Physics 201 Course Information: Spring 2009

The Physics 201 course is a study of two beautiful equations:

$$\mathbf{F} = \mathrm{m}\mathbf{a};$$

and,

$$\mathbf{F} = \mathcal{G}\ \tfrac{mM}{R^2}\ \mathbf{R}^0.$$

That is it! Other topics in Phys.201 are simple extensions of the two fundamental $\mathcal{L}$aws. The ramifications of the two laws are daedal and immense. Armed with these laws forays into the realm of ideas and applications lead to new horizons. These topics are delightful. And they are easy. They form the basis for all of the physics, and of the engineering, you will learn at Carolina. We shall simply master the two $\mathcal{L}$aws.

About the Lectures and the Professor

Salient information about the lectures and the professor are as follows:

Lectures: We shall begin promptly at the appointed hour. The first few minutes of each lecture will be devoted to a brief recapitulation of previous discussions. Let the lecture be a conversation! A discussion participated by all!

Please note:

Time: Tuesday & Thursday 9:30am—10:45am

Place: PSC-Building: Room-002

Professor: Sanjib R. Mishra

Office/Telephone: PSC-604; Tel:803-777-2668, 776-5848; Fax:803-777-2667

e-mail: srm@physics.sc.edu

Office Hours: Thursday:–11:00am–12:00pm; Thursday:–12:00pm–1:00pm; or by appointment **any day and any time between noon and midnight including weekends**.

<u>**Text Book:**</u> The text book is **"Physics", by Cutnell & Johnson**, 7^{th} Edition (CJ). It has a good selection of examples and problems. The text book is meant to be read **before** lectures: it is **NOT** a **substitute** for lectures. Your lecture notes and your CAPA-solutions are the principal source of material relevant to this course. Any college level introductory physics text book will suffice as an additional reference. However, I discourage the practice of reading reference books. Think for yourself! Once you 'get' it, you will not need any book.

<u>**Reading Assignments:**</u> I shall assign reading assignments — chapters from Cutnell & Hohnson — before starting a new topic. I **require** of you to complete your reading assignments **before** the lecture. Do not read the textbook as you would a novel. May I propose the following steps for this assignment:

(i) Read the first section of a given chapter highlighting the new terms, concepts and formula;

(ii) Close the book, and write in your notebook — the **same** notebook you take down the lecture notes — the new terms, concepts, and formula you have just read;

(iii) When you encounter an example, do not rush into the solution. Read the problem, and try to solve it. Give yourself a few minutes. Then compare what you have written on your notebook with the worked out solution in the book. Now, close the book and work the example out for yourself;

(iv) Go to the next section.

Give yourself 1hr to complete the assignment before each lecture.

<u>**The Most Important Assignment:**</u> We shall discuss at least two problems in each lecture. Try to follow the steps toward the answer. Do ask questions. "Prof. I did not follow; Could you repeat the argument? I did not get the Trignometry. Please slow down!, etc." are music to my ears. What is not is apathy and lack of participation. After the lecture, on the **same day**, when the topic is fresh in your mind, spend 30–45 minutes redoing the same problems in your notebook *without* looking at the solution. If you follow this simple rule, I assure you that getting a grade better than a "B" will be a easy.

<u>**Syllabus:**</u> The primary focus of the course is an elucidation of the two fundamental $\mathcal{L}$aws of Newton. The salient topics we will cover are:

- Vectors and Motion: Position, Velocity, Acceleration; CJ-Chapters: 1—3
- Forces and Newton's Laws of Motion; CJ-Chapters: 4—5
- Kinetic and Potential Energy; Work; CJ-Chapter: 6
- Impulse and Momentum; CJ-Chapter: 7
- Rotation; CJ-Chapters: 8—9
- Oscillations and Elasticity; CJ-Chapter: 10
- Fluids; CJ-Chapter: 11

The *tentative*, perhaps ambitious, syllabus, based on the chapters of the text book by Cutnell & Johnson (CJ), is outlined in the Table 1. For example, "Ch.1/2" means Chapter-1 and -2 of CJ. Also, "Week of .." refers to the Monday heralding the week. We will continually evaluate our progress and proclivity, and, if need be, deviate with intent from the following topics and time-table (see the following page).

