SCHOOL OF PHYSICS

First Year Teaching Unit

PHYS1131 Higher Physics 1A

HOMEWORK PROBLEMS BOOKLET

- **Syllabus**
- **Course Outline**
- **Schedule**
- **Formulae and Data Sheets**
- **Homework Problem Sets 0 - 6**

Session 1 2016

PHYSICS 1A / HIGHER PHYSICS 1A/(SPECIAL) HIGHER PHYSICS 1A (PHYS1121/PHYS1131/PHYS1141)

Textbook: 'Fundamentals of Physics', Halliday & Resnick 10th Edition

TOPIC 1: Mechanics
• **MOTION ALONG A STRAIGHT LINE** (§2.1 – 2.6) Displacement, velocity and acceleration; motion with constant acceleration. (Much of this will be assumed knowledge with revision resources supplied.)
• **VECTORS** (§3.1 – 3.3) Vectors; resolution and unit vectors; vector addition; dot and scalar products
• **MOTION IN TWO AND THREE DIMENSIONS** (§4.1 – 4.7) Equations of motion in vector form; average and instantaneous velocities and accelerations; projectile motion; uniform circular motion; relative motion.
• **FORCE AND MOTION** (§5.1 - 5.3, 6.1 – 6.3) Newton's laws of motion; mass; contact forces (normal and frictional components); dynamics of circular motion. Applications of all of these in mechanics.
• **WORK AND ENERGY** (§7.1 – 7.6, §8.1 – 8.5) Mechanical work; vector dot product; variable forces inc. Hooke's Law. Kinetic energy and the work-energy theorem; potential and internal energies, power.
• **CENTRE OF MASS AND LINEAR MOMENTUM** (§9.1 – 9.8) Extended objects and many particle systems, centre of mass; linear momentum; collisions in 1 and 2 dimensions.
• **ROTATION AND TORQUE** (§10.1 – 10.8, §11.1-11.8) Angular velocity and acceleration; rotational kinetic energy; moment of inertia; torque, rotational kinematics and mechanics. *Note: Parts of this section will be covered in the lab and problem solving classes and may not be covered in lectures. They are examinable.* **PHYS 1141 only** §11.9 on gyroscopes in problem solving classes
• **GRAVITATION** (§13.1 – 13.3, 13.5 – 13.7) Newton's law of gravitation; Gravitation, g and its variation; the Principle of Superposition; Gravitational Potential Energy; Kepler's laws; motion of planets and satellites.

TOPIC 2: Thermal Physics
• **TEMPERATURE** (§18.1 – 18.3) Heat, temperature and thermal equilibrium; absolute zero; thermal properties of matter; measuring temperature, specific and latent heats.
• **KINETIC THEORY OF GASES** (§19.1 – 19.9) Macroscopic properties of a gas and the ideal gas law; molecular model of the ideal gas; kinetic interpretation of temperature; mean free path; the distribution of molecular speeds; molar specific heats; adiabatic processes; equipartition of energy.
• **HEAT AND THE FIRST LAW OF THERMODYNAMICS** (§18.4 – 18.6) Energy transfer mechanisms in thermal processes; work and internal energy; work and heat in thermodynamic processes; the First Law of Thermodynamics.
• **1141 ONLY: ENTROPY AND THE SECOND LAW OF THERMODYNAMICS** (§20.1-20.4) This will be covered in problem solving classes

TOPIC 3: Waves
• **OSCILLATIONS** (§15.1 – 15.6) Oscillating systems; Simple Harmonic Motion, including energy of oscillations; Examples, including uniform circular motion, pendulums; Damped and forced oscillations (qualitative only).
• **WAVE MOTION** (§16.1 – 16.5, 16.7) Propagation of a disturbance; travelling waves; wave speed; reflection and transmission; power and intensity in wave motion; the principle of superposition; interference of waves; standing waves.
• **SOUND WAVES** (§17.1 – 17.8) The speed of sound; pressure variations; travelling longitudinal waves; power, intensity and level of sound waves; interference; the Doppler effect; resonance; standing longitudinal waves; beats; shock waves

Weeks 1-6: Mechanics

Weeks 7-12: Thermal Physics; Waves

First Year Physics – Physics 1A/Higher Physics 1A
PHYS1121/PHYS1131
Session 1, 2016 – Course Outline and Administrative Arrangements

Website

The main website for these courses is Moodle. Moodle can be accessed through myUNSW. On the Moodle page you will find important course information, lecture notes, laboratory information as well as quizzes.

Course Staff

PHYS1121 and PHYS1131 are taught by a large team of people. In session 1 2016, the lecturers are Prof. John Webb and Prof. Joe Wolfe (first 6 weeks) and Prof. Michael Burton and Prof. Alex Hamilton (weeks 7-12). Contact details and consultation times for your lecturers will be advertised during lectures. Teaching Assistants are available for consultation on Mondays, Wednesdays and Fridays, 12-2 PM, in room 5 in the OMB from week 2.

Ms Ranji Balalla is the First Year Physics Coodinator and may be contacted in the First Year Physics Office, in Rm LG03 in the Old Main Building. See Ranji about administrative matters.

Dr Elizabeth Angstmann is the First Year Physics Director and may be contacted in the First Year Physics Office, in Rm LG04 in the Old Main Building. See Elizabeth about academic matters.

Course information

- Six units of credit
- Three hours of lectures, two hours of laboratory and one hour of problem solving workshops each week.
- The course is run under the Moodle elearning system, accessed from the URL http://moodle.telt.unsw.edu.au/ .
- PHYS1121 is the standard introductory physics course taken in first year. PHYS1131 has the same syllabus, but covers more difficult problems and has more challenging assessment. These two courses are commonly taken by science and engineering students. PHYS1141 is a similar course, it has a slightly different laboratory component and is for people intending to major in physics.
- Note that there is also PHYS1111, an introductory level course for those with weaker mathematical skills. It is typically taken by life science students or by those who need an introductory physics course before tackling Physics 1A. If you feel that you would be better transferring to this course, please come into the First Year Office to arrange a transfer. If you have not studied physics before we strongly advise you to take this introductory course first.

Learning and Teaching Philosophy

This is not a course about physics — it is physics. Students learn physics by doing it, by solving problems, whether on paper or in the lab. Concepts and principles are learned in context, by example and then by development. It is important to understand the limits of applicability. Mathematical skills (such as solving simultaneous and differential equations) are essential tools in much problem solving. However, the art of problem solving in physics is understanding the principles and where they apply, and how and when to use them and the relevant mathematical or other tools.

Aims

This course gives an introduction to mechanics, thermal physics and waves, and to the techniques of analysis and problem solving in the physical world. With its companion subject (Physics 1B, Higher Physics 1B or Higher Physics 1B (Special)), this constitutes a broad introduction to physics. This background supports higher level study not only in physics, but in engineering and technology, chemistry, biology and other areas.

Learning outcomes
By the end of this course, you will understand the important principles and laws of classical mechanics, thermal physics and waves and you will be able:

- to interpret problems involving these areas of physics,
- to analyse and to quantify them, invoking appropriate principles,
- to solve such problems and to interpret the solutions,
- to plan an experimental investigation,
- to make careful measurements,
- to analyse experimental results, to test hypotheses and to discuss their implications.

The syllabus for the course can be downloaded from Moodle and is printed in your homework booklet.

Teaching formats and assessment
- Lectures are used to present theoretical and practical material and to teach some of the skills of physical analysis and problem solving. These skills and the understanding of principles are rehearsed in the Problem Solving Workshops, and are assessed in the Exam and Quizzes.
- In problem solving workshops you will be solving problems. It is very important that you practice solving problems yourself, this is how you learn and the skill that you will be tested on in the final exam. You are also provided with a homework booklet. This contains problems that you should try yourself or with other students in your own time. Videos showing how to solve these problems can be found on Moodle.
- The Laboratory classes teach skills in planning an investigation, experimentation, measurement, analysis and hypothesis testing. The laboratory component is assessed in the lab. There is a focus on uncertainties in data.
- If you wish to perform well in your Physics course it is essential for you to spend at least as much time on self-study per week as class time (i.e. 6 hours per week), in particular solving homework problem sets and quiz questions.

Assessment (Summary)
Note: You must pass the end of session final examination and attempt all laboratory exercises to pass the course.
Laboratory (cumulative mark) - 20%
Online Quizzes (cumulative mark) – 10 %
Final Examination – 70%

Laboratories
Every student takes a 2 hour laboratory each week at the time slot chosen on enrolment. Please check you own timetable for this. Laboratories start in Week 2. You must complete the safety induction on Moodle during week 1. Laboratories count 20% towards your final assessment for the course. Before each class you need to complete a pre-lab test. These tests will form 25% of your laboratory mark (5% of your total physics mark). You may try each question up to three times, a 33.3% penalty is applied for each incorrect attempt. Short videos describing the experiments can be viewed before each class, the links to these are provided on Moodle.

To pass the course you must attempt all laboratory exercises.

If you miss a lab make sure you either provide a doctor's certificate or book a catch-up lab. Note that the prelab quizzes are not reopened if you are sick and miss a lab. You must complete the prelab quiz in the week prior to the lab being scheduled.

Plagiarism is considered a serious offence in the first year lab. If you turn up to lab with data already recorded in your lab book you will automatically receive zero for that lab. If this happens a second time you may receive zero for the course.

If you are a repeating student you may apply for a laboratory exemption. You are required to complete a laboratory exemption form for this request before week 2 of session. This form can be downloaded from Moodle. Your previous lab grade will determine whether you qualify for a laboratory exemption, you need a mark of 15 or above. It is an expectation that you will spend the time you would have otherwise spent in lab studying physics. To keep your lab exempt status you need to show the teaching assistant physics problems that you have been working on at least three times during the session. The teaching assistant will record your name when you show them. This does not exempt you from the fortnightly quizzes.

Online Quizzes
In odd-numbered weeks online quizzes are due. The quizzes can be accessed from the course Moodle site. All quizzes are available on Monday, of odd weeks and due Sunday evening of odd weeks (3, 5, 7, 9, 11 and 13) at 9 PM. Quizzes 1-6 are assessed and are each worth 1.67%, for a total of 10% of the course marks. Make sure that you do not miss any of these quizzes. The purpose of these quizzes is to give you practice answering questions on the material you have covered in class. The quizzes will also provide you with feedback about your level of understanding of the lecture material. If you struggle with any of the questions in the quiz you can ask the teaching assistant, in problem solving workshops or on the discussion forums how to answer these questions once the quiz has closed.

To apply for special considerations for a quiz in the course you must have a doctor's certificate or other acceptable documentation covering at least 3 days during the period for which the quiz is available. You can use this doctor's certificate to apply for special consideration through myUNSW. Note that a doctor's certificate covering only the day the quiz is due will not be accepted. Do not leave attempting the quiz until the last minute!

Final Examination
The examination takes place during the exam period. It is a two hour written exam which is worth 70% of your course mark***. It is necessary to pass this exam to pass the course.*** The time and date will appear on your examination timetable available through myUNSW. You need to provide your own UNSW approved calculator for the examination. Additional assessment (a supplementary examination) is available for those students who are unable to take the Final Test for a legitimate reason. You must apply for, and be granted, Special Consideration. Please see the information on special consideration.

The supplementary exam will be held on the morning of 20th July. You should take this into account when planning travel as being overseas is not considered adequate grounds for missing an examination.

The Course Pack: Laboratory Manual and Homework Problem Booklets
You can either download the course pack from Moodle and print it out yourself or purchase it from the UNSW bookshop.

Please note that the cost from the bookshop is $35, this includes course material for any first year physics course you enrol in. The lab manual in the bookshop includes the lab exercises for Physics 1A and Physics 1B. If you have previously bought a lab manual either for Physics 1A or for Fundamentals of Physics please take it to the lab. Once your previous enrolment has been confirmed the lab staff will give you a homework booklet and update your lab manual if necessary.

If you choose to print the lab manual please ensure that you bind it. You can either have it spiral bound or store it in a folder. Scientists have to record all their important experimental results in a bound book and we would like you too as well. You will find that the lab manual is a useful resource for studying for this course and so you should keep it neat so that you can revise the material throughout the session and also for the examinations. If you are going onto 1B you will be able to print the 1B part of the lab manual when you are enrolled in Physics 1B.

Problem Solving Workshops, Homework Booklet and Teaching Assistants
Problem solving workshops start in week 1. In problem solving workshops you will be solving physical problems in small groups. Every three weeks you will have a practice test, you should regard your results in these tests as feedback about how you are going in the course.

The Homework Problems booklet contains problems for you to work on at home. Solutions in written and video format are available on Moodle. Each of the homework sets covers 2 week's work so set 1 covers material from weeks 1 and 2 of lectures.

Teaching assistants are available during weeks 2-13 for consultation. This service will be available 12-2 PM Monday, Wednesday and Friday in room 5 in the OMB. The teaching assistant can help you with problems from the problem booklet or any other physics problems. They can not help you with the current quiz but they can help you as soon as it closes. They can also help you prepare for a lab if there is something you do not understand.

Physics, Higher Physics or Higher Physics (Special)?
In several programs (e.g. Elec. Eng., Telecommunications, Photovoltaics) students are required to do Higher Physics 1A and 1B courses (PHYS1131 and PHYS1231) and *not* the Physics 1A and 1B courses (PHYS1121 and PHYS1221). If you are unsure what your program requirements are please check with your Program Office. To enroll in Higher Physics 1B (PHYS1231) you need a mark of 50 in Higher Physics 1A (PHYS1131) *or* 65 in Physics 1A (PHYS1121). Higher Physics (Special), PHYS1141 and PHYS1241 are for students intending to major in physics. These courses have a different lab component. They are slightly more challenging than Higher Physics.

