PHYSICS EXAMINATION PROBLEMS
SOLUTIONS AND HINTS FOR STUDENT SELF-STUDY

Module Code	**PHY1002**
Name of module	**Thermal Physics**
Date of examination	**June 2006**

1

(a) $A = 3.906 \times 10^{-3}\ °C^{-1}$ $B = -6.00 \times 10^{-7}\ °C^{-2}$

(b) $T = 380.68\ °C$

(c) $\dfrac{dR}{dT} = R_0(A + 2BT)$

2

The number of gas molecules is 25.
The only true statement is (a).
The estimated size of the nitrogen molecule is 0.25 nm.

(d) $\gamma = 1.4$

(e) The number of degrees of freedom is $\nu = 5$. Therefore the gas consists of diatomic molecules with 3 translational and 2 rotational degrees of freedom.

(f) $C_V = 20.79\ \text{J mol}^{-1}\ \text{K}^{-1}$ $C_P = 29.10\ \text{J mol}^{-1}\ \text{K}^{-1}$

3

The thermal conductivity of human skin is $k = 0.0181\ \text{W m}^{-1}\ \text{K}^{-1}$.

$t = 30$ s

4

(d) $W = 207.85$ J

(e) $\Delta U = 311.78$ J

(f) $Q = 519.63$ J

5

(a) $T = 5.56 \times 10^{9}$ K

(b) $v_{rms} = 8.3 \times 10^{6}\ \text{m s}^{-1}$

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Module Code	**PHY1002**
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1 The temperature of the water before the insertion of the thermometer was 41.4°C.

2 The temterature of the water in half an hour will be 21.03°C.

$$\frac{r_1}{r_2} = \sqrt{\frac{k_c}{2(k_c - k_l)}} = 0.741,$$

where k_c and k_l are the thermal conductivities of copper and lead, respectively.

$R = 2.8 \times 10^{11}$ m.

3 (d) $W = 1548.4$ J
(e) $\Delta U = 0$
(f) $Q = 1548.4$ J
(h) $\Delta U = -1275.8$ J
(i) $W = 1275.8$ J

4 $\Delta U = 1.3 \times 10^6$ J

5 (c) $\frac{\langle E_1 \rangle}{\langle E_2 \rangle} = 2.098$

(d) $\frac{v_1}{v_2} = 1$

PHYSICS EXAMINATION PROBLEMS
SOLUTIONS AND HINTS FOR STUDENT SELF-STUDY

Module Code	**PHY1003**
Name of module	**Properties of Matter**
Date of examination	**January 2007**

1

(a) Stress: between 0 and 1×10^{10} Pa.
Strain: between 0 and 0.01.

(c) $Y = 1 \times 10^{12}$ Pa.

(d) Maximum elongation $\Delta l_{max} = 5.85$ cm.

(e) $R = 6$ mm.

2

$P = 2.53 \times 10^5$ Pa

$$\frac{V_0}{V} = 0.89$$

4

(a) $I = 2.698 \times 10^{-47}$ kg m^2

(b) $m = 5.15 \times 10^{-26}$ kg

PHY1104, June 2007, Hints and Tips

1) The nett charge is zero.

3) For the last part, take only the downwards component of the force from each element.

5) Use conservation of energy for the last part.

PHYSICS EXAMINATION PROBLEMS
SOLUTIONS AND HINTS FOR STUDENT SELF STUDY

Module Code	PHY1105
Name of Module	Relativity 1 and Vectors
Date of Examination	January 2007

1 Make use of work-energy theorem.

(i).d. answer is 35.3 m s^{-1}.
(ii) a. you should find the KE to be the same
(ii) c. you should find the ration to be $1/\sqrt{2}$

2 the 1250 rpm machine is best

Windmill – key here is to note that tip moves though air with a combination of tip speed (rotation) and air speed.

Max radius is 21 m.

Force is 3.3 kN.

3

(ii) a. 0.6 c.
(ii) b. 3.2 m.
(ii) c. No

4

(a) final mass is $7.7\text{x}10^5$ kg.
(b) time = 149 s.
(c) 2 ms^{-2}.
(d) 34 ms^{-2}.

5

(ii) a. $7.9\text{x}10^8$ m.

(ii) b. $2\text{x}10^8$ ms^{-1}.