Attendance: The attendance at the lectures is not mandatory. However, I shall take attendance in the class. If you choose not to attend classes, it *will not* adversely affect your grade, see Table 4. However, attending the classes *will* help you — after all this is why you have chosen to attend the flagship University of Carolina! Know that your lecture notes and examples are the *most important* reading material for your Tests and the Final. Attendance will be an important measure of your effort to learn Newton's $\mathcal{L}$aws and it will help me write a stong letter of recommendation for you, should you need it.

It is rude to solve your CAPA homework or not pay attention during lectures! If you are preoccupied, it is better not to attend lectures; there is no point! (There is no penalty for nonattendance.) I urge you: Do not 'just attend lectures' — participate! Let us have fun!

Attendance at the CAPA session is strongly encouraged but not required. Please attend these sessions. Try to learn TWO problems at each CAPA session.

Review Session: Unless mentioned otherwise, I will hold a review session approximately every other week on **Tuesday Evenings** in the Rogers Room, PSC-409. Let me suggest **≃5:30pm on Tuesday Evenings** for review. Please keep your Tuesday evenings free. Review sessions will last for about an hour or two. Your attendance is not mandatory. You

Week-Number	Week of ...	Tuesday	Thursday
#1	12/Jan	13/Jan: Chap.1	15/Jan: Chap.2
#2	19/Jan	20/Jan: Chap.2	22/Jan: Chap.2
#3	26/Jan	27/Jan: Chap.3	29/Jan: Chap.3
#4	02/Feb	03/Feb: Chap.4	05/Feb: **1st. Test on Thr. (5.Feb.09)**
#5	09/Feb	10/Feb: Chap.4	12/Feb: Chap.4/5
#6	16/Feb	17/Feb: Chap.6	19/Feb: Chap.6
#7	23/Feb	24/Feb: Chap.7	26/Feb: Chap.7
#8	02/Mar	03/Mar: Chap.7	05/Mar: **2nd. Test on Thr. (5.Mar.09)**
#9	09/Mar	**Spring Brk.**	**Spring Brk.**
#10	16/Mar	17/Mar: Chap.8	19/Mar: Chap.8
#11	23/Mar	24/Mar: Chap.8	26/Mar: Chap.9
#12	30/Mar	31/Mar: Chap.9	02/Apr: Chap.9/10
#13	06/Apr	07/Apr: Chap.10	09/Apr: **3rd. Test on Th. (9.Apr.09)**
#14	13/Apr	14/Apr: Chap.10	16/Apr: Chap.11
#15	20/Apr	21/Apr: Last Week :)	23/Apr: Review :))
FINAL Note!!	6/May/09 (Wed)	Final for Phys.201 **Different Time/Day!!**	2:00am at PSC-002

Table 1: Tentative Syllabus for the course Phys.201 in Spring, 2009: Chapters are from Cutnell & Johnson. **NOTE:** The time (**2pm**) & day (**Wed**) of the Final (9am) is different from that of the lecture (**T/Th 9:30am)!**)

may come and go as you please. The review session is to have fun with the ideas. It should be informal. We will clarify confusions, solve problems, and talk physics. I hope you will freely participate in discussions, ask questions and offer to solve problems posed by your colleagues or me.

Working Group: The most fun way to learn physics is from each other. I strongly recommend that you form study groups. Three to four students in a group is ideal. Discuss and critique the lectures and homework assignments within the group. You will observe that the correct approach will build consensus quickly. Good friends do not necessarily make good study partners. Remember Wilde: "I choose my friends for their look, my acquaintances for their character, and my enemies for their intellect". Although he might not have followed the apothegm, I hope you do.

Computer Assisted Personalized Approach — CAPA — System

I am an ardent fan of the CAPA system. The CAPA system allows you to test your understanding by solving problems and check your answers. Every erroneous effort you make is an invaluable experience. Do not discard the wrong solution: keep note of the erroneous approach. The CAPA teaches you when **not** to use an equation. When you do get the correct answer, compare the 'right' ideas and formulae to the earlier erroneous ones. Save all the incorrect and correct solution for each problem. It is a wonderful self tutorial. The grading of this course is largely based upon the CAPA system.

