anxiety help, make an appointment with one of us. I encourage you to work together on homework, but *you must ultimately write your own answers.* **IT IS CHEATING TO TURN IN IDENTICAL ANSWERS!** These include identical essay answers AND glaringly identical numerical answers, so **WRITE YOUR OWN ANSWERS!** We will form study groups from those who indicate an interest on their initial blue sheet. The exams will draw heavily on homework. Several graders will grade your homework and try to have it back to you by the dates on the schedule.

Exams The first two exams will be 60% objective, 40% short answer. The third exam will be all objective. Your green review sheet before each exam is taken from recent exams (with answers), to help you prepare for the exam. You may bring *one* 8 1/2 × 11 *page of notes* **(both sides)** to each exam. **The notes must be your own, not my handouts.** You may bring outlines for essay questions, but not complete paragraphs. Do not photocopy reduced versions of my handouts for your notes! THE FIRST TWO EXAMS WILL BE ON TUESDAY EVENINGS AT 7:30 PM, OCTOBER 11 AND NOVEMBER 15. SEE ME OR LEAVE ME A NOTE ON THE PINK "LEAVE MESSAGES HERE" SHEET IF YOU HAVE A CONFLICT. THE THIRD EXAM IS WEDNESDAY, DECEMBER 21, AT 7:45 AM. **DO NOT MAKE TRAVEL PLANS TO LEAVE BEFORE THEN. IF YOU SKIP THIS EXAM, YOU WILL LOSE 20 POINTS OUT OF 100 ON YOUR FINAL GRADE.** THERE WILL BE NO LATE EXAMS GIVEN, EXCEPT FOR VALIDATED MEDICAL OR FAMILY EMERGENCIES. **ANY ARRANGEMENTS FOR ANY ALTERNATIVE EXAM TIMES MUST BE MADE BY FRIDAY, SEPTEMBER 16, NO LATER!** See one of us *soon* if you have serious test anxiety, or other problems which necessitate special exam arrangements.

Review Sessions The Monday night before all these exams I will hold a question-and-answer review session in Room 1300 for one and a half hours.

Math There will not be much emphasis on math as a tool, but to understand physics conceptually you must use some high-school level math. Homework, essays, and exams will emphasize writing more than mathematics. See one of us *soon* if you have serious math anxiety.

Regrades If you don't understand how a homework or exam question was graded, first read my solution—you may then understand. If not, write me a note stating which question you want me to regrade, and why. Staple or clip the note to your *whole* homework set or exam, and give it to me. I will process it as soon as possible. (I may not raise the grade, but I'll explain why.) Also give your homework or exam to me if the score is mis-added.

Tutors *I do not recommend getting a tutor for this course.* The University Physics Society, Room 2321 Sterling, 263-2805, does have a tutoring service, but unfortunately many physics majors have not yet studied the material in Units II and III, or are unlikely to be able to discuss the material in words instead of equations. Please just ask us for help, and start early to get help!

Reserve Materials All handouts, my lecture notes, and a copy of the text will be on reserve in the **Physics Library**, 4220 Chamberlin, hours M–Th 8–9, F 8–5, Sat and Sun 1–5, 262-9500. A copy of the text is on reserve in the **College Library**. Videotapes of the lectures for the TV version of the course, are on reserve in the College Library for building use only, and in the Physics Library, where they may be checked out if you're enrolled in the TV course.

Physics Museum Two museum rooms, to the right as you enter Sterling Hall, have demonstrations of physics phenomena which are both fun and instructive. There is an interactive computer animation of some Physics 107 demonstrations, on one of the Macintoshes in the second room.

PHYSICS 107-TV
INFORMATION PACKET
FALL 1994
Professor Bernice Durand

WELCOME TO PHYSICS 107-TV (Lecture 2), the Ideas of Modern Physics for nonscience majors. THIS IS YOUR COURSE INFORMATION PACKET. It is identical to the packet passed out in the first lecture to the MWF 9:55 (Lecture 1) students, except for this cover memo and your special instructions for handing in blue sheets and homework sets, and picking up materials. READ IT! FOLLOW THE INSTRUCTIONS!

The TV lectures are always filmed in advance, sometimes in the lecture hall, sometimes in a studio, and sometimes in my office. The material covered is the same as in the live lectures MWF 9:55, though no two presentations of a lecture are ever identical. Videotapes of the lectures are on reserve at College Library for building use only, and in the Physics Library.

Your 41 homework problems (about one per lecture) and three exams are the same as for the MWF 9:55 class. You may come to any of the same discussion sections as those students—see the gray information sheets. The TA assigned to keep track of your papers and grades is Chris Greiveldinger, but you may also ask for help from TA Jonathan Hessler or me.

At the end of many lectures will be announcements reminding you of due dates, etc. Stay tuned! On the other side of this sheet are important dates.

Enjoy this physics course. I think any questions you have will be answered in this packet, or can be answered in discussion sections. You are also welcome to call me at my office 262-3827, where I have an answering machine in case I'm away from my desk, or to email me. My Internet address is: bdurand@wishep.physics.wisc.edu

Professor Bernice Durand

COLOR CODING FOR HANDOUTS

Gray—Course information
Buff—Supplementary material
Blue—Homework assignments
Yellow–Homework solutions
Green—Review sheets for exams
White—Exams
Pink—Exam solutions, Message sheets

TODAY'S HANDOUTS

1 3-page gray
1 7-page blue
1 2-page buff

FUTURE HANDOUTS

see right column of schedule

OVER

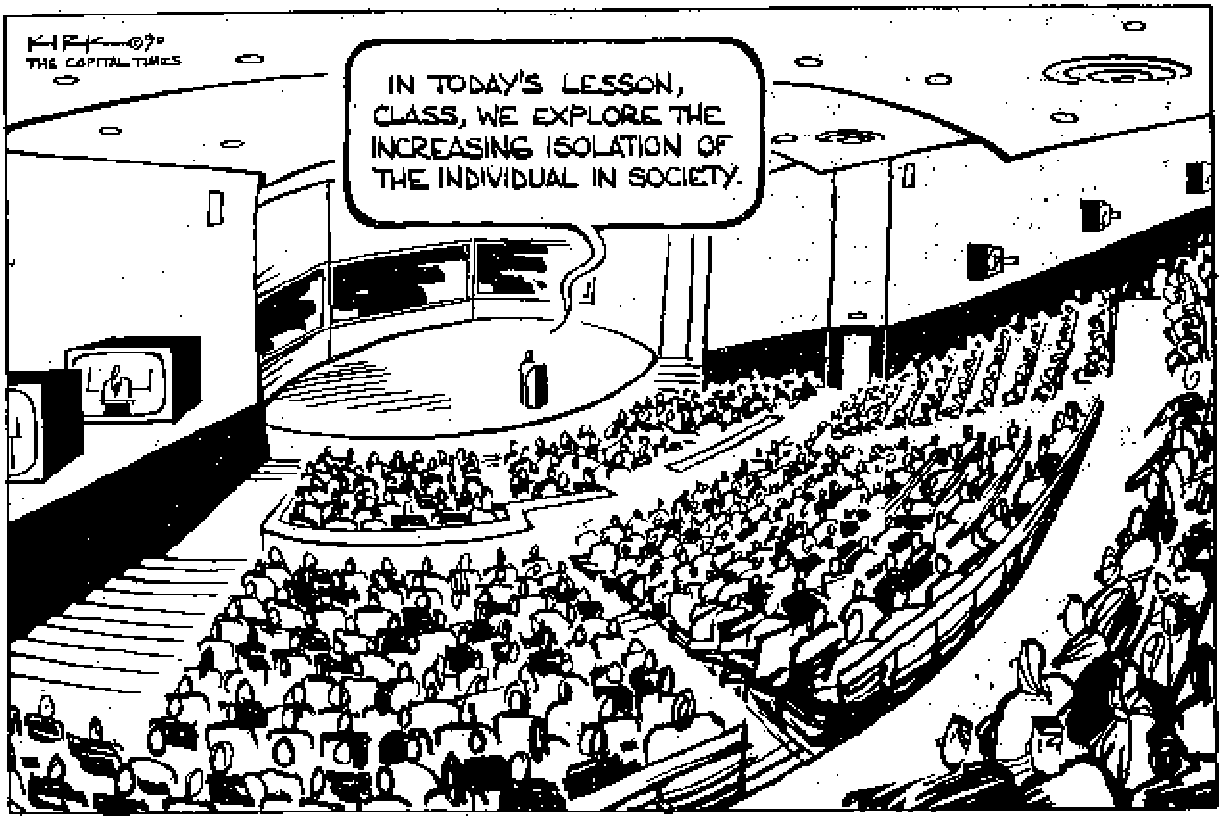
Important dates for you are when you hand in or pick up material at the Physics Department Office, 2531 Sterling Hall, hours 8:00-12:00, 1:00-4:30. You must hand in your own homework and will be asked to initial a class roster so we know you have turned in or picked up your materials. Late homework must be brought directly to my office, 4205 Chamberlin (see homework info elsewhere).