PHYSICS EXAMINATION PROBLEMS
SOLUTIONS AND HINTS FOR STUDENT SELF-STUDY

Module Code and Lecturer	PHY1106: PV
Name of module	Waves and Oscillations
Date of examination	June 2007

1. Each term (e.g. mx, -bx, -kx and $F_0\exp(j\omega t)$) represent forces such as net force, damping force, restoring force and driving force etc. This must be specified in detail.
Then specify that "net force = sum of forces" and show how this leads to the final equation of motion.

Differentiate x in the normal way; once to derive the equation for velocity and a second time to derive the equation for acceleration. Then state the relevance of the "j" operator w.r.t. phase (i.e. 90 degrees phase change" and show how this is represented in each of the derived expressions.

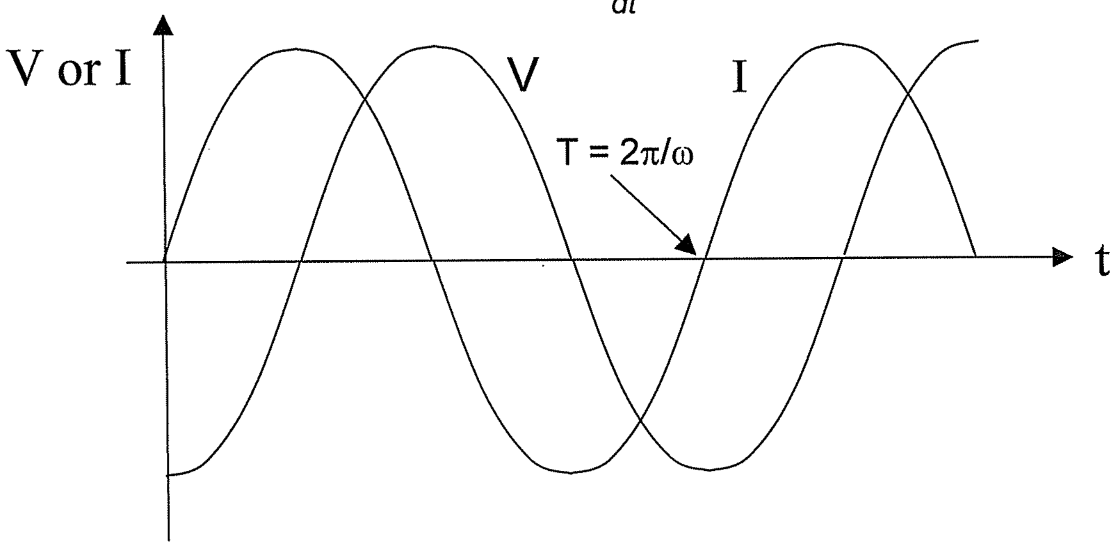
At resonance, $\phi = 0$, so the velocity and driving force are in phase (refer to expressions).

Power factor is defined as **cos** ϕ, where $\cos\phi = \frac{R}{|Z_m|} = \frac{R}{\sqrt{R^2 + \left(\omega m - \frac{k}{\omega}\right)^2}}$

At resonance, $\omega m - \frac{k}{\omega} = 0$ and therefore $\cos\phi = 1$.

Max. power is absorbed when $|Z_m|$ is minimum. Therefore when; $P_{av}(\text{max}) = \frac{F_0^2}{2R}$.

2. For an inductor, $V_L = j\omega L I_L$. Therefore, V and I are 90 degrees out of phase w.r.t. each other. Here, V leads I. Explain that this occurs due to the nature of Lenz's law working in the principle behind an inductor due to; $V = -L\frac{dI}{dt}$.



The type of behaviour in an LCR circuit is dependent on the driving frequency ω due to the nature of the impedances associated with each component (these should be stated clearly). Therefore,

at high ω, capacitive behaviour dominates
at low ω, inductive behaviour dominates.

For this calculation, use formula for resonant frequency; $\omega_0 = \frac{1}{\sqrt{LC}}$ and rearrange to find C.

Remember to convert (Hertz) frequency to angular freq. !

$C = 1.8 \times 10^{-12}$ F = 1.8 pF.

For the next calculation, use both the formula for Q provided and also the resonant freq. formula given above (i.e. for ω_0).

Then calculating; $R = 6283\ \Omega$ and $C = 2.533 \times 10^{-13}$ F = 0.2533 pF.

Use the formula for electrical power; $P_{av} = \frac{V_0^2}{2|Z|}\cos\phi$ and the fact that at resonance, $P_{av} = \frac{V_0^2}{2R}$.

Therefore; $P_{av} = 8\times 10^{-3}$ W.