The CAPA section for this course will be held each week or as announced in the class. The time and place for various CAPA sections are given in Table 2. A Lon-Capa "Cookbook" is appended to this handout.

Grading

The grading for this course will include homework, three hourly tests, and a final. The most important of these is the CAPA homework. If you can do your homework, there is no reason why you should not ace the tests and the final.

Homework: Approximately each week and a half you will be given your personalised set of CAPA homework assignments. Typically, we shall have a new CAPA set each Thursday,

Section	Day	Time	Location	Instructor
001	Mon	11:15–12:05pm	PSC-208	Prof.
002	Mon	12:20–1:10pm	PSC-208	Prof.

Table 2: Time and Location of the Phys.201 CAPA Sections.

and it will be due a week from the following Monday; thus, giving you two weekends to work it out. Do work the problem with your group. But **do not** copy solutions. It will prove fatal. Be convinced of the correct procedure and equations.

• If you copy a formula and plug in the numbers, it is **CHEATING!** It constitutes a violation of the Carolinian Code.

• While working on the CAPA homework, CLOSE your book and lecture notes. You should ONLY keep the formulae sheet, appended below, a non-programmable calculator, pencil, and a cheerful disposition: Just like the hourly Tests, or the Final. This work ethics will serve you well in the Tests and the Final. If you need to look at the book or the notes, go to it, review the material, close the book, and return to your CAPA work.

• Do not discard your erroneous calculations; save them along with the final correct answer. The former will tell you what not to do.

• Having worked the problem, get on the Internet and log into the CAPA computer, and enter your solution. **Important:** Please make sure to log out correctly otherwise your answers are not recorded. (Please follow the instructions in the Lon-Capa "Cookbook" appended below.)

• If you are unable to solve a problem, first discuss it within your group, and with other colleagues. Then there are the CAPA sessions (look at Table 2) where an instructor will give you essential hints and help you understand the concepts. Finally, there are the review sessions. The instructor(s) will not solve the problem for you. There is no point in it; it defeats the purpose of the CAPA system. They will, however, give you sufficient hint and help so that *you* can solve the problem.

Of course, you are ALWAYS welcome to come to me!

• There is a deadline for the homework answer to be entered in the computer. **Please do not wait till the last hour to enter your answers.** No answer will be accepted after the deadline since the answers are made available after the appointed hour.

I strongly recommend you to work on the homework problem *the day* it is given to you. Enter your answers. The ones you do not get right will reveal the weak parts of your understanding which in turn will help you focus in the required direction.

There will be **no** make-up for a missed homework. Only a debilitating illness lasting a week or more (may it never happen!), or some emergency, will induce me to grant you a make-up.

The homework will carry a **30**% weight for the course.

Hourly Tests: Three hourly tests will be administered. Each test **will** count. Tests will consist predominantly, approximately 80%, of problems drawn from the CAPA sets. The remaining 20% of the problems will be drawn from the examples discussed in the class and from simple variants of the CAPA problems. If you have mastered the CAPA homework, you should have no trouble in the Tests. The Tests and the Final are strictly closed book and notes. Except for the **Fundamental Laws** you do not need to remember **any formula**. Either the formula will be given or I will expect you to derive it during the tests. I append a list of formulae and constants at the end of this handout.

The grades of the hourly test typically will be posted no **earlier** than **seven WORKING days** from the day the test is administered.

There will be **no make-up** for the hourly test. Only an exigency will induce me to grant you a reprieve. I will decide it upon a case-by-case basis.

The hourly tests will carry a **35**% weight for the course.

Calculators in Hourly Tests and the Final: You will need a Non-Prgrammable scientific calculator. In the hourly tests and the final, however, **a programmable calculator is strictly forbidden.** The Director of Undergraduate Studies has issued the following instruction:

"There seems to be evidence that programmable graphing calculators are being used in the lower level physics courses for cheating on the exams, especially in CAPA type exams. The best way to circumvent this practice is to make a statement in your syllabus and in the first few classes that no programmable graphing calculators will be allowed on exams of any kind. And then, of course, to enforce your requirement."