Textbook
The recommended textbook for this course is "Fundamentals of Physics", 10th Edition (Earlier editions are nearly as good, and there are several other excellent textbooks), by Halliday, Resnick and Walker. It can be purchased for a reduced price directly from the publisher:
http://www.wileydirect.com.au/buy/fundamentals-of-physics-10th-edition/

Other Enquiries
Are dealt with in the First Year Office, Rm LG03, School of Physics.
email: firstyear@phys.unsw.edu.au
Phone: 9385 4976

School of Physics Special Consideration and Supplementary Examination Policy and Procedures for Final Exams

A student who misses a final exam, due to illness or misadventure, must submit a request for special consideration via myUNSW within three working days of the exam. Supporting documentation must be presented to the university for verification.

A panel, consisting of the Year Directors and other nominated staff, will consider all applications for Special Consideration concerning the final exam in a course.

The outcome from lodging a special consideration request for a final examination is the granting, or not, of a supplementary exam.

The criteria used in determining the granting, or not, of a supplementary exam will be:

- Severity of the illness (or other misadventure) stated by the authority
- Satisfactory performance in the course to date
- Did the student attend the exam? (except in rare or exceptional circumstances, if a student is well enough to attend the original exam, they will not be granted a supplementary exam.)
- Does the request for special consideration conform to university rules? (supporting documentation which is not verified, or applications submitted more than three working days after the final exam will not be granted a supplementary exam.)

If a student feels ill on the day of the exam they should not attend the exam, but see their doctor, and submit special consideration. In the exceptional circumstance where a student who sat the original exam is permitted to sit the supplementary exam, their final exam mark may be the average of their two results.

The date/s for supplementary exams will be publicised before the start of the exam period. If a student lodges a special consideration request for a final exam, they are indicating they will be available on these days.

Students will be notified via email to their university account of the outcome of their request for special consideration. If they are granted a supplementary exam, details will be sent to their email account at least five days before the supplementary exam. It is a student's responsibility to regularly check their email.

The panel of Year Directors may override these criteria in exceptional circumstances.

Schedule for Physics 1A and Higher Physics 1A

Lectures: 3 hours a week during weeks 1-12. The times are on your timetable.

Laboratory: 2 hours a week. You should complete the online safety induction in week 1 and then attend your first laboratory session in week 2. Before each laboratory session you need to complete a prework test on Moodle. You can download the laboratory schedule from Moodle.

Problem Solving Workshop: one hour a week in weeks 1-12

Quizzes: Due at 9 PM Sunday at the end of weeks 3, 5, 7, 9, 11 and 13.

Teaching assistants will be available from week 2 on Mondays, Wednesdays and Fridays from 12 - 2 PM in room 5 in the old main building.

The schedule is summarised in the Table below:

<table>
<tr><th>Week</th><th>Timetabled this week</th></tr>
<tr><td>1</td><td>• Lectures start (Mechanics)
• Do online laboratory safety induction
• First problem solving workshop, bring your laboratory manual with you or a print out of the “Introductory Experimentation” exercise.</td></tr>
<tr><td>2</td><td>• Lectures
• First lab is this week, you will be doing “Introductory experimentation” (do the prework test before your lab session)
• Problem solving workshop</td></tr>
<tr><td>3</td><td>• Lectures
• Problem solving workshop
• Laboratory (The Pendulum)
• Quiz 1 is due at 9 PM on Sunday</td></tr>
<tr><td>4</td><td>• Lectures
• Problem solving workshop, practice test 1 in class this week
• Laboratory (make sure you know which stream you are in as different streams start doing different experiments this week), if you have a Friday lab you will do it in week 8</td></tr>
<tr><td colspan="2" align="center">Mid-session break</td></tr>
<tr><td>5</td><td>• Lectures
• Problem solving workshop
• Laboratory
• Quiz 2 due at 9 PM on Sunday</td></tr>
</table>

6	• Lectures • Problem solving workshop • Laboratory
7	• Lectures (Start Thermal Physics) • Problem solving workshop, practice test 2 in class this week • Laboratory • Quiz 3 due at 9 PM on Sunday
8	• Lectures • Problem solving workshop • Catch up labs run this week, everyone with a Friday lab should attend at the normal time.
9	• Lectures • Problem solving workshop • Laboratory • Quiz 4 due at 9 PM on Sunday
10	• Lectures • Problem solving workshop, practice test 3 in class this week • Laboratory
11	• Lectures • Problem solving workshop • Laboratory • Quiz 5 due at 9 PM on Sunday
12	• Last week of lectures • Last week of problem solving workshop, practice test 4 in class this week • Last week of scheduled laboratory exercises
13	• Catch-up labs: you need to book in to do one (or more) of these if you missed labs during session. If you miss one lab and have a medical certificate you can choose to receive your average mark for that lab. • Quiz 6 due at 9 PM on Sunday

PHYS1121/1131 - Formula Sheet

This information will be provided to students in all examinations in the course.
The symbols in formulae have their conventional meaning.

Kinematics

Constant acceleration:
$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$
$v = v_{x0} + a_x t$
$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

Circular motion:
$v = r\omega \qquad a_c = \dfrac{v^2}{r}$

Dynamics

Newton's 2^{nd} law $\sum \mathbf{F} = \dfrac{d\mathbf{p}}{dt}, \quad \sum \mathbf{F} = m\mathbf{a}$

Hooke's law $F = -kx$

Work $dW = \mathbf{F} \cdot \mathbf{dx}$

Power $P = \dfrac{dW}{dt} = Fv\cos\theta$

Kinetic energy $K = \frac{1}{2}mv^2$

$F = -\frac{dU}{dx} \qquad U = mgh \qquad U = \frac{1}{2}kx^2$

Momentum $\mathbf{p} = m\mathbf{v}$

Centre of mass $\mathbf{r}_{CM} = \dfrac{\sum m_i \mathbf{r_i}}{M}$ or $= \dfrac{\int \mathbf{r} dm}{M}$

Rotational Dynamics

$\omega = \frac{d\theta}{dt} \qquad \alpha = \frac{d\omega}{dt}$
$\tau = rF\sin\theta = I\alpha$

$I = \sum_i m_i r_i^2$ or $= \int r^2 dm$

$\mathbf{L} = \mathbf{r} \times \mathbf{p} \qquad \tau = \mathbf{r} \times \mathbf{F}$

$L = mrv\sin\theta$ or $= I\omega$

$W = \int \tau d\theta$

$K = \frac{1}{2}I\omega^2$

$I = \frac{2}{5}MR^2$ solid sphere

Thermal Physics

$\Delta L = \alpha L \Delta T \qquad \Delta V = \beta V \Delta T$
$Q = mc\Delta T \qquad Q = mL$

$PV = nRT = Nk_B T$

$\overline{\epsilon} = \frac{3}{2}k_B T = \frac{1}{2}m\overline{v^2}$

$\Delta E_{int} = \frac{f}{2}Nk_B\Delta T = \frac{f}{2}nR\Delta T$

$PV^\gamma =$ constant $\qquad \gamma = \frac{C_P}{C_V}$

$P = kA|\dfrac{dT}{dx}| \qquad P = \sigma A e T^4$

$dW = -PdV$

$\Delta E_{int} = Q + W$

$C_V = \frac{1}{2}fR \qquad C_P - C_V = R$

for monatomic gas $f = 3$

for diatomic gas:

$0 < T < 100$ K $f = 3$
$100 < T < 1000$ K $f = 5$
$T > 1000$ K $f = 7$

Gravitation

Gravitation $|F| = \dfrac{Gm_1m_2}{r^2}$

$U = -\dfrac{Gm_1m_2}{r}$

Keppler's 2^{nd} Law $\dfrac{dA}{dt} = \dfrac{L}{2M_P}$

Keppler's 3^{rd} Law $T^2 = (\dfrac{4\pi^2}{GM_S})a^3$

Trigonometric identities

$\sin A \pm \sin B = 2\sin(\frac{A\pm B}{2})\cos(\frac{A\mp B}{2})$

$\cos A + \cos B = 2\cos(\frac{A+B}{2})\cos(\frac{A-B}{2})$

$\cos A - \cos B = -2\sin(\frac{A+B}{2})\sin(\frac{A-B}{2})$

$\sin^2\theta + \cos^2\theta = 1$

$a^2 = b^2 + c^2 - 2bc\cos A$

$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B$

$\cos(A \pm B) = \cos A\cos B \mp \sin A\sin B$

Waves and Oscillations

$v = \sqrt{\dfrac{T}{\mu}}$ $\quad v = \sqrt{\dfrac{B}{\rho}}$

$v = f\lambda$ $\quad \omega = 2\pi f$

$k = \dfrac{2\pi}{\lambda}$ $\quad T = \dfrac{1}{f}$

$F = -kx$ $\quad \Delta P_{max} = v\rho\omega S_{max}$

$T = 2\pi\sqrt{\dfrac{l}{g}}$ $\quad \omega^2 = \dfrac{k}{m}$

$f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$

$\beta = 10\log_{10}(\dfrac{I}{I_0})$ $\quad I_0 = 10^{-12}\mathrm{Wm}^{-2}$

$I = \dfrac{\text{power}}{\text{area}}$ $\quad I = \dfrac{P}{4\pi r^2}$

$I = \frac{1}{2}\rho v\omega^2 S_{max}^2$ $\quad P = \frac{1}{2}\mu v\omega^2 A^2$

$f' = f(\dfrac{c \pm v_o}{c \mp v_s})$ $\quad f_{\text{beat}} = f_1 - f_2$

$y = A\sin(kx - \omega t + \phi)$

$f_n = \dfrac{n}{2L}\sqrt{\dfrac{T}{\mu}}$ $\quad \lambda_n = \frac{\lambda}{n}$

DATA SHEET

1 atmosphere (Standard air pressure)	1.013×10^{5} Pa
Latent heat of vaporisation of water at constant pressure	2.260×10^{6} J kg^{-1}
Latent heat of fusion of ice, L_f	3.335×10^{5} J kg^{-1}
Avogadro's constant, N	6.022×10^{23} particles/mol
Elementary Charge, e	1.602×10^{-19} C
Gas constant, R	8.314 J K^{-1} mol^{-1}
	0.08206 litre-atm K^{-1} (mol)$^{-1}$
Atomic mass unit , u	1.661×10^{-27} kg = 931.5 MeV/c^{2}
Mass of electron, m_e	9.109×10^{-31} kg = 5.486×10^{-4} u
Mass of neutron, m_n	1.675×10^{-27} kg = 1.009 u
Mass of proton, m_p	1.673×10^{-27} kg = 1.007 u
Boltzmann's constant, k_B	1.381×10^{-23} JK^{-1}
Earth's gravitational acceleration, g	9.80 m s^{-2}
Speed of light, c	2.998×10^{8} m s^{-1}
Universal gravitation constant, G	6.673×10^{-11}N m^{2} kg^{-2}
Density of water, ρ	1.000×10^{3} kg m^{-3}
Mass of Earth	5.972×10^{24} kg
Average radius of Earth	6.371×10^{6} m
Mass of Moon	7.348×10^{22} kg
Average Earth-Moon distance	3.844×10^{8} m
Mass of Sun	1.989×10^{30} kg
Radius of Sun	6.958×10^{8} m
Average Earth-Sun distance	1.496×10^{11} m
Volume of 1 mole ideal gas at 101.3 kPa (1 atm) and at 0°C (273 K)	2.241×10^{-2}m^{3}
at 25°C (298 K)	2.447×10^{-2}m^{3}
Specific Heat of Water	4186 J/kg °C
Mechanical equivalent of heat, 1 cal	4.186 J
Stefan's Constant, σ	5.670×10^{-8} Js^{-1}m^{-2}K^{-4}
Wien's Constant, B	2.898×10^{-3} m.K.
1 eV	1.602×10^{-19} J
Reference Intensity, I_o, (near the threshold of hearing),	1.000 x 10^{-12} W m^{-2}
Plancks constant, h	6.626×10^{-34} Js
1 amu ≡ 1 u	1.661×10^{-27} kg
Permittivity of free space ε_0	8.854×10^{-12} C^{2}/Nm^{2}
Permeability of free space, μ_0	$4\pi\times10^{-7}$ Tm/A

Coulomb's constant, $k_e = \frac{1}{4\pi\varepsilon_0} = 8.988\times10^{9}\ \text{Nm}^2/C^2$

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 0

Practice and Revision

THE PHYSICS HOMEWORK PROGRAM

The Homework Program is an essential part of your course. **Homework problems are your main source of regular feedback on your progress.** Doing homework problems at home is like training for the exam. Do the work effectively and carefully and it will greatly aid your learning program. These problems are provided for you to complete in your own time to reinforce the concepts you are covering in lectures.

It is important that you keep up to date on the homework problems. Being able to do these problems will assist you with the online quizzes. (Homework Set 0 covers work with which you should be familiar from previous studies: we assume that you have a working knowledge of these topics. It also has general suggestions for problem solving.) It is permitted to discuss homework problems with another student outside of class: this will help your understanding.

You can find solutions to these problems on Moodle in written and video format. You should always attempt the problems for yourself before looking at the solutions. You will learn more from having made mistakes than from watching someone explain to you how to solve a problem that you have not attempted.

WHAT SHOULD YOU DO IF YOU CAN'T ANSWER MOST OF THE QUESTIONS/PROBLEMS?

(1) Have you read and understood the material in the text, lecture notes, links from course web site or other sources?

(2) Have you looked at the Additional Learning Materials (see below)?

(3) Have you visited the Teaching Assistants (TAs)-on-duty (Room 5, Ground Floor, Old Main Building, available at 12-2 PM on Monday, Wednesday and Friday)?

(4) Have you talked to other students about the problems?

Don't worry if you are unsure of *some* of the questions/problems: that is what the TAs are for. However if you can't answer *most* of them, you should try (1), (2), (3), or (4) above.