3. Use standard lecture notes for definitions of dispersion, phase velocity and group velocity.

Relation for group velocity: $v_g = \frac{d\omega}{dk}$

Use standard relation for phase velocity: $v_{ph} = \frac{\omega}{k} = \left(\frac{T}{\rho} + \alpha k^2\right)^{1/2}$.

Standard differentiation required to verify expression for group velocity.

Show that $V_{ph} < V_g$ and therefore if this is the case you can say that the dispersion is anomalous.

4. The variable v represents phase velocity where $v = \sqrt{\frac{T}{\rho}}$.

Verify this is dimensionally correct in the normal way.

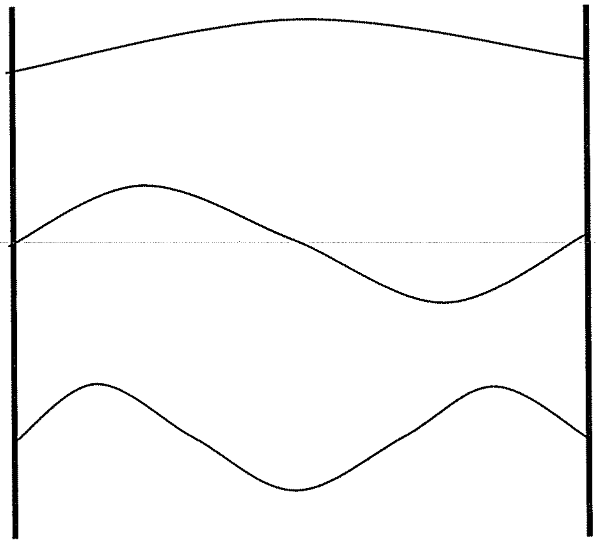
Mass density $\rho = 0.1$ kg m^{-1}. $v = 20$ ms^{-1}.

To show that z(x,t) is a solution, differentiate and substitute in the normal way (shown in lectures) to yield that $v = \omega/k$.

General form of solutions:

Since $k = \dfrac{2\pi}{\lambda}$

then; $k = 2\pi . \dfrac{n}{2L} = \dfrac{n\pi}{L}$



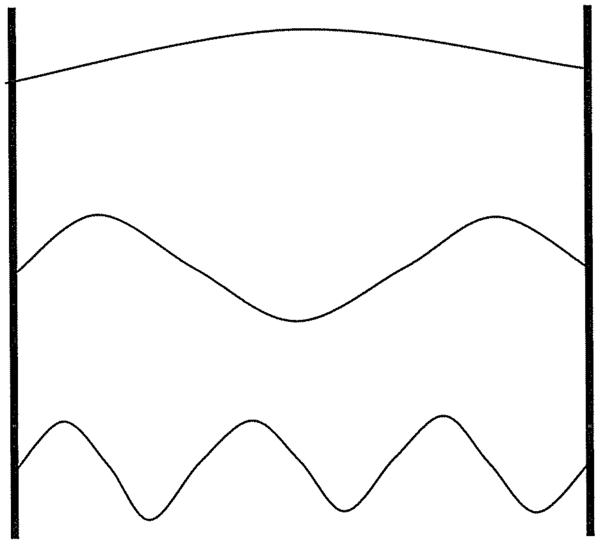
$L = \dfrac{\lambda}{2}$

$L = \dfrac{2\lambda}{2}$

$L = \dfrac{3\lambda}{2}$

Therefore, $L = \dfrac{n\lambda}{2}$ and hence $\lambda_n = \dfrac{2L}{n}$

Therefore the first, third and fifth vibrational modes are:

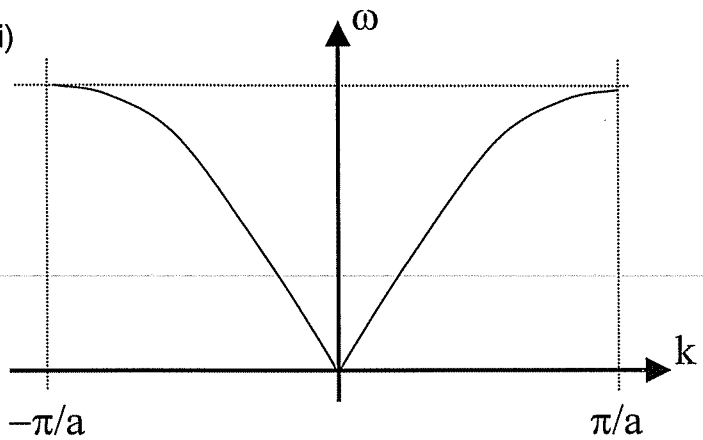


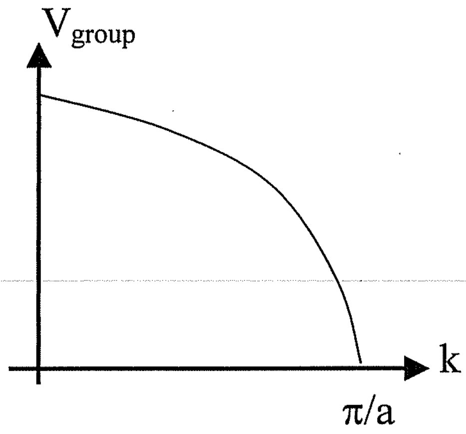
1st mode $k_1 = \dfrac{\pi}{L}$

3rd mode $k_3 = \dfrac{3\pi}{L}$

5th mode $k_5 = \dfrac{5\pi}{L}$

5. (i)





Cut-off frequency $\omega_{max} = 2\left(\frac{T}{ma}\right)^{1/2} = 283\ s^{-1}$.

(ii) a) Amplitude is unchanged. Resonant freq. decreases by $\sqrt{2}$. PE and KE are unchanged.

b) Standard equation of motion (i.e. use net force = restoring force).
Differentiate $x = A \cos \omega t$ to produce velocity and acceleration. Substitute into equation of motion to obtain standard expression for resonant frequency ($\omega = \sqrt{(k/m)}$).

c) Calculate k (=50 N/m) and then use resonant frequency formula to give
$\omega = 7.1\ s^{-1}$ and then f = 1.1 Hz.

Hints for PHY1115

1. (a)

$$x = 19/6 \pm \sqrt{313}/6 = 6.1153, \quad .21803$$

(b) Multiply the columns to eliminate two variables gives $x = 20/3,\ y = 4/3,\ z = 46/3$.

2. (a)

$$\frac{19x + 10}{(2x-5)(3x+4)}$$

(b) Dividing through yields

$$(x-5)(x^2 - 6x - 5)$$

3. (a)

$$4\cosh x - 5\sinh x = \frac{1}{2}(9e^{-x} - e^{x})$$

(b) Use $e^x = 1 + x,\ \exp(2y) = 1 + 2y$ to get

$$\cosh y = (1 + 2y + 1 - 1 - 2y)/2 = 1 + 2y^2 + O(y^4)$$

4.

$$\mathbf{a} \wedge \mathbf{b} = (10, -14, 13)$$
$$\mathbf{a} \cdot \mathbf{b} = 17$$

Angle between vectors is $\cos^{-1}(17/\sqrt{754}) = \cos^{-1} .61910 = 0.903$.

5. (a)

$$f(x) = \exp(\frac{1+x}{1-x})$$
$$f'(x) = (-\frac{1}{1+x} - \frac{1-x}{(1+x)^2})f(x)$$
$$= \frac{-2}{(1+x)^2}f(x)$$

(b)

$$f'(x) = -e^x(3x^2 - 5x - 1)$$

Hence $f'(x) = 0$ when $x = 5/6 \pm \sqrt{37}/6$ where $f''(x) < 0$ for positive root $x = 1.8471$.

6. (a)

$$f(x) = \exp(\sqrt{x}) = \exp(1) + \frac{(x-1)}{2}\exp(1) + 0(x-1)^2\exp(1) + O(x^3)$$

(b)

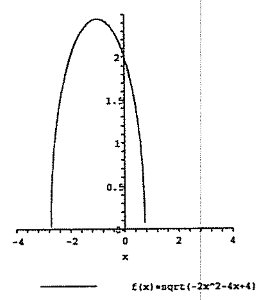
$$\int dx\ x\ln x = \frac{x^2}{2}\ln x - \frac{1}{4}x^2 + C$$
$$\int \frac{dx}{4 - x^2} = -\frac{1}{4}\ln(x-2) + \frac{1}{4}\ln(x+2) + C$$
$$\int_0^\pi dxx\ \sin x = sin(\pi) - \pi\cos(\pi) = \pi$$

7. (a)

$$\frac{1}{2+3i} + \frac{3}{2-3i} = \frac{8}{13} + \frac{6i}{13}$$

(b) $z = 2 - 3i = r\exp(i\theta) = \sqrt{13}\exp(i\tan^{-1}(-3/(-2))) = \sqrt{13}\exp(-2.159i)$.

8. (a) See sketch.