DATE			TURN IN	PICK UP
Wed	Sept 14	at latest	blue sheet	information packet
Wed	Sept 14			list of willing study partners
Wed	Sept 21	by 9:55 am	Homework IA	
Fri	Sept 30			graded Homework IA, solutions
Wed	Oct 5	by 9:55 am	Homework IB	Review Sheet I, Unit II packet
Fri	Oct 7			Homework IB solutions
Mon	Oct 10 at Review Session in 1300 Sterling	7:00 pm		graded Homework IB
Tues	Oct 18			graded Exam I, solutions, curve
Wed	Oct 26	by 9:55 am	Homework IIA	
Fri	Nov 4			graded Homework IIA, solutions
Wed	Nov 9	by 9:55 am	Homework IIB	Review Sheet II, Unit III packet
Fri	Nov 11			Homework IIB solutions
Mon	Nov 14 at Review Session in 1300 Sterling	7:00 pm		graded Homework IIB
Tues	Nov 22			graded Exam II, solutions, curve
Wed	Nov 30	by 9:55 am	Homework IIIA	
Fri	Dec 9			graded Homework IIIA, solutions
Wed	Dec 14	by 9:55 am	Homework IIIB	Review Sheet III
Fri	Dec 16			Homework IIIB solutions
Mon	Dec 19 at Review Session in 1300 Sterling	7:00 pm		graded homework IIIB

PHYSICS 107 SYLLABUS FALL 1994 PROF. B. DURAND

Week	*Lec*	*Date*	*Subject*	*Chap*	*Take notice!*
1	1	F Sep 2	Understanding Our Planet: Seasons and Moon	X[1]	Course Info, Unit I Packet
	2	W Sep 7	Galileo: Kinematics, Two Leaps of Logic	1	
	3	F Sep 9	Galileo: Falling Motion, Uniform Acceleration	1	
2	4	M Sep 12	Galileo: Three Great Principles	2	
	5	W Sep 14	Descartes, Huygens: Conservation of Momentum	2	Last day to drop w/o record
	6	F Sep 16	Newton: Dynamics, Three Great Laws of Motion	3	Last day to add
3	7	M Sep 19	Tycho, Kepler, Galileo: Demystifying the Heavens	4	
	8	W Sep 21	Newton: Universal Law of Gravitation	4	HOMEWORK IA DUE
	9	F Sep 23	Conservation of Energy	5	
4	10	M Sep 26	Coulomb, Faraday: Electromagnetic Force and Field	6	
	11	W Sep 28	Maxwell: The First Unified Field Theory	6	END OF UNIT I
	12	F Sep 30	Waves I: Simple Harmonic Behavior of a Simple System	7	HW IA back, Solutions
5	13	M Oct 3	Waves II: Sound Waves	7	
	14	W Oct 5	Waves III: Light Waves	7	HOMEWORK IB DUE Rev Sheet I, Unit II Packet
	15	F Oct 7	Chaos: Complex Behavior of a Simple System	X[1]	Homework IB Solutions
6	16	M Oct 10	The Famous γ (gamma) Factor, Right Triangle	8	
	Rev	M Oct 10	REVIEW SESSION, 7:00-8:30 pm, 1300 Sterling		HW IB back, use Rev Sht I
	Exam	T Oct 11	EXAM ON UNIT I, 7:30-8:30 pm, Rooms to be anncd		EXAM I 1 pg notes allowed
	17	W Oct 12	Einstein: Two Postulates of Special Relativity	9	
	18	F Oct 14	Gedanken Experiments: Simultaneity, Length	9	
7	19	M Oct 17	Gedanken Experiments: Clock Slowdown, Time Ordering	9	
	20	W Oct 19	Spacetime: γ Factor, Triangle, 4th Dimension	10	Exam I back, Solns, Curve
	21	F Oct 21	Albert/Henry Video; Spacetime Diagrams	X[1]	
8	22	M Oct 24	Albert/Henry Video; Mass and Energy	11	
	23	W Oct 26	Albert/Henry Video; Real Life Examples of γ Factor	X[1]	HOMEWORK IIA DUE
	24	F Oct 28	$E = mc^2$ and Bombs	11	
9	25	M Oct 31	Equivalence Principle; Geodesics; Inertia	12	
	26	W Nov 2	Curved Spacetime: Physics is Math	12	
	27	F Nov 4	Cosmology: Big Bang, Expanding Universe	12	Last day to drop HW IIA back, Solutions
10	28	M Nov 7	Understanding Our Universe: Black Holes, Dark Matter	12	END OF UNIT II
	29	W Nov 9	The Atom and its Structure	13,14	HOMEWORK IIB DUE Rev Sheet II, Unit III Packet
	30	F Nov 11	Planck: Light is Quantized	15	Homework IIB Solutions
11	31	M Nov 14	Einstein: The Photoelectric Effect, Waves are Particles	15	
	Rev	M Nov 14	REVIEW SESSION, 7:00-8:30 pm, 1300 Sterling		HW IIB back, Use Rev Sht II
	Exam	T Nov 15	EXAM ON UNIT II, 7:30-8:30 pm, Rooms to be anncd		EXAM II 1 pg notes allowed
	32	W Nov 16	Bohr: The Hydrogen Atom (Dumping Classical Physics)	15	
	33	F Nov 18	deBroglie, Schrodinger, Born: Particles are Waves	16,17	
12	34	M Nov 21	Heisenberg: Uncertainty Principle; Philosophy	17,18	Exam II back, Solns, Curve
	35	W Nov 23	Examples of Quantum Mechanics: Atomic Clock and Superconductivity	X[1]	Superconductivity Sheet
		F Nov 25	NO LECTURE - THANKSGIVING RECESS		Last Day to Withdraw
13	36	M Nov 28	Understanding our Sky: Sunsets, Ozone, and Greenhouse	X[1]	
	37	W Nov 30	Feynman: Quantum Field Theory, Dynamics	19	HOMEWORK IIIA DUE
	38	F Dec 2	Four Forces: Bosons	19	Four Forces Sheet
14	39	M Dec 5	Building Blocks: Quarks, Leptons	19	Building Blocks Sheet
	40	W Dec 7	The Nobel Prize: Great 20th Century Physicists	X[1]	Nobel Sheets
	41	F Dec 9	Inner Space/Outer Space; Course Evaluation END OF MATERIAL FOR HOMEWORK IIIB	X[1]	Inner Space/Outer Space Sht HW IIIA back, Solutions
15	42	M Dec 12	Understanding Devices: Lasers and Computer Chips	X[1]	
	43	W Dec 14	Understanding Science News: You're Ready! END OF UNIT III	X[1]	HOMEWORK IIIB DUE Review Sheet III
		F Dec 16	Homework IIIB Solutions available at 2531 Sterling Hall		Homework IIIB Solutions
16	Rev	M Dec 19	REVIEW SESSION 7:00-8:30 pm, 1300 Sterling		HW IIIB back, Use Rev Sht III
	Exam	W Dec 21	EXAM ON UNIT III, 7:45-9:15 am, Rooms to be anncd		EXAM III 1 pg notes allowed
	Gr	Th Dec 22	Final Grades posted, noon, 4205 Chamberlin		Grades

[1]X indicates that the subjects covered in lecture are *not* covered in Prof. March's text. *Some* of these subjects are covered in supplements written by Prof. Durand. Attendance at lecture is always important!



LEC 1 ↑ LEC 2 ↓

"Timothy, if you never watch TV you'll never know what's going on in the world."

PHYSICS 107 FALL 1994 PROF. B. DURAND

HOMEWORK IA ASSIGNMENT

DUE WEDNESDAY, SEPTEMBER 21, 1994, 9:55 AM

Lecture 1 students put these in the alphabetical boxes across from 1300 Sterling. Lecture 2 students hand them in at 2531 Sterling (hours 8:00–12:00, 1:00–4:30) by 9:55. Late homeworks must have a valid excuse. CALL ME if you're having a last-minute problem (leave a message on my machine) or are sick. All late homework must be delivered to me in my office, 4205 Chamberlin.

Be sure you follow the instructions on the first blue page! When I say "show your work", I mean that part of your credit comes from *how* you got your answer. You won't get full credit for just a numerical answer.

HOMEWORK IA covers Lectures 1–6. Each question is worth 1 point, graded in tenths. Each counts one percent of your grade. **ONLY TURN IN ANSWERS TO THE QUESTIONS, NOT TO THE WARMUPS!** The warmups are included to help you understand better, and to give me more to choose from when I make up exam questions. When I make up the exam, I will use material from the warmups and questions, and not much else. Since I make up the homework questions before giving the lectures, I may include something in the question which I then forget to say in lecture. Be sure to ASK if you don't understand the question!

1. WARMUPS

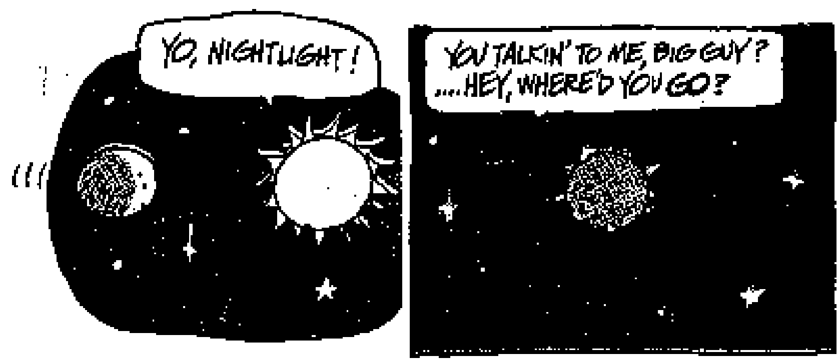
- Define the four seasons in terms of length of day, how the length of the day is changing, northern or southern hemisphere, nearness to the sun.
- Define the four phases of the moon, called new, first quarter, full, third quarter, in terms of where the moon is at sunset or sunrise, how much is illuminated, and the orientation of the bright part.
- Why don't we have lunar and solar eclipses every month?

QUESTIONS, worth one point total

(a) If the earth's orbit were noticeably elliptical, instead of so close to circular, the sun would not be in the center, but would be toward one end at a "focus" of the ellipse. Sketch carefully (from above) the true orbit and the more elliptical orbit, placing the sun. Now write what you think would happen to the seasons if we had this more elliptical orbit. Say why you reached your conclusion.

