UNSW SYDNEY

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 1 - 6**

Session 1 2018

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.*
• **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

Faculty of Science - Course Outline

1. Information about the Course

NB: Some of this information is available on the UNSW Handbook[1]

Year of Delivery	*2018*
Course Code	*PHYS1131*
Course Name	*Higher Physics 1A*
Academic Unit	*School of Physics*
Level of Course	*1*
Units of Credit	*6UOC*
Session(s) Offered	*Session 1, Session 2*
Assumed Knowledge, Prerequisites or Co-requisites	Assumed Knowledge : HSC Physics and Mathematics Extension 1 or equivalent. If you have not reached this level of physics and mathematics you may wish to take PHYS1111 Fundamentals of Physics before enrolling in this course. *MATH1131 or MATH1141 or MATH1151 are co-requisites*
Hours per Week	*3 hours lectures per week (or online if enrolled in web stream), 1 hour problem solving workshop, 2 hour lab. It is expected that students will spend an additional 6 hours per week solving problems.*
Number of Weeks	*12 weeks*
Commencement Date	26th February
Component	**Details**
Lectures	*In lectures you will be introduced to new material, shown demonstrations and examples of how to solve problems. Lectures are 3 hours per week. Check your timetable for times.*
Laboratories	*This course has 10 laboratory experiments, approximately one each week. In laboratory classes you will collect data, design experiments and make use of the theories covered in lectures. You will need to complete a prelab quiz before each experiment.*
Problem solving workshops	*In problem solving workshops you will solve problems related to the theory covered in lectures. You will have practice tests in some classes to give you feedback about how you are going.*
Tutorial problems	*Each fortnight there will be a set of tutorial problems. You should work through these at home. Video solutions are provided to all the tutorial problems.*
Online quizzes	*Every fortnight you will have an online quiz due. The questions are pulled randomly from a bank of questions. You can try these quizzes as many times as you want. Your highest mark counts. You will have invigilated quizzes in the lab in weeks 8 and 13 pulled from this same*

[1] UNSW Online Handbook: http://www.handbook.unsw.edu.au

	bank.

2. Staff Involved in the Course

Staff	Role	Name	Contact Details	Consultation Times
Course Convenor		*Dr Elizabeth Angstmann*	*e.angstmann@unsw.edu.au* *Room G61F, Old Main Building* *School of Physics*	Email to arrange a time
Additional Teaching Staff	Lecturers	*Prof. Joe Wolfe* *Prof Alex Hamilton* *Dr Elizabeth Angstmann (Web stream)*	*j.wolfe@unsw.edu.au* *alex.hamilton@unsw.edu.au* *e.angstmann@unsw.edu.au*	Times will be advertised during lectures
	Lab director	*Dr Krystyna Wilk*	*k.wilk@unsw.edu.au*	Email to arrange a time
	Other Support Staff	Ranji Ballala	firstyear@phys.unsw.edu.au Room G06 School of Physics office, Old Main Building	9:30-12:30 2:00-5:00
	Teaching assistants		There will be teaching assistants in room 201A in the old main building if you have questions about physics	12-2 PM Monday, Wednesday and Friday

3. Course Details

Course Description (Handbook Entry)	This course provides an introduction to Physics. It is a calculus based course. The course is examined at two levels, with Physics 1A being the lower of the two levels. Mechanics: particle kinematics in one dimension, motion in two and three dimensions, particle dynamics, work and energy, momentum and collisions. Thermal physics: temperature, kinetic theory and the ideal gas, heat and the first law of thermodynamics. Waves: oscillations, wave motion, sound waves. Assumed Knowledge : HSC Physics and Mathematics Extension 1 or equivalent. If you have not reached this level of physics and mathematics you may wish to take PHYS1111 Fundamentals of Physics before enrolling in this course.
Course 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 (Special) Higher Physics 1B), this constitutes a broad introduction to physics. This background supports higher level study in physics and engineering.
Student Learning Outcomes	By the end of this course students should be able to: • Analyse motion in two dimensions using vectors. Apply Newton's laws of motion to objects undergoing uniform translational or rotational acceleration. • Analyse problems involving friction and the forces and deformations described by Hooke's law • Explain the difference between kinetic and potential energy and use the law of conservation of energy and the work-energy theorem to solve mechanics problems. • Apply the conservation laws of momentum and energy to solve mechanics problems, including problems involving collisions, extended objects and their centres of mass. • Apply the law of universal gravitation and Kepler's laws in combination with other laws covered in this course to describe, predict and explain the motion of satellites, planets, stars and galaxies. • Explain how energy conservation is related to the first law of thermodynamics. Apply the first law to solve problems. • Recognise and solve problems relating to different thermodynamic processes, including adiabatic, isothermal, isobaric and isovolumetric processes. For cyclic processes, calculate changes in internal energy, work done and heat

	transferred in cycles. • Describe different heat transfer mechanisms and calculate the amount of heat transferred in different processes. • Identify physical systems that can be understood using models of simple harmonic oscillation and write down equations to describe this motion. • Write down and solve equations describing wave motion, and use these equations to explain physical phenomena such as (but not limited to) standing waves and interference. • Recognise that physics is an experimental science, plan and conduct experiments and analyse the outcomes, and include reliable estimates of uncertainties in measurements.
Relationship to Other Courses within the Program	PHYS1121 is a pre requisite for PHYS1221, Physics 1B. Students need to score at least 65 in PHYS1121 to enroll in PHYS1231, Higher Physics 1B.

4. Rationale and Strategies Underpinning the Course

Teaching Strategies	Students will be introduced to new ideas and concepts during lectures (which they can choose to attend in person or online). These will include demonstrations, discussions of applications and examples of how to solve problems. Students are encouraged to actively participate during lectures. Students will apply this knowledge in laboratory and problem solving workshops. Students will also be provided with tutorial problems to practice with worked solutions.
Rationale for learning and teaching in this course	Many studies have shown that students learn effectively by solving problems (see Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. Psychological Science in the Public Interest, 14(1), 4-58. for example). After being presented with new concepts and ideas students are given many opportunities to solve problems including in the lab, problem solving workshops and online quizzes.

5. Course Schedule

Week	Scheduled activities (check lecture, lab and problem solving workshop times on your timetable on myUNSW)	Assignment and Submission dates (see also 'Assessment Tasks & Feedback')
Week 1	Three lectures First problem solving workshop: uncertainties Complete the online safety induction for the lab	
Week 2	Three lectures Problem solving workshop on Motion in one and two dimensions Laboratory class: Introductory experimentation	Lab Complete homework set 1
Week 3	Three lectures Laboratory class: The pendulum	Lab First online at home quiz due
Week 4	Three lectures Problem solving workshop: forces and friction Laboratory class: see schedule	Lab Complete homework set 2
Week 5	Three lectures Problem solving workshop: Practice test 1 Laboratory class: see schedule	Lab Second online at home quiz due
Week 6	Two lectures (Due to Good Friday holiday the last lecture this week will not be held) Problem solving workshop: Changes in energy and momentum Laboratory class: see schedule	Lab Complete homework set 3
Week 7	Three lectures Problem solving workshop: Distinguishing effects of net force and net torque Laboratory class: see schedule	Lab Third online at home quiz due
Week 8	Three lectures Problem solving workshop: Practice test 2 Online quiz held in lab time this week in lab	Invigilated online quiz Complete homework set 4
Week 9	Three lectures Problem solving workshop: Ideal gas law Laboratory class: see schedule	Lab Fourth online at home quiz due
Week 10	Two lectures (due to ANZAC day one lecture this week will be cancelled)	Lab

