McGill University

PHYS 101

(Introduction to Mechanics for the Life Sciences)

FINAL EXAM

December 12, 2006
9:00 AM – noon

Examiner: K.J. Ragan x6518
Associate Examiner: J. Crawford x7029

The exam comprises two parts on four pages (including this page): 10 short answer questions, and 7 problems. A formula sheet is attached to the back of the exam. No books or notes of any kind are allowed. Calculators are allowed.

Answer **all the short answer questions** with a few words or a few short phrases.
For the problems, your grade will be calculated with the **best five problems**. Show your work.

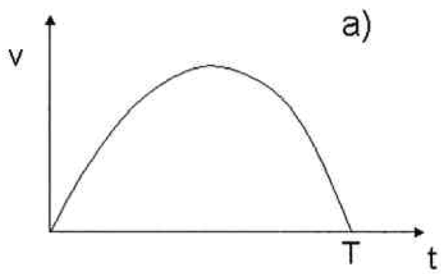
The short answer problems are worth two points each, and the problems are worth 10 points each. Put all answers in the **answer booklets** provided; you may keep this exam.

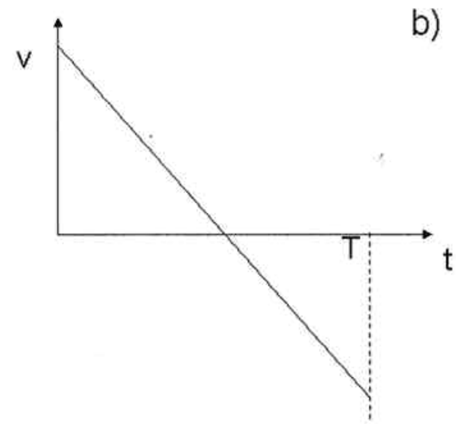
Good luck !

Short answer questions (answer all): you should not need to do any calculations for these questions, and should answer in **a few words, a few short phrases, or a simple sketch.** In some cases you might find it useful to quote an appropriate formula.

1) [2 pts] Tarzan is perfecting the timing of his vine-swinging, hoping to be able to impress Jane. He wonders if he has to change his timing when he has Jane on the vine with him. Assuming that the vine length is the same, what can you saw about the period of the swing of the vine when he is alone, or with Jane? Assume small amplitude swings.

2) [2 pts] For the two plots of velocity vs. time (v vs. t) shown below, which, if any, best represents the motion of a ball thrown vertically up in the air and caught some time T later?





3) [2 pts] Would you expect sound waves, or light waves, to diffract more (ie, have a larger diffraction angle) when they pass through the same opening such as a doorway? Why?

4) [2 pts] Two balls of different mass (but equal size) are thrown vertically upwards into the air, with the same initial velocity. They do not collide. Which ball, if any, reaches the greatest height ?

5) [2 pts] A physics student plays with two examples of simple harmonic motion: a mass on a spring and a simple pendulum. She finds that each of the two has a period of 1.0 sec. She's an astronaut, and on her next trip to the moon takes each along and measures the periods there (on the surface of the moon). For each system, state whether she will find the new period to be shorter than 1.0 s, longer than 1.0 s, or equal to 1.0 s (you don't need to calculate the new periods).

6) [2 pts] You are standing on Sherbrooke Street and you hear an emergency vehicle siren at 580 Hz. You know that the 'natural' frequency of the siren (if you are motionless with respect to the vehicle) is 600 Hz. Should you jump out of the way? Why or why not?

7) [2 pts] A rocket following a parabolic path suddenly explodes. What can you say about the resulting motion of the 'system' composed of all of the pieces?

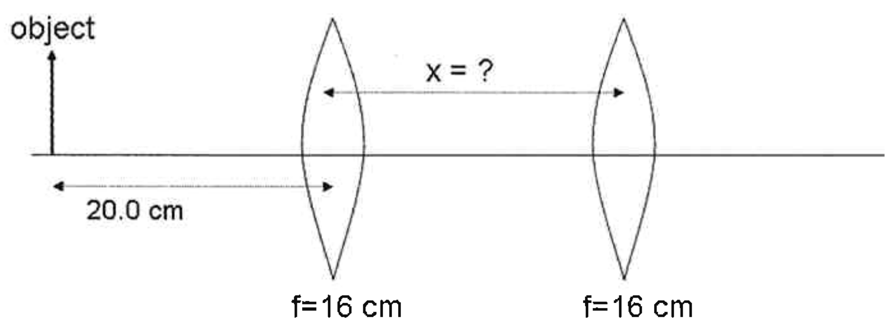
8) [2 pts] Using the concept of torque, explain how a screwdriver helps you to loosen a tightly attached screw.