(b) Monday, September 5, 1994, is the next new moon, and Monday, September 19, is the next full moon. *Starting as early in the semester as you can* (preferably by September 5), look at the moon at sunset every evening it's visible. Write a log of where it is and draw how it looks, with sunset (west) on the right of the sketch. Did you ever see the "dark" piece of the moon, which is not directly illuminated by the sun? Write what the source of dim light for seeing that piece would be, and sketch how the light gets to the moon.

(c) Why does a total solar eclipse last only a few minutes and a total lunar eclipse a few hours? Hint: Draw a picture of each and think of the distances and sizes involved.



2. WARMUPS

- Why did Aristotle think stasis is natural? What counter-example is available to us that wasn't to him?
- Why did Aristotle think heavier objects fall fast than lighter ones? Again, give a counter-example (heavier falling *slower*) available to us that wasn't to him.
- Why did Aristotle think that falling objects acquire their speed instantly? What *simple* experiment could he have done as an immediate counter-example?

QUESTIONS, one point

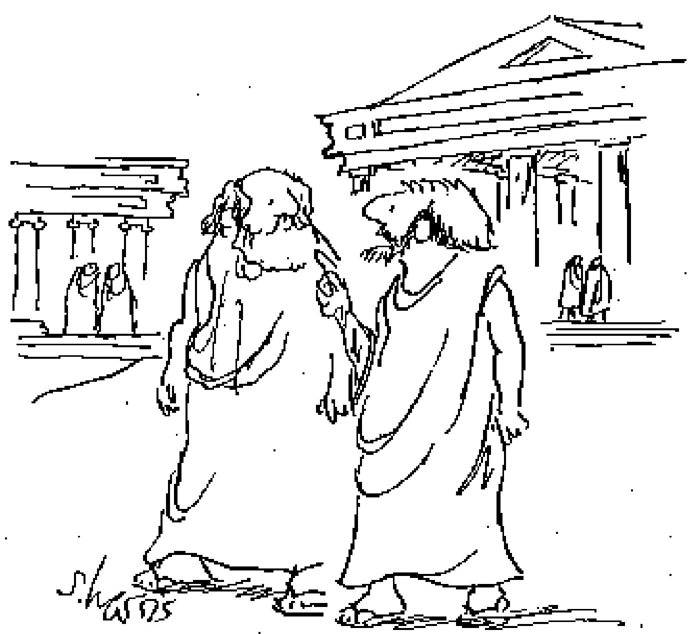
(a) How did Galileo overcome the problem of how *fast* falling objects move, in order to study the nature of falling motion?

(b) What insight did Galileo have which overcame the problem of the dependence of falling motion on the *shape* of the object, in order for him to study the nature of falling motion?

(c) How do *you* think Galileo deduced that motion, not stasis, is natural?

(d) An object, initially at rest, is dropped from a height $80m$. Taking $g = 10m/s^2$, calculate how many seconds before it hits the ground. Show the equation you use, and label units. Put a [box] around your [answer].

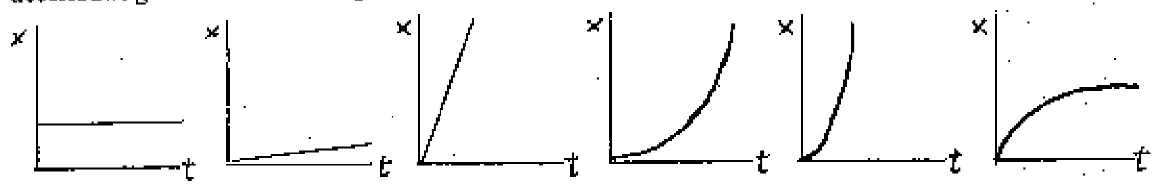
(e) Estimate how many stories tall an $80m$ building is. Write all your reasoning.



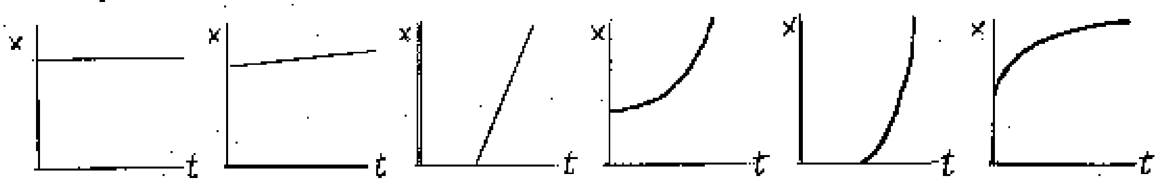
"OF COURSE THE ELEMENTS ARE EARTH, WATER, FIRE AND AIR. BUT WHAT ABOUT CHROMIUM? SURELY YOU CAN'T IGNORE CHROMIUM."

3. WARMUPS

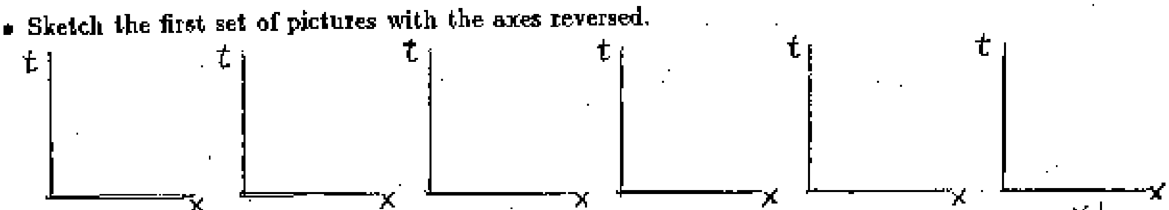
- Describe how motion down an inclined plane is of the same nature as falling motion. What is this kind of motion called?
- "0 to 60 just got faster!" proclaims a billboard advertising a car. What does the "faster" refer to?
- Study these figures. For each, say if the object is standing still, moving with slow or fast constant velocity, or accelerating with small or large acceleration.



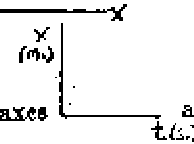
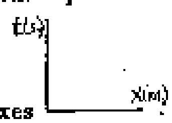
- Now say what has changed for each picture from the one above it.



- Sketch the first set of pictures with the axes reversed.



QUESTIONS, one point

Your entire question is to carefully draw two graphs of a motion I will describe, one on axes  and the other on axes . These are called *spacetime diagrams* in relativity. Your answer must include a table giving at least an outline of your calculations of a, v, x at time t. Your graph must be accurate. Wavy or sloppy lines, or uneven spacing on the axes, will not get credit. Use a ruler and be sure to label the *meters* and *seconds* on the axes.

Motion: $t =$ 0 *to* 4 *seconds*, car sits still.

$t =$ 4 *to* 9 *seconds*, car accelerates uniformly in a straight line from rest to $v = 10m/s$ (about 23 mph).

$t =$ 9 *to* 11 *seconds*, car travels in a straight line with the velocity it just acquired.

$t =$ 11 *to* 13 *seconds*, car accelerates uniformly in a straight line with $a = -5m/s^2$. That is, the brakes are applied!

Be sure you draw both graphs. Use plenty of space: two or three pages would be OK. Use graph paper if you want. The last part is tricky, because there is forward motion to start with. Look at the average speed in each of the last two seconds to see how far the car moves. Hint: my vertical axis goes to x equals more than 50m.

4. WARMUPS

- Use *inertia* in a sentence the way you would in nonscience English. Now define it in physics English.
- How does the monkey/hunter demonstration illustrate that all objects do fall at the same rate? (The ball hit the monkey, in case you couldn't see well.)
- "Hard" and "soft" catches were illustrated in lecture, with motion *toward* or *away from* the receiver or passer. Satisfy yourself that you understand how a ball's path looks if the two athletes are running *side by side* at the same speed and toss it back and forth. Analyse the paths *relative to* each athlete and *relative to* you as an outside observer.

QUESTIONS, one point

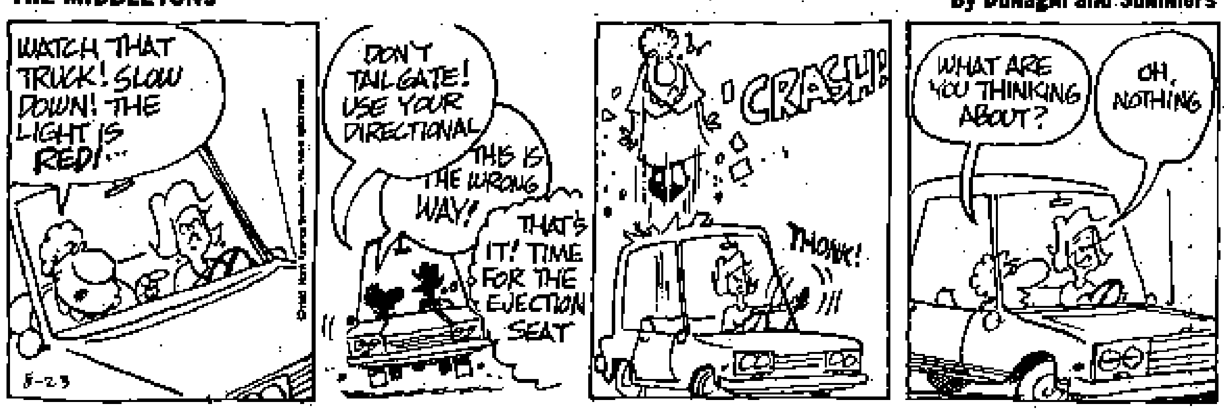
(a) State Galileo's Principle of Inertia and give an example of inertial motion. (Learn this! It is *very* important later in Einstein's theory of general relativity!)