The calculator can have editing options. It must never have any capability to store formulae. If you already own a programmable calculator, kindly buy a non-programmable calculator of the type suggested above.

I strongly recommend you to commence using your **non-programmable** calculator from the **start** while you do your CAPA homework. It will make you facile with its use and its various functions.

Final Examination: The Final examination will constitute a comprehensive test of the material covered in the course. Its format will be identical to that of the hourly test. The Final Examination for Phys.201 will be held on: **6/May/09, Wednesday, at 2pm in PSC-002**. Please NOTE the different time/day.

The final examination will carry a **35**% weight for the course.

Important Dates: The important dates pertaining this course are listed in Table 3.

Course Grade: Let me repeat: the most important part of the evaluation is the CAPA homework. If you simply copy the formulation of the problem, worked out by your colleague or tutor, and plug in 'your-numbers', you cannot do well in the tests. It is imperative that you understand the problem and make its solution your own. If you do this, the tests will be a breeze!

I will not grade on a curve. The grades will be decided on an absolute rating whose **approximate** cut-off points are as follows in Table 4. There is, thus, no competition among you. In principle, everyone can get an "A". May you do!

Overall Midterm Grading: You can continually evaluate your midterm grade using the following formula:

Course Percentage = [0.30*H + 0.35*((T1+T2+T3)/3)]/0.65,

where, 'H', and 'T' refer to the home-work and hourly test scores in "percentage". Once you have the course percentage, please look up the Table 4 to find your grade. Thus, if you are

Date	Subject
16/Jan/09(Fri)	Last date to drop without a “W” grade
19/Jan/09(Mon)	Dr. King’s Birthday; Happy Birthday Dr. King!
5/Feb/09(Thr) at 2pm	**1st. Test**
23/Feb/09(Mon)	Last date to drop without a “WF” grade
2/Mar/09(Mon)	Midpoint in Semester
5/Mar/09(Thr) at 2pm	**2nd. Test**
8/Mar–15/Mar/09(Sun.–Sun.)	Spring Break
9/Apr/09(Tu) at 2pm	**3rd. Test**
27/Apr/09(Mon)	Last Day of Classes
6/May/09 (Wed) at 2pm (!!)	**Final Exam in PSC-002**

Table 3: Important Dates for Phys.201, Spring’09.

Range	Grade
91-100%	A
81- 90%	B^+
71- 80%	B
66- 70%	C^+
56- 65%	C
46- 55%	D^+
36- 46%	D
$<$ 35%	Grade Assigned in Swahili

Table 4: Range of Score in Percentage and Grades.

keeping a grade, in homework and hourly tests, above 90%, you have an 'A'; if your score in homework and hourly tests is between 71% and 80%, you have a 'B', and so on. Specifically, suppose in March your homework score is 90%, and the hourly test score, averaged over two tests, is 80%, then your midterm percentage is:
(90*0.30 + 80*0.35)/0.65 = 84.6% which corresponds to a B^+.

Keep an eye but do not obsess over midterm grades. Instead focus on learning and *enjoying* the ideas. Trust me, such an outlook will help you get a *better* grade!

Borderline Case & Recommendation Letter: I exhort you to participate in the class, ask questions, offer solutions. I urge you to offer critiques — boldly and with a sense of fairness — of the course, of the lectures, and of the CAPA. I request of you to be a 'good citizen' by helping your colleagues and helping your professor to teach better. I want you to think creatively and enquire without fear of errors. These will signify your effort and sincerity, and mark you for excellence. Please note that the tasks I ask of you have little to do with how much training you have had in physics, or what grades you score; it has more to do with your learning, perseverance, and participation in this course. I will consider all those who thus excel in the course. And it would be my pleasure to write a recommendation letter for you.

An After Thought...

If I were to ask you to name 'The Person of the Millenium', the one that just passed, whom would you choose? ... Aquinas? Rumi? Gutenberg? Genghis Khan? Dante? da Vinci? Elisabeth-I? Shakespeare? Washington? Gandhi? Einstein?