Additional Learning Material

Additional material is available from the course Moodle pages. This includes lecture notes, homework solutions, and video clips and other multimedia material that may have been shown in lectures. You can also enrol in the coursera course Mechanics: Motion, Forces, Energy and Gravity from Particles to Planets. It can be found here: https://www.coursera.org/learn/mechanics-particles-planets .

PROBLEM SOLVING

Applying your knowledge to solve problems of varying degrees of difficulty is an important guide to your understanding of the topic. Physics is based on understanding, not on rote learning of laws or formulas. Being able to solve difficult problems is one of the main reasons for studying physics.

Solution of problems is a multi-step process and is usually approached in a systematic manner. The following is a useful guide.

1. Read and visualise the problem. Draw sketches or graphs to represent the problem. Identify known and unknown quantities.

2. Try to identify the physical principles or concepts that are important in the problem. Using these find relationships between the known quantities and those which must be calculated.

3. Where possible, write these relationships, laws and principles in the form of equations. Sometimes there will be several equations with several unknowns. Check that you have (at least) as many equations as unknowns. (Remember that a vector equation can yield two or three scalar equations.) Solve the equations. Where numerical values are required, express answers with an appropriate number of significant figures.

4. Check your solution. Are the dimensions consistent? Are the magnitudes reasonable? In the algebraic answer, can you think of special cases to check?

It is a good general principle to keep your solution in algebraic form for as long as possible, before substitution and evaluation. Often variables may cancel, saving work. It is easier to check special cases and that dimensions are correct.

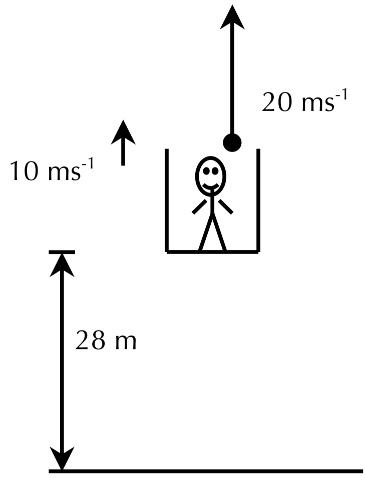
Problem Solving - An Example

A lift without a ceiling is ascending with a constant speed of 10 ms^{-1}. A boy on the lift throws a ball directly upwards, from a height of 2.0 m above the lift floor, just as the lift floor is 28 m above the ground. The initial speed of the ball with respect to the lift is 20 ms^{-1}.

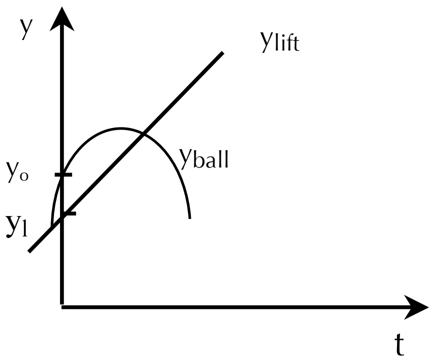
(a) What is the maximum height attained by the ball (relative to the ground)?

(b) How long does it take for the ball to return to the lift?

Step 1 Draw a sketch



Step 2 Physical principles: vertical motion under gravity. The lift and ball move independently. Let us sketch position-time graphs for both the lift and the ball.



lift: $y_{lift} = y_l + v_l t$ (linear) (i)

ball: $y_{ball} = y_o + v_o t + \frac{1}{2}at^2$ (quadratic) (ii)

The point of intersection represents the time when the ball and lift floor are at the same height, i.e. when the ball hits the floor.

Step 3 Identify values:

y_o = 30 m, v_o = initial velocity of ball relative to ground = (20 + 10)ms^{-1}, a = -g = -9.8 ms^{-2}

Step 4

Hence there are two methods. We show only one.

(a) to find maximum in a function, use derivative

$$v_{ball} = \frac{d}{dt} y_{ball} = v_o - gt = 0 \quad \therefore t = \frac{v_o}{g}$$

Substitute in (ii)

$$y_{ball} = y_o + v_o\left(\frac{v_o}{g}\right) - \frac{1}{2}g\left(\frac{v_o}{g}\right)^2$$

$$= y_o + \left(\frac{v_o^2}{g}\right) - \frac{1}{2}\left(\frac{v_o^2}{g}\right) = 76 \text{ m}$$

(b) to find the time at which it collides with the floor (i.e. has the same height as the floor) set

$y_{ball} = y_{lift}$

$$y_o + v_o t - \frac{1}{2}gt^2 = y_l + v_l t$$

$$\frac{1}{2}gt^2 - (v_o - v_l)t - (y_o - y_l) = 0$$

$4.9\ t^2 - 20t - 2.0 = 0$ (t in seconds)

Solve: $t = -0.10$ s, $+4.2$ s

The physical solution is $t = 4.2$ s.

What is the meaning of the other solution? See figure!

TOPIC: MOTION IN 1 DIMENSION (REVISION) ***TEXT REFERENCE: chapter 2***
See also www.physclips.unsw.edu.au

LEARNING GOALS

- Displacement, velocity and acceleration
- Graphical and calculus methods
- Motion with constant acceleration
- Vertical motion under gravity

DISCUSSION TOPICS

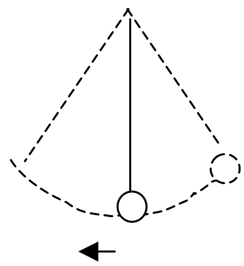
1. Discuss the sample problem above.

2. Revise the use of calculus in 1-dimensional motion.

3. Can a particle have
   (i) zero velocity and non-zero acceleration?
   (ii) positive velocity and negative acceleration?
   Give examples.

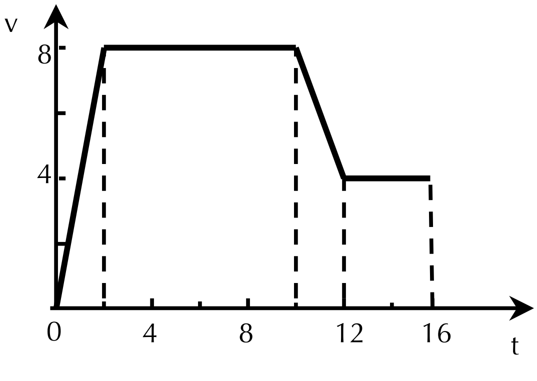
4. The bob of a simple pendulum is passing through its lowest point.

   What is the direction of the acceleration? Discuss.



PROBLEMS

1.



time (s)

This is a velocity-time graph for a runner running along a straight track.

(a) What is the acceleration of the runner at times t = 1, 5, 11, 14 sec.?
(b) What is the total distance travelled in 16 s?
(c) What is the average velocity during the first 10 s?

[Ans: (a) 4, 0, –2, 0 ms^{-2}; (b) 100 m; (c) 7.2 ms^{-1}]

2. A train started from rest and moved with constant acceleration. At one time it was travelling at 30 ms^{-1} and 160 m farther on it was travelling at 50 ms^{-1}. Calculate:
   (a) the acceleration;
   (b) the time required to travel the 160 m mentioned;
   (c) the time required to attain the speed of 30 ms^{-1} starting from rest;
   (d) the distance moved from rest to the time the train had a speed of 30 ms^{-1}.
   [Ans: (a) 5.0 ms^{-2}; (b) 4.0 s; (c) 6.0 s; (d) 90 m]

3. At the instant the traffic light turns green, an automobile starts with a constant acceleration of 2.2 ms^{-2}. At the same instant a truck, travelling with a constant speed of 9.5 ms^{-1}, overtakes and passes the automobile.
   (a) How far beyond the starting point will the automobile overtake the truck?
   (b) How fast will the car be travelling at the instant? (It is instructive to plot a qualitative graph of x versus t for each vehicle).

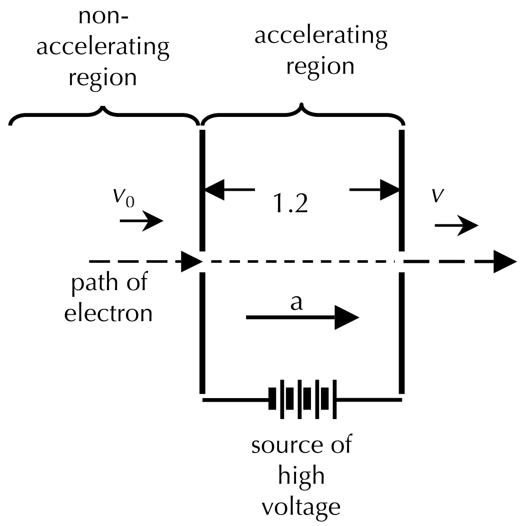
   [Ans: (a) 82 m; (b) 19 ms^{-1}]

4. A particle moves along the x axis according to the equation $x = 50t + 10t^2$, where x is in metres and t is in seconds. Calculate:
   (a) the average velocity and the average acceleration between t = 1 and t = 2s; and
   (b) the instantaneous velocities and the instantaneous accelerations at t = 1 and t = 2s.
   (c) Compare the average and instantaneous quantities and in each case explain whey the larger one is larger.

   [Ans: (a) 80 ms^{-1}, 20 ms^{-2}; (b) 70 ms^{-1} 90 ms^{-1}; 20 ms^{-2}]

5. An electron with initial velocity $v_{xo} = 1.0 \times 10^4$ ms^{-1} enters a region of width 1.0 cm where it is electrically accelerated. It emerges with a velocity $v_x = 4.0 \times 10^6$ ms^{-1}. What was its acceleration, assumed constant?
   (Such a process occurs in the electron gun in a cathode-ray tube, used in television receivers and oscilloscopes.)

   [Ans: 8.0×10^{14} ms^{-2} in the x direction]



6. A rocket is fired vertically and ascends with a constant vertical acceleration of 20 ms^{-2} for 60s. Its fuel is then all used and it continues as a free particle.
   (a) What is the maximum altitude reached?
   (b) What is the total time elapsed from take-off until the rocket strikes the earth?

   [Ans: (a) 110 km; (b) 330 s]

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 1

PARTICLE MOTION IN ONE DIMENSION

1. Two bodies begin a free fall from rest from the same height. If one starts 1.0 s after the other, how long after the first body begins to fall will the two bodies by 10 m apart?
[Ans: 1.5 s]

2. A lift ascends with an upward acceleration of 1.5 ms^{-2}. At the instant its upward speed is 2.0 ms^{-1}, a loose bolt drops from the ceiling of the lift 3.0 m from the floor. Calculate:
(a) the time of flight of the bolt from ceiling to floor, and
(b) the distance it has fallen relative to the lift shaft.
[Ans: (a) 0.73 s; (b) 1.1 m]

3 . The position of a particle moving along the x-axis depends on time according to the relation:

$$x = \frac{v_o}{k}\left(1 - e^{-kt}\right)$$

in which v_o and k are constants.
(a) Plot a curve of x versus t. Notice that x = 0 at t = 0 and that $x = v_o/k$ at $t = \infty$; that is, the total distance through which the particle moves is v_o/k.
(b) Show that the velocity v, is given by: $v_x = v_o\, e^{-kt}$, so that the velocity decreases exponentially with time from its initial value of v_o coming to rest only in infinite time.
(c) Show that the acceleration a, is given by: $a = -kv$, so that the acceleration is directed opposite to the velocity and has a magnitude proportional to the speed.
(d) This particular motion is one with variable acceleration. Give a plausible physical argument explaining how it can take an infinite time to bring to rest a particle that travels a finite distance.

PAST EXAM QUESTION

A scientist is standing at ground level, next to a very deep well (a well is a vertical hole in the ground, with water at the bottom). She drops a stone and measures the time between releasing the stone and hearing the sound it makes when it reaches the bottom.

i) Draw a clear displacement-time graph for the position of the falling stone (you may neglect air resistance). On the diagram, indicate the depth h of the well and the time T_1 taken for the stone to fall to the bottom.

ii) Showing your working, relate the depth h to T_1 and to other relevant constants.

iii) The well is in fact 78 m deep. Take $g = 9.8\ ms^{-2}$ and calculate T_1.

iv) On the same displacement-time graph, show the displacement of the sound wave pulse that travels from the bottom to the top of the well. Your graph need not be to scale.

v) Taking the speed of sound to be 344 ms^{-1}, calculate T_2, the time taken for the sound to travel from the bottom of the well to reach the scientist at the top. Show T_2 on your graph.

vi) State the time T between release of the stone and arrival of the sound. Think carefully about the number of significant figures.

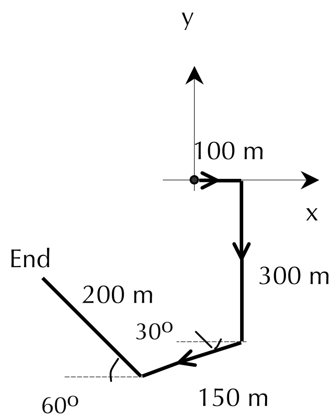
The scientist, as it happens, doesn't have a stop watch and can only estimate the time to the nearest second. Further, because of this imprecision and because she is solving the problem in her head, she neglects the time taken for the sound signal to reach her. For the same reason, she uses $g \cong 10\ \mathrm{ms}^{-2}$.

vii) What value does the scientist get for the depth of the well?

viii) Comment on the relative size of the errors involved in (a) neglecting the time of travel of sound, (b) approximating the value of g and (c) measurement error.