	Problem solving workshop: PV plots Laboratory class: see schedule	Complete homework set 5
Week 11	Three lectures Problem solving workshop: Practice test 3 Laboratory class: see schedule	Lab Fifth online at home quiz due
Week 12	Three lectures Problem solving workshop: Revision Laboratory class: see schedule	Lab Complete homework set 6
Week 13	Problem solving workshop: Practice test 4 Online quiz held in lab time this week in lab	Invigilated online quiz Sixth online at home quiz due

6. Assessment Tasks and Feedback

<table>
<tr><th rowspan="2">Task</th><th rowspan="2">Knowledge & abilities assessed</th><th rowspan="2">Assessment Criteria</th><th rowspan="2">% of total mark</th><th colspan="2">Date of</th><th colspan="3">Feedback</th></tr>
<tr><th>Release</th><th>Submission</th><th>WHO</th><th>WHEN</th><th>HOW</th></tr>
<tr><td>Lab Exercises and prelab quizzes</td><td>Recognise that physics is an experimental science, plan and conduct experiments and analyse the outcomes, and include reliable estimates of uncertainties in measurements.</td><td>Marking rubric for each exercise can be found in the laboratory manual. Prelab quizzes are 5% of total mark, lab exercises 15%.</td><td>2 % × 10 = 20%</td><td>1 week prior to lab</td><td>Prelab quizzes before the start of your lab time, lab book at the end</td><td>Demonstrator</td><td>During lab</td><td>Your demonstrator will talk to you</td></tr>
<tr><td>Online quizzes</td><td>Recognise the quantitative nature of physics and be able to solve simple problems – tests entire syllabus of this course</td><td>Students need to correctly perform calculations and solve problems</td><td>1.67 % x 6 = 10%

10%

10%</td><td>1 week prior to due date

Week 8

Week 13</td><td>9 PM Sunday at ends of weeks 3, 5, 7, 9, 11, 13</td><td colspan="3">These quizzes use a question bank. Every fortnight you will have a quiz to complete at home. You may attempt this as many times as you wish. Your highest mark will count. At the end of each attempt you will receive feedback on how to answer any questions you answered incorrectly.
In weeks 8 and 13 you will have a 40 minute 4 question quiz drawn from the same question banks during your lab time in the first year lab. Check on Moodle to see which hour you need to attend for.</td></tr>
<tr><td>Final exam</td><td>Recognise the quantitative nature of physics and be able to solve simple problems – tests entire syllabus of this course</td><td>Students need to correctly perform calculations and solve problems</td><td>50 %</td><td colspan="5">You can view your exam timetable on myUNSW. This is a 2 hour exam.</td></tr>
</table>

7. Additional Resources and Support

Text Books	Halliday, D., Resnick, R., & Walker, J. (2014). Fundamentals of Physics, John Wiley & Sons. Note: the library has an eBook subscription to this. The link is provided on the Moodle site. The book can be purchased from the publisher here: http://www.wileydirect.com.au/buy/fundamentals-of-physics-10th-edition/
Course Manual	Laboratory manual can be purchased from the bookshop or downloaded from Moodle, printed and bound. You can will receive the homework booklets when you purchase the lab manual. Alternatively you can print them from Moodle.
Required Readings	Lecture notes provided on Moodle.
Additional Readings	Most calcus based introductory physics text books are suitable. Physics Vol 1 by Serway, Jewett, Wilson and Wilson is an example of one of these.
Recommended Internet Sites	Will be made available on Moodle
Computer Laboratories or Study Spaces	Room 201A in the old main building is available for group or individual study.

8. Required Equipment, Training and Enabling Skills

Equipment Required	Access to a computer to complete online quizzes. There are suitable computers in the UNSW library.
Enabling Skills Training Required to Complete this Course	ELISE It is highly recommended that you complete the Moodle module on academic integrity before submitting assessment for this course.

9. Course Evaluation and Development

Student feedback is gathered periodically by various means. Such feedback is considered carefully with a view to acting on it constructively wherever possible. This course outline conveys how feedback has helped to shape and develop this course.

Mechanisms of Review	Last Review Date	Comments or Changes Resulting from Reviews
Major Course Review		
myExperience		In 2018 the assessment of this course has changed based on student feedback. The final exam is now worth 50% (down from 70%). There are two invigilated quizzes each worth 10%.
Other		

10. Administration Matters

<table>
<tr><td>Expectations of Students</td><td colspan="3">There is an assumption that sutudents will spend six hours per week in face-to-face classes (or completing the web stream lectures) and six hours per week working through problems and online quizzes.</td></tr>
<tr><td>Assignment Submissions</td><td colspan="3">If a student is sick and misses a lab they should complete the “Missed experiment for medical reasons” form on Moodle. If a student misses a la for any other reason they should complete a catch up lab within a fortnight of the missed lab exercise.

If a student is sick and misses an online quiz they should apply for special consideration through myUNSW, a doctor’s certificate will be needed and this must be verified at student central. For the at home quizzes this certificate needs to cover at least three days while the quiz was available. For the quizzes held in the lab the certificate needs to cover the day of the lab.</td></tr>
<tr><td>Occupational Health and Safety[2]</td><td colspan="3">Is very important. You must complete and abide by a risk assessment for each of the investigations you conduct, including the one for your final report.</td></tr>
<tr><td>Assessment Procedures

UNSW Assessment Policy[3]</td><td colspan="3">The school of physics special consideration policy can be found here: https://www.physics.unsw.edu.au/current-students/special-consideration</td></tr>
<tr><td>Equity and Diversity</td><td colspan="3">Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course Convenor prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equity and Diversity Unit (9385 4734 or http://www.studentequity.unsw.edu.au/).

Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.</td></tr>
<tr><td rowspan="2">Student Complaint Procedure[4]</td><td>School Contact</td><td>Faculty Contact</td><td>University Contact</td></tr>
<tr><td>Dr Elizabeth Angstmann
First year Physics Director
e.angsmtann@unsw.edu.au
Tel: 9385 4542

Or

A. Prof. Yvonne Wong
Director of Teaching, Physics
info@phys.unsw.edu.au
Tel: 9385 5618</td><td>A. Prof. Janelle Wheat
Deputy Dean education
j.wheat@unsw.edu.au
Tel: 9385 0752

Or

Dr Gavin Edwards
Associate Dean
(Undergraduate Programs)
g.edwards@unsw.edu.au
Tel: 9385 6125</td><td>Student Conduct and Appeals Officer (SCAO) within the Office of the Pro-Vice-Chancellor (Students) and Registrar.

Telephone 02 9385 8515, email studentcomplaints@unsw.edu.au

University Counselling and Psychological Services[5]
Tel: 9385 5418</td></tr>
</table>

2 UNSW OHS Home page
3 UNSW Assessment Policy
4 UNSW Student Complaint Procedure
5 University Counselling and Psychological Services

UNSW Academic Honesty and Plagiarism

What is Plagiarism?

Plagiarism is the presentation of the thoughts or work of another as one's own.
*Examples include:

- direct duplication of the thoughts or work of another, including by copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person's assignment without appropriate acknowledgement;
- paraphrasing another person's work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- piecing together sections of the work of others into a new whole;
- presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a tutor; and
- claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed.†

For the purposes of this policy, submitting an assessment item that has already been submitted for academic credit elsewhere may be considered plagiarism.

Knowingly permitting your work to be copied by another student may also be considered to be plagiarism.

Note that an assessment item produced in oral, not written, form, or involving live presentation, may similarly contain plagiarised material.

The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does *not* amount to plagiarism.