... I, without hesitation, would say Newton. His Principia Mathematica was, in my opinion, the most influential intellectual work ever accomplished by one person. This course, Phys.201, gives you the gems that Newton found 'on the shore, while the vast ocean of truth...'.

Toward the end of the course, do let me *know* if you agree with my choice! I leave you with a coronation by Beddoes:

"Creep not, nor climb.
As they who put their topmost
Of sublime
On some peak of this planet, pitifully.
Dart eagle wise with open wings, and fly:
Until you meet the gods."

LON-CAPA Cookbook

Access URL: http://loncapa2.physics.sc.edu

If this website is unavailable, please try: http://loncapa3.physics.sc.edu

Browser requirements: Cookies, Javascript, and Java must all be enabled. For some browsers pop-up windows must be enabled. For some course material, you will need the Apple Quick-Time plug-in.

Username: Your USC username (you can find it on the technology tab of VIP).

Password: Your nine-digit student ID.

Domain: "sc", which is provided as a default.

Navigation: After login you may choose to work with a main menu in the main window or with a "Remote Control" which appears as a separate browser window. The Remote provides quick access to the various features of LON-CAPA. If the Remote does not appear when you log in, it is either behind the browser window or you are in the single-window mode. Placing the Remote and the content windows side-by-side is convenient. The first content screen shows the currently available courses. A click on your course takes you to the course navigation page on which you will find links to the syllabus, the problem sets, and other course materials. With the Remote Control you can move forward and backward in the content with the respective buttons. The NAV button returns you to the navigation page. EXIT will log you out of LONCAPA, a requirement if you want to ensure that no one other than yourself will access your account.

Communication: LON-CAPA has built-in communication support. You can send messages regarding the course content by clicking the FDBK ("Feedback") button. Feedback goes to the Instructor/TA. To send internal e-mail or to view replies to your feedback, click the COM ("Communication") button. For issues specific to the homework problems the internal communication is preferable to ordinary e- mail because it automatically provides context for your questions and concerns. For most other purposes ordinary e-mail is generally preferable. Please note that I encourage discussions in the lecture hall or in my office where a blackboard is available and interaction is quick and more efficient.

Formulae: Physics 201

IMPORTANT: Please show your calculations on the sheets provided.

Simple Units: [Length]=m; [Time]=s; [Mass]=kg; [Force]=N; [Energy or Work]=J; 1eV=1.602×10^{-19}J;

Constants:

- Newton's Gravitational Constant: $G = 6.666 \times 10^{-11} N.m^2/kg^2$; $g = 9.81 m/s^2$;
- Masses and Radii of Celestial Bodies:

Mass and radius of the sun: 1.99×10^{30}kg & 6.96×10^{8}m;
Mass and radius of the Earth: 5.98×10^{24}kg & 6.37×10^{6}m;
Mass and radius of the Moon: 7.36×10^{22}kg & 1.74×10^{6}m;
Distance from the Earth to the Moon: 3.82×10^{8}m;
Distance from the Sun to the Earth: 1.5×10^{11}m;

- Escape Speed on Earth: 11.2 km/s
- eV -vs- Joules: 1eV=1.602×10^{-19}J;
- Speed of light: $c = 1/\sqrt{\mu_0 \epsilon_0} = 2.99792 \times 10^{8} m/s$;
- Electron: Charge(e) = -$1.6022 \times 10^{-19} C$, Mass(m_e) = $9.109389 \times 10^{-31} kg$;
- Proton/Deuteron/Alpha: Proton Mass $m_P = 1.672 \times 10^{-27} kg$; Deuteron has twice the mass of proton and the same charge; Alpha particle has four times the mass of protons and twice its charge.
- Plank's constant: $h = 6.626 \times 10^{-34} Js = 4.135 \times 10^{-15} eVs$;
- Avagadro-number: $\mathcal{N}_A = 6.02 \times 10^{23}$ molecules/mole;
- Universal Gas Constant: $R = 8.314 J/mol.K$
- Boltzmann Constant: $k = 1.381 \times 10^{-23} J/K$; also $k = 8.617 \times 10^{-5} eV/K$
- Stefan-Boltzman Constant: $\sigma = 5.666 \times 10^{-8} W m^{-2} K^{-4}$.