(b) Integrating we get

$$\frac{dx}{dt} = -2e^{-2t} + c$$
$$x = e^{-2t} + ct + d$$

9. (a)

$${}^{52}C_3 = 52 \times 51 \times 50/6 = 22100$$

Ace occurring exactly once in $4 \times {}^{48}C_2 = 4512$

PHYSICS EXAMINATION PROBLEMS
SOLUTIONS AND HINTS FOR STUDENT SELF-STUDY

Module Code	**PHY1116**
Name of module	**MATHEMATICS FOR PHYSICISTS**
Date of examination	**June 2007**

1. (i) $\dfrac{\sin ax}{ax} = \sum_{n=0}^{\infty} (-1)^n \dfrac{(ax)^{2n}}{(2n+1)!}$; limit is 1 (ii) $\sqrt[3]{i} = \exp\left(\dfrac{i\pi}{6}\right)$, $\exp\left(\dfrac{5i\pi}{6}\right)$, $\exp\left(\dfrac{3i\pi}{2}\right)$

   (iii) 0.2079 (4sf)

2. (i) $\mathbf{AB} = \begin{pmatrix} 3 & -4 & 0 \\ 4 & 3 & 0 \\ 0 & 0 & -1 \end{pmatrix}$ (ii) determinant is zero (one row all zeros)

   (iii) there are non trivial solns (det of matrix is zero)

3. (i) $(x,y,z) = (0.5, 0.866, 0)$; $(\rho,\varphi,z) = (1, \pi/3, 0)$

   (ii) $f_x = -y\sin xy + \cos(x-y)$; $f_y = -x\sin xy - \cos(x-y)$

   $\dfrac{dy}{dx} = \dfrac{-y\sin xy + \cos(x-y)}{x\sin xy + \cos(x-y)} = 1$ at $(0,0)$

4. Length = 2.086 (4sf)

5. Volume = $(e-1)^2 = 2.95$ (3sf)

6. (i) coplanar $\rightarrow \mathbf{a}\bullet(\mathbf{b}\times\mathbf{c}) = 0$; (ii) require grad (phi) to be perpendicular to vector

7. (i) $\nabla\phi = 3r\mathbf{r} = 3r^2\hat{\mathbf{r}}$ (ii) $4\pi R^3$

8. (i) $y = \dfrac{5}{3} + \dfrac{C}{(1+x^2)^{3/2}}$

9. $\sin^2 x = \dfrac{1}{2} - \dfrac{1}{2}\cos(2x)$ (Note this is exact, and can be arrived at using trig formulae, avoiding any integrals altogether)

10. $F(k) = \sqrt{\dfrac{2}{\pi}}\dfrac{1}{k^2}(1-\cos ka)$

PHY1118

UNIVERSITY OF EXETER

SCHOOL OF PHYSICS

QUANTUM AND ASTROPHYSICAL PHENOMENA

January 2007

Hints and tips

1. vii) Convert 400 nm to energy in eV; subtract 0.6 eV. What energy remains?

2. ii) Differentiate the expression relating λ, f and c.

   iii) Convert $\Delta\lambda$ to Δf, then use uncertainty relation involving Δt.

   iv) Do not forget that this is a three dimensional problem.

3. iv) alpha particle is a helium-4 nucleus. Potential energy diagram should indicate regions of attractive strong nuclear force, electrostatic repulsion and the Coulomb barrier.

   v) The radioactivity would drop to 10% of its initial value after 5315years.

4. i) Big Bang nucleosynthesis (elements up to lithium and beryllium) and stellar nucleosynthesis (which can form heavier elements in stars and in supernova collapse).

   ii) a) Solar mass star ends life as a white dwarf, after core nuclear burning first to helium, then to carbon.

   b) Massive star will end life as a supernova, after it burns its core to iron (with fusion of lighter elements in surrounding shells). Fusion of iron is endothermic, causing rapid collapse and creation of a black hole or neutron star; the shock-wave destroys the star in a supernova explosion.

   iii) Main sequence is where a star is core-hydrogen-burning. The O-star converts a mass of 8.5×10^{13} kg to energy per second, creating 1.9×10^{42} He atoms per second.

Assuming the core contains 10% of the mass, this corresponds to a lifetime of 7.5×10^6 years.

5. ii) Line redshifted due to the expansion of the Universe.

Hubble's constant (H_0) relates the distance (d) to the recession velocity (v): $v=H_0d$

$v=2\times10^7$ m s^{-1} , d=285Mpc

PHY1118

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