The Learning Centre website is main repository for resources for staff and students on plagiarism and academic honesty. These resources can be located via:

www.lc.unsw.edu.au/plagiarism

The Learning Centre also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- correct referencing practices;
- paraphrasing, summarising, essay writing, and time management;
- appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is available on request from The Learning Centre.

Students are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting, and the proper referencing of sources in preparing all assessment items.

* Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle
† Adapted with kind permission from the University of Melbourne

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.

PHYS1131 - 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

$\Delta L = \alpha L \Delta T \qquad \Delta V = \beta V \Delta T$

$Q = mc\Delta T \qquad Q = mL$

$PV = nRT = Nk_BT$

$\bar{\epsilon} = \frac{3}{2}k_BT = \frac{1}{2}m\overline{v^2}$

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

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

$P = kA|\dfrac{dT}{dx}| \qquad P = \sigma AeT^4$

$dW = -PdV$

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

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

for monatomic gas $f = 3$

for diatomic gas:

$0 \lesssim T \lesssim 100$ K $f = 3$
$100 \lesssim T \lesssim 1000$ K $f = 5$
$T \gtrsim 1000$ K $f = 7$

Gravitation

Gravitation $|F| = \dfrac{Gm_1 m_2}{r^2}$

$U = -\dfrac{Gm_1 m_2}{r}$

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

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

Waves and Oscillations

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

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

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

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

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

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

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

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

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

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

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

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

Trigonometric identities

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

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

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

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

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

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

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

Standard Integral

$\int \dfrac{1}{x}dx = \ln(x) + C$

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^{o}C (273 K) .... $2.241\times10^{-2}m^{3}$

at 25^{o}C (298 K)... $2.447\times10^{-2}m^{3}$

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), ... $1.000 \text{ x } 10^{-12}$ 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, $k_e = \dfrac{1}{4\pi\varepsilon_0} = 8.988\times10^{9}\ \text{Nm}^2/C^2$

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 201A, 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.

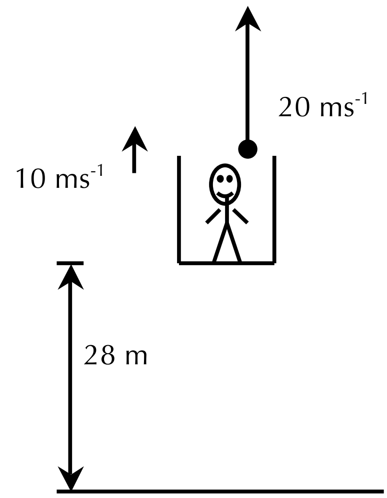
Problem Solving - An Example

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}.

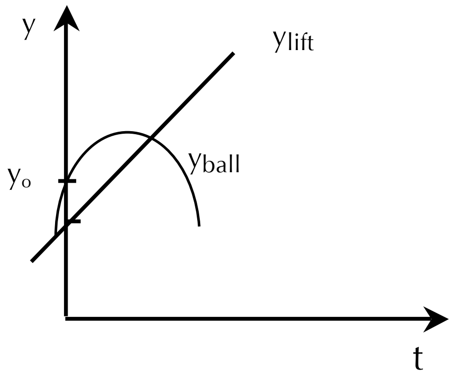
(a) What is the maximum height attained by the ball (relative to the ground)?

(b) How long does it take for the ball to return and hit the floor of 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

Here there are a few different methods. We show only one.

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

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

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

$y_{ball} = y_{lift}$

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

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

$4.9\, t^2 - 20t - 2.0 = 0$ (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

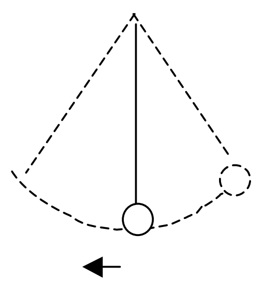
1. Discuss the sample problem above.

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.

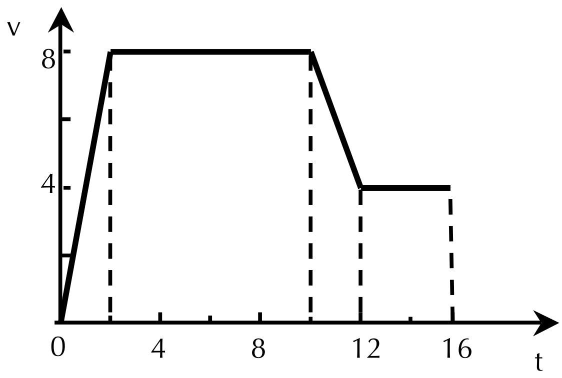
4. The bob of a simple pendulum is passing through its lowest point.

   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.

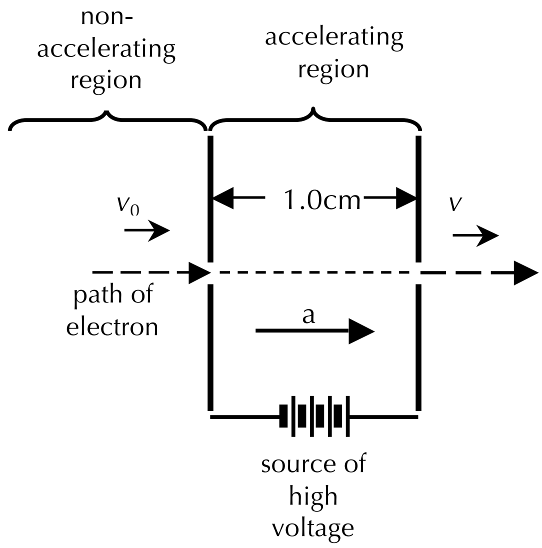
(a) What is the acceleration of the runner at times t = 1, 5, 11, 14 sec.?
(b) What is the total distance travelled in 16 s?
(c) What is the average velocity during the first 10 s?

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}.

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).

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.

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.)



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?

Answers to Set 0:

1. (a) 4, 0, –2, 0 ms^{-2}; (b) 100 m; (c) 7.2 ms^{-1}
2. (a) 5.0 ms^{-2}; (b) 4.0 s; (c) 6.0 s; (d) 90 m
3. (a) 82 m; (b) 19 ms^{-1}
4. (a) 80 ms^{-1}, 20 ms^{-2}; (b) 70 ms^{-1} 90 ms^{-1}; 20 ms^{-2}
5. 8.0 x 10^{14} ms^{-2} in the x direction
6. (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?

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.

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.

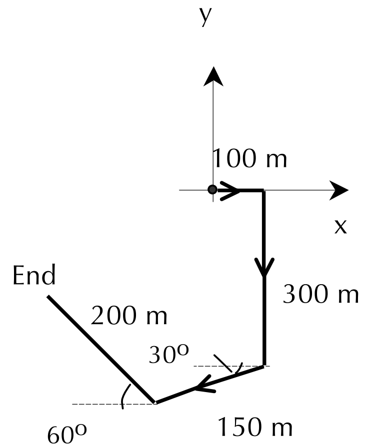
vi) State the time T between release of the stone and arrival of the sound. Think carefully about the number of significant figures.

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 $g \cong 10\ ms^{-2}$.

