Physics 110

Spring 2008

Exam #1

April 23, 2008

Name___Solutions_________

Part	
Multiple Choice	/ 20
Problem #1	/ 28
Problem #2	/ 24
Problem #3	/ 28
Total	/ 100

In keeping with the Union College policy on academic honesty, it is assumed that you will neither accept nor provide unauthorized assistance in the completion of this work.

Part I: Free Response Problems

Please show all work in order to receive partial credit. If your solutions are illegible no credit will be given. Please use the back of the page if necessary, but number the problem you are working on.

1. The Late Show host, David Letterman, likes to have people perform some stunts to get on TV. Suppose that Letterman has a person stand on top of the Ed Sullivan Theater (where the Late Show is taped) and throw a ball at a building next door. If the person throws the ball at 24.0 m/s (ignoring any air friction) at an angle of 40^o with respect to the vertical, and that the neighboring building is 40m away.

a. What are the x- and y-components of the initial velocity?

$$v_{ix} = v\cos\theta = 24\tfrac{m}{s}\cos 50 = 15.4\tfrac{m}{s}$$
$$v_{iy} = v\sin\theta = 24\tfrac{m}{s}\sin 50 = 18.4\tfrac{m}{s}$$

b. How far above or below the person's position (on the rooftop) does the ball hit?

$$x_f = x_i + v_{ox}t \rightarrow t = \frac{x_f}{v_{ox}} = \frac{40m}{15.4\tfrac{m}{s}} = 2.6s.$$
$$y_f = y_i + v_{oy}t + \tfrac{1}{2}a_y t^2 = 18.4\tfrac{m}{s}(2.6s) - 4.9\tfrac{m}{s^2}(2.6s)^2 = +14.7m$$

c. What is the final velocity of the ball just before it strikes the building?

$$v_{fx} = v_{ix} = 15.4\tfrac{m}{s}$$
$$v_{fy} = v_{iy} - gt = 18.4\tfrac{m}{s} - 9.8\tfrac{m}{s^2}(2.6s) = -7.1\tfrac{m}{s}$$
$$v = \sqrt{v_{fx}^2 + v_{fy}^2}\ @\ \theta = \tan^{-1}\frac{v_{fy}}{v_{fx}} \rightarrow v = 17\tfrac{m}{s}\ @\ \theta = -24.8^0$$

d. What is the acceleration of the ball just before it strikes the building?

The acceleration is due to gravity and has a value of 9.8 m/s^2 in the vertically downward direction.

2. Suppose that a Western Pacific Boeing 737 (shown below) sits on the runway of Albany International Airport waiting for takeoff clearance. When given clearance, the pilot applies full power to the plane's engines and accelerates at a constant rate of 2 m/s^2 down the runway.

a. If the plane takes off when its velocity reaches 165 mi/hr (which is 144 knots or nautical miles per hour) and not before, what is the minimum time before the plane can take off? (Hint: 1 km = 0.62 mi and 1hr = 3600 s.)

$v_f = v_i + at$; with $v_0 = 0\,\tfrac{m}{s}$ and $v_f = 165\,\tfrac{mi}{hr} = 73.9\,\tfrac{m}{s}$,

so $t = \dfrac{v_f}{a} = \dfrac{73.9\,\frac{m}{s}}{2\,\frac{m}{s^2}} = 37.0s.$

b. How far down the runway does the plane travel before it takes off?

$$x_f = x_i + v_0 t + \tfrac{1}{2}at^2 = \tfrac{1}{2}at^2 = \tfrac{1}{2}\left(2\,\tfrac{m}{s^2}\right)(37s)^2 = 1366m = 1.37km.$$

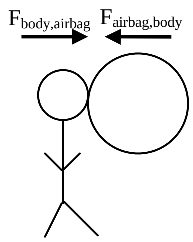
c. Suppose that after 1.5 km the pilot decides that takeoff is not safe and decides to stop the plane. If the thrust reversers (on the engines) are engaged and the brakes are applied, the plane experiences a force that brings it to rest in 1km. What is the magnitude of this force if the plane has a mass of 287,000 kg and the plane is traveling at 165 mi/hr when the brakes and reversers are applied?

