Physics 15
Second Hour Exam

Name________Answer Key________________

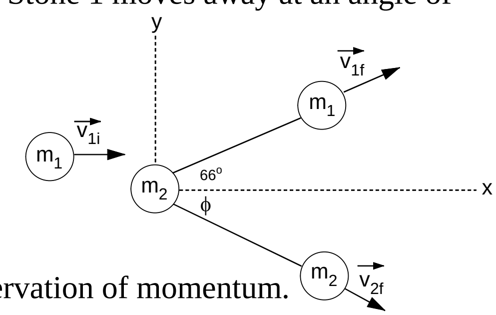
Multiple Choice	/20
Problem 1	/30
Problem 2	/26
Problem 3	/24

Total	/100

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.

1. Consider the collision of two 7.0 Kg Olympic curling stones as shown below. One stone is initially at rest and the other approaches with a speed of v_{1i}=1.5 m/s. The collision is not head-on, but rather a glancing one. Stone 1 moves away at an angle of 66°. (Note that the picture is not to scale.)



a. Write the ***simplest*** equations that govern conservation of momentum.

$$p_x:\ m_1v_{1i} = m_1v_{1f}\cos 66 + m_2v_{2f}\cos\phi \rightarrow v_{1i} = 0.407v_{1f} + v_{2f}\cos\phi$$
$$p_y:\ 0 = m_1v_{1f}\sin 66 - m_2v_{2f}\sin\phi \rightarrow 0 = 0.914v_{1f} - v_{2f}\sin\phi$$

b. Write the ***simplest*** equations that govern conservation of energy.

$$\tfrac{1}{2}m_1v_{1i}^2 = \tfrac{1}{2}m_1v_{1f}^2 + \tfrac{1}{2}m_2v_{2f}^2 \rightarrow v_{1i}^2 = v_{1f}^2 + v_{2f}^2$$

c. What is the deflection angle, with respect to the initial line of motion, of stone 2?

Since $m_1 = m_2$ and the collision is glancing, $\phi + 66 = 90$, therefore $\phi = 24^o$.

d. What is the final velocity of stone 1?

$$v_{2f} = 2.25v_{1f};\quad v_{1i} = (0.407 + 2.25\times 0.914)v_{1f} = 2.46v_{1f} \rightarrow v_{1f} = 0.61\tfrac{m}{s}$$

e. What is the final velocity of stone 2?

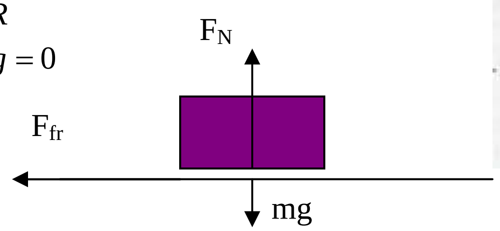
$$v_{2f} = 2.25v_{1f} = 1.37\tfrac{m}{s}$$

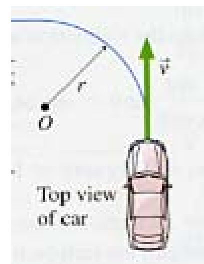
2. Civil engineers that design roadways have to worry about the maximum speed cars can have and still negotiate turns in the roadway safely. Consider the two cases below. In the first case consider a level road where static friction is the force that is responsible for the car negotiating the curve safely. In the second case, the roadway is banked at an angle θ with respect to the horizontal, in order to ***not*** rely on friction to turn the corner, but instead some part of the weight of the car.

a. Draw the free-body diagram for the car making the left hand turn on the flat roadway. (Hint: Where the tire makes contact with the road, the tire is momentarily at rest and what allows the car to turn the corner is static friction, which is the product of $\mu_s F_N$, where $\mu_s = 1.00$.)

$$\sum F_x: \quad F_{fr} = \frac{mv^2}{R}$$

$$\sum F_y: \quad F_N - mg = 0$$





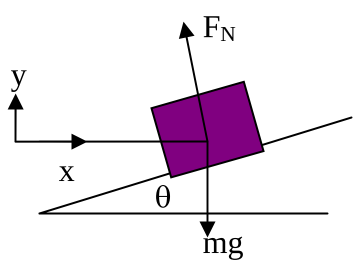
b. What is the maximum speed with which a 1500 kg car can make a left hand turn around a curve of radius 50 m on the level road without sliding?