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



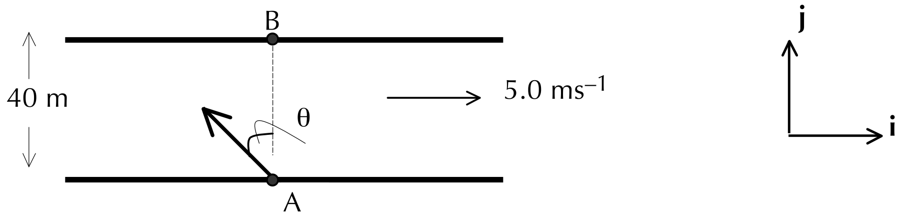
4. A person going for a walk follows the path shown in the diagram. Taking the starting point as the origin and using **i**, **j**, **k** notation
   (a) write a vector displacement for each straight line segment of the walk.
   (b) determine the person's resultant vector displacement at the end of the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

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

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.

7.



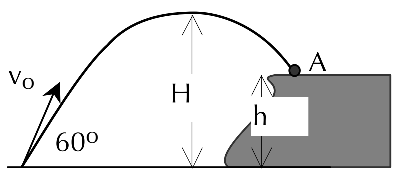
A rower wishes to cross a rapidly flowing river of width 40 m, which is flowing uniformly at a rate of 5.0 ms^{-1}. The rower starts at point A and heads in a direction θ, as shown, rowing at a speed of 2.0 ms^{-1} relative to the water.
   (a) Write down an expression for the velocity of the rower relative 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?
   Hint: what technique do you use to find the minimum of a function?

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?

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?

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.



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?

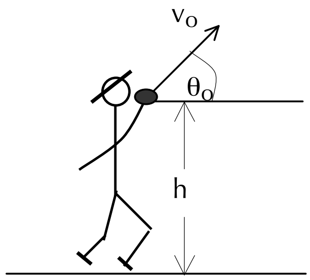
12. In a cathode-ray tube a beam of electrons is projected horizontally with a speed of $1.0 x 10^7 ms^{-1}$ into the region between a pair of horizontal plates $2.0x10^{-2}$ m long. An electric field between the plates exerts a constant downward acceleration on the electrons of magnitude
$1.0x10^{15}$ 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.

13. (a) At what speed must an automobile round a turn having a (vertical) 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?

14. (a) Write an expression for the position vector **r** for a particle describing uniform circular motion about the origin, 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.

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.

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).
(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_0 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.

Answers to set 1:

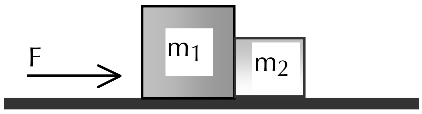
1. 1.5 s
2. (a) 0.73 s; (b) 1.1 m
4. (b) – 130 **i** – 202 **j**; (c) 240 m, 237°
5. (a) **r** = 11.0 **i** + 5.0 **j** – 7.0 **k**, 14.0 (b) 120°
6. Wind comes from NW, 5.7 km hr^{-1}
7. (a) [(5 – 2 sin θ)**i** + 2 cos θ **j**] ms^{-1}; (b) t[(5 – 2 sin θ)**i** + 2 cos θ **j**] ms^{-1}; (c) 20 s, 100 m; (d) 22 s, 92 m
8. -8.3**i** - 33**j** ms^{-2}
9. (a) **v** = 8t **j** + **k**, **a** = 8**j**; (b) parabola
10. 52 m, 27 ms^{-1}, 68 m
11. 2^{nd}
12. (a) 2.0 mm; (b) 1.0×10^{7} ms^{-1}, 11 ° below horizontal
13. (a) 20 ms^{-1}
14. (a) **r** = r(cos θ **i** + sin θ **j**); (b) **v** = rω(-sin θ **i** + cos θ **j**); **a** = -rω^2(cos θ **i** + sin θ **j**) with θ = ωt
15. (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. (e) 42°, 22 m

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 2

FORCES AND PARTICLE DYNAMICS

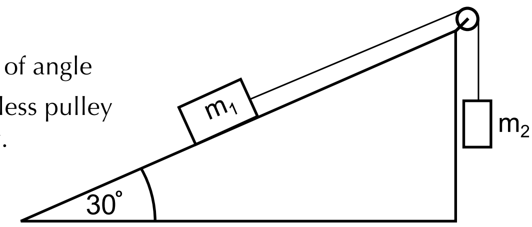
1. Two blocks are in contact on a frictionless table. A horizontal force is applied to one block, as shown.
   (a) If m_1 = 2.0 kg, m_2 = 1.0 kg and F = 3.0 N, find the force of contact between the two blocks.



   (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.

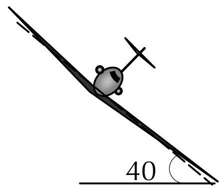
2. A man of mass 100 kg stands in a lift. What force does the floor exert on him when a lift is:
   (a) stationary,
   (b) moving up with constant velocity,
   (c) accelerating upwards at 2.0 ms^{-2},
   (d) moving up but decelerating at 3.0 ms^{-2},
   (e) moving down with acceleration of 4.0 ms^{-2},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

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?

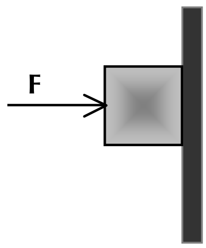


4. A plumb bob hanging from the ceiling of a railway carriage acts as an accelerometer.
   (a) Derive the general expression relating the steady horizontal acceleration a of the carriage to the angle θ made by the bob with the vertical.
   (b) Find a when θ = 20°. Find θ when a = 2.0 ms^{-2}.

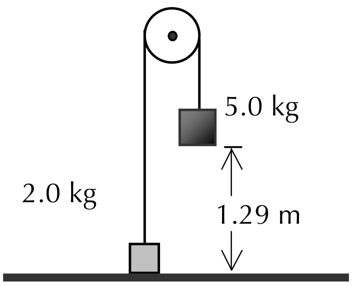
5. An airplane is flying in a horizontal circle at a speed of 480 km/h. If the wings of the plane are tilted 40^o to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the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



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 (include the direction)?



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.

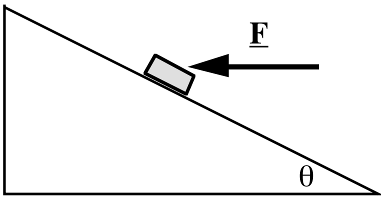
8. (a) A particle of mass m is travelling along the x-axis such that at t = 0 it is located at x = 0 and has speed v_o. The particle is acted upon by a force which opposes the motion and has magnitude proportional to the square of the instantaneous speed. Aerodynamic drag obeys this relationship. (Take 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.

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.

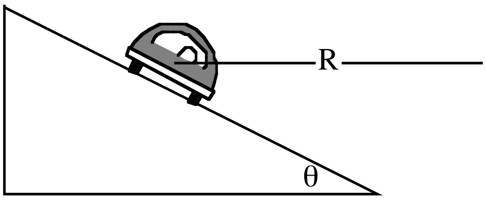
(ii) Take $\mu_s = 0.85$ and $\mu_k = 0.78$. Calculate the braking distances for the two cases v = 50 kilometers per hour and 80 kilometers per hour.

(b)



(i) A mass m is on a plane inclined at an angle θ to the horizontal. A **horizontal** force $\underline{\mathbf{F}}$ 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 $\underline{\mathbf{F}}$.

(ii) Derive an expression for the power applied by $\underline{\mathbf{F}}$ in case (i). (i.e., for the rate at which $\underline{\mathbf{F}}$ 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

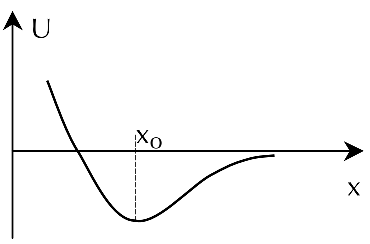
WORK, ENERGY, CONSERVATION OF ENERGY

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.