VECTORS AND RELATIVE MOTION

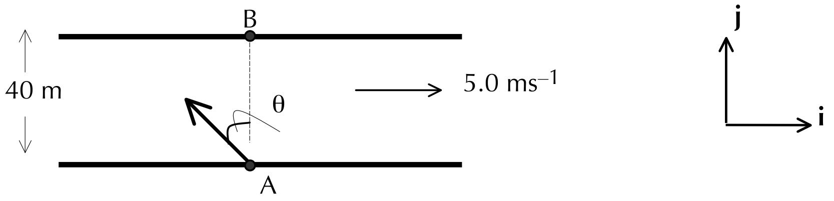
4. A person going for a walk follows the path shown in the diagram. Taking the starting point as the origin and using **i**, **j**, **k** notation
   (a) write a vector displacement for each straight line segment of the walk.
   (b) determine the person's resultant vector displacement at the end of the walk.
   (c) determine the distance and direction of the end point from the start point.
   [Ans: (b) – 130 **i** – 202 **j**; (c) 240 m, 237°]



5. If $\mathbf{a} = 5.0\,\mathbf{i} + 4.0\,\mathbf{j} - 6.0\,\mathbf{k}$
   $\mathbf{b} = -2.0\,\mathbf{i} + 2.0\,\mathbf{j} + 3.0\,\mathbf{k}$
   $\mathbf{c} = 4.0\,\mathbf{i} + 3.0\,\mathbf{j} + 2.0\,\mathbf{k}$
   Determine:
   (a) the components and magnitude of $\mathbf{r} = \mathbf{a} - \mathbf{b} + \mathbf{c}$
   (b) the angle between r and the positive z axis
   [Ans: (a) $\mathbf{r} = 11.0\,\mathbf{i} + 5.0\,\mathbf{j} - 7.0\,\mathbf{k}$, 14.0 (b) 120°]

6. A person, travelling eastward at the rate of 4.0 km hr^{-1}, observes that the wind seems to blow directly from the north; on doubling his speed the wind appears to come from the northeast; determine the direction of the wind and its velocity.
   [Ans: Wind comes from NW, 5.7 km hr^{-1}]

7.



A rower wishes to cross a rapidly flowing river of width 40 m, which is flowing uniformly at a rate of 5.0 ms^{-1}. The rower starts at point A and heads in a direction θ, as shown, rowing at a speed of 2.0 ms^{-1} relative to the water.

(a) Write down an expression for the velocity of the rower relative to the river bank, in terms of unit vectors **i** and **j**.
(b) Write down the displacement of the rower at time t.
(c) If the rower wishes to cross the river in minimum time, in what direction should she head? What is the crossing time and how far from point B will she land?
(d) If the rower wishes to land as close to B as possible, in what direction should she head? What will be the crossing time and distance of landing point from B in this case?

[Ans: (a) $[(5 - 2\sin\theta)\mathbf{i} + 2\cos\theta\,\mathbf{j}]$ ms^{-1}; (b) $t[(5 - 2\sin\theta)\mathbf{i} + 2\cos\theta\,\mathbf{j}]$ ms^{-1};
(c) 20 s, 100 m; (d) 22 s, 92 m

MOTION IN TWO AND THREE DIMENSIONS

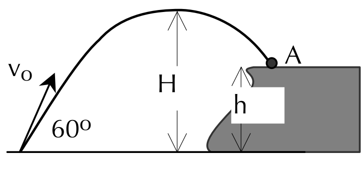
8. At time t_o the velocity of an object is given by $\mathbf{v}_o = 125\mathbf{i} + 25\mathbf{j}$ ms^{-1}. At 3.0s later the velocity is
$v = 100\mathbf{i} - 75\mathbf{j}$ ms^{-1}. What was the average acceleration of the object during this time interval?

[Ans: $-8.3\mathbf{i} - 33\mathbf{j}$ ms^{-2}]

9. A particle moves so that its position as a function of time in SI units is: $\mathbf{r}(t) = \mathbf{i} + 4t^2\mathbf{j} + t\mathbf{k}$.
(a) Write expressions for its velocity and acceleration as functions of time.
(b) What is the shape of the particle's trajectory?

[Ans: (a) $\mathbf{v} = 8t\,\mathbf{j} + \mathbf{k}$, $\mathbf{a} = 8\mathbf{j}$; (b) parabola]

10. A stone is projected at a cliff of height h with an initial speed of 42.0 ms^{-1} at an angle of 60^o above the horizontal, as shown. The stone lands at A after 5.50 sec. Find



(a) the height of the cliff, h
(b) the speed of the stone just before impact
(c) the maximum height H reached above the ground.

[Ans: 52 m, 27 ms^{-1}, 68 m]

11. A ball rolls horizontally off the top of a stairway with a speed of 1.5 ms^{-1}. The steps are 20 cm high and
25 cm wide. Which step will the ball land on first?

[Ans: 2nd]

12. In a cathode-ray tube a beam of electrons is projected horizontally with a speed of $1.0 \times 10^{7} \text{ms}^{-1}$ into the region between a pair of horizontal plates 2.0×10^{-2} m long. An electric field between the plates exerts a constant downward acceleration on the electrons of magnitude
$1.0 \times 10^{15} \text{ ms}^{-2}$. Find:
(a) the vertical displacement of the beam in passing through the plates, and
(b) the velocity of the beam (direction and magnitude) as it emerges from the plates.

[Ans: (a) 2.0 mm; (b) $1.0 \times 10^{7} \text{ ms}^{-1}$, 11 ° below horizontal]

13. (a) At what speed must an automobile round a turn having a radius of curvature of 40 m in order that its radial acceleration be equal to g?
(b) Suppose that the automobile is travelling at this speed along a straight roadway but over a hill having a radius of curvature of 40 m. What is the behaviour of unattached objects within the car?

[Ans: (a) 20 ms^{-1}]

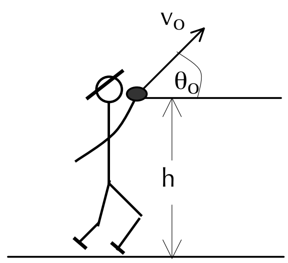
14. (a) Write an expression for the position vector **r** for a particle describing uniform circular motion, using polar coordinates and also the unit vectors **i** and **j**.
(b) From (a) derive vector expressions for the velocity **v** and the acceleration **a**.
(c) Prove that the acceleration is directed toward the centre of the circular path.

[Ans: (a) $\mathbf{r} = r(\cos\theta\, \mathbf{i} + \sin\theta\, \mathbf{j})$; (b) $\mathbf{v} = r\omega(-\sin\theta\, \mathbf{i} + \cos\theta\, \mathbf{j})$; $\mathbf{a} = -r\omega^{2}(\cos\theta\, \mathbf{i} + \sin\theta\, \mathbf{j})$ with $\theta = \omega t$]

15. A particle moves in a plane according to: $x = R \sin \omega t + \omega R t$, $y = R \cos \omega t + R$ where ω and R are constants. This curve, called a cycloid, is the path traced out by a point on the rim of a wheel which rolls without slipping along the x-axis.
(a) Sketch the path.
(b) Calculate the instantaneous velocity and acceleration when the particle is at its maximum and minimum value of y.

[Ans: (b) At max. $v_x = 2\omega R$, $v_y = 0$, $a_x = 0$, $a_y = -\omega^{2}R$. At min. $v_x = 0$, $y_y = 0$, $a_x = 0$, $a_y = +\omega^{2}R$]

16. In the athletic contest of shot-putt a brass sphere of mass m is propelled starting at a height h, above the ground, with initial speed v_o at an angle θ.



(a) Write down equations giving the horizontal and vertical coordinates of the shot at time t.
(b) By eliminating t show that the horizontal range R satisfies the equation

$$0 = h + R \tan\theta - \frac{g}{2v_o^2} R^2 \sec^2\theta$$

(c) By differentiating this equation with respect to θ and setting $\frac{dR}{d\theta} = 0$, show that the maximum range R_m and corresponding angle θ_m are related by

$$R_m = \frac{v_o^2}{g \tan\theta_m}$$

(d) By substituting for R in (b) show that the angle θ_m is given by

$$\sin^2 \theta_m = \frac{1}{2}\frac{1}{1+gh/v_o^2}$$

(e) A champion shot-putter is able to impart an initial speed of about 14.0 ms^{-1} to the shot. Calculate the optimum angle and the distance of the throw (take h = 2.1 m). [Ans: 42.3^o, 22.0 m]

(f) Explain, without any mathematics, why the angle for maximum range will be slightly less than 45^o (A diagram is useful!).

PAST EXAM QUESTION

A bird flies at speed v_b = 5.0 $m.s^{-1}$ in a straight horizontal line that will pass directly above you, at a height h = 5.0 m above your head. You are eating grapes and it occurs to you that the bird might want one and so you decide to throw it a grape. Of course, you don't want to hurt the bird, so you will throw the grape so that, at some time t, it has the same position, same height and same velocity as the bird. (Hint: what will be the height and velocity of the grape when the bird takes it?)

You throw the grape from a position very close to your head, with initial speed v_0 and at an angle θ to the horizontal. Air resistance is assumed to be negligible.

i) Should the bird be behind you, or ahead of you when you throw the grape, and by how much? Explain your answer briefly. (3-5 clear sentences should suffice.)

ii) Calculate the required values of v_o and θ.

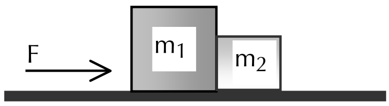
iii) If air resistance on the grape were *not* negligible, how would that change your answer to (i)? A qualitative but explicit answer is required.

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 2

FORCES AND PARTICLE DYNAMICS

1. Two blocks are in contact on a frictionless table. A horizontal force is applied to one block, as shown.



   (a) If m_1 = 2.0 kg, m_2 = 1.0 kg and F = 3.0 N, find the force of contact between the two blocks.

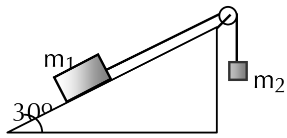
   (b) Show that if the same force F is applied to m_2 rather than to m_1 the force of contact between the blocks is 2.0N, which is not the same value derived in (a). Explain.

   [Ans: (a) 1.0 N]

2. A man of mass 100 kg stands in a lift. What force does the floor exert on him when a lift is:
   (a) stationary,
   (b) moving up with constant velocity,
   (c) accelerating upwards at 2.0 ms^{-2},
   (d) moving up but decelerating at 3.0 ms^{-2},
   (e) moving down with acceleration of 4.0 ms^{-2},
   (f) moving down with deceleration of 5.0 ms^{-2}.

   [Ans: (a) $9.8x10^2$N up; (b) $9.8x10^2$N up; (c) $1.2x10^3$N up; (d) $6.8x10^2$N up; (e) $5.8x10^2$N up; (f) $1.5x10^3$N up]

3. A block of mass m_1 = 3.0 kg on a smooth inclined plane of angle 30˚ is connected by a massless cord over a small frictionless pulley to a second block of mass m_2 = 2.0 kg hanging vertically.



   (a) What is the acceleration of each body?

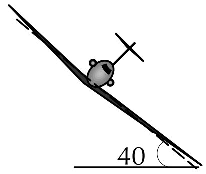
   (b) What is the tension in the cord?

   [Ans: (a) 0.98 ms^{-2}; (b) 18 N]

4. A plumb bob hanging from the ceiling of a railway carriage acts as an accelerometer.
   (a) Derive the general expression relating the steady horizontal acceleration a of the carriage to the angle θ made by the bob with the vertical.
   (b) Find a when θ = 20˚. Find θ when a = 2.0 ms^{-2}.

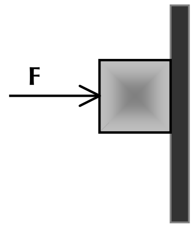
   [Ans: (a) a = g tan θ; (b) 3.6 ms^{-2}, 12˚]

5. An airplane is flying in a horizontal circle at a speed of 480 km/h. If the wings of the plane are tilted 40º to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface.



   [Ans: (a) 2.16 km]

6. A horizontal force F of 60 N pushes a block of mass 3.0 kg against a vertical wall. The coefficient of static friction between the wall and the block is 0.60 and the coefficient of kinetic friction is 0.40. Assume the block is not moving initially.

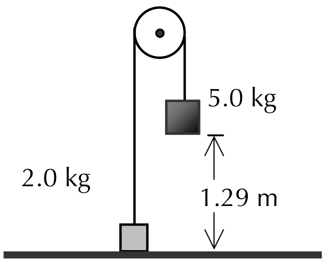


(a) Will the block start moving?

(b) What is the force exerted on the block by the wall?

[Ans: (a) No; (b) 67 N, directed 64^{o} away from the vertical wall]

7. Masses of 2.0 kg and 5.0 kg are connected over a pulley as shown. The 2.0 kg mass rests on the floor and the 5.0 kg mass is at a height of 1.29 m. The pulley and string are assumed massless. The system is released at time t = 0.0 s.



(a) Calculate the acceleration of each mass and the tension in the string.
(b) Calculate the position and velocity of each mass at t = 0.30 s.

At t = 0.3 s the string breaks. Calculate:
(c) The acceleration of each mass.
(d) The time taken for each mass to reach the floor, after the string breaks.

[Ans: (a) 4.2 ms^{-2}, 28 N; (b) 0.19 m, 1.3 ms^{-1}, 1.10 m. –1.3 ms^{-1}; (c) –9.8 ms^{-2}; (d) 0.36 s]

8. (a) A particle of mass m is travelling along the x-axis such that at t = 0 it is located at x = 0 and has speed v_o. The particle is acted upon by a force which opposes the motion and has magnitude proportional to the square of the instantaneous speed. (Take constant of proportionality as $\beta > 0$). Find:
(i) the speed;
(ii) the position; and
(iii) the acceleration of the particle at any time t > 0.

(b) Determine:
(i) the speed; and
(ii) the acceleration of the particle as a function of the distance x from 0.