9) [2 pts] A beacon in a lighthouse is supposed to produce a parallel beam of light. The beacon consists of a light bulb and a single converging lens. Where should the bulb be placed to produce the parallel beam?

10) [2 pts] An astronaut in deep space is taking a space walk and the tether connecting him to the spaceship breaks while he is at rest (with respect to the spaceship). He is carrying only a large wrench. How can he get back to the ship?

Long problems (do five out of seven):

1) [10 pts] Two converging lenses, each of focal length f = 16.0 cm, are arranged with an object 20.0 cm to the left of one lens. The image formed by the combination of lens is upright and of the same size as the original object. Find the distance x between the lenses.



2) [10 pts] A mass of 500 grams is vibrating in simple harmonic motion according to the equation

$$x = 0.60 \cos(6.40\, t)$$

where x is in meters and t is in seconds. Find:

a) the amplitude of the motion
b) the frequency of the harmonic motion
c) the total energy in the system

3) [10 pts] A small ball (of mass 750 grams) is swung at the end of a string in a horizontal circle of radius 1.5 m. Find:

a) the moment of inertia of the ball around the centre of the circle
b) the torque needed to keep the ball at constant speed (constant angular velocity) if air resistance exerts a force of 0.35 N on the ball.

You should treat the ball as a point mass and ignore the mass of the string.

4) [10 pts] A golf ball (mass = 39 grams) is hit off of a tee at a speed of 52 m/s. The golf club was in contact with the ball for 3.7 milliseconds (3.7×10^{-3} s). Find:

a) the impulse imparted to the ball
b) the average force exerted on the ball by the club

5) [10 pts] Two piano strings are supposed to be vibrating at 131 Hz (this is approximately the note that is one octave below middle C on a piano). But when they are played together, you hear 3 beats every 2.0 seconds. If one of them is truly at 131 Hz, find:

a) the other frequency (there are two possible answers; choose one);
b) the percentage by which the tension of the string must be adjusted to bring it into tune at 131 Hz (indicate whether the tension should be increased or decreased for the answer you have chosen in a)

6) [10 pts] Light of wavelength 540 nm (green) in air falls on a two-slit apparatus where the two slits are 7.50×10^{-2} mm apart. However, the two-slit apparatus is immersed in water (n=1.33). How far apart are the bright fringes on the screen that is 50 cm away from the slits?

7) [10 pts] A train is traveling at a constant speed around a curve of radius 275 m. A lamp suspended in the train swings out to an angle of 19° from the vertical. What is the speed of the train?

PHYS 101 Formulae

Vectors are in **bold**

General equations and constants:

Solution to quadratic:	$ax^2 + bx + c = 0 \rightarrow x = (-b \pm \sqrt{(b^2-4ac)})/2a$
Law of cosines:	$\lvert \mathbf{a}+\mathbf{b} \rvert^2 = a^2 + b^2 + 2ab\cos(\Theta)$
Acceleration due to gravity:	$g = 9.8\ m/s^2$
Gravitational constant:	$G = 6.67\times10^{-11}\ N\ m^2/kg^2$
Mass of the Earth :	$M_E = 6.0\times10^{24}\ kg$
Moment of inertia of a point mass:	$I = mr^2$
Moment of inertia of a sphere:	$I = (2/5)\ mr^2$
Speed of sound in air at sea level:	$v = 343\ m/s$
Speed of light	$c = 3.00 \times 10^8\ m/s$
Threshold intensity of audible sound:	$I_0 = 1.0 \times 10^{-12}\ W/m^2$
Threshold pressure of audible sound:	$p_0 = 3.0 \times 10^{-5}\ Pa$
Index of refraction of water:	$n = 1.33$
Index of refraction of glass:	$n = 1.5$

Motion at constant a:	$\mathbf{v} = \mathbf{v_0} + \mathbf{a}t$
	$x = x_0 + v_0t + \frac{1}{2}at^2$
	$v^2 = v_0^2 + 2a(x-x_0)$
	$v_{aver} = (v + v_0)/2$
Reference frames:	$\mathbf{v}_{in\ frame\ A} = \mathbf{v}_{in\ frame\ B} + \mathbf{v}_{B\ in\ A}$
Newton's 2nd law:	$\mathbf{F} = m\mathbf{a} = \Delta\mathbf{p}/\Delta t$
Force of friction	$F_{friction} = \mu_{(kinetic,\ static)}F_N$
Centripetal acceleration	$a = v^2/r$
Banked curve, frictionless surface:	$\tan\Theta = v^2/(rg)$
Force of gravity:	$F = G\ (m_1m_2)/r^2$
Kepler's 3rd law:	$T^2/r^3 = 4\pi^2/(GM)$
Work:	$W = \mathbf{F} \cdot \mathbf{d}$
Kinetic energy:	$KE = \frac{1}{2}mv^2$
Work-energy	$W_{net} = \Delta KE$
Gravitational potential:	$PE_{grav} = mgh$ (near Earth's surface)
Elastic potential energy:	$PE_{spring} = \frac{1}{2}kx^2$
Hooke's law:	$F = -k\ x$
Power:	power = energy/time = $W/t = \mathbf{F} \cdot \mathbf{v}$
Linear momentum	$\mathbf{p} = m\mathbf{v}$