10. The potential energy between two molecules is modeled as

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

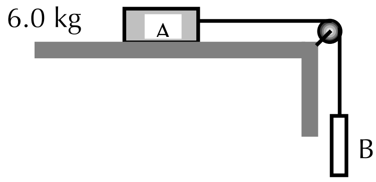
where A, B are positive constants.



   (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.

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.

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.

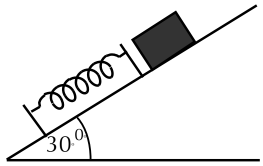


(a) By applying Newton's second law (or otherwise), calculate the acceleration of the system and the tension force in the string.

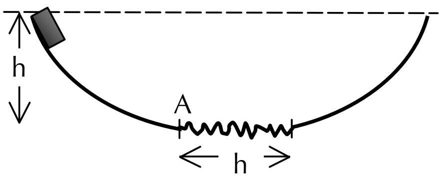
(b) Calculate the kinetic energy of the system after each block has moved a distance of 1.5 m from rest.

(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?

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.



14.

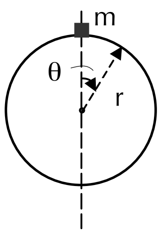


A block of mass m is released from one end of a track with the shape shown. The curved parts are frictionless and the horizontal part has coefficient of kinetic friction $\mu_k = 0.15$

(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)?

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.

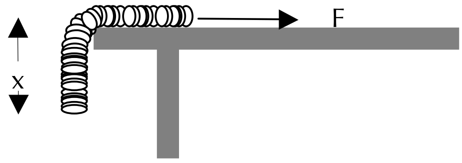
16. A uniform rope of total mass m and length ℓ is **slowly** pulled onto a smooth table as shown.

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

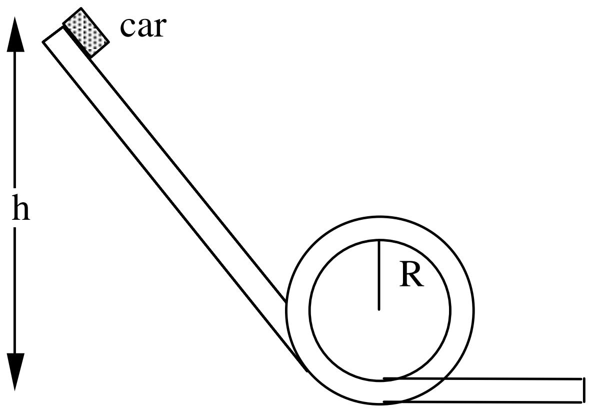
(b) Sketch F as a function of x

(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.



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 track throughout the trip? Explain briefly.

Answers to set 2

1. (a) 1.0 N
2. (a) 9.8×10^2N up; (b) 9.8×10^2N up; (c) 1.2×10^3N up; (d) 6.8×10^2N up; (e) 5.8×10^2N up; (f) 1.5×10^3N up
3. (a) 0.98 ms^{-2}; (b) 18 N
4. (a) a = g tan θ; (b) 3.6 ms^{-2}, 12°]
5. (a) 2.16 km
6. (a) No; (b) 67 N, directed 64° away from the vertical wall
7. (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) (i) $v = \frac{mv_o}{\beta v_o t + m}$, (ii) $x = \frac{m}{\beta}\,\ell n\left(1+\frac{\beta v_o t}{m}\right)$, (iii) $a = -\frac{\beta m v_o^2}{(m+\beta v_o t)^2}$

   (b) (i) $v = v_o e^{-\beta x/m}$ (ii) $a = -\frac{\beta v_o^2}{m}\,e^{-2\beta x/m}$
9. (a) zero; (b) 30 J; (c) –30 J; (d) 0.23
10. (a) $F = \frac{12A}{x^{13}} - \frac{6B}{x^7}$; (b) $\left(2A/B\right)^{1/6}$
11. (a) 28.8 J; (b) 5.15 ms^{-1} towards origin
12. (a) 2.2 ms^{-2}; 31 N; (b) 32 J; (c) 26 J
13. 4.0 m
14. (a) 0.85 h; (b) 7
15. (a) –mgr(1 – cos θ); (b) mgr(1 – cos θ), (c) 2g(1 – cos θ); g sin θ; (d) cos^{-1} 2/3
16. (a) mgx/ℓ; (c) 1/2 mgℓ; (d) 1/2 mgℓ

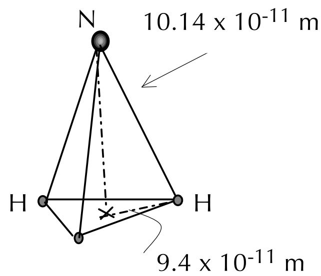
PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 3

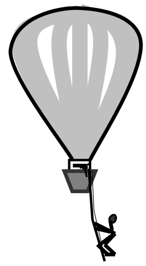
MOMENTUM AND CENTRE OF MASS

1. 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.

2. 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.



3. 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?

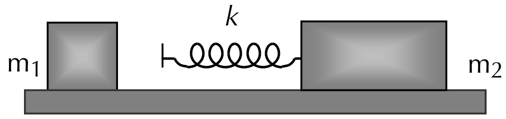


CONSERVATION OF MOMENTUM, COLLISIONS

4. 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?

5. 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.)

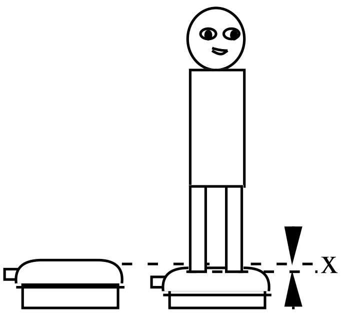
6. A radioactive nucleus, initially at rest, decays by emitting an electron and neutrino at right angles to one another. The momentum of the electron is 1.2×10^{-22} kg ms^{-1} and that of the neutrino is 6.4×10^{-23} kg ms^{-1}.

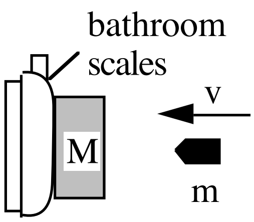
(a) Find the direction and magnitude of the momentum of the recoiling nucleus.

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

7. 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 after a very brief collision.

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

8. 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.

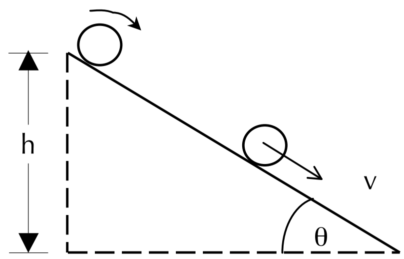
9. Assume the Earth to be a sphere of uniform density.

(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.

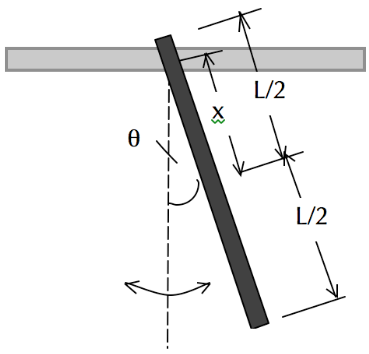
(b) Suppose this energy could be harnessed for peoples' use. For how long could the Earth supply 1 kW of power to each of the ~ 10^{10} persons on Earth?

10. 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.

11. 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?



12.



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.