[Ans: (a) (i) $v = \dfrac{mv_o}{\beta v_o t + m}$, (ii) $x = \dfrac{m}{\beta}\,\ell n\left(1+\dfrac{\beta v_o t}{m}\right)$, (iii) $a = -\dfrac{\beta m v_o^2}{(m+\beta v_o t)^2}$

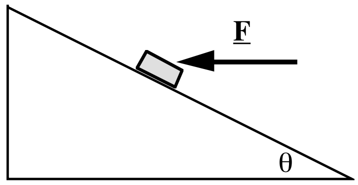
(b) (i) $v = v_o e^{-\beta x/m}$ (ii) $a = -\dfrac{\beta v_o^2}{m} e^{-2\beta x/m}$]

PAST EXAM QUESTION

(a) (i) A car is travelling at initial speed v. The coefficients of kinetic and static friction between tires and the (horizontal) road are μ_k and μ_s, with $\mu_s > \mu_k$. Determine the braking distance s_b, the shortest distance in which the car can stop using the brakes. Each time you use one of Newton's laws of motion, mention it.

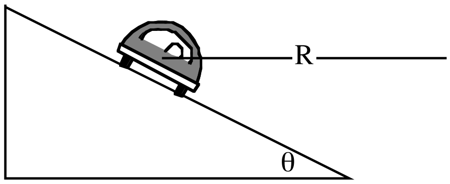
(ii) Take $\mu_s = 0.85$ and $\mu_k = 0.78$. Calculate the braking distances for the two cases v = 50 kilometers per hour and 80 kilometers per hour.

(b)



(i) A mass m is on a plane inclined at an angle θ to the horizontal. A **horizontal** force **F** is pushing it up the slope at a steady speed v. The coefficient of kinetic friction between the mass and the plane is μ_k. Derive an expression for the magnitude of **F**.

(ii) Derive an expression for the power applied by **F** in case (i). (i.e., for the rate at which **F** is doing work.)



(iii) In the lower sketch, a roadway is banked at angle θ for a curve of radius R. Derive an expression for the angle θ at which the road must be banked if a car goes round the bend at uniform speed v and exerts no frictional force either up or down the plane (i.e. no frictional forces in the plane of the diagram).

(iv) State the direction of the force that the car exerts on the driver in case (iii). Explain your answer in one or two clear sentences.

IMPORTANT: Would you like some feedback on your progress so far? How would you go in a real test?
Download the trial test from the course web page and find out. The link is:
http://www.phys.unsw.edu.au/~jw/1131/prelimtest.pdf

WORK, ENERGY, CONSERVATION OF ENERGY

9. A block of mass m = 3.57 kg is dragged at constant speed a distance d = 4.06 m across a horizontal floor by a rope exerting a constant force of magnitude F = 7.68 N making an angle $\theta = 15^{o}$ with the horizontal. Compute:

   (a) the total work done on the block

   (b) the work done by the rope on the block

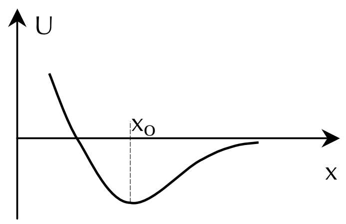
   (c) the work done by the friction on the block, and

   (d) the coefficient of kinetic friction between the block and the floor.

   [Ans: (a) zero; (b) 30 J; (c) –30 J; (d) 0.23]

10. The potential energy of a diatomic molecule is

$$U(x) = \frac{A}{x^{12}} - \frac{B}{x^6}$$



   where A, B are positive constants.

   (a) Calculate the force F(x) between the atoms and sketch this as a function of x, using the same x axis as the plot of U(x) shown.

   (b) Find the equilibrium separation between the atoms.

   [Ans: (a) $F = \frac{12A}{x^{13}} - \frac{6B}{x^7}$; (b) $\left(2A/B\right)^{1/6}$]

11. A certain peculiar spring is found NOT to conform to Hooke's law. The force (in Newtons) it exerts when stretched a distance x (in metres) is found to have magnitude $52.8x + 38.4\,x^3$ in the direction opposing the stretch.

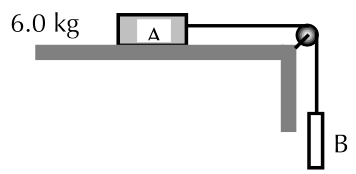
   (a) Compute the total work required to stretch the spring from x = 0.500 to x = 1.00 m.

   (b) With one end of the spring fixed, a particle of mass 2.17 kg is attached to the other end of the spring when it is extended by an amount x = 1.00 m. If the particle is then released from rest, compute its speed at the instant the spring has returned to the configuration in which the extension is x = 0.500 m.

   (c) Is the force exerted by the spring conservative or non conservative? Explain.

   [Ans: (a) 28.8 J; (b) 5.15 ms^{-1} towards origin]

12. In the system shown, block A (of mass 6.0 kg) rests on a horizontal surface where the coefficient of kinetic friction between the block and the surface is 0.30. Block A is attached by a light string passing over a light frictionless pulley to block B (of mass 4.0 kg) which hangs freely.



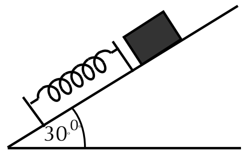
   (a) By applying Newton's second law (or otherwise), calculate the acceleration of the system and the tension force in the string.

   (b) Calculate the kinetic energy of the system after each block has moved a distance of 1.5 m from rest.

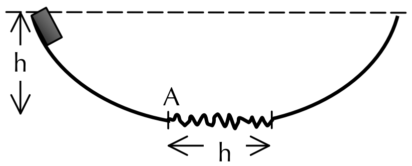
   (c) How much heat energy is developed by the friction between block A and the surface as the system moves a distance of 1.5 m from rest?

   [Ans: (a) 2.2 ms^{-2}; 31 N; (b) 32 J; (c) 26 J]

13. A 2.0 kg block is placed against a compressed spring on a frictionless incline. The spring, whose force constant is 1960 Nm^{-1}, is compressed 20 cm, after which the block is released. What distance along the incline will travel before coming to rest? Assume that the spring has negligible mass and that the spring and block are not attached to each other. [Ans: 4.0 m]



14.



A block of mass m is released from one end of a track with the shape shown. The curved parts are frictionless and the horizontal part has coefficient of kinetic friction $\mu_k = 0.15$

(a) How high will the block rise for the first time on the right hand end of the track?

(b) How many times will the block pass point A (in either direction)?

[Ans: (a) 0.85 h; (b) 7]

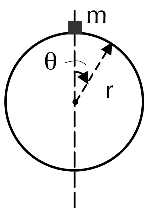
15. A small mass m starts from rest and slides down the surface of a frictionless solid sphere of radius r as shown in the diagram. Measure angles from the vertical and potential energy from the top. Find:

(a) the change in potential energy of the mass with angle;

(b) the kinetic energy as a function of angle;

(c) the radial and tangential accelerations as a function of angle;

(d) the angle at which the mass flies off the sphere.



[Ans: (a) $-mgr(1 - \cos\theta)$; (b) $mgr(1 - \cos\theta)$, (c) $2g(1 - \cos\theta)$; $g \sin\theta$; (d) $\cos^{-1} 2/3$]

16. A uniform rope of total mass m and length ℓ is **slowly** pulled onto a smooth table as shown.

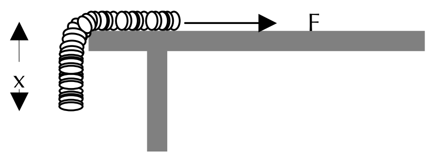
(a) Calculate the magnitude of the applied force when a length x of chain remains hanging.

(b) Sketch F as a function of x

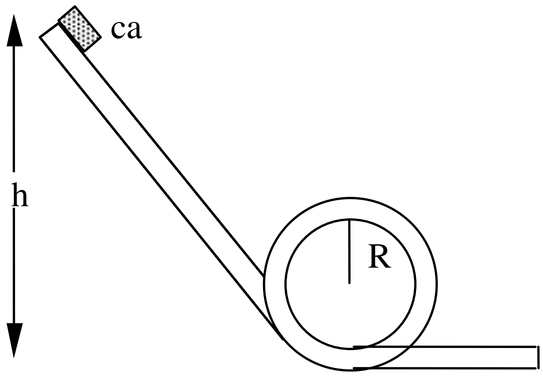
(c) Calculate the total work needed to pull all of the rope onto the table.

(d) Calculate the change in potential energy of the rope, if initially, it is all hanging.

[Ans: (a) mgx/ℓ; (c) $1/2\ mg\ell$; (d) $1/2\ mg\ell$]



PAST EXAM QUESTION



A toy racing car is placed on a track, which has the shape shown in the diagram. It includes a loop, which is approximately circular with radius R. The wheels of the car have negligible mass, and turn without friction on their axle. You may also neglect air resistance. The dimensions of the car are much smaller than R.

i) Showing all working, determine the minimum height h from which the car may be released so that it maintains contact with the track throughout the trip.

ii) Does your answer depend on the mass of the car? Comment briefly.

iii) If a solid ball were released from the height you calculate in (i), would it maintain contact with the throughout the trip? Explain briefly.

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 3

GRAVITATION

DATA: The following constants are needed in some of the calculations.

Universal Gravitation Constant	$G = 6.673 \times 10^{-11}$ Nm^2 kg^{-2}
Mass of Earth	$M_e = 5.98 \times 10^{24}$ kg
Radius of Earth	$R_e = 6.38 \times 10^6$ m

1. How does g, the acceleration due to gravity, vary with height above the Earth? (Neglect the Earth's rotation)
   (a) Assuming a uniform Earth calculate the value of g:
      (i) at a height of 10,000 m above the Earth
      (ii) at a height of 200 km (in the top of the ionosphere)
   (b) How high above the Earth (in Earth radii) must one be if g is 50% of the value at the Earth's surface.

   [Ans: (a) 0.997 g_o (where g_o is value on surface of Earth); 0.94 g_o; (b) 0.41 R_e]

2. Certain neutron stars (extremely dense stars) are believed to be rotating at about one revolution per second. If such a star has a radius of 20 km, what must be its minimum mass so that objects on its surface will be attracted to the star and not 'thrown off' by the rapid rotation? What is its density? Comment on your answer.

   [Ans: (a) 4.7×10^{24} kg]; (b) 1.4×10^{11} kg/m^3]

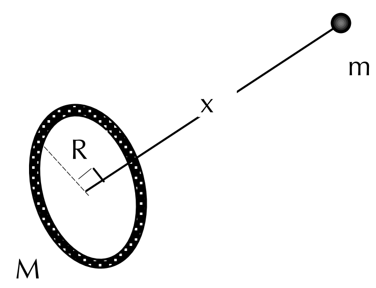
3. It is desired to place a satellite into an orbit so that it remains fixed above a given point on the Earth.
   (a) Explain why the orbit must be in the equatorial plane
   (b) Calculate the radius of the orbit
   (c) If the satellite has a mass of 240 kg calculate its potential energy, kinetic energy and total energy.

   [Ans: (b) 4.22×10^7 m; (c) -2.27×10^9, 1.13×10^9, -1.13×10^9 J]

4. Our Sun, with a mass 2.0×10^{30} kg, revolves about the centre of the Milky Way Galaxy, which is 2.2×10^{20} m away, once every 2.5×10^8 years. Assuming that each of the stars in the galaxy has a mass equal to that of our Sun, that the stars are distributed uniformly in a sphere about the galactic center, and that our Sun is essentially at the edge of that sphere, estimate roughly the number of stars in the galaxy.

   [Ans: 5×10^{10}]

5. A body of mass m, lies at a distance x from a thin uniform ring of radius R and total mass M.
   (a) Calculate the net gravitational force on the body.
   (b) Calculate the gravitational potential energy of the body.
   (c) If the body is released from rest calculate its speed as it passes through the center of the ring.



[Ans: (a) $GmMx/\left(R^2+x^2\right)^{3/2}$; (b) $-\,GmM/\left(R^2+x^2\right)^{1/2}$; (c) $\left[2GM\left(\frac{1}{R}-\frac{1}{\sqrt{R^2+x^2}}\right)\right]^{1/2}$]

MOMENTUM AND CENTRE OF MASS

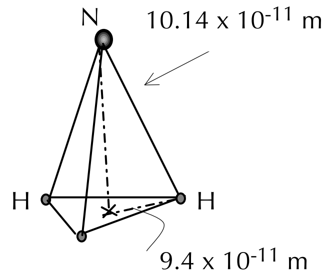
6. Three particles of masses 2, 1, 3 respectively have position vectors: $\mathbf{r}_1 = 5t\mathbf{i} - 2t^2\mathbf{j} + (3t-2)\mathbf{k}$, $\mathbf{r}_2 = (2t-3)\mathbf{i} + (12-5t^2)\mathbf{j} + (4+6t-3t^3)\mathbf{k}$, $r_3 = (2t-1)\mathbf{i} + (t^2+2)\mathbf{j} - t^3\mathbf{k}$ where t is the time and all quantities are in SI units. Find:

   (a) the velocity of the center of mass at time t = 1, and

   (b) the total linear momentum of the system at t = 1.

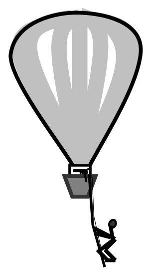
   [Ans: (a) $3\mathbf{i} - 2\mathbf{j} - \mathbf{k}$; (b) $18\mathbf{i} - 12\mathbf{j} - 6\mathbf{k}$]

7. In the ammonia (NH_3) molecule, as shown in the figure, the three hydrogen (H) atoms form an equilateral triangle; the center of the triangle is 9.40×10^{-11} m from each hydrogen atom. The nitrogen (N) atom is at the apex of a pyramid, the three hydrogens forming the base. The nitrogen-to-hydrogen distance is 10.14×10^{-11} m, and the nitrogen-to-hydrogen atomic mass ratio is 13.9. Locate the center of mass relative to the nitrogen atom.



