McGill University
Faculty of Science

PHYS 101 FINAL EXAM

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Dec. 10, 2004   9:00 AM – 12:00 noon

The exam comprises 6 questions. Calculators are allowed. Useful formulae and constants are listed on the last three pages.

Answer in the **exam booklets** provided; use two booklets if necessary. PLEASE RETURN EXAMS inside exam booklet(s).

Name: ______________________________

Student ID: ___________________________

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Attempt all questions, and show all your work. Calculators and a formula sheet (attached) are allowed. Take $g = 9.80\ m/s^2$. All problems have equal weight. Good luck !

1) Earth is in an approximately circular orbit around the Sun, of radius 1.5×10^{11} m.

   a) Verify that the angular velocity of the Earth in its orbit around the Sun, in radians/sec, is approximately 2.0×10^{-7} (take a year to be 365.25 days).

   b) After an unpleasantly close approach by a large asteroid, the Earth's orbital radius is reduced to 1.49×10^{11}m. What is the length of the new Earth year, in days?

   c) Because the Earth is now closer to the Sun, the polar ice-caps melt. Water from the ice-caps covers the globe uniformly. Apart from the significant damage to life, there is also an effect on the length of the Earth day. Estimate the change in the length of the day if the water from the ice-caps is distributed uniformly as a spherical shell over the Earth's surface.

   The polar ice-caps contain about 2.3×10^{19} kg of ice. The ice contributes nothing to the moment of inertia of the earth because it is located at the poles close to the axis of rotation. However, the water has a moment of inertia of a spherical shell of mass m and radius r, which is $I = (^2/_3)\, mr^2$.

The mass of the Earth is 5.98×10^{24} kg, and the radius of the Earth is 6.37×10^6 m. Consider the Earth to be of uniform density.

2) An airplane of mass 5,000 kg is climbing at a 15° angle from the horizontal while accelerating at $2\ m/s^2$. The wings produce a lift force that is perpendicular to the direction of motion, and a drag force (resistive, or frictional force) parallel to the direction of motion that is 1500 N.

   a) Draw a free body diagram showing all the forces acting on the airplane. Label each.

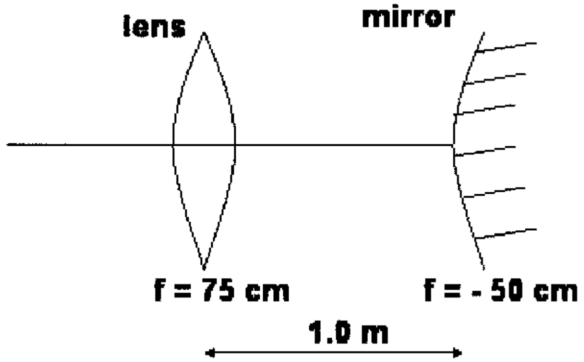
   b) Calculate the force (thrust) supplied by the jet engine.

3) A lens and mirror are placed as in the diagram below. The focal lengths are f = +75 cm and f = -50 cm, respectively, and they are 1.0 m apart. An object is placed 1.0 m to the left of the lens.

a) Draw an approximate ray diagram (it doesn't have to be to scale, but should show the key features of the object and the image). Use it to predict approximately where the final image will be located.

b) Calculate the location of the final image.

c) Calculate the total magnification. Is the final image upright or inverted?



4) A bungee jumper jumps off a bridge attached to a cord that will (hopefully) brake her fall before she hits the ground. The jumper has a mass of 65 kg, and jumps from a bridge 50 m high. The cord is 32 m long, unstretched. The jumper initially stops (before bouncing) j just at ground level. Treat the cord as a massless spring which follows Hooke's law.

a) What is the period of the jumper's oscillations?

b) After the jumper oscillates she comes to rest hanging from the bridge at what height above the ground ?

5) A rocket is launched at a 60° angle from the horizontal. The rocket engine accelerates the rocket at 20 m/s^2 throughout its burn, maintaining the rocket's angle with the horizontal, but unfortunately the engine fails after 12 sec.

   a) What is the final height the rocket achieves?

   b) What is the final range (ie, how far from the launch point does the rocket touch down)?

6) Two schoolboys with identical whistles (of frequency 440 Hz) are in two trains. One of the trains is motionless. A bystander (also motionless) hears a beat frequency of 3 Hz.

   a) What is the speed of the moving train? Calculate **both** possible solutions.

   b) If you model the whistles as closed pipes, how long are they if the 440 Hz frequency is the fundamental ?

Take the speed of sound in air to be 343 m/s.

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:	$p_0 = 3.0 \times 10^{-10}\ Pa$
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:	$\mathbf{v}_{\text{in frame A}} = \mathbf{v}_{\text{in frame B}} + \mathbf{v}_{\text{B in A}}$
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	$\mathbf{p} = m\mathbf{v}$

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:	$\omega = \omega_0 + \alpha t$
	$\Theta = \omega_0 t + \frac{1}{2}\alpha t^2$
	$\omega^2 = \omega_0^2 + 2\alpha\Theta$
	$\omega_{aver} = (\omega + \omega_0)/2$
Newton's second law for rotation:	$\tau = I\,\alpha$ $I = \Sigma\, m\, r^2$
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:	$v = \pm v_{max}\sqrt{(1-x^2/A^2)}$ $v_{max} = 2\pi A/T$
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:	$f_n = nf_1 = n\,(v/2L)$
Harmonics of closed tubes:	$f_n = (2n+1)\,f_1 = (2n+1)\,v/4L$ (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):	$d \sin(\Theta) = m\lambda$	$m = 0,1,2...$
Destructive interference:	$d \sin(\Theta) = (m + \frac{1}{2})\lambda$	$m = 0,1,2...$
Single slit diffraction:	$D \sin(\Theta) = m\lambda$	$m = 1,2,3...$ (<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:	$\Theta = 1.22\, \lambda/D$	