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

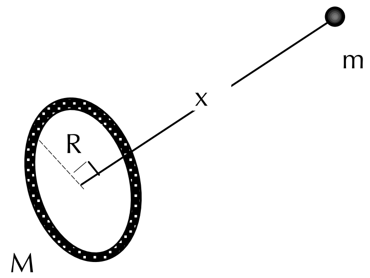
13. How does g, the acceleration due to gravity, vary with height above the Earth? (Neglect the Earth's rotation)
   (a) Assuming a uniform Earth calculate the value of g:
      (i) at a height of 10,000 m above the Earth
      (ii) at a height of 200 km (in the top of the ionosphere)
   (b) How high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

14. Certain neutron stars (extremely dense stars) are believed to be rotating at about one revolution per second (they are sending radio waves towards the Earth at this frequency). 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.

15. 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.

16. 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, that we can neglect dark matter, and that our Sun is essentially at the edge of that sphere, estimate roughly the number of stars in the galaxy.

17. 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.



REVISION

18. A particle of mass 2 kg moves in the X-Y plane so that its position is $\mathbf{r}(t) = 3t\mathbf{i} + (1+t^2)\mathbf{j}$ 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 $\tau = \frac{d\mathbf{L}}{dt}$

19. An α-particle collides with an oxygen nucleus, initially at rest. The α-particle is scattered at an angle of 64^o from its initial direction of motion and the oxygen nucleus recoils at an angle of 51^o 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.

Answers to Set 3

1. (a) 3**i** – 2**j** – **k**; (b) 18**i** – 12**j** – 6**k**
2. 0.675 x 10^{-11} m toward the plane of the hydrogens, along the axis of symmetry
3. (a) downward with speed mv/(m+M); (b) stationary
4. (a) 35 N.s; (b) 1800 N
5. 24.6 cm
6. (a) 1.4 x 10^{-22} kg ms^{-1}, 150º from the electron track and 120º from the neutrino track. (b) 1.0 eV
8. (a) –2.5 x 10^{-22} rad s^{-2}; (b) 26.5 hrs
9. (a) 2.6x10^{29} J; (b) ~10^9 years
10. a = 5.7 ms^{-2}, T_1 = 37 N, T_2 = 34 N
11. (a) 7/10 Mv^2 ; (b) $(10gh/7R^2)^{1/2}$; (c) 5/7 g sin θ ; (d) $(14h/5g\sin^2\theta)^{1/2}$
12. (a) Mgx sin θ; (c) $2\pi\sqrt{\dfrac{x^2+\frac{1}{12}L^2}{gx}}$; (e) 1.53s, 0.29 m
13. (a) 0.997 g_o (where g_o is value on surface of Earth); 0.94 g_o; (b) 0.41 R_e
14. (a) 4.7 x 10^{24} kg]; (b) 1.4 x 10^{11} kg/m^3
15. (b) 4.22 x 10^7 m; (c) –2.27 x 10^9, 1.13 x 10^9, –1.13 x 10^9 J
16. 5 x 10^{10}
17. (a) $GmMx/(R^2+x^2)^{3/2}$; (b) $-GmM/(R^2+x^2)^{1/2}$; (c) $\left[2GM\left(\frac{1}{R}-\frac{1}{\sqrt{R^2+x^2}}\right)\right]^{1/2}$
18. (a) $y = 1 + \frac{1}{9}x^2$; (b) 3**i** + 2t **j**, 2 **j**; (c) 4 **j**; (d) 12 t**k**, $(6t^2 - 6)$**k**
19. 3.47

PHYS1131 HIGHER PHYSICS 1A

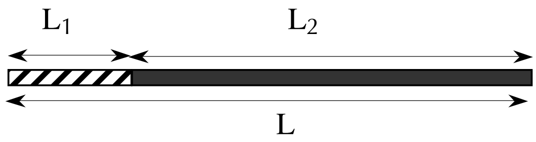
HOMEWORK SET 4

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?

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, $\alpha = 1.1\text{x}10^{-5}$ ºC^{-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 x 10^{-6}/C°. For steel, $\alpha = 1.1\text{x}10^{-5}$ ºC^{-1}, for brass, $\alpha = 1.9\text{x}10^{-5}$ ºC^{-1}.

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?

5. The mass of the H_2 molecule is 3.3x10^{-24} g. If 1.0x10^{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 1.0x10^5 cm/s, what pressure do they exert on the wall?

6. A steel tank contains 315 g of ammonia gas (NH_3) at an absolute pressure of 1.35x10^6 Pa and temperature 77.0˚C.

(a) What is the volume of the tank?

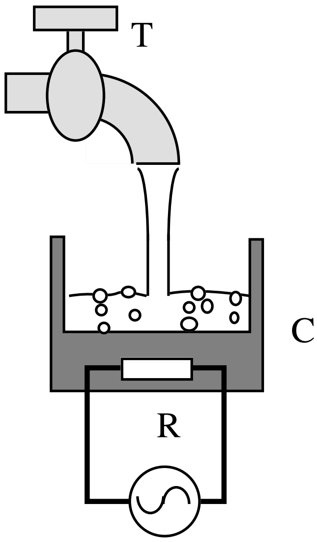
(b) The tank is checked later when the temperature has dropped to 22.0˚C and the absolute pressure has fallen to 8.68x10^5 Pa. How many grams of gas leaked out of the tank?

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)

PAST EXAM QUESTION

a)



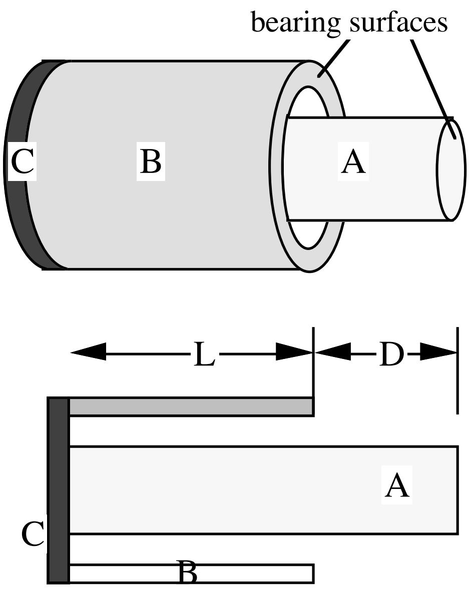
Water at temperature 20 °C flows from a tap T into a heated container C. The container has a heating element (a resistor R) which is supplied with electrical power P, that may be varied.

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)



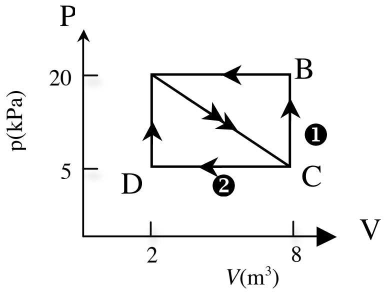
The diagrams show a sketch (top) and cross section of a low expansion mounting. It is designed so that the two bearing surfaces remain separated by a constant distance D, independent of temperature. Part A is a rod, which has length L_o+D_o at reference temperature T_o and is made of material with linear 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.