Trignometry: Consider a Right-Angle Triangle with 'h' as the hypotenuse, 'b' as the base, and 'p' as the perpendicular; let the angle between b and h be θ, i.e. θ is "opposite" p. Then $h = \sqrt{p^2 + b^2}$; and **sin**θ is opposite(p)/h; **cos**θ is adjacent(b)/h

- sin $\theta = p/h$, cos $\theta = b/h$, and tan $\theta = p/b$

- $\sin 2\theta = 2 \times \sin\theta \times \cos\theta$

Vector Components: In two-dimension (x-y plane), if **A** is be vector, then $A_x = |A| cos\theta$ and $A_y = |A| sin\theta$, where θ is the angle with respect to x-axis and $|A|$ is the magnitude. It follows that $|A| = \sqrt{A_x^2 + A_y^2}$, and tan$\theta$=$A_y/A_x$.

Radians -vs- Degrees: π radians = 180^0; 1 Rad=0.159 revolution=57.3^0;

Perimeter, Area, and Volume:

- For a **Square** of side "R", the Perimeter=$4R$, the Area=R^2.
- For a **Cube** of side "R", the Area=$6R^2$, the Volume=R^3.
- For a **Circle** of radius "R", the Circumference =$2\pi R$, the Area=πR^2.
- For a **Sphere** of radius "R", the Area=$4\pi R^2$, the Volume=$\frac{4\pi}{3} R^3$
- For a **Cylinder** of radius "R"and length "L", the Area=$2\pi RL$, the Volume=$\pi R^2 L$

Kinetic Energy: For small speed, i.e. $v << c$, the Kinetic Energy (KE) is (1/2)mv^2; Rigrously, KE =$mc^2 - m_0c^2$;

Centripetal Force : Centripetal Force = $mv^2/R = m\omega^2 R$.

Quadratic Equation: The solution of a quadratic equation, $ax^2 + bx + c = 0$ is:
$\mathbf{x} = \left[-\mathbf{b} \pm \sqrt{(\mathbf{b^2} - \mathbf{4ac})}\right]/\mathbf{2a}$.

Vector Operation: The 'Dot' or 'Scalar' product of two vectors **A** and **B**, which yields a scalar, is **A.B**=$|A||B|cos\theta = A_xB_x + A_yB_y + A_zB_z$.

The 'Cross' or 'Vector' product of two vectors **A** and **B**, which results in a vector **C**, whose magnitude is —**A '×' B**—=$|A||B|sin\theta$, and **C** is perpendicular to the plane defined by **A** and **B** according to "Right Hand Rule".

In component form, the resulting vector **C** from the Cross-Product, (C_x, C_y, C_z), is:
$((a_yb_z - a_zb_y)i + (a_zb_x - a_xb_z)j + (a_xb_y - a_yb_x)k$, where "i", "j", and "k" are unit vectors in "x", "y", and "z" directions.

Linear Motion :— Distance/Velocity/Acceleration: For motion in "x" direction:

- $\mathbf{x_f = x_i + v_{ix}t + (1/2)a_xt^2}$;
- $\mathbf{v_{fx} = v_{ix} + a_xt}$;
- $\mathbf{v_{fx}^2 = v_{ix}^2 + 2a_x(x_f - x_i)}$.

• **Motion in "y" direction:** Replace "x" with "y" in the above:

• $\mathbf{y_f = y_i + v_{iy}t + (1/2)a_y t^2}$;

• $\mathbf{v_{fy} = v_{iy} + a_y t}$;

• $\mathbf{v_{fy}^2 = v_{iy}^2 + 2a_y(y_f - y_i)}$.

Projectile Motion:

•Horizontal: Initial velocity along x-axis, $\mathbf{v_{ix} = v_0 cos}\ \theta$, remains constant;

•Vertical: $a_y = -g = -9.81m/s^2$. The kinematic equations become:

• $\mathbf{y_f = y_i + v_{iy}t + (1/2)(-g)t^2;}$

• $\mathbf{v_{fy} = v_{iy} - gt;}$

• $\mathbf{v_{fy}^2 = v_{iy}^2 - 2g(y_f - y_i);}$

where $\mathbf{v_{iy} = v_0 sin}\theta$ is the initial velocity along y-axis.