$$v_f^2 = v_i^2 + 2a\Delta x \rightarrow \left(0\,\tfrac{m}{s}\right)^2 = \left(73.9\,\tfrac{m}{s}\right)^2 + 2a(1000m) \rightarrow a = -2.73\,\tfrac{m}{s^2}$$

The force: $F = ma = (287{,}000kg)\left(2.73\,\tfrac{m}{s^2}\right) = 7.84\times10^5\,N.$

3. The human body is capable of sustaining rather large forces without drastic injury. Consider, for example, an automobile accident in which an inflatable safety device (an airbag) is suddenly and quickly inflated.

   a. Draw a diagram of this situation labeling only the forces that act on the airbag (once it is fully inflated) and on your body. What can you conclude about the force of your head on the airbag and the force of the airbag on your head?



   The forces are equal in magnitude and opposite in direction by Newton's 3rd law.

   b. Derive an expression for the force from the airbag on your body assuming that you were initially traveling at an initial speed of v_i and were brought to rest over a distance $\Delta x = x_f - x_i = x$.

$$v_{fx}^2 = v_{ix}^2 - 2a_x \Delta x \rightarrow 0 = v_i^2 - 2\frac{F}{m}x \rightarrow F = \frac{mv_i^2}{2x}$$

   c. If your body (of mass 70 kg) comes to rest over a distance of 30 cm and if your initial speed was 19.6 m/s (~ 44 mph), what is the magnitude of the force that the bag exerted on your body?

$$F = \frac{mv_i^2}{2x} = \frac{70kg \times \left(19.6\,\tfrac{m}{s}\right)^2}{2 \times 0.3m} = 4.48 \times 10^4\,N = 4.5 \times 10^4\,N$$

   c. There is a probability that the airbag could trigger and inflate while the car is in motion and there was no accident at all. This could impair the vision of the driver and hence the airbag is designed to expand and collapse over a very short time interval. Given the information above, how long would it take the airbag to deflate if the inflation was almost instantaneously and assuming that the airbag is fully deflated as soon as the automobile is brought to rest?

$$F = ma = \left|\frac{m(v_f - v_i)}{t_f - t_i}\right| \rightarrow t = \frac{mv_i}{F} = \frac{70kg \times 19.6\,\tfrac{m}{s}}{4.48 \times 10^4\,N} = 0.03s$$

   Or, $x_f = x_i + v_{ix}t - \tfrac{1}{2}a_x t^2 \rightarrow 0 = -0.3 + 19.6t - \tfrac{1}{2}\left(\frac{4.48 \times 10^4}{70}\right)t^2 \rightarrow t = 0.03s$

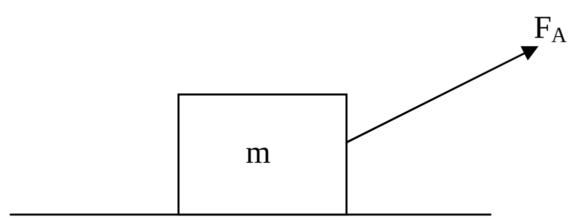
   noting that when solving the quadratic equation, the square root term is zero!

Part II: Multiple-Choice

Circle your best answer to each question. Any other marks will not be given credit. Each multiple-choice question is worth 2 points for a total of 20 points.

1. From the diagram below, if the block of mass *m* is pulled to the right at constant speed by an applied force F_A oriented at an angle θ above the horizontal, the magnitude of the frictional force is given by

   a. $F_A \sin\theta$ b. $F_A \cos\theta$ c. mg   d. F_N



2. Suppose that a mosquito flies head-on into an oncoming car and during the collision the mosquito exerts a force *F* on the car. The force that the car exerts on the mosquito is

   a. zero.   b. *F*.   c. less than *F*.   d. greater than *F*.