(b) State Galileo's Principle of Superposition and say how the monkey/hunter demonstration illustrates it.

(c) State Galileo's Principle of Relativity. (Learn this! It is *very* important later in Einstein's theory of special relativity!)

(d) For a ball with speed $10m/s$ relative to the passer's hand, say what speed the ball will have relative to the receiver's hands if the passer is running toward the receiver at $5m/s$, then if the receiver is running away from the passer at $5m/s$. Show your equations. Label the speeds appropriately (I deliberately didn't, so you could make up your own labels). Say which is a hard or soft catch, and don't forget those boxes around your (labeled) numerical answers. (Learn the hard/soft rules. They are important later in special relativity.)

THE MIDDLETONS By Dunagin and Summers



5. WARMUPS

- What does *kinematics* refer to in physics?
- Use *momentum* in a sentence in nonscience English.
- What new kinematical quantity is introduced in *momentum*? Give an example of when momentum is necessary, instead of just velocity, to describe an event.
- How is a conservation law an example of "symmetry" in physics?

QUESTIONS, one point

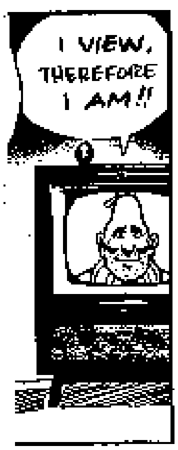
(a) Define *momentum* in a *vector* equation, defining each symbol you use.

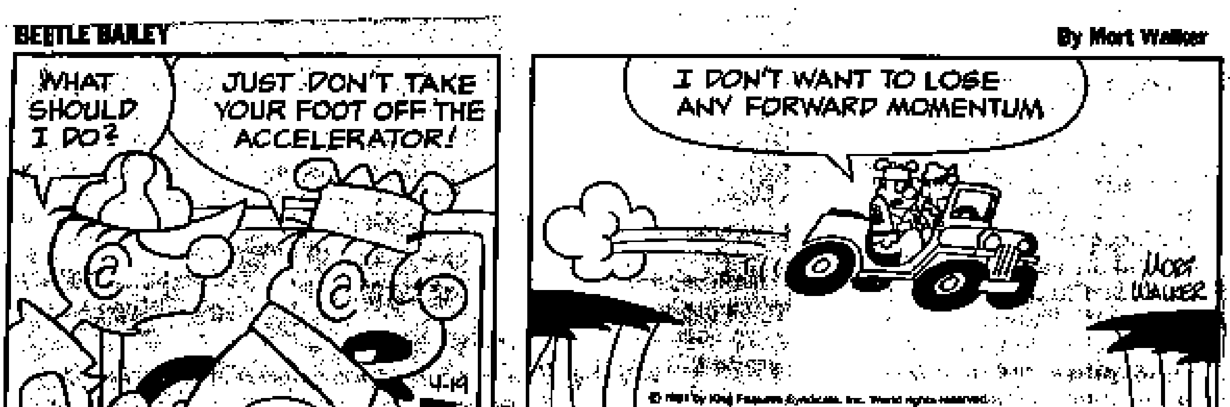
(b) State the law of Conservation of (total) Momentum in words. (This law is slightly modified and joined to the law of Conservation of Energy in Relativity. Otherwise, it stays the same throughout 20th Century physics.)

(c) State the law of Conservation of Momentum for objects A and B in a *vector* equation, defining each symbol.

(d) Use conservation of momentum to solve this problem. Draw a picture if you wish, to help visualize the equations. Show your work!

A bike hits a jogger from behind, and the jogger lands on the handlebars, with the bike still moving. The bike has mass $10kg$, the rider has mass $70kg$, and the jogger has mass $50kg$. Before the collision, the bike plus rider have velocity $12.5m/s$ and the jogger has velocity $6m/s$. Find the velocity of the bike plus rider plus jogger after the collision.





6. WARMUPS

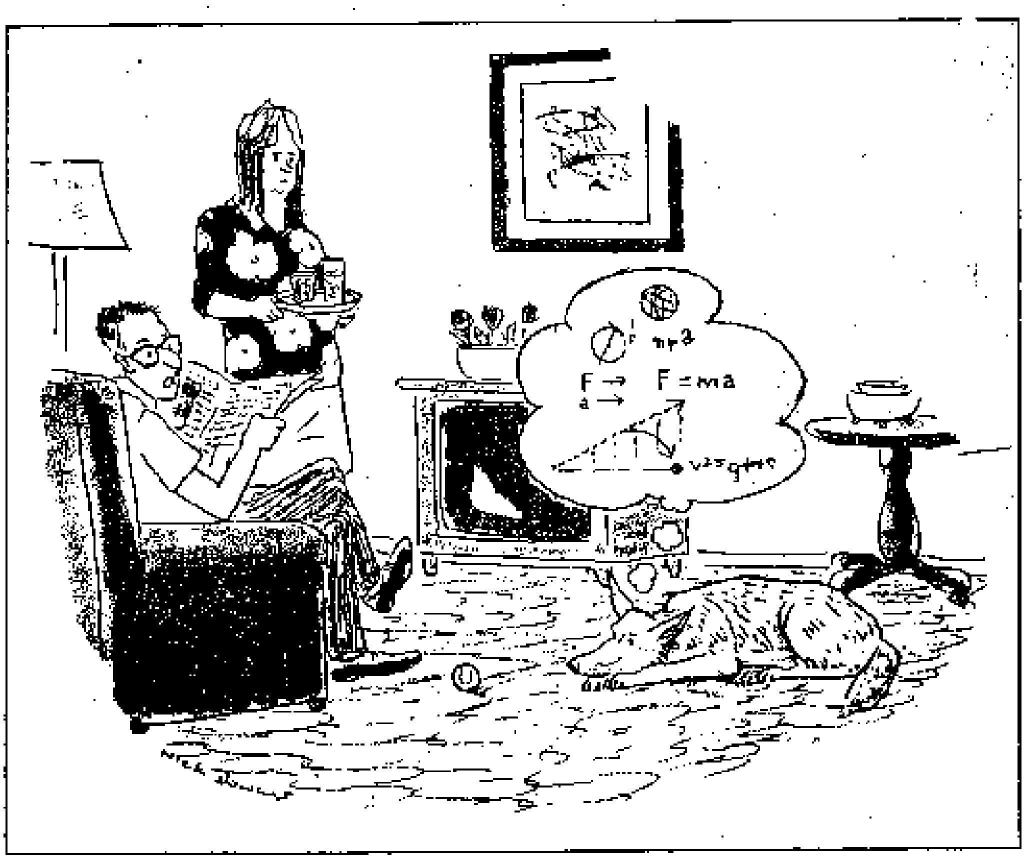
- How does *each* of Newton's three laws of motion contribute to the definition or understanding of the new concept *force*? This is a fairly hard question.
- Think of three of your own examples, sports or otherwise, of how $F = ma$ can be used to analyse a change of motion.
- Say how the third law of motion is the law of conservation of momentum. This is fairly hard, too.

QUESTIONS, one point

(a) Define *kinematics* and *dynamics* in physics. (Learn these! They are important later in special relativity and quantum mechanics, and *very* important in general relativity!)

(b) Give an example of uniform positive acceleration, uniform negative acceleration, constant perpendicular acceleration, and nonconstant sideways acceleration. For each example, incorporate a force which could cause the acceleration. (Example, which you may not use: Nonconstant sideways acceleration: I was walking beside you at constant speed and suddenly used my arm to shove you sideways, changing both the direction and speed you were going.)

(c) State each of Newton's three laws of motion. Say how the first is related to Galileo's Principle of Inertia. State the second in two ways, in term of momentum as well as force. (Use equations for the second law.) Say how the third *implies* conservation of momentum in a mutual interaction. (This is not as hard as the third warmup question.)



"All he thinks about is that stupid ball."

PHYSICS 107 FALL 1994 PROF. B. DURAND

HOMEWORK IB ASSIGNMENT

DUE WEDNESDAY, OCTOBER 5, 1994, 9:55 AM

Lecture 1 students put these in the alphabetical boxes across from 1300 Sterling. Lecture 2 students hand them in at 2581 Sterling (hours 8:00–12:00, 1:00–4:30) by 9:55. Late homeworks must have a valid excuse. CALL ME if you're having a last-minute problem (leave a message on my machine) or are sick. All late homework must be delivered to me in my office, 4205 Chamberlin.

Be sure you follow the instructions on the first blue page! When I say "show your work", I mean that part of your credit comes from *how* you got your answer. You won't get full credit for just a numerical answer.

HOMEWORK IB covers Lectures 7–11. Each question is worth 1 point, graded in tenths. Each counts one percent of your grade. **ONLY TURN IN ANSWERS TO THE QUESTIONS, NOT TO THE WARMUPS!** Remember, when I make up the exam, I will use material from the warmups and questions, and not much else.

7. WARMUPS

- The Aristotelian heritage in astronomy included "The heavens are perfect and don't change, and all heavenly motion is comprised of perfect circles". Also, up to the time of Copernicus, the earth was considered to be unique and at the center of the universe. What was Tycho's observation which shot down "perfect and unchanging heavens"?
- What did Kepler contribute to shoot down "perfect circles" and "earth-centered"?
- What observations of Galileo's contradicted "perfect and unchanging heavens" and "unique earth"?

QUESTIONS, worth one point total

(a) Tycho, Kepler, and Galileo all contributed to the *scientific method* of "observe, hypothesize, predict, observe again to check predictions". From what you have learned of these three men, say how the work of each *in astronomy* bolstered the scientific method.