   [Ans: 0.675×10^{-11} m toward the plane of the hydrogens, along the axis of symmetry]

8. A man of mass m clings to a rope ladder suspended below a balloon of mass M. The balloon is stationary with respect to the ground.



   (a) If the man begins to climb the ladder at speed v (with respect to the ladder), in what direction and with what speed (with respect to the Earth) will the balloon move?

   (b) What is the state of the motion after the man stops climbing?

   [Ans: (a) downward with speed mv/(m+M);
   (b) stationary]

CONSERVATION OF MOMENTUM, COLLISIONS

9. A 1.0 kg ball drops vertically onto the floor with a speed of 25 ms^{-1}. It rebounds with an initial speed of 10 ms^{-1}.

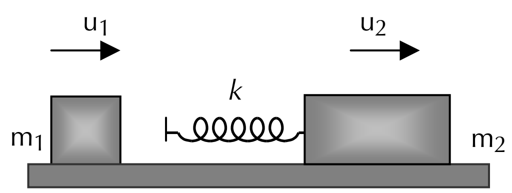
   (a) What impulse acts on the ball during contact?

   (b) If the ball is in contact for 0.020 s, what is the average force exerted on the floor?

   [Ans: (a) 35 N.s; (b) 1800 N]

10. A block of mass m_1 = 1.88 kg slides along a frictionless table with a speed of 10.3 ms^{-1}. Directly in front of it, and moving in the same direction, is a block of mass m_2 = 4.92 kg moving at 3.27 ms^{-1}.

    A massless spring with a force constant k = 11.2 N cm^{-1} is attached to the backside of m_2, as shown in the figure.



    When the blocks collide, what is the maximum compression of the spring? (Hint: At the instant of maximum compression of the spring, the two blocks move as one.)

    [Ans: 24.6 cm]

11. A radioactive nucleus, initially at rest, decays by emitting an electron and neutrino at right angles to one another. The momentum of the electron is 1.2×10^{-22} kg ms^{-1} and that of the neutrino is 6.4×10^{-23} kg ms^{-1}.

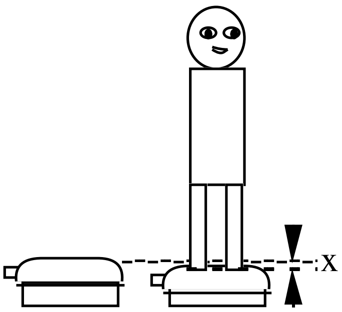
(a) Find the direction and magnitude of the momentum of the recoiling nucleus.

(b) The mass of the residual nucleus is 5.8×10^{-26} kg. What is its kinetic energy of recoil?

[Ans: (a) 1.4×10^{-22} kg ms^{-1}, 150^{o} from the electron track and 120^{o} from the neutrino track. (b) 1.0 eV]

12. Two masses m and M are initially at rest a large distance apart, and are pulled together by their gravitational attraction. Show that when the separation of the bodies is d their relative speed of approach is $\sqrt{2G(M+m)/d}$. (Hint: Are linear momentum and/or energy conserved? Why?).

PAST EXAM QUESTION

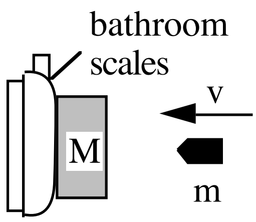


Can a bathroom scale (a device usually used for measuring one's weight) be used to measure the speed of a bullet fired from a gun?

A student decides to find out. When she stands on the scale, it accurately reads her mass (60 kg). She observes that, when she stands on the scale, its lid is lowered by x = 5.0 mm. Assume that the scale behaves like an undamped spring, with spring constant k.

i) Calculate the value of the spring constant k.

(Hint: be careful with units.)



The student then mounts the scale vertically, and fixes a block (M = 10 kg) on its surface. Its mass is considerably greater than that of the scale. In this orientation, and with the block fixed, the scale reads zero. In a preliminary experiment, she discovers that the bullet does not penetrate through the block, and comes to rest inside it.

Her research tells her that a particular model gun fires bullets at a speed of v = 400 m.s^{-1} (called its muzzle velocity) and that the bullets have a mass m = 6.0 g.

ii) Showing all working, and using the values given, calculate the maximum compression of the scale when a bullet is fired into it at normal incidence (as shown in lower diagram). State any assumptions you make and justify any conservation laws that you use.

iii) Calculate the reading on the scale at this point.

(**Important warning:** Under no circumstances should you try to answer this problem experimentally.)

ROTATIONAL KINEMATICS

13. Because of tidal friction, the Earth's period of rotation is increasing at roughly 2.5×10^{-8} s per day.

(a) What is the angular acceleration?

(b) What would the Earth's period be in a billion years (10^9) time, assuming α remains constant.

[Ans: (a) -2.5×10^{-22} rad s^{-2}; (b) 26.5 hrs.]

14. Assume the Earth to be a sphere of uniform density.

(a) What is its rotational kinetic energy? Take the radius of the Earth to be 6.4×10^3 km and the mass of the Earth to be 6.0×10^{24} kg.

(b) Suppose this energy could be harnessed for peoples' use. For how long could the Earth supply 1 kW of power to each of the ~ 10^{10} persons on Earth?

[Ans: (a) 2.6×10^{29} J; (b) ~10^9 years]

15. A 3.0 kg block is put on a plane inclined 30° to the horizontal and is attached by a cord parallel to the plane over a pulley at the top to a hanging block weighing 9.0 kg. The pulley weighs 1.0 kg and and has a radius of 0.10 m. There is sufficient frictional force so that the cord does not slip on the pulley. The coefficient of kinetic friction between block and plane is 0.10. Find the acceleration of the hanging block and the tension in the cord on each side of the pulley. Assume the pulley to be a uniform disk.

[Ans: a = 5.7 ms^{-2}, T_1 = 37 N, T_2 = 34 N]

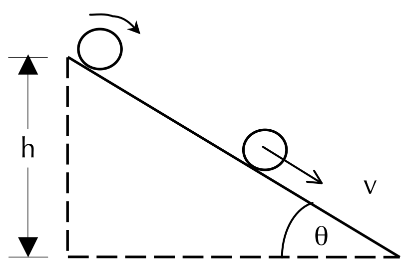
16. A uniform sphere of mass M and radius R rolls without slipping down an incline of height h and angle θ. At some point the linear velocity of the centre of mass is v.

(a) Derive an expression for the total kinetic energy of the sphere in terms of M, v.

(b) What is the angular velocity of the sphere when it reaches the bottom of the incline?

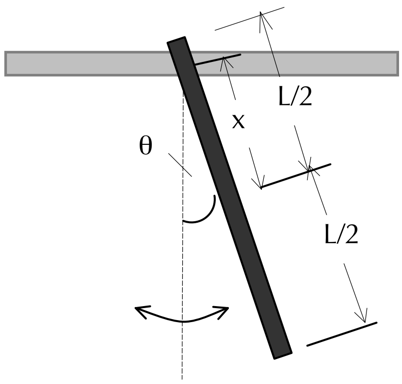
(c) What is the magnitude of the linear acceleration of the centre of mass.

(d) What is the time taken to roll down the incline, if the sphere starts from rest?



[Ans: (a) 7/10 Mv^2 ; (b) $(10gh/7R^2)^{1/2}$; (c) 5/7 g sin θ ; (d) $(14h/5g \sin^2\theta)^{1/2}$]

17.



A uniform stick of mass M and length L oscillates as a physical pendulum, about a pivot as shown.

(a) What is the torque acting on the pendulum when its angular displacement from the vertical is θ.

(b) Show that the rotational inertia is

$$I = Mx^2 + \frac{1}{12}ML^2$$

(c) Assuming θ small derive an expression for the period T of the pendulum in terms of x and L.

(d) Show that T is a minimum for a particular value of x.

(e) If L = 1.00 m find the minimum period and the value of x.

[Ans: (a) Mgx sin θ; (c) $2\pi\sqrt{\dfrac{x^2 + \frac{1}{12}L^2}{gx}}$; (e) 1.53s, 0.29 m]

REVISION

18. A particle of mass 2 kg moves in the X-Y plane so that its position is **r**(t) = 3t**i** + (1+t^2)**j** m

    (a) Sketch the trajectory of the particle.

    (b) Calculate the velocity and acceleration of the particle

    (c) Determine the force acting on the particle

    (d) Calculate the vector torque and angular momentum of the particle about the origin

    (e) Show that you results in (d) satisfy $\tau = \dfrac{d\mathbf{L}}{dt}$

    [Ans: (a) $y = 1 + \dfrac{1}{9}x^2$; (b) 3**i** + 2t **j**, 2 **j**; (c) 4 **j**; (d) 12 t**k**, ($6t^2$ – 6)**k**]

19. An α-particle collides with an oxygen nucleus, initially at rest. The α-particle is scattered at an angle of 64° from its initial direction of motion and the oxygen nucleus recoils at an angle of 51° on the other side of this initial direction. What is the ratio, α-particle to nucleus, of the final speeds of these particles? The mass of the oxygen nucleus is four times that of the α-particle.

    [Ans: 3.47]

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 4

TEMPERATURE

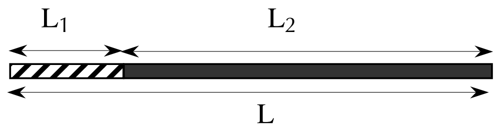
1. The amplification or gain of a transistor amplifier may depend on the temperature. The gain for a certain amplifier at room temperature (20.0˚C) is 30.0, whereas at 55.0˚C it is 35.2. What would the gain be at 28.0˚C if the gain depends linearly on temperature over this limited range?

   [Ans: 31.2]

2. A rod is measured to be 20.05 cm long using a steel ruler at a room temperature of 20˚C. Both the rod and the ruler are placed in an oven at 270˚C, where the rod now measures 20.11 cm using the same ruler. Calculate the coefficient of thermal expansion for the material of which the rod is made. For steel, $\alpha = 1.1\text{x}10^{-5}\ ^{o}C^{-1}$.

   [Ans: $2.3 \text{ x } 10^{-5}\ C^{-1}$]

3. A composite bar of length $L = L_1 + L_2$ is made from a bar of material 1 and length L_1 attached to a bar of material 2 and length L_2, as shown in the figure.



   (a) Show that the effective coefficient of linear expansion α for this bar is given by:

   $\alpha = (\alpha_1 L_1 + \alpha_2 L_2)/L$.

   (b) Using steel and brass, design such a composite bar whose length is 52.4 cm and whose effective coefficient of linear expansion is $13 \text{ x } 10^{-6}/C^{\circ}$. For steel, $\alpha = 1.1\text{x}10^{-5}\ ^{o}C^{-1}$, for brass, $\alpha = 1.9\text{x}10^{-5}\ ^{o}C^{-1}$.

   [Ans: 39.3 cm steel and 13.1 cm brass]

KINETIC THEORY AND THE IDEAL GAS

4. A weather balloon is partially inflated with helium at a pressure of 1.00 atm (= 76.0 cm Hg) and a temperature of 22.0˚C. The gas volume is 3.47 m^3. At an elevation of 6.50 km, the atmospheric pressure is down to 36.0 cm Hg and the helium has expanded, being under no restraint from the confining bag. At this elevation the gas temperature is -48.0˚C. What is the gas volume now?

   [Ans: 5.59 m^3]

5. The mass of the H_2 molecule is $3.3\text{x}10^{-24}$ g. If $1.0\text{x}10^{23}$ hydrogen molecules per second strike 2.0 cm^2 of wall at an angle of 55° with the normal when moving with a speed of $1.0\text{x}10^5$ cm/s, what pressure do they exert on the wall?

   [Ans: 0.19 N/cm^2]

6. A steel tank contains 315 g of ammonia gas (NH_3) at an absolute pressure of 1.35×10^6 Pa and temperature 77.0˚C.

   (a) What is the volume of the tank?

   (b) The tank is checked later when the temperature has dropped to 22.0˚C and the absolute pressure has fallen to 8.68×10^5 Pa. How many grams of gas leaked out of the tank?

   [Ans: (a) 0.0399 m^3; (b) 75 g]

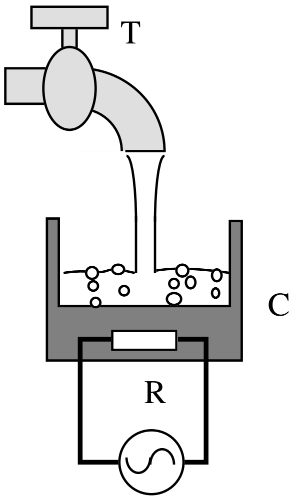
7. The envelope and basket of a hot-air balloon have a combined mass of 249 kg, and the envelope has a capacity of 2180 m^3. When fully inflated, what should be the temperature of the enclosed air to give the balloon a lifting capacity of 272 kg (in addition to its own mass)? Assume that the surrounding air, at 18.0˚C, has a density of 1.22 kg/m^3.

   (HINT: the buoyancy force is equal to the weight of the displaced air, this is Archimedes principle)

   [Ans: 89.0˚C]

PAST EXAM QUESTION

a)



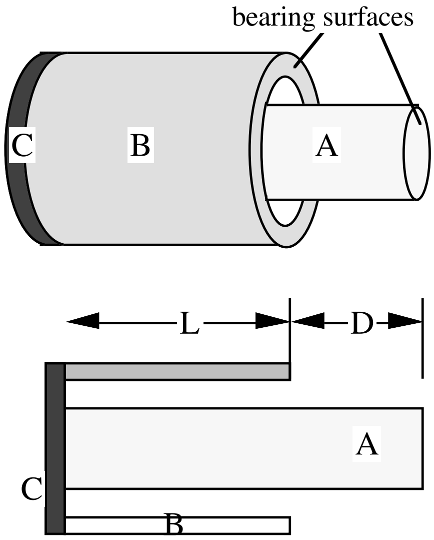
Water at temperature 20 °C flows from a tap T into a heated container C. The container has a heating element (a resistor R) which is supplied with electrical power P, that may be varied.