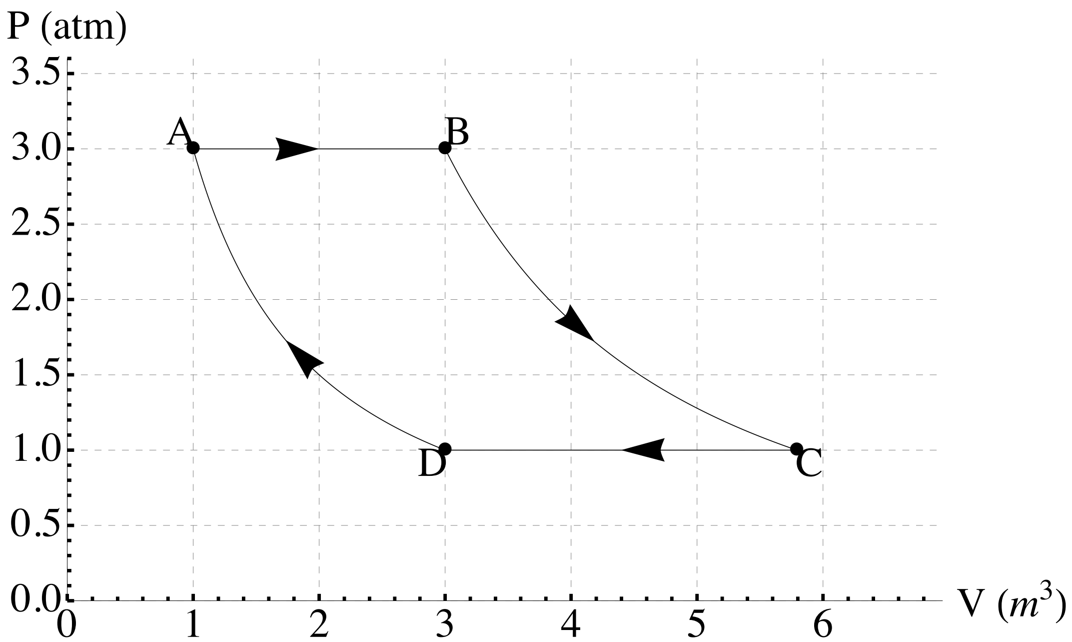
9. A thin tube, sealed at both ends, is 1.00 m long. It lies horizontally, the middle 10.0 cm containing mercury and the two equal ends containing air at standard atmospheric pressure. If the tube is now turned to a vertical position, by what amount will the mercury be displaced? Assume that the process 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.)

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 $c_V = 5R/2$.

PAST EXAM QUESTION

The diagram below shows a monatomic ideal gas undergoing a cyclic process. The states A, B, C and D are marked on the diagram. As the gas goes from state A to state B 1515 kJ of heat energy enter the system. As the gas goes from state C to state D 704.5 kJ of heat energy leaves the system. The process from B to C is adiabatic and from D to A is isothermal. The volume at C is 5.79 m^3.



(i) Calculate the work done on the gas as it goes from state A to state B.
(ii) What is the change in internal energy as the gas goes from state D to state A?
(iii) What is the change in internal energy as the gas goes from state B to state C?
(iv) Write down an equation relating P and V as the system goes from state B to state C. You should calculate as many of the constants in the equation as possible, giving an explanation of how you have calculated each one.

Answers to set 4

1. 31.2
2. 2.3×10^{-5} C^{-1}
3. 39.3 cm steel and 13.1 cm brass
4. 5.59 m^3
5. 0.19 N/cm^2
6. (a) 0.0399 m^3; (b) 75 g
7. 89.0˚C
8. 45 kJ along path 1; -45 kJ along path 2
9. (a) 2.95 cm; (b) 2.11 cm
10. 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, **(^{o}C)$^{-1}$**	**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

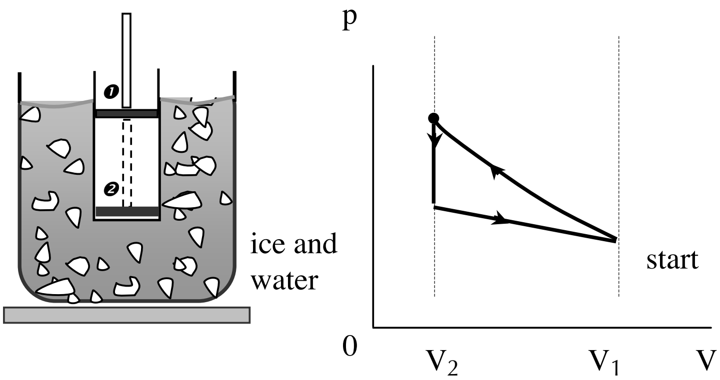
Quantity	**Value**
Specific Heat (liquid)	4186 Jkg^{-1}K^{-1}
Latent heat of Fusion	3.33×10^{5} Jkg^{-1}
Latent heat of vaporization	2.26×10^{6} Jkg^{-1}
Density (at 4^{o} C)	1000 kgm^{-3}
Melting point (at 1 atm)	0.000 °C
Boiling point (at 1 atm)	100.0 °C
Volume expansion coefficient (β) (at 20^{o}C: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

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?

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 ?

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?

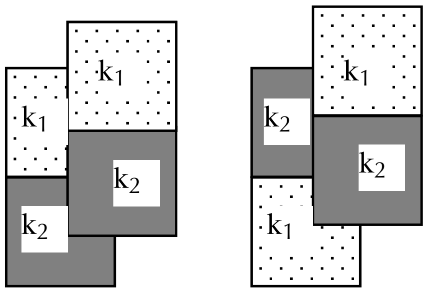


(a) *(b)*

HEAT TRANSFER

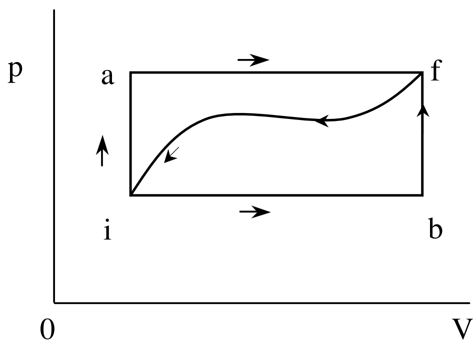
4. (a) Calculate the rate at which body heat flows out through the clothing of a skier, given the following data: the body surface area is 1.8 m^2 and the clothing is 1.0 cm thick; skin surface temperature is 33˚C, whereas the outer surface of the clothing is at 1.0˚C; the thermal conductivity of the 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.

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.

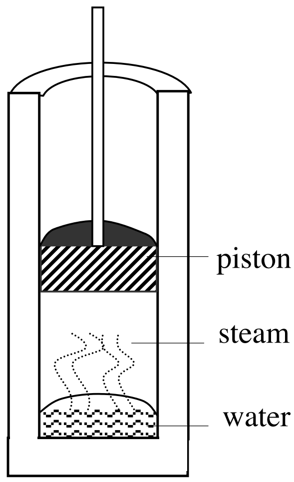
(a) What is **W** along the path **ibf**?
(b) If **W** = +13 J for the curved return path **fi**, what is **Q** for this path?
(c) Take $E_{int,i}$ = 10 J. What is $E_{int,f}$?
(d) If $E_{int,b}$ = 22 J, find **Q** for process **ib** and process **bf**.

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.

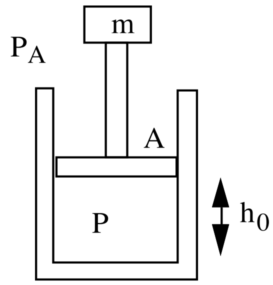
(a) Calculate the rate of condensation of steam.

(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?



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

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 $t=0$.

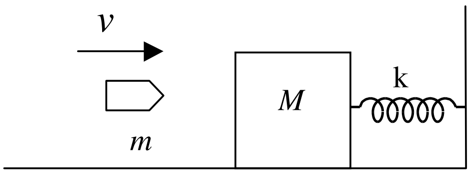
10. A block is on a piston which is moving vertically with simple harmonic motion of period 1.0 seconds.

   (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?

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.

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.

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. After a very hard collision, the bullet remains embedded in the block. Determine the amplitude of the resulting simple harmonic motion, in terms of m, M, v and k.