(b) State Kepler's three laws of planetary motion. (Learn these! Newton needed them for his Universal Law of Gravity.)

(c) Use Kepler's Third Law, showing your work in symbols, to find how many Earth years are in one Mars year, if Mars has an orbit 1.52 times as big as Earth's. Check your answer on page 261 of the text, in the exercises for Chapter 4. Then box it!

8. WARMUPS

- What does *universal* refer to in Newton's Universal Law of Gravitation?
- Explain in words the nature of a $1/r^2$ force as objects get closer together or farther apart.
- What is *weight?*
- Why is there a constant G in Newton's expression for the force of gravity?

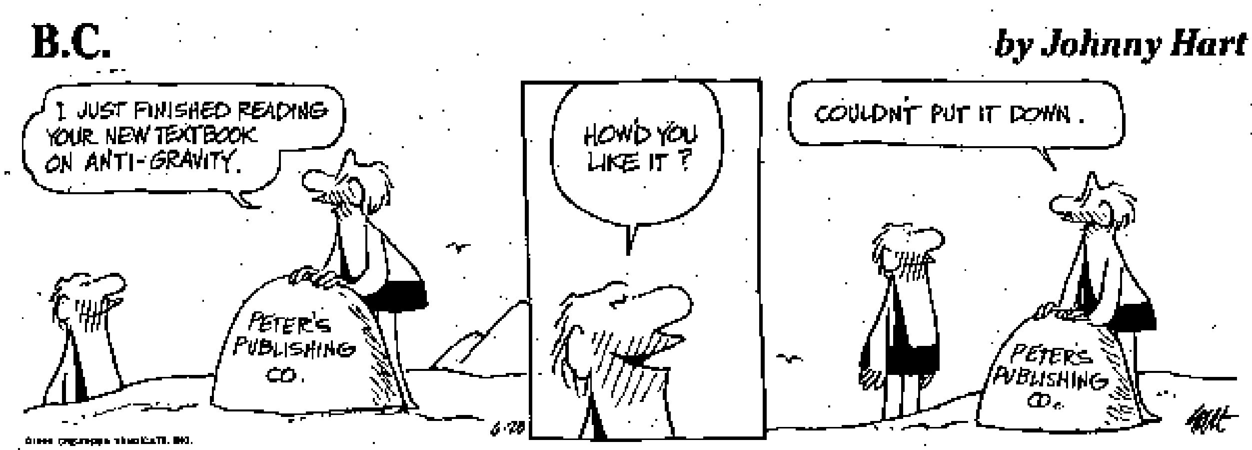
QUESTIONS, one point

(a) Write Newton's Universal Law of Gravitation in equation form, including a statement of its directionality.

(b) Write the expression for weight W of mass m at the surface of the earth, $W = mg$, in terms of the gravitational force law between the earth and mass m. Now manipulate the expression to find g, Galileo's acceleration due to gravity at the surface of the earth, in terms of G, M_{earth}, R_{earth}.

(c) The mass of the moon M_{moon} is $.012 M_{earth}$, and the radius of the moon R_{moon} is $.173 R_{earth}$. What acceleration g_{moon} did the astronauts feel on the moon? What fraction of their earth weight did they weigh? Take $g = 10 m/s^2$, show your work, and $\boxed{\text{box}}$ the $\boxed{\text{answers}}$.

(d) The mean distance of the earth from the sun, r_{earth}, is 150 *million km*. The mean distance of Mars from the sun, r_{mars}, is 228 *million km*. What multiple of the gravitational force the *sun* exerts on a space probe at Earth would it feel at Mars? (Neglect the pull of the planets on the space probe. Only calculate the relative pull of the sun.) Show your work and $\boxed{\text{box}}$ the $\boxed{\text{answer}}$.



9. WARMUPS

- How does *kinetic energy* differ from *momentum* as a kinematic (descriptive) "quantity of motion"?
- What does the concept of *potential energy* add to our understanding of *force*?
- Write a sentence using *work* and one using *power* in nonscience English. Define *work* in an equation, as a precise dynamical (which means related to force) physical quantity. What is surprising about the technical usage? Define *power* similarly.
- Bench-press or arm-lift a known mass (watch out: pounds are weight, not mass!) through a known distance as many times as you can in 15 *seconds*, and calculate your power output in watts. Is it what you expected?

QUESTIONS, one point

(a) State the law of Conservation of Energy, for *all types of energy*, first in words, then in an equation with all symbols defined.

(b) Write your *weight in pounds*. Now calculate your *mass in kilograms*, using the fact that *one kilogram weighs 2.2 pounds*. Now estimate your fastest speed or write down the fastest you've been timed to go. Note that the *fastest* humans seldom run faster than $10m/s$ for longer than $10s$. Now calculate your *momentum* p and *kinetic energy* KE at that speed. The units to use are p in $kg\ m/s$ and KE in *joules* $J = kg\ m^2/s^2$. (You'll use the number you just got for your momentum later, in a Unit III homework question on quantum mechanics!)

(c) Suppose you are running at your fastest speed from part (b) and jump onto a skateboard as you come to the bottom of a hill. How far up the hill will you coast before stopping? If you weighed $10kg$ more, how far up would you coast? (Hint: you don't have to calculate to answer this!) You *must* use conservation of energy to solve this, including only KE and *gravitational potential energy* $PE = mgh$.

(d) A physics major with mass $m = 75kg$ runs as fast as he can up three flights of stairs in Sterling Hall, gaining height $h = 12m$. It takes him a time $t = 12s$ to do this. Calculate his power output over that short period. Use $g = 10m/s^2$. Does the answer seem reasonable in terms of 100-watt lightbulbs? Show your work and box your answers to parts (b), (c), and (d)!

HARVEY CONSERVED ENERGY AT INAPPROPRIATE MOMENTS.

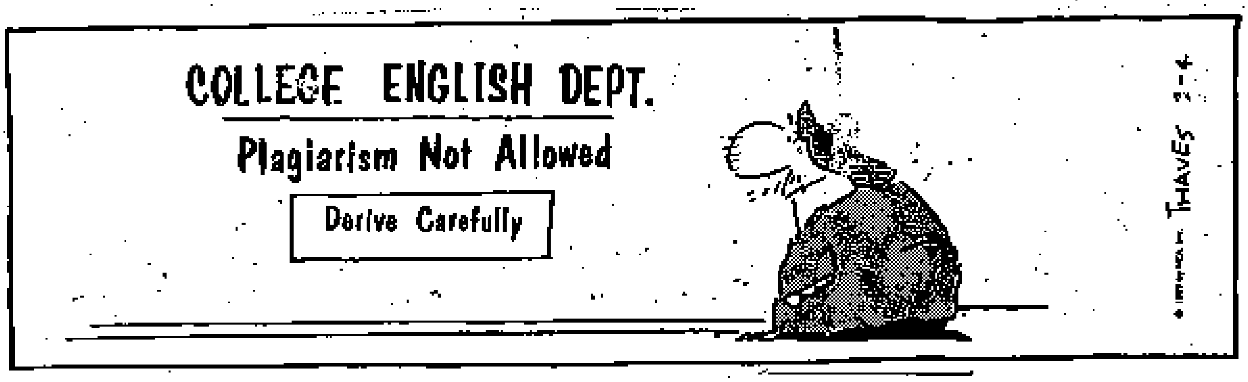
10. WARMUPS

- Think of an example for each showing that the electric force and magnetic force are *much* stronger than the gravitational force.
- Write the equations for the three force laws for gravity, electricity, and magnetism. (These force laws lull us into thinking *all* forces are "$1/r^2$" forces, but the weak and strong nuclear forces *aren't*, and it has taken into the late 20th century to understand them.)
- Why did Newton conclude that gravity acts "at a distance", across space instantaneously?

QUESTIONS, one point

(a) We have a strong bias that force laws must be *causal*. What does causal mean? Causality implies a *connection* between interacting objects. Write an example of a force in everyday life and the physically tangible object which transmits it. By "force in everyday life" I mean what physicists call *derived*, not *fundamental*, forces, that is, *not* gravitational, electomagnetic, or nuclear strong or weak. For example, a string's tension is ultimately due to electromagnetic forces between the atoms of the string, but we experience it as a simple pull of the string. An example you may not use as your answer would be that my hand exerts a centripetal force on a ball whirling on a string, via the tension in the tangible string.

(b) Describe Faraday's concept of *field*, including how it reinstates causality in Newton's force law as well as in electricity and magnetism. A complete answer should define a field, then use the "pincushion" image to illustrate the field of a $1/r^2$ force. (Again, the weak and strong nuclear fields *don't* have such simple "pincushion" visualizations.)



"Sure, we all watch television—but how many of us really see television?"

11. WARMUPS

- In 20th Century physics *field* often replaces *force* as the concept we find useful for predicting physical situations. What mathematical advantage did Maxwell find in rewriting the force laws of electricity and magnetism in terms of the fields $\vec{E}$ and $\vec{B}$?
- After completing the four electromagnetic field equations, what did Maxwell discover about light?