The rate of water flow is F = 0.020 litres per minute. The electrical power is sufficient that the water in the container is boiling. What is the minimum power P that must be supplied in steady state so that the amount of liquid water in the container neither increases nor decreases with time? (Neglect other losses of heat, such as conduction from the container to the air.)

For water, $c = 4.2\ \mathrm{kJ.kg^{-1}K^{-1}}$, $L_{vap} = 2.3\ \mathrm{MJ.kg^{-1}}$,

$\rho = 1000\ \mathrm{kg.m^{-3}}$

b)



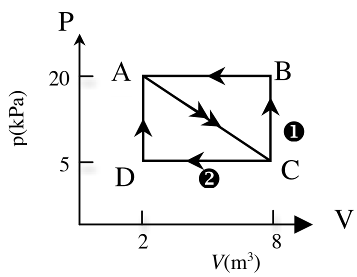
The diagrams show a sketch (top) and cross section of a low expansion mounting. It is designed so that the two bearing surfaces remain separated by a constant distance D, independent of temperature. Part A is a rod, which has length L_O+D_O at reference temperature T_O and is made of material with linear coefficient of thermal expansion α_A. Part B is a hollow cylinder which has length L_O at T_O and is made of material with linear coefficient of thermal expansion α_B. Both are mounted on a rigid plate C.

i) Showing all working, derive an expression for the length D as a function of temperature, in terms of the parameters given above.

ii) Give an expression for the value of ratio D_O/L_O which produces the result that D is independent of temperature.

WORK DONE ON AN IDEAL GAS

8. Suppose that a sample of gas expands from 2.0 to 8.0 m^3 along the diagonal path AC in the pV diagram shown. It is then compressed back to 2.0 m^3 along either path 1 or path 2. Compute the net work done on the gas for the complete cycle in each case.
[Ans: 45 kJ along path 1; -45 kJ along path 2]



9. A thin tube, sealed at both ends, is 1.00 m long. It lies horizontally, the middle 10.0 cm containing mercury and the two equal ends containing air at standard atmospheric pressure. If the tube is now turned to a vertical position, by what amount will the mercury be displaced? Assume that the process is (a) isothermal and (b) adiabatic. (For air, $\gamma = 1.40$.) Which assumption is more reasonable? The density of mercury at room temperature is 13.534 gcm^{-3}.

(Hint: $(1+x)^a \approx 1 + xa$, for small x values.)

[Ans: (a) 2.95 cm; (b) 2.11 cm]

10. In an experiment, 1.35 mol of oxygen (O_2) are heated at constant pressure starting at 11.0˚C. How much heat must be added to the gas to double its volume? You may use without proof, that the molar specific heats are $c_P = 7R/2$ and $c_V = 5R/2$.

[Ans: 11.2 kJ]

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 5

In this set make use of the data provided in these tables.

Specific Heats and Thermal conductivities of selected metals

Substance	**Specific Heat** *c*, **($Jkg^{-1}K^{-1}$)**	**Linear thermal expansion coefficient** α, **($(^oC)^{-1}$)**	**Thermal conductivity** *k*, **($Wm^{-1}K^{-1}$)**
Aluminium	910	24×10^{-6}	205.0
Brass	377	19×10^{-6}	109.0
Copper	390	17×10^{-6}	385.0
Lead	130	29×10^{-6}	34.7
Steel	456	11×10^{-6}	50.2

Water

Quantity	**Value**
Specific Heat (liquid)	4186 $Jkg^{-1}K^{-1}$
Latent heat of Fusion	3.33×10^5 Jkg^{-1}
Latent heat of vaporization	2.26×10^6 Jkg^{-1}
Density (at 4^o C)	1000 kgm^{-3}
Melting point (at 1 atm)	0.000 °C
Boiling point (at 1 atm)	100.0 °C
Volume expansion coefficient (β) (at 20^oC: you may assume it is constant between 15^oC and 100^o C)	207×10^{-6} $(^oC)^{-1}$

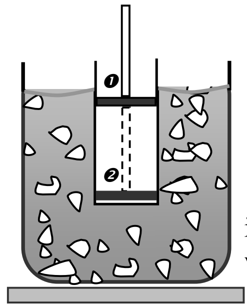
HEAT AND THE FIRST LAW OF THERMODYNAMICS

1. A 146 g copper bowl contains 223 g of water; both bowl and water are at 21.0˚C. A very hot 314 g copper cylinder is dropped into the water. This causes the water to boil, with 4.70 g being converted to steam, and the final temperature of the entire system is 100˚C. Specific heats of copper and water are 387 and 4200 $J.kg^{-1}.K^{-1}$ respectively, latent heat of vapourisation for water is 2.26 x 10^6 J/kg
   (a) How much heat was transferred to the water?
   (b) How much to the bowl?
   (c) What was the original temperature of the cylinder?
   [Ans: (a) 84.8 kJ; (b) 4.46 kJ; (c) 835˚C.]

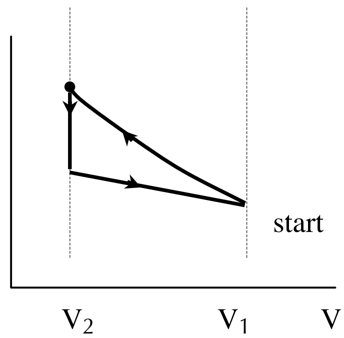
2. A person makes a quantity of iced tea by mixing 520 g of the hot tea (essentially water) with an equal mass of ice at 0˚C. What are the final temperature and fraction of the mass of ice remaining if the initial hot tea is at a temperature of (a) 90.0˚C and (b) 70.0˚C ?
   [Ans: (a) 5.2˚C; no ice left; (b) 0˚C, 0.062 kg ice left]

3. The figure shows a cylinder containing gas and closed by a movable piston. The cylinder is submerged in an ice-water mixture. The piston is quickly pushed down from position 1 to position 2. The piston is held at position 2 until the gas is again 0˚C and then is slowly raised back to position 1. Figure (b) is a pV diagram for the process. If 100g of ice are melted during the cycle, how much work has been done on the gas?

[Ans: 3.4×10^4 J]



(a)



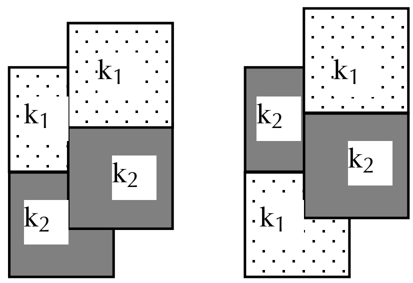
(b)

HEAT TRANSFER

4. (a) Calculate the rate at which body heat flows out through the clothing of a skier, given the following data: the body surface area is 1.8 m^2 and the clothing is 1.0 cm thick; skin surface temperature is 33˚C, whereas the outer surface of the clothing is at 1.0˚C; the thermal conductivity of the clothing is 0.040 W/m•K.
   (b) How would the answer change if, after a fall, the skier's clothes become soaked with water? Assume that the thermal conductivity of water is 0.60 W/m•K.

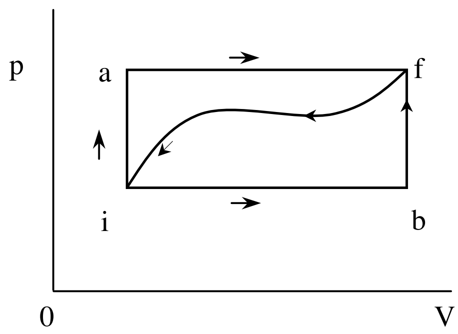
   [Ans: (a) 230 J/s; (b) Heat flows out about 15 times as fast.]

5. Four square pieces of insulation of two different materials, all with the same thickness and area A, are available to cover an opening of area 2A. These materials are aligned so that the two square sections forming the rectangle are on top of each other. This can be done in either of the two ways shown in the figure. Which arrangement, (a) or (b), would give the lower heat flow if $k_2 \neq k_1$?



(a) *(b)*

6.



When a system is taken from state **i** to state **f** along the path **iaf** in the figure, it is found that **Q** = 50 J and **W** = -20 J. Along the path **ibf**, **Q** = 36 J.

(a) What is **W** along the path **ibf**?

(b) If **W** = +13 J for the curved return path **fi**, what is **Q** for this path?

(c) Take $E_{int,i}$ = 10 J. What is $E_{int,f}$?

(d) If $E_{int,b}$ = 22 J, find **Q** for process **ib** and process **bf**.

[Ans: (a) -6.0 J; (b) -43J; (c) 40 J; (d) 18 J; 18 J.]

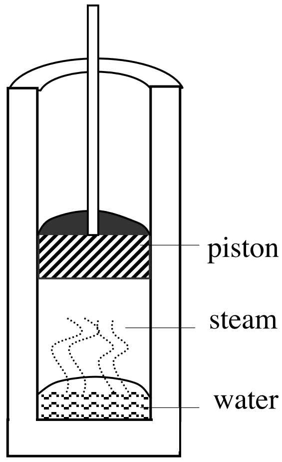
7. A cylinder has a well-fitted 2.0 kg metal piston whose area is 2.0 cm^2, as shown in the figure. The cylinder contains water and steam at constant temperature. The piston is observed to fall slowly at a rate of 0.30 cm/s because heat flows out of the cylinder through the cylinder walls. As this happens, some steam condenses in the chamber. The density of the steam inside the chamber is 6.0×10^{-4} g/cm^3 and the atmospheric pressure is 1.0 atm.

(a) Calculate the rate of condensation of steam.

(b) At what rate is heat leaving the chamber?

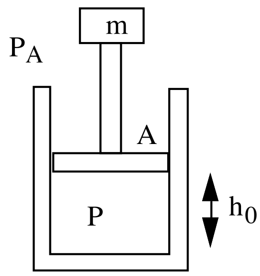
(c) What is the rate of change of internal energy of the steam and water inside the chamber?

[Ans: (a) 0.360 mg/s; (b) 0.814 J/s; (c) –0.694 J/s]



PAST EXAM QUESTION

(a) Pneumatic or air suspension has some advantages (and some disadvantages) in comparison with springs. In this question we consider an idealised version of air suspension. A volume V_0 of air at atmospheric pressure P_A and temperature T_0 is sealed in a piston of area A that slides without leaks or friction in a cylinder. The air may be considered as an ideal gas with molar mass 0.029 kg.kmol^{-1}. The piston is then loaded with a mass m, that includes the mass of the piston. The system is allowed to reach mechanical and thermal equilibrium at T_0.



Showing your working, derive an expression for h_0, the equilibrium height of the piston in the cylinder as shown in the sketch in terms of the parameters given above and the gas constant.

(b) For the suspension system in part (a), the stiffness (ie the ratio of force to displacement, just like the spring constant of a spring) depends on the speed of the displacement. Would the system be stiffer for a rapid displacement or a slow one? Explain your answer in a few short, clear sentences.

OSCILLATION

8. A body oscillates with simple harmonic motion according to the equation:

$$x = 6.0 \cos(3\pi t + \frac{\pi}{3}) \text{ metres .}$$

At t = 2 seconds, what is:
(a) the displacement,
(b) the velocity; and
(c) the acceleration?

Find also:
(d) the phase,
(e) the frequency, f; and
(f) the period of motion

[Ans: a) 3.0m, b) $v = -9\pi\sqrt{3}$ ms^{-1}, c) $a = -27\pi^2$ ms^{-2}, d) $\phi = \pi/3$ is the phase constant,
e) v = 1.5Hz. f) 2/3 sec.]

9. A ball moves in a circular path with a radius of 2.00 meters with a constant speed of 3.00 m/s.
(a) Find the period and frequency of the motion of the ball.
(b) Write down an equation for the x component of the position of the ball as a function of time *t*. Assume the ball is on the positive x axis at *t=0*.

[Ans: a) *T*=4.19s, f=0.239Hz, b) x=2cos(1.5t)]

10. A block is on a piston which is moving vertically with simple harmonic motion of period 1.0 seconds.

(a) At what amplitude of motion will the block and piston separate?
(b) If the piston has an amplitude of 5.0cm, what is the maximum frequency for which the block and piston will be in contact continuously?

[Ans: a) x = 0.25m, b) *f* = 2.2Hz]

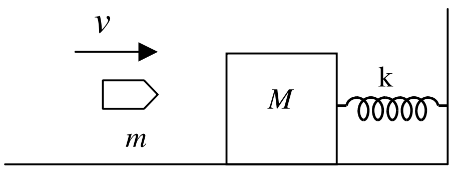
11. A uniform spring whose unstressed length is *l* has a force constant *k*. The spring is cut into two pieces of unstressed lengths l_1 and l_2, where $l_1 = nl_2$ where *n* is an integer. What are the corresponding force constants k_1 and k_2 in terms of *n* and *k*? Check your result for *n* = 1 and *n* = infinity.

[Ans: $k_1 = k\left(\frac{n+1}{n}\right)$; $k_2 = k(n+1)$]

12. A mass is in simple harmonic motion with amplitude A. What is the fraction of the kinetic energy component to the total energy when x = A/3.

[Ans: 8/9]

13. A block of mass M, at rest on a horizontal, frictionless table, is attached to a rigid support by a spring of force constant k. A bullet of mass m and speed v strikes the block as shown in the figure. The bullet remains embedded in the block. Determine the amplitude of the resulting simple harmonic motion, in terms of m, M, v and k.