Impulse:	$\Delta p = F\Delta t$
Center of mass:	$x_{CM} = (x_A m_A + x_B m_B + ...)/(m_A + m_B + ...)$
Linear and angular velocity:	$v = r\,\omega$
Angular motion at constant α:	$\omega = \omega_0 + \alpha t$
	$\Theta = \omega_0 t + \frac{1}{2}\alpha t^2$
	$\omega^2 = \omega_0^2 + 2\alpha\Theta$
	$\omega_{aver} = (\omega + \omega_0)/2$
Torque:	$\tau = F_{\perp} r$
Newton's second law for rotation:	$\tau = I\,\alpha$ $\qquad I = \Sigma\, m\, r^2$
Rotational kinetic energy	$KE_{rot} = \frac{1}{2} I\,\omega^2$
Rotational (angular) momentum:	$L = I\omega$
Frequency/period relationship:	$f = 1/T$
Period of SHM (spring):	$T = 2\pi\sqrt{(m/k)}$
Speed of object undergoing SHM:	$v = \pm v_{max}\sqrt{(1-x^2/A^2)}$ $\qquad v_{max} = 2\pi A/T$
Maximum acceleration:	$a_{max} = (k/m)\,A$
Sinusoidal motion of SHM:	$x = A\sin(2\pi\, t/T) = A\sin(\omega t)$
Pendulum SHM:	$T = 2\pi\sqrt{(L/g)}$
Wave speed, wavelength, frequency:	$v = \lambda\, f$
Speed of wave on a cord:	$v = \sqrt{(F_T/[m/L])}$
Intensity of wave:	$I = 2\pi^2 v\rho\, f^2 A^2$
	$I = p^2/(2v\rho)$
Standing waves on string:	$\lambda_n = 2L/n$
Reflection:	$\Theta_{inc} = \Theta_{ref}$
Refraction (waves):	$v_1\sin(\Theta_2) = v_2\sin(\Theta_1)$
Sound intensity (decibels)	$\beta = 10\log(I/I_0) = 20\log(P/P_0)$
Harmonics of open tubes:	$f_n = nf_1 = n\,(v/2L)$ $\qquad$ for n=1,2,3...
Harmonics of closed tubes:	$f_{2n-1} = (2n-1)\,f_1 = (2n-1)\,v/4L$ $\qquad$ for n=1,2,3... (only odd harmonics)
Beat frequency:	$f_b = \lvert f_1 - f_2 \rvert$
Doppler shift:	$f' = f\,[1/\{1 \pm (v_{source}/v_{wave})\}]$
	(source moving away from(+)/towards(-) observer)
	$f' = f\,[1 \pm (v_{obs}/v_{wave})]$
	(observer moving towards(+)/away from(-) source)
Focal length of spherical mirror:	$f = r/2$
Mirror and lens equation:	$1/f = 1/d_o + 1/d_i$

Magnification:	$m = h_i/h_o = -d_i/d_o$	
Index of refraction:	$n = c/v_{light}$	
Snell's law of refraction:	$n_1 \sin(\Theta_1) = n_2 \sin(\Theta_2)$	
Critical angle for TIR:	$\sin(\Theta_c) = n_2/n_1$	
Lensmaker's equation:	$1/f = (n - 1)(1/R_1 + 1/R_2)$	
Lens power:	$P = 1/f$	
Diffraction around object:	$\Theta_{diff} \approx \lambda/D$	
Constructive interference (2-slit):	$d \sin(\Theta) = m\lambda$	$m = 0,1,2\ldots$
Destructive interference:	$d \sin(\Theta) = (m + \frac{1}{2})\lambda$	$m = 0,1,2\ldots$
Single slit diffraction minima:	$D \sin(\Theta) = m\lambda$	$m = 1,2,3\ldots$ (<u>not</u> 0!)
Intensity reduction by polarizer:	$I = I_o \cos^2(\Theta)$	polarized light
	$I = \frac{1}{2} I_o$	unpolarized light
Brewster's angle	$\tan(\Theta_p) = n_2/n_1$	
Magnification of magnifying glass:	$M = N/f$	eye focused at ∞
	$M = N/f + 1$	eye focused at near point
Magnification of telescope:	$M = -fo/fe$	
Diffraction spot size/resolution:	$\Theta = 1.22\lambda/D$	