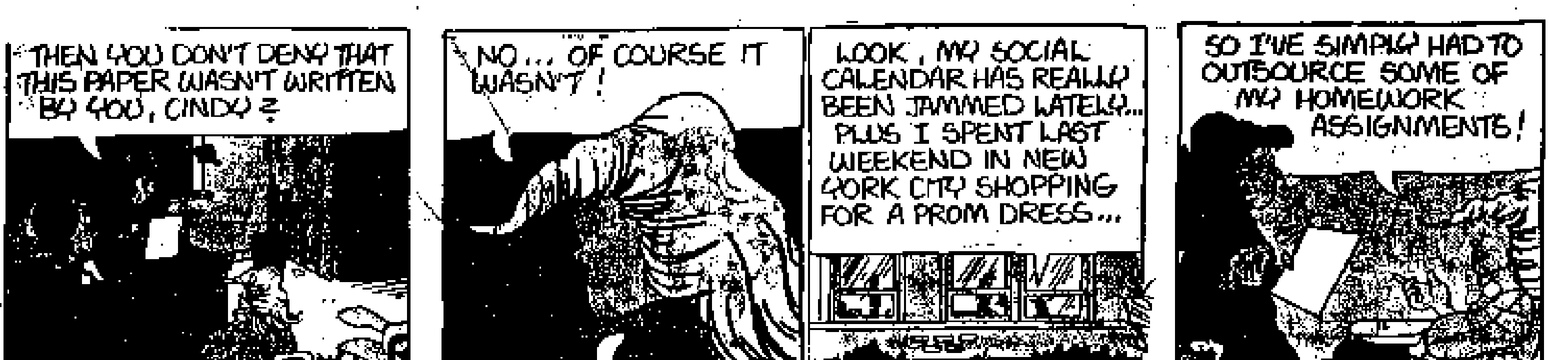
QUESTIONS, one point

(a) Maxwell added the *displacement current* term to the four electromagnetic equations. Give a *tangible physical analogy* to having this term missing. (I did this in lecture.) What *mathematical clue* suggested this term had to exist? (Hint: What was missing from one equation?) What *symmetry-type conservation law* is restored by this term?

(b) The constants analogous to Newton's constant G for gravity are $1/4\pi\epsilon_0$ for electricity and $\mu_0/4\pi$ for magnetism. Without giving you the names or units for these, I will tell you that $\epsilon_0 = 8.85 \times 10^{-12}$ and $\mu_0 = 1.26 \times 10^{-6}$. Calculate the quantities $\epsilon_0\mu_0$, then $1/\sqrt{\epsilon_0\mu_0}$. (Be sure to borrow a calculator before the last minute if you don't have one!) $\boxed{\text{Box}}$ your $\boxed{\text{answers}}$. The speed of light is $3 \times 10^8 m/s$. Compare this to the quantities you just calculated, and comment.

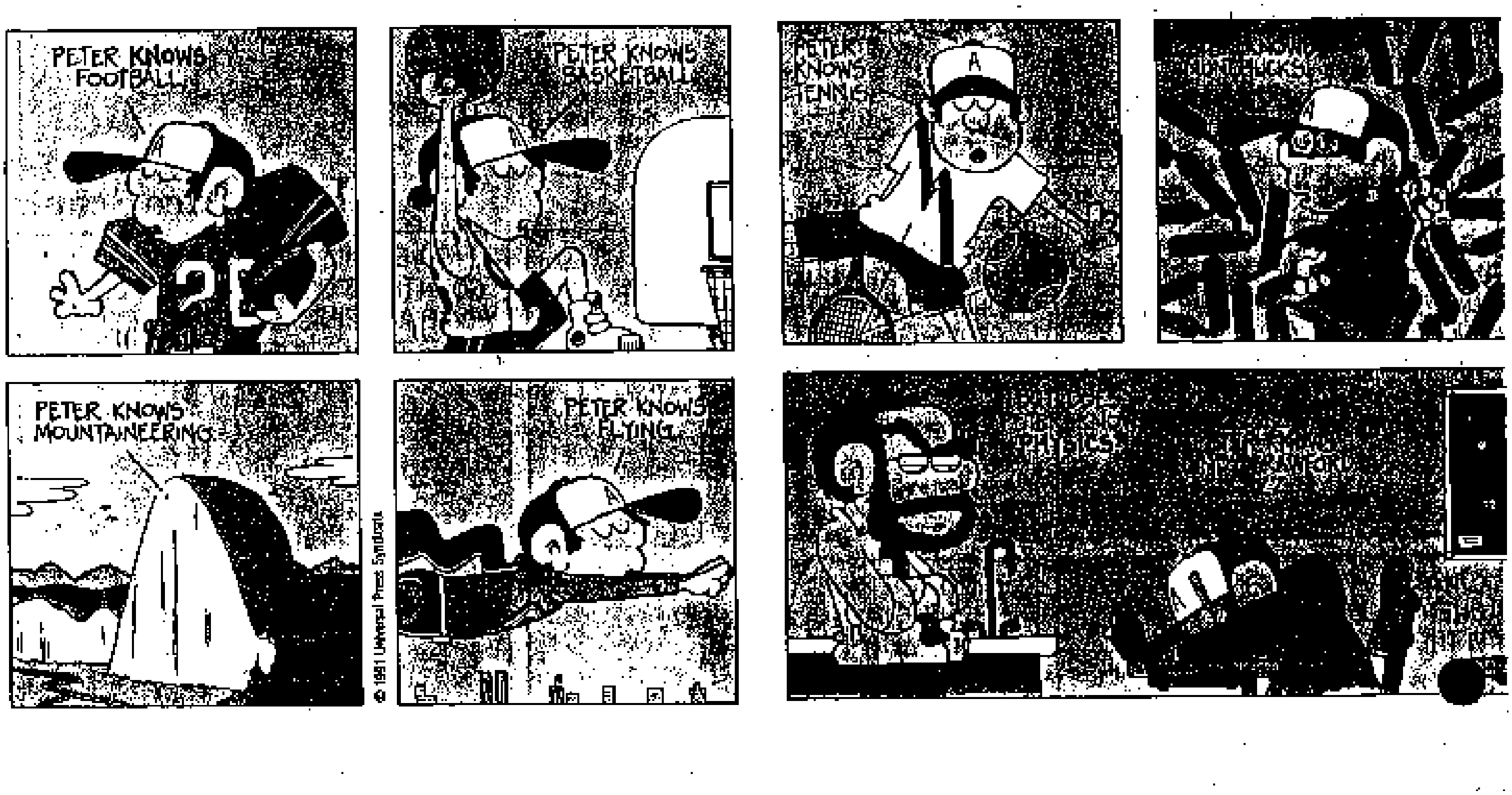
Here are my comments: You just did the *numerical* (not the calculus) calculation Maxwell did when he realised light is an electromagnetic wave! Furthermore, you can now see why the displacement current effect had never been detected in experiments before Maxwell said it should be looked for: it is down in magnitude by the factor $\sqrt{\epsilon_0\mu_0}$ from the other contribution to Ampère's Law for getting $\vec{B}$ from a changing $\vec{E}$.

"FRANKLY, I HAVE A LOT OF TROUBLE RELATING TO ALL THIS SYMBOLISM."



WARMUP POSTSCRIPTS

- A great exam essay question is a "standing on shoulders" question. Write how A stood on B's shoulders for A,B= Kepler, Tycho; Newton, Kepler; Newton, Galileo; Newton, Descartes/Huygens; Maxwell, Faraday.
- Another one is the "Copernican Revolution" question. Copernicus took the Earth out of the center of the universe by putting the sun at the "center" (OK, focus) of the planetary system. How did each of the following bolster the Copernican Revolution? Tycho, Kepler, Galileo, Newton, Faraday. A variation is to extend the Copernican Revolution to pulling *humans* out of the center of the universe and ask how various scientists bolstered that new worldview (scientific method is one answer).
- I spared you the following question on $\vec{F}_{grav}$. Explain how Newton's Third Law led him to the m_1m_2.
  Explain how Newton's Third Law led him to the directionality.
  Explain what Newton had to invent calculus to demonstrate. (Answer: the connection between one of Kepler's laws and $1/r^2$).
  (This next one is the hardest one.) Explain how g = same for all falling objects at the surface of the earth leads to $\vec{F}_{grav}$ on m is proportional to m.
  The other item in this analysis of the force law is one I already told you to think about: Why is G in the law?
  All but the one I said is hardest are fair game for an exam.



Physics 107 History Sheet I Galileo's Setting Prof. B. Durand

Galileo 1564 - 1642: - - - - indicates Galileo's lifetime

Renaissance: 12th C. Awakening
14th - 16th C. flourishing
1300's, 1400's, 1500's

Exploration

1451 - 1506 Columbus It
1454 - 1512 Amerigo Vespucci It
1485 - 1528 Verrazano It
- - - -
1552 - 1618 Raleigh Eng
1590 - 1657 Wm Bradford Eng
1620 Plymouth Rock

Church

1079 - 1142 Abelard Fr
1182 - 1226 Francis of Assisi It
1225 - 1274 Thomas Aquinas It
1483 - 1546 Martin Luther Ger
- - - -
1505 - 1572 John Knox Scot
1509 - 1564 John Calvin (Fr)Swiss
1623 Pope Urban VIII It

Art

1083 Bayeux Tapestry Fr
1266 - 1337 Giotto It
1444 - 1510 Botticelli It
1452 - 1519 Leonardo It
1475 - 1564 Michelangelo It
- - - -
1477 - 1576 Titian It
1483 - 1520 Raphael It
1528 - 1588 Veronese It
1577 - 1640 Rubens Flem
1606 - 1669 Rembrandt Dutch
1632 - 1672 Vermeer Dutch

Literature

1265 - 1321 Dante It
1313 - 1375 Boccaccio It
1343 - 1400 Chaucer Eng
1400 - 1468 Gutenberg Ger
1495 - 1553 Rabelais Fr
- - - -
1533 - 1592 Montaigne Fr
1547 - 1616 Cervantes Sp
1564 - 1616 Shakespeare Eng
1573 - 1631 Donne Eng
1573 - 1637 Ben Jonson Eng
1608 - 1674 Milton Eng
1613 - 1680 Rochefoucauld Fr
1622 - 1673 Moliere Fr
1639 - 1699 Racine Fr