• The "Trajectory" is $\mathbf{y = (tan\theta_0)x - 0.5gx^2/(v_0 cos\theta_0)^2}$, which is a parabola where $x_0 = y_0 = 0$.

Circular Motion: $\theta = s/r$; $\omega = \Delta\theta/\Delta t = d(\theta)/dt$; $\alpha = \Delta\omega/\Delta t = d\omega/dt$; Thus $v = \omega r$; $\mathbf{a = v^2/r = \omega^2 r}$. The time-period of revolution, $\mathbf{T = 2\pi R/v = 2\pi/\omega}$. Kinematic relations between θ, ω, and α are identical to those between x, v, and a.

Hooke's Law Governing Springs or Elastic Force: The elastic force is $\mathbf{F = -kx}$, where "k" is the spring constant, and the direction of the force is opposite to that of the displacement x (hence the "-" sign). The potential energy of the elastic force is $\mathbf{(1/2)k(x_f^2 - x_i^2)}$.

If the mass of the object, attached to a spring, be "m", then the time-period (T) of oscillation is: $\mathbf{T = 2\pi\sqrt{(m/k)}}$. The frequency is: "f = 1/T".

Frictional Force: It is defined as $\mathbf{F} = \mu\mathbf{N}$, where μ is the coeffient of friction. The coefficent of static friction (μ_s) is always greater than the coefficent of kinetic friction (μ_k).

Drag Force: The drag force, $\mathbf{D}$, exerted on a body with the cross-sectional area A, moving with speed v, through a fluid (e.g. air, water, etc) of density ρ, is parametrised as: $\mathbf{D = (1/2)C\rho Av^2}$, where C is the drag-coefficient typically $0.4 < C < 1.0$. The terminal speed is $\mathbf{v_t = \sqrt{2mg/(C\rho A)}}$.

Work, Kinetic Energy, etc.: Work is $\mathbf{\Delta W = F.\Delta X}$ — it is a "dot-product", i.e.

$\mathbf{\Delta W} = |\mathbf{F}||\mathbf{\Delta X}|\mathbf{cos}\theta$. The kinetic energy is derived to be $\mathbf{KE} = (\mathbf{1/2})\mathbf{mv^2}$. Power is defined as $\mathbf{P} = \mathbf{\Delta W/\Delta t} = \mathbf{F.v}$, where $\mathbf{v}$ is the velocity.

Potential Energy, etc.: The potential energy of the field is defined as $\mathbf{\Delta U} = -\mathbf{W}$. For gravity, $\mathbf{U} = \mathbf{mg(y_f - y_i)} = \mathbf{mgh}$. For conservative forces, the potential energy is path independent.

Energy Conservation: The TOTAL energy is always conserved. However, only if dissipative forces, such as friction or viscosity, are absent, is the mechanical energy — kinetic plus potential — conserved.

Centre of Mass: The x-position of the centre of mass (CM) is defined as: $x_{cm} = \Sigma x\Delta(m)/M$, where $M = \Sigma\Delta(m)$ is the total mass; ditto for y- and z-position.

Linear Momentum: The rate of change of linear momentum, $\mathbf{p} = m\mathbf{v}$, is the force: $\mathbf{F} = \mathbf{\Delta p/\Delta t}$. For an isolated system, *i.e.* no external force, 'p' is always conserved but not necessarily the kinetic energy.

Rotation: The rotational displacement is: $\theta = \mathbf{s/r}$. The rotational speed and acceleration are: $\omega = \mathbf{v/r}$ and $\alpha = \mathbf{a/r}$. The corresponding kinematic relations for rotation are: $\theta_\mathbf{f} = \theta_\mathbf{i} + \omega_\mathbf{i}\mathbf{t} + (\mathbf{1/2})\alpha\mathbf{t^2}$; $\omega = \omega_\mathbf{i} + \alpha\mathbf{t}$; $\omega_\mathbf{f}^\mathbf{2} = \omega_\mathbf{i}^\mathbf{2} + \mathbf{2}\alpha(\theta_\mathbf{f} - \theta_\mathbf{i})$.