3. A baseball "diamond" is a square with sides 90 feet in length. Taking home plate to 1st base as the positive x-axis and the y-axis from home plate to 3rd base, the displacement of a runner show hit a double is

   a. 90 ft   b. 180 ft   c. 9.5 ft   d. 127 ft

4. You and a friend stand on a snow covered roof. You both throw snowballs with the same initial speed, but in different direction. You throw your snowball downward, at 40^o below the horizontal; your friend throws her snowball, at 40^o above the horizontal. When the snowballs land on the ground, the speed (the magnitude of the velocity) of your snowball compared to your friends is

a. the same.   b. greater.   c. less.   d. unable to be determined.

5. A salmon of mass m is weighed by hanging it from a scale attached to the ceiling of an elevator while the elevator is at rest and the weight is found to be $F_W = mg$. If the elevator is accelerating downwards at a rate of a, the reading on the scale would be

a. $F_N = mg$.   b. $F_N = mg + ma$.   c. $F_N = mg - ma$.   d. $F_N = g$.

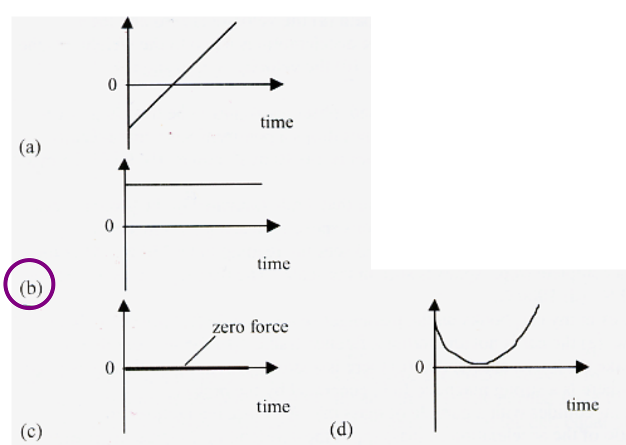
6. You drop a rock from a bridge into some water below. When the rock has fallen 4m, you drop a 2nd rock. As the rocks continue their free fall, their separation

a. increases.
b. decreases.
c. stays the same.
d. cannot be determined since not enough information is given to answer.

7. If an object travels in the positive x-direction 75m over 36 seconds and the turns around and travels in the negative x-direction 75m for 71 seconds, the average velocity is

a. 0 m/s   b. 33.3 m/s   c. 25 m/s   d. 50 m/s

8. If the x-component of the velocity of an object is sampled every 5 seconds and plotted, it is found that the result increases linearly in time. Which graph below best represents the net force on the particle as a function of time?



9. Sometimes strange quotes are attributed to famous people. Here is one example of one supposedly uttered by Albert Einstein: “Gravitation cannot be held responsible for people falling in love.” Could this be true? What is the gravitational attraction between two people each with mass 70 kg that are separated by 0.25m?

a. 1.91×10^{5} N   b. 5.22×10^{6} N   c. 1.91×10^{-7} N   d. 5.22×10^{-6} N

10. Suppose that your heart is “racing” and that the blood in the aorta is accelerated by the action of the heart beating at this fast pace and thus changes the velocity from 0 m/s to 0.5 m/s over a distance of 0.02 m. What is the acceleration of the blood?

a. 1.5 m/s^2 b. 6.3 m/s^2 c. 9.8 m/s^2 d. 87.5 m/s^2

Useful formulas:

Motion in the x, y or z-directions

$r_f = r_0 + v_{0r}t + \frac{1}{2}a_r t^2$

$v_{fr} = v_{0r} + a_r t$

${v_{fr}}^2 = {v_{0r}}^2 + 2a_r \Delta r$

Uniform Circular Motion

$a_r = \frac{v^2}{r}$

$F_r = ma_r = m\frac{v^2}{r}$

$v = \frac{2\pi r}{T}$

$F_G = G\frac{m_1 m_2}{r^2}$

Geometry /Algebra

Circles	*Triangles*	*Spheres*
$C = 2\pi r$	$A = \frac{1}{2}bh$	$A = 4\pi r^2$
$A = \pi r^2$		$V = \frac{4}{3}\pi r^3$

$\textit{Quadratic equation}: ax^2 + bx + c = 0,$

$\textit{whose solutions are given by}: x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Vectors

$\textit{magnitude of a vector} = \sqrt{{v_x}^2 + {v^2}_y}$

$\textit{direction of a vector} \rightarrow \phi = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

Useful Constants

$g = 9.8\,{}^{m}\!/\!_{s^2}$ $\quad G = 6.67\times10^{-11}\,{}^{Nm^2}\!/\!_{kg^2}$

$N_A = 6.02\times10^{23}\,{}^{atoms}\!/\!_{mole}$ $\quad k_B = 1.38\times10^{-23}\,{}^{J}\!/\!_{K}$

$\sigma = 5.67\times10^{-8}\,{}^{W}\!/\!_{m^2K^4}$ $\quad v_{sound} = 343\,{}^{m}\!/\!_{s}$

Linear Momentum/Forces

$\vec{p} = m\vec{v}$

$\vec{p}_f = \vec{p}_i + \vec{F}\Delta t$

$\vec{F} = m\vec{a}$

$\vec{F}_s = -k\vec{x}$

$F_f = \mu F_N$

Work/Energy

$K_t = \frac{1}{2}mv^2$

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

$U_g = mgh$

$U_S = \frac{1}{2}kx^2$

$W_T = FdCos\,\theta = \Delta E_T$

$W_R = \tau\theta = \Delta E_R$

$W_{net} = W_R + W_T = \Delta E_R + \Delta E_T$

Heat

$T_C = \frac{5}{9}[T_F - 32]$

$T_F = \frac{9}{5}T_C + 32$

$L_{new} = L_{old}(1 + \alpha\Delta T)$

$A_{new} = A_{old}(1 + 2\alpha\Delta T)$

$V_{new} = V_{old}(1 + \beta\Delta T): \ \beta = 3\alpha$

$PV = Nk_BT$

$\frac{3}{2}k_BT = \frac{1}{2}mv^2$

$\Delta Q = mc\Delta T$

$P_C = \frac{\Delta Q}{\Delta t} = \frac{kA}{L}\Delta T$

$P_R = \frac{\Delta Q}{\Delta T} = \varepsilon\sigma A\Delta T^4$

$\Delta U = \Delta Q - \Delta W$

Rotational Motion

$\theta_f = \theta_i + \omega_i t \frac{1}{2}\alpha t^2$

$\omega_f = \omega_i + \alpha t$

$\omega^2{}_f = \omega^2{}_i + 2\alpha\Delta\theta$

$\tau = I\alpha = rF$

$L = I\omega$

$\Delta s = r\Delta\theta: \ v = r\omega: \ a_t = r\alpha$

$a_r = r\omega^2$

Fluids

$\rho = \frac{M}{V}$

$P = \frac{F}{A}$

$P_d = P_0 + \rho gd$

$F_B = \rho gV$

$P_1 + \frac{1}{2}\rho v^2{}_1 + \rho gh_1 = P_2 + \frac{1}{2}\rho v^2{}_2 + \rho gh_2$

Simple Harmonic Motion/Waves

$\omega = 2\pi f = \frac{2\pi}{T}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{l}{g}}$

$v = \pm v_{\max}\left(\sqrt{1 - \frac{x^2}{A^2}}\right)$

$v_{\max} = \omega A$

$a_{\max} = \omega^2 A$

$v = f\lambda$

$v = \sqrt{\frac{F_T}{\mu}}$

$f_n = nf_1 = n\frac{v}{2L}$