Government

1389 - 1464 Medici, Cosimo It
1449 - 1492 Medici, Lorenzo the Magnificent It
1469 - 1527 Machiavelli It
1491 - 1547 Henry VIII Eng
1516 - 1558 "Bloody" Mary Tudor Eng
- - - - -
1519 - 1574 Medici, Cosimo the Great It
1519 - 1589 Medici, Catherine It
1533 - 1603 Elizabeth Eng
1542 - 1587 Mary Queen of Scots Scot
1599 - 1658 Cromwell Eng
1642 - 1652 English Civil War Eng

Mathematics

- - - -
1601 - 1665 Fermat Fr
1646 - 1716 Leibniz Ger (calculus)

Physics

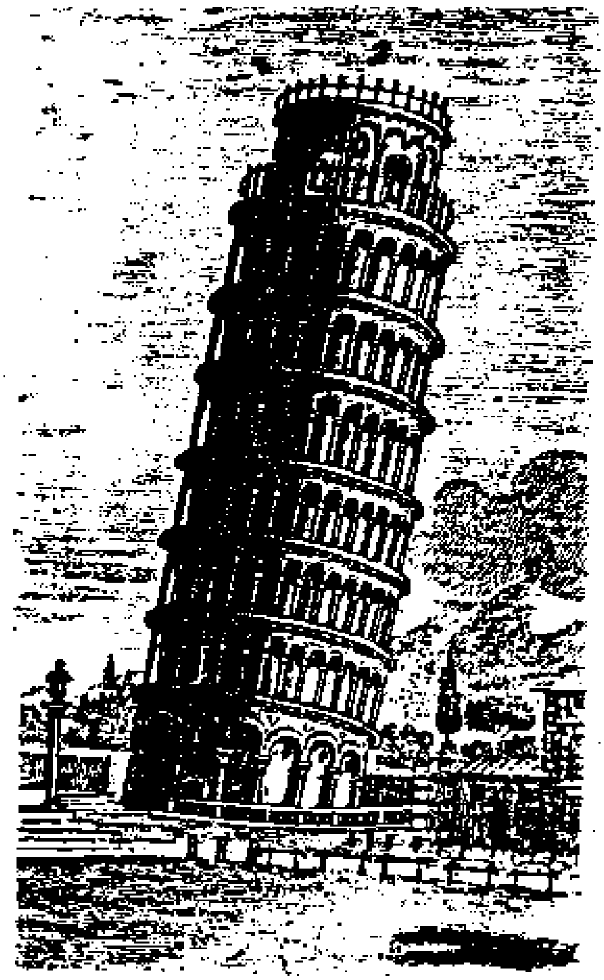
1473 - 1543 Copernicus Pol
- - - - -
1546 - 1601 Tycho Brahe Dan
1564 - 1642 Galileo It
1571 - 1630 Kepler Ger
1596 - 1650 Descartes Fr
15 - 1600 Giordano Bruno It
1608 - 1647 Torricelli It
1629 - 1695 Huyghens Dutch
1632 - 1723 Wren Eng
1642 - 1727 Newton Eng
1656 - 1742 Halley Eng
1662 - Royal Society Eng

Music

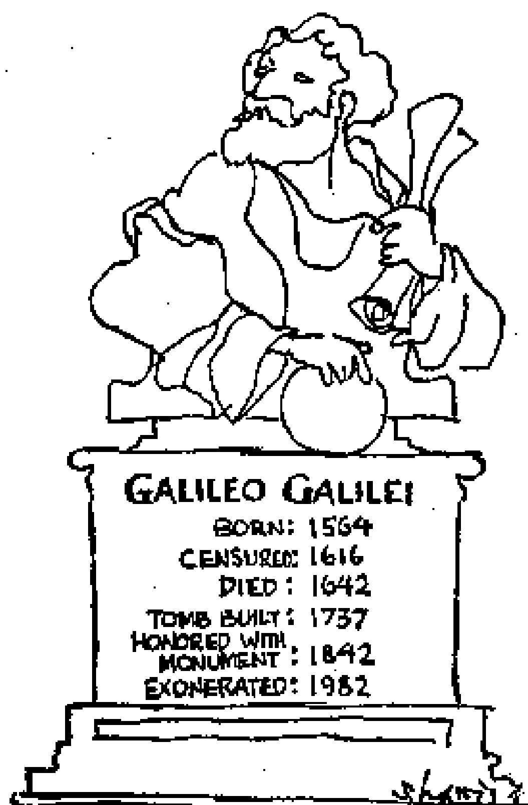
- - - -
1644 - 1737 Stradivarius It
1658 - 1695 Purcell Eng
1659 - 1725 A. Scarlatti It
1675 - 1741 Vivaldi It
1685 - 1750 J.S. Bach Ger
1685 - 1757 D.Scarlatti It
1685 - 1759 Handel Ger

The sun, with all those planets revolving around it and dependent upon it, can still ripen a bunch of grapes as if it had nothing else in the universe to do.

Galileo



The First Particle Accelerator



Physics 107 History Sheet II
Newton through Maxwell
1700's, 1800's
Prof. B. Durand

Newton 1642 - 1727
Faraday 1791 - 1867
Maxwell 1831 - 1879
Enlightenment 18th C. 1700's
Romanticism Late 18th & 19th C.'s ~ 1780 - 1900
Capitalism/Industrial Revolution Mid 18th to Mid 19th C.'s

Physics

1642-1727 Newton,Eng.
1687 Principia
1706-1790 Franklin,Am.
1731-1810 Cavendish, Eng.
1736-1806 Coulomb, Fr.
1753-1814 Thompson/Rumford,Am.
1775-1836 Ampère,Fr.
1777-1855 Gauss,Gr.
1787-1854 Ohm,Gr.
1791-1867 Faraday,Eng.
1797-1878 Henry,Am.
1818-1889 Joule,Eng.
1821-1894 Helmholtz,Gr.
1824-1907 Kelvin,Irish
1831-1879 Maxwell,Scot.
1839-1903 Gibbs,Am.
1852-1931 Michelson,Am.
1879-1955 Einstein,Gr.

Science/Math/Technology

1662 Royal Society
1736-1819 Watt, Scot.
1749-1827 Laplace, Fr.
1765-1825 Whitney, Am.
1778-1829 Davy, Eng.
1809-1882 Darwin, Eng.
1847-1931 Bell, Am.

Literature

1667-1745 Swift,Eng.
1694-1778 Voltaire,Fr.
1712-1778 Rousseau,Fr.
1749-1832 Goethe,Gr.
1757-1827 Blake,Eng.
1795-1821 Keats,Eng.
1797-1856 Heine,Gr.
1799-1850 Balzac,Fr.
1802-1870 Dumas,Fr.
1802-1885 Hugo,Fr.
1803-1882 Emerson,Am.
1804-1876 Sand,Fr.
1806-1861 E.Browning,Eng.
1807-1882 Longfellow,Am.
1809-1849 Poe,Am.
1812-1889 R. Browning,Eng.
1812-1870 Dickens,Eng.
1817-1862 Thoreau,Am.
1819-1891 Melville,Am.
1821-1881 Dostoyevsky,Rus.
1828-1906 Ibsen,Nor.
1828-1910 Tolstoy,Rus.
1832-1898 Carroll,Eng.
1835-1910 Twain,Am.
1843-1916 H.James,Am.
1860-1904 Chekhov,Rus.
1869-1951 Gide,Fr.
1871-1922 Proust,Fr.
1874-1946 Stein,Am.

Music

See 1st page for 7 names 1644-85
1752-1809 Haydn, Aus.
1756-1791 Mozart,Aus.
1770-1827 Beethoven,Gr.
1792-1868 Rossini,It.
1797-1828 Schubert,Aus.
1803-1869 Berlioz,Fr.
1809-1847 Mendelssohn,Gr.
1810-1849 Chopin,Pol/Fr.
1810-1856 Schumann,Gr.
1811-1886 Liszt,Hung.
1813-1901 Verdi,It.
1813-1883 Wagner,Gr.
1822-1890 Franck,Fr.
1824-1896 Bruckner,Aus.
1825-1899 J.Strauss,Aus.
1833-1897 Brahms,Gr.
1840-1893 Tchaikovsky,Rus.