Moment of Inertia: The moment of Inertia is defined as: $I = \Sigma(r^2\Delta m^2)$. It is axis dependent.

• **Parallel Axis Theorem:** The moment of inertia of an object about an axis parallel to, and at a distance h away from, the axis through centre-of-mass is: $\mathbf{I} = \mathbf{I_{cm}} + \mathbf{Mh^2}$.

Moments of inertia for a few objects with respect to specified axes are given as follows. Using the parallel axis theorem, we can find $\mathbf{I}$ through other parallel axes.:

• **Thin Rod:** Axis through centre: $\mathbf{I} = (\mathbf{1/12})\mathbf{ML^2}$

• **Hollow Cylinder or Hoop:** Axis through centre and normal to the circular surface: $\mathbf{I} = \mathbf{MR^2}$

• **Solid Cylinder or Disk:** Axis through centre and normal to the circular surface $\mathbf{I} = (\mathbf{1/2})\mathbf{MR^2}$

• **Solid Sphere:** Axis through centre: $\mathbf{I} = (\mathbf{2/5})\mathbf{MR^2}$

• **Thin Spherical Shell:** Axis through centre: $\mathbf{I} = (\mathbf{2/3})\mathbf{MR^2}$

• **Rectangular Slab:** Length=a, width=b, and axis through centre: $\mathbf{I} = (\mathbf{1/12})\mathbf{M}(\mathbf{a^2} + \mathbf{b^2})$

Torque, Angular Momentum: Torque is defined as, $\tau = \mathbf{\Delta L/\Delta T} = \mathbf{r} \times \mathbf{F} = \mathbf{I}\alpha$ (note the 'cross-product' between r and F). The angular momentum is defined as: $\mathbf{L} = \mathbf{r} \times \mathbf{p} = \mathbf{I}\omega$. In absence of external forces, the 'L' is conserved. The rotational kinetic energy is: $KE = (1/2)I\omega^2$.

Work, Power in Rotation: Just like linear displacement, $\mathbf{\Delta W} = \tau\mathbf{\Delta}\theta$, and $\mathbf{P} = \tau\omega$.

Gravitation: I expect you to remember Newton's Law; the Newton's universal constant $\mathcal{G} = \mathbf{6.67 \times 10^{-11} Nm^2/(kg^2)}$.

• The gravitational force on an object due to a spherically symmetric mass distribution is as if the entire mass of the spherically symmetric mass distribution were centered at the origin **provided** the object is outside the radius of the sphere. (We recognise this as the Gauss's Law.)

• The gravitational potential (PE) energy between two point, or sperically symmetric, masses, M and m, separated by a distance R, is:
$\mathbf{PE} = -\mathcal{G}\mathbf{\frac{Mm}{R}}$

• Planet or a satellite, of mass m, in a *circular* orbit of radius R around the Sun, or gravitating object, of mass M: $\mathbf{mv^2/R} = \mathcal{G}\mathbf{\frac{Mm}{R^2}}$.

• It follows that $\omega = \mathbf{v/R} = \sqrt{\mathcal{G}\mathbf{M/R^3}}$; and the time-period is $\mathbf{T} = \mathbf{2}\pi/\omega$.

Fluids: The pressure $\mathbf{P} = \mathbf{P_0} + \rho\mathbf{gh}$, where the atmospheric pressure P_0 is 1.01×10^5Pa. The density of water is 0.998×10^3kg$/m^3$.

Archimedes' Principle: The apparent weight of an object submerged in a liquid is: $\mathbf{mg} - \mathbf{F_b}$, where, the bouyant force upward, $\mathbf{F_b} = \rho\mathbf{Vg}$, where ρ is the density of the liquid and V is the volume of the submerged object.

Bernoulli's Equation: $\mathbf{P} + (\mathbf{1/2})\rho\mathbf{v^2} + \rho\mathbf{gh}$ is a constant.