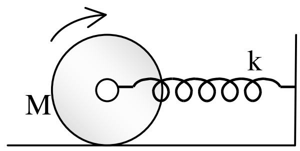
[Ans: $\dfrac{mv}{\sqrt{k(m+M)}}$]

14. A solid cylinder is attached to a horizontal massless spring so that it can roll without slipping along a horizontal surface, as shown in the figure. The force constant k of the spring is 2.94 $\mathrm{Ncm^{-1}}$. If the system is released from rest at a position in which the spring is stretched by 23.9 cm, find:

(a) the translational kinetic energy, and
(b) the rotational kinetic energy of the cylinder as it passes through the equilibrium position.
(c) Show that under these conditions the centre of mass of the cylinder executes simple harmonic motion with a period:

$$T = 2\pi\sqrt{\frac{3M}{2k}}$$

where M is the mass of the cylinder

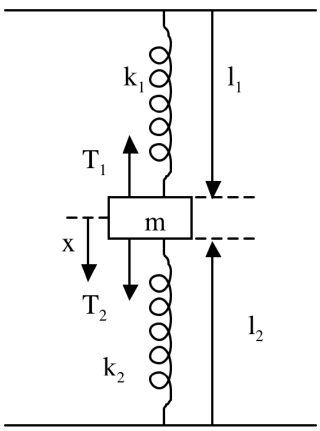


Rotational kinetic energy; $K = \dfrac{1}{2}I\omega^2$

Moment of Inertia $I = \dfrac{1}{2}MR^2$

[Ans: (a) 5.60 J,(b) 2.80 J]

15. The system shown undergoes SHM in a vertical direction. Find the frequency for the system.



[Ans: $\dfrac{1}{2\pi}\sqrt{\dfrac{k_1+k_2}{m}}$]

16. The equation of a transverse wave travelling in a rope is given by:

$$y = 0.1 \sin \pi(x - 2.00t) \text{ m}$$

where y and x are expressed in metres and t in seconds.

(a) Find the amplitude, frequency, velocity and wavelength of the wave.

(b) Find the maximum *transverse* speed of a 'particle' (by particle we mean any small element of the rope which will be set in motion as the wave moves past a chosen position) in the rope.

[Ans: (a) 0.1 m, 1.0 Hz, 2 ms^{-1}, 2m; (b) 0.63 ms^{-1}]

17. What is the speed of a transverse wave in a rope of length 2.0 metres and mass 0.060 kg under a tension of 500 N?

[Ans: 130 ms^{-1}]

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 6

WAVE MOTION

1. A wave of frequency 500 Hz has a *phase* velocity of 350 ms^{-1}. *["Phase" velocity is "speed" or "velocity" of wave. It is the velocity that any given "phase" propagates at; eg. The crest or trough of a wave.]*
   (a) How far apart are two points 60° out of phase?
   (b) What is the phase difference between two displacements at a certain point at times 10^{-3} sec apart?

   [Ans: (a) 0.12 m; (b) 180°]

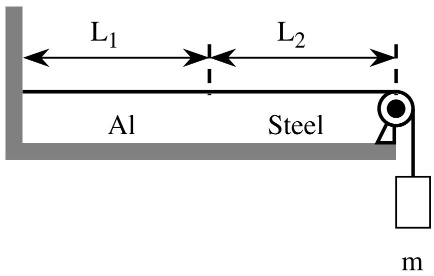
2. A string vibrates according to the equation:

$$y = 0.5 \sin\frac{\pi x}{3} \cos 40\pi t$$

   where x and y are in centimetres and t is in seconds.
   (a) What are the amplitude and velocity of the component waves whose superposition can give rise to this vibration?
   (b) What is the distance between nodes?
   (c) What is the velocity of a particle of the string at the position x = 1.5 cm when t = 9/8s?

   [Ans: (a) 0.25 cm, 120 cm s^{-1}; (b) 3.0 cm; (c) zero]

3. An aluminium wire of length L_1 = 60.0 cm and of cross-sectional area 1.00×10^{-2} cm^2 is connected to a steel wire of the same cross-sectional area. The compound wire; loaded with a block m of mass 10.0 kg is arranged as shown in the diagram so that the distance L_2 from the joint to the supporting pulley is 86.6 cm. Transverse waves are set up in the wire by using an external source of variable frequency.



   The density of aluminium is 2.60 g cm^{-3}, and that of steel is 7.80 g cm^{-3}.

   (a) Find the lowest frequency of excitation for which standing waves are observed such that the joint in the wire is a node.
   (b) What is the total number of nodes observed at this frequency, excluding the two at the ends of the wire?

   [Ans: (a) 323 vib/sec; (b) 6]

4. A harmonic wave is given by the function

$$y = (2.0\ \text{m}) \sin 2\pi/\lambda (x - vt)$$

   where y is the displacement of the wave travelling in the x-direction at speed v. If the frequency of the wave is 2.0 Hz, what is the displacement y at x=0 when t=4.0s?

   [Ans: 0 m]

5. Wavelength λ and propagation number (or 'wave number') k are related by $k = 2\pi/\lambda$. Show that a harmonic wave travelling in the positive x-direction at velocity v with wave function

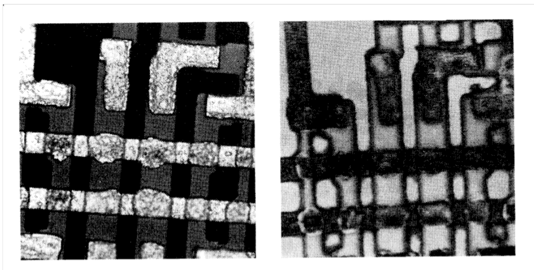
$$y(x,t) = A \sin \frac{2\pi}{\lambda}(x - vt)$$

can be written in the alternative forms

(i) $y = A \sin k(x - vt)$

(ii) $y = A \sin(kx - \omega t)$

6. The figure here shows part of a computer circuit (the surface of a processor or memory chip) viewed in two different types of microcope. The left figure was obtained by a regular optical light microscope. The view on the right was produced by an acoustic microscope by focusing 3 GHz ($3\text{x}10^9$ Hz) ultrasonic waves through a droplet of water on the chip's surface. The ultrasonic wave speed in water is 1.5 km/s. Find the wavelength of the ultrasonic travelling waves and compare this to the wavelength of green light (approximately middle of the visible spectrum) in air.



(Interested students can find some background at http://www.soest.hawaii.edu/~zinin/Zi-SAM.html)
Ans: 500 nm

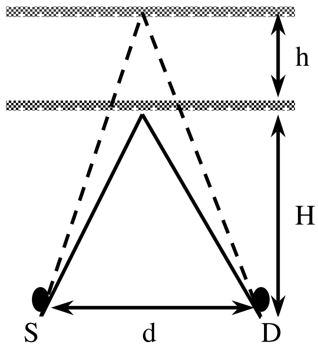
SOUND WAVE

7. Calculate the energy density in a sound wave 4.82 km from a 47.5 kW siren, assuming the waves to be spherical, the propagation isotropic with no atmospheric absorption, and the speed of sound to be 343 m/s.

[Ans: 474 nJ m^{-3}]

8. A source S and a detector D of high-frequency waves are a distance d apart on the ground. The direct wave from S is found to be in phase at D with the wave from S that is reflected from a horizontal layer at an altitude H. The incident and reflected rays make the same angle with the reflecting layer. When the layer rises a distance h, no signal is detected at D and no other maximum or minimum occurs in between. Neglect absorption in the atmosphere and find the relation between d, h, H, and the wavelength λ of the waves.

Ans: $\lambda = 2\sqrt{4(H+h)^2 + d^2} - 2\sqrt{4H^2 + d^2}$



9. Two waves give rise to pressure variations at a certain point in space given by:

$p_1 = P \sin 2\pi ft$, $p_2 = P \sin 2\pi(ft - \phi)$.

What is the amplitude of the resultant wave at this point when $\phi = 0$, $\phi = \frac{1}{4}$, $\phi = \frac{1}{6}$, $\phi = \frac{1}{8}$?

[Ans: 2.00P, 1.41P, 1.73P, 1.85P]

10. A note of frequency 300 Hz has an intensity of 1.0 μW m^{-2}. What is the amplitude of the air vibrations caused by this sound? Assume that the velocity of sound in air is 343 m/s and the density of air at room temperature is 1.21 kgm^{-3}.

[Ans: 3.7×10^{-8} m]

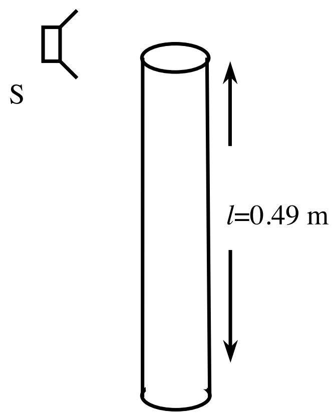
11. A certain sound level is increased by an additional 30 dB. Show that:
   (a) its intensity increases by a factor of 1000; and
   (b) its pressure amplitude increases by a factor of 32.

12. Two loudspeakers, S_1 and S_2, each emit sound of frequency 200 vib/sec uniformly in all directions. S_1 has an acoustic output of 1.2×10^{-3} watt and S_2 one of 1.8×10^{-3} watt. S_1 and S_2 vibrate in phase. Consider a point P which is 4.0 m from S_1 and 3.0 m from S_2.
   (a) How are the phases of the two waves arriving at P related?
   (b) What is the intensity of sound at P if S_1 is turned off (S_2 on)?
   (c) What is the intensity of sound at P if S_2 is turned off (S_1 on)?
   (d) Describe qualitatively how the intensity at P with both S_1 and S_2 on would compare with the sum of your answers to (b) and (c).

   [Ans: (a) Differ in phase by 3.8 radians; (b) 1.6×10^{-5} Wm^{-2}; (c) 6.0×10^{-6} Wm^{-2}; (d) less than]

13. S in the figure opposite is a small loudspeaker driven by an audio oscillator and amplifier, adjustable in frequency from 1000 to 2000 Hz only. D is a cylindrical pipe, length l=0.49 m.
   Assume that the tube is open at both ends.
   (a) If the velocity of sound in air is 339 m s^{-1} at the ambient temperature, at what frequencies will resonance occur when the frequency emitted by the speaker is varied from 1000 to 2000 Hz?
   (b) Sketch the displacement modes for each. Neglect end effects.
   (c) Explain what end effects are and how they would change your results in the real case.

   [Ans: (a) 1038, 1384, 1730 Hz]



14. A tuning fork of unknown frequency makes three beats per second with a standard fork of frequency 384 Hz. The beat frequency decreases when a small piece of wax is put on a prong of the first fork. What is the frequency of this fork?

   [Ans: 387 Hz]

SOUND WAVES AND DOPPLER EFFECT

15. Sinusoidal vibrations of 20 Hz propagate along a coil spring. The distance between successive condensations (positions of maximum compression) in the spring is 30 cm.
   (a) What is the speed of motion of the condensations along the spring?
   (b) The maximum longitudinal displacement of a particle of the spring is 4 cm. Write down an equation for this wave motion for waves moving in the positive x direction and which have zero displacement at x = 0 at time t = 0.
   (c) What is the maximum velocity experienced by a particle of the spring?

   [Ans: (a) 6 ms^{-1}; (b) $y = 0.04 \sin 2\pi(20t - \frac{x}{0.3})$; (c) 1.6π ms^{-1}]

16. For a sound wave, the pressure amplitude ΔP_{max} is the maximum value of the change in pressure from the ambient pressure (when no wave is present in the medium). ΔP_{max} is related to the wave amplitude A by

$$\Delta P_{max} = (\frac{2\pi}{\lambda})\rho v^2 A$$

where ρ is the density of the medium and v is the wave velocity. Humans can tolerate values of pressure amplitude up to $\Delta P_{max} \sim 30$ Pa ; for these loud sounds, the pressure wave varies by ±30 Pa with respect to the ambient atmospheric pressure $P \sim 10^5$ Pa . What value of displacement amplitude does this correspond to at a frequency f = 1000Hz ? Take the density of air to be $\rho_{air} = 1.22$ kgm^{-3} and the speed of sound at 37° C to be 353.7 ms^{-1}.

[Ans: 0.011 mm]

17. A siren emitting a sound of frequency 1000 Hz moves away from you towards a cliff at a speed of 10 ms^{-1}.

(a) What is the wavelength of the sound you hear coming directly from the siren?

(b) What is the wavelength of the sound you hear reflected from the cliff?

(c) What is the difference in frequency between cases (a) and (b)?

(Velocity of sound in air = 340 ms^{-1})

[Ans: (a) 0.35 m; (b) 0.33 m; (c) 58 Hz]

18. A tuning fork, frequency 297 Hz, is used to tune the D-string of two guitars at a temperature of 27°C when the velocity of sound in air is 340 ms^{-1}.

(a) What difference in frequency will the audience detect if one player is stationary and the other is moving towards the audience at 3 ms^{-1}?

(b) What difference in sound would there be if one player plucked the string at the centre point and the other at a point 1/7th the length of the string from one end?

(c) What length of open organ pipe would give a fundamental of 297 Hz at 27°C? Derive the formula used.

(d) What different frequency would the organ pipe have if the temperature fell to 7°C?

(e) What changes would occur in the note produced by the organ pipe if it had a hole at its half-way point?

[Ans: (a) increased by 2.64 Hz; (c) 0.572 m; (d) 287 Hz; (e) 594 Hz]

19. A girl is sitting near the open window of a train that is moving at a velocity of 10.00 m/s to the east. The girl's uncle stands near the tracks and watches the train move away. The locomotive whistle emits sound at frequency 500.0 Hz. The air is still. Take the sound speed to be 343 m/s.

(a) What frequency does the uncle hear?

(b) What frequency does the girl hear?

A wind begins to blow from the east at 10.0 m/s.

(c) What frequency does the uncle now hear?

(d) What frequency does the girl now hear?

[Ans: (a) 485.8 Hz; (b) 500.0 Hz; (c) 486.2 Hz; (d) 500.0 Hz]