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 Ncm^{-1}. If the system is released from rest at a position in which the spring is stretched by 23.9 cm, find:

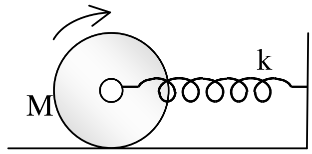
(a) the translational kinetic energy, and

(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:

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

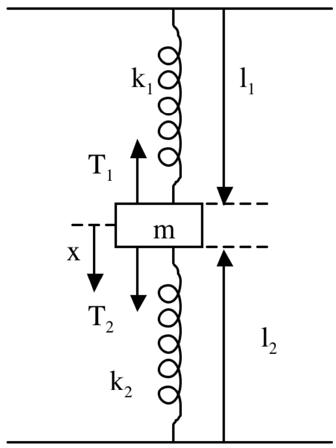
where M is the mass of the cylinder



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

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

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



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

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

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.

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?

Answers to set 5

1. (a) 84.8 kJ; (b) 4.46 kJ; (c) 835˚C.]
2. (a) 5.2˚C; no ice left; (b) 0˚C, 0.062 kg ice left
3. 3.4 x 10^4 J
4. (a) 230 J/s; (b) Heat flows out about 15 times as fast
5. (a)
6. (a) -6.0 J; (b) -43J; (c) 40 J; (d) 18 J; 18 J
7. (a) 0.360 mg/s; (b) 0.814 J/s; (c) –0.694 J/s
8. (a) 3.0m, b) $v = -9\pi\sqrt{3}$ $\mathrm{ms^{-1}}$, c) $a = -27\pi^2$ $\mathrm{ms^{-2}}$, d) $\phi = \pi/3$ is the phase constant, e) v = 1.5Hz. f) 2/3 sec
9. (a) T=4.19s, f=0.239Hz, b) x=2cos(1.5t)
10. a) x = 0.25m, b) f = 2.2Hz
11. $k_1 = k\left(\frac{n+1}{n}\right)$; $k_2 = k(n+1)$
12. 8/9
13. $$\frac{mv}{\sqrt{k(m+M)}}$$
14. (a) 5.60 J,(b) 2.80 J
15. $$\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m}}$$
16. (a) 0.1 m, 1.0 Hz, 2 $\mathrm{ms^{-1}}$, 2m; (b) 0.63 $\mathrm{ms^{-1}}$
17. 130 $\mathrm{ms^{-1}}$

PHYS1131 HIGHER PHYSICS 1A

HOMEWORK SET 6

WAVE MOTION

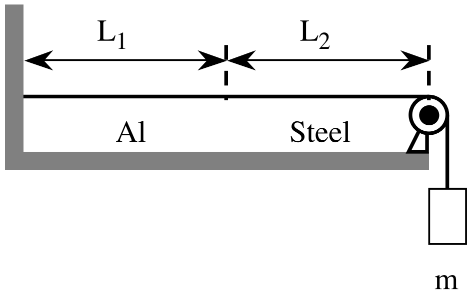
1. A wave of frequency 500 Hz has a *phase* velocity of 350 ms^{-1}. *["Phase" velocity is "speed" or "velocity" of wave. It is the velocity that any given "phase" propagates at; eg. The crest or trough of a wave.]*
   (a) How far apart are two points 60° out of phase?
   (b) What is the phase difference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

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?

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 displacement nodes observed at this frequency, excluding the two at the ends of
   the wire?

4. A harmonic wave is given by the function

$$y = (2.0m)\sin\left(2\pi(x - vt)/\lambda\right)$$

   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?

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

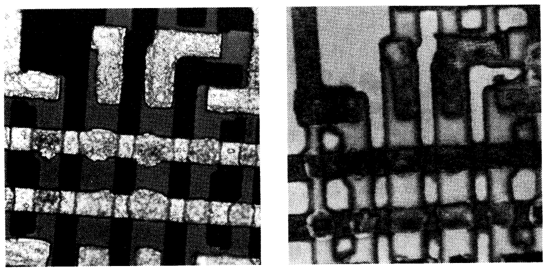
$$y(x,t) = A \sin \frac{2\pi}{\lambda}(x - vt)$$

   can be written in the alternative forms

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

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

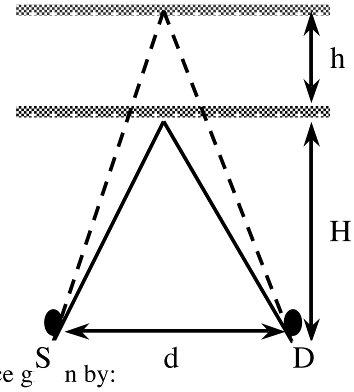
6. The figure here shows part of a computer circuit (the surface of a processor or memory chip) viewed in two different types of microcope. The left figure was obtained by a regular optical light microscope. The view on the right was produced by an acoustic microscope by focusing 3 GHz ($3x10^9$ Hz) 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)



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.
Hint: Consider a thin spherical shell with thickness $v.dt$.

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.



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

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

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

10. A note of frequency 300 Hz has an intensity of $I = 1.0\ \mu W\ m^{-2}$. 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 $1.21\ kgm^{-3}$. What about if $I = 10$ pW m^{-2}, close to the threshold of human hearing at this frequency?

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).

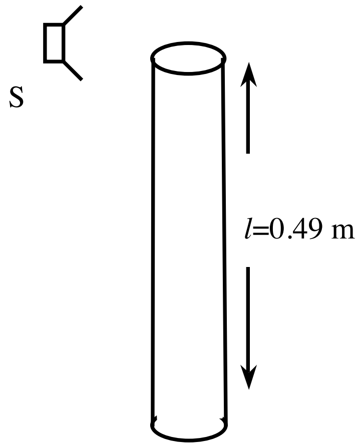
13. S in the figure opposite is a small loudspeaker driven by an audio oscillator and amplifier, adjustable in frequency from 1000 to 2000 Hz only. D is a cylindrical pipe, length l=0.49 m.

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? Neglect end effects.

(b) Sketch the displacement modes for each.

(c) Explain what end effects are and how they would change your results in the real case.



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?

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?

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 ~ 10^5 Pa . What value of displacement amplitude does this correspond to at a frequency f = 1000Hz ? Take the density of air to be ρ_{air} =1.22 kgm^{-3} and the speed of sound at 37° C to be 353.7 ms^{-1}.

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})

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 you expect 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?

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?

Set 6 answers

1. (a) 0.12 m; (b) 180°
2. (a) 0.25 cm, 120 cm s^{-1}; (b) 3.0 cm; (c) zero
3. (a) 323 vib/sec; (b) 6
4. 0 m
5. –
6. 500 nm
7. 474 nJ m^{-3}
8. $$\lambda = 2\sqrt{4(H+h)^2 + d^2} - 2\sqrt{4H^2 + d^2}$$
9. 2.00P, 1.41P, 1.73P, 1.85P
10. 3.7×10^{-8} m, 1.1×10^{-10} m (about the size of an atom!)
11. –
12. (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. (a) 1038, 1384, 1730 Hz
14. 387 Hz
15. (a) 6 ms^{-1}; (b) $y = 0.04 \sin 2\pi(20t - \frac{x}{0.3})$; (c) 1.6π ms^{-1}
16. 0.011 mm
17. (a) 0.35 m; (b) 0.33 m; (c) 58 Hz
18. (a) increased by 2.64 Hz; (c) 0.572 m; (d) 287 Hz; (e) 594 Hz
19. (a) 485.8 Hz; (b) 500.0 Hz; (c) 486.2 Hz; (d) 500.0 Hz