Art

1798-1863 Delacroix,Fr.
1832-1883 Manet,Fr.
1834-1903 Whistler,Am.
1834-1917 Degas,Fr.
1840-1926 Monet,Fr.
1841-1919 Renoir,Fr.
1844-1910 Rousseau,Fr.
1848-1903 Gauguin,Fr.
1853-1890 vanGogh,Dutch
1874-18[illegible]mpressionists

U.S. History

1732-1799 Washington
1743-1826 Jefferson
1786-1836 Crockett
1787 Constitution
1805-1859 de Tocqueville
1809-1865 Lincoln
1812 War, Britain
1822-1885 Grant
1835-1919 Carnegie
1839-1937 Rockefeller
1858-1919 T.Roosevelt
1861-1865 Civil War
1863-1947 H.Ford
1882-1945 F.D.Roosevelt
1884-1962 E.Roosevelt

Philosophy

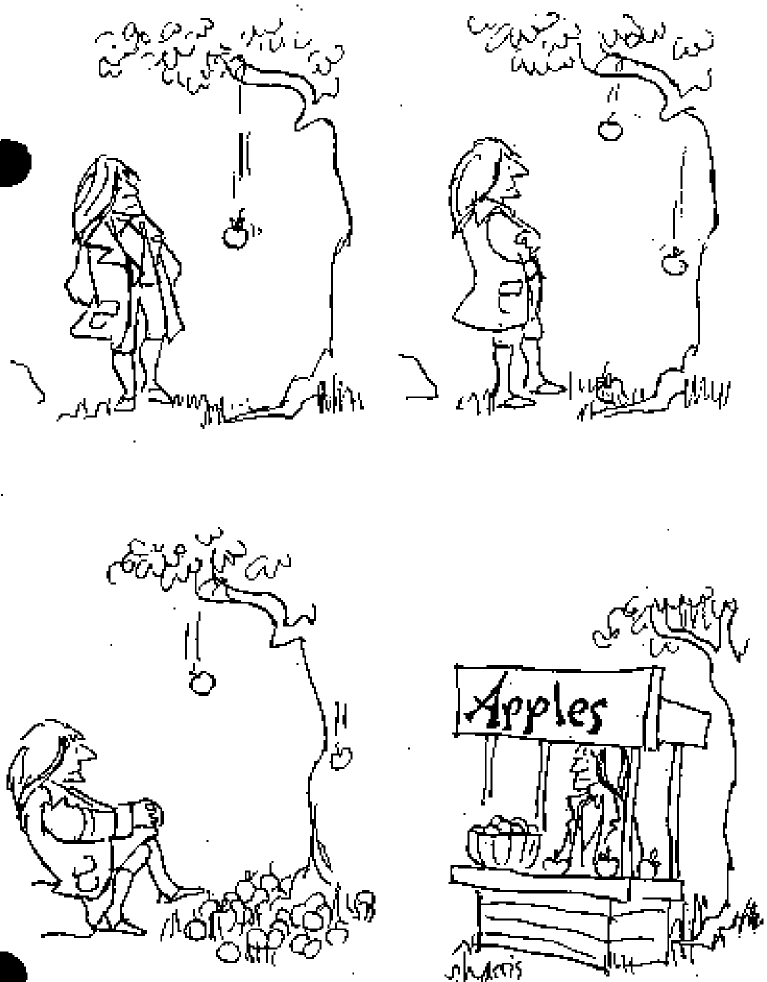
1632-1704 Locke,Eng.
1703-1758 Edwards,Am.
1711-1776 Hume,Scot.
1712-1778 J. Rousseau,Fr.
1724-1804 Kant,Gr.
1770-1831 Hegel,Gr.
1806-1873 Mill, Eng.
1813-1855 Kierkegaard,Dan.
1818-1883 Marx,Gr.
1842-1910 W.James,Am.
1844-1900 Nietzche,Gr.
1863-1952 Santayana,Sp/Am.
1883-1943 Keynes, Eng.

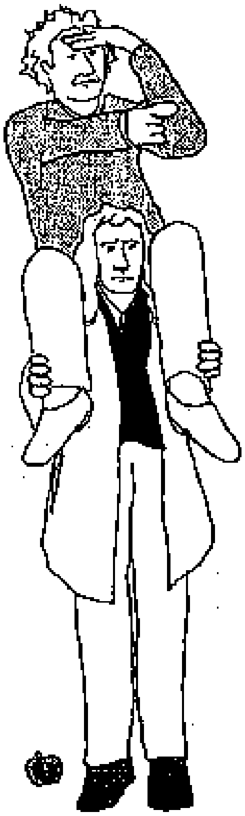
Other Government

1650-1702 Wm of Orange,Eng.
1755-1793 Antoinette,Fr.
1769-1821 Napoleon,Fr.
1769-1852 Dk of Wellington,Eng.
1804-1881 Disraeli,Eng.
1819-1901 Victoria,Eng.
1870-1924 Lenin,Rus.
1874-1965 Churchill,Eng.
1879-1953 Stalin,Rus.

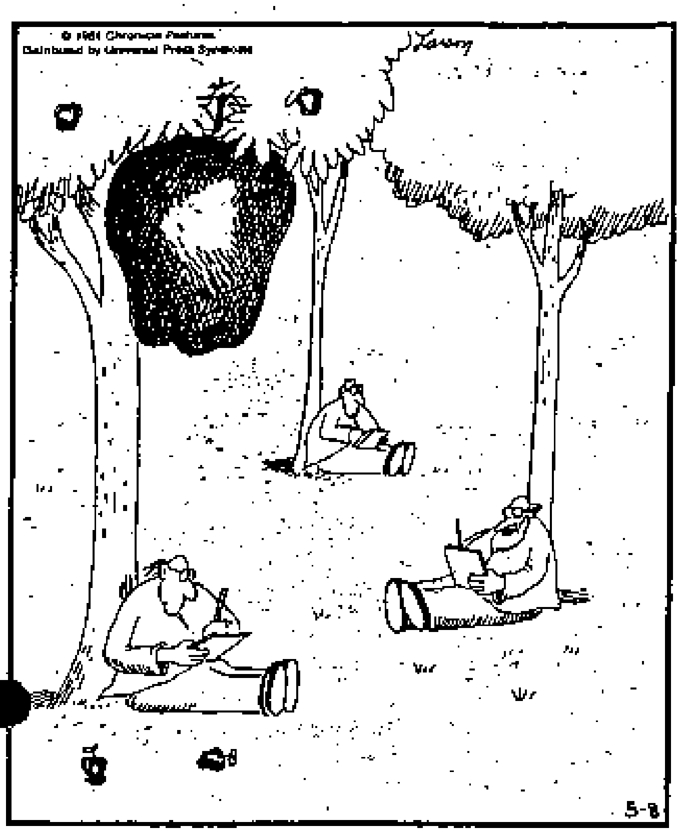
Exploration

1841-1904 Stanley,Eng.
1856-1920 Peary,Am.

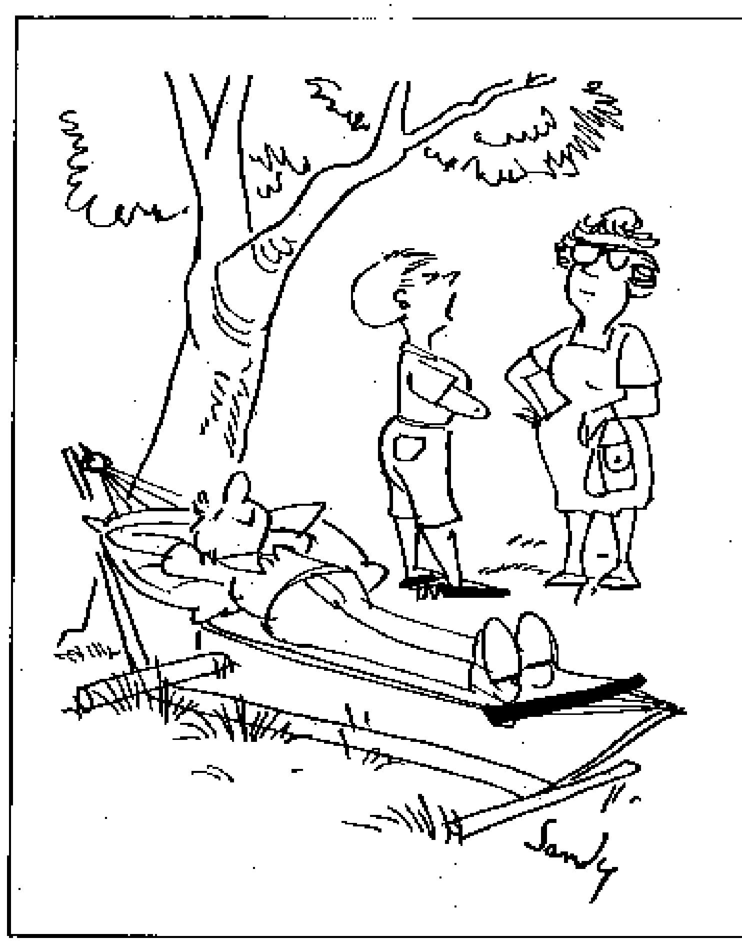




If I have been able to see further than others, it was because I stood on the shoulders of giants.
Sir Isaac Newton



"Nothing yet . ... How about you, Newton?"



"Thom wants to prove Newton's law— 'A body at rest, tends to remain at rest'."

PHYSICS 107

FALL 1994

FILL OUT THIS SHEET AND HAND IT IN RIGHT NOW, TO GET YOUR INFORMATION PACKET.

Please write clearly

Your name, including nickname ______________________

local address, including apartment ______________________

number and zip code ______________________

local phone ______________________

age ______________________

hometown/high school/year graduated ______________________

your UW classification (e.g. BA1) ______________________

major or intended major ______________________

Important: I encourage you to work together on homework and studying for the exam. I will try to help you form study groups. If you are interested please check this box, and I will compile a list for you of names and phone numbers, sorted by address. TV students can pick up this compiled list Wed, Sept 14 at 2531 Sterling. ☐

Please tell me any special problems you would like me to know about, such as vision or hearing problems, dyslexia, test or math anxiety. PLEASE FOLLOW THROUGH IN PERSON IF YOU WANT TO TALK ABOUT THE PROBLEM. Talk with me initially, then I can advise you whether to work with me, a TA, or someone specially trained.

If you must miss lectures or exams due to athletic or other extracurricular activities, warn me here. I can accommodate almost any problem, *if* I know about it *early*. Note: ANY arrangements for ANY alternative exam times must be made by Friday, September 16, no later. The exams are Tuesdays, October 11 and November 15, 7:30–8:30 pm, and Wednesday, December 21, 7:45–9:15 am. PLEASE FOLLOW THROUGH IN PERSON IF YOU HAVE REQUESTS.