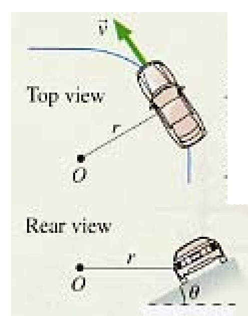
$$F_{fr} = \mu_s F_N = \mu_s mg = \frac{mv^2}{R} \rightarrow v = \sqrt{\mu_s Rg} = \sqrt{1 \times 50m \times 9.8\tfrac{m}{s^2}} = 22\tfrac{m}{s}$$

c. Draw the free-body diagram for the car making the left hand turn on the ***banked*** roadway. (Hint: Do not use a tilted coordinate system, similar to that used in inclined plane problems. The center of the circle around which the car is traveling is in the same horizontal plane as the car and this defines R for circular motion problems.)

$$\sum F_x: \quad F_N \sin\theta = \frac{mv^2}{R}$$

$$\sum F_y: \quad F_N \cos\theta - mg = 0$$





d. What is the speed at which the 1500 kg car can take this curve without relying on friction, if the radius of the curve is 70 m and the roadway is banked at 15°?

$$mg\tan\theta = \frac{mv^2}{R} \rightarrow v = \sqrt{Rg\tan\theta} = \sqrt{70m \times 9.8\tfrac{m}{s^2} \times \tan 15} = 13.6\tfrac{m}{s}$$

3. You have been asked to design a "ballistic-spring system" to measure the speed of bullets. A spring whose spring constant *k* is suspended from the ceiling and a block of mass *M* hangs from the spring. A bullet of mass *m* is fired vertically upward into the bottom of the block. The spring's maximum compression *d* is measured.

a. Find an expression for the bullet's initial speed v_b in terms of *m*, *M*, *k*, and *d* (ignore any changes in gravitational potential energy).

$$Cons.of\ p:\ \ m_b v_b = (M + m_b)V_f$$

$$Cons.of\ E:\ \tfrac{1}{2}(M + m_b)V_f^2 = \tfrac{1}{2}ky^2$$

$$\tfrac{1}{2}(M + m_b)\left(\frac{m_b v_b}{(M + m_b)}\right)^2 = \tfrac{1}{2}ky^2 \rightarrow v_b = \sqrt{\frac{M + m_b}{m_b^2}k}\,y$$

b. What is the speed of a 10 g bullet if the block's mass is 2 kg and if the spring with spring constant k = 50 N/m, was compressed 45 cm?

$$v_b = \sqrt{\frac{M + m_b}{m_b^2}k}\,y = \sqrt{\frac{2.01kg}{(0.01kg)^2}50\,\tfrac{N}{m}}\,(0.45m) = 451.1\,\tfrac{m}{s}$$

c. The speed of sound in air is 343 m/s. Does your result above make sense with respect to the speed of sound? Explain.

This seems like a reasonable speed when compared to the speed of sound.

d. What is the period of the resulting oscillation of the block-bullet-spring system?

$$T = 2\pi\sqrt{\frac{m_{total}}{k}} = 2\pi\sqrt{\frac{2.01kg}{50\,\tfrac{N}{m}}} = 1.26s$$

Part II: Multiple-Choice

Circle your answer to each question. Each multiple-choice question is worth 2 points for a total of 20 points.

1. What is the change in momentum for an 80 kg person falling from a height of 32 m above the ground when they collide with the ground?
a. 224 kgm/s b. 2000 kgm/s c. 2560 kgm/s d. 0 kgm/s

2. A 10 kg block pulled across a horizontal surface (with coefficient of kinetic friction μ_k = 0.6) by a 15 N force directed at 30^o above the horizontal. How much work is done by gravity if the block is pulled along the horizontal surface a distance of 6 m?
a. 0 J b. 52 J c. 98 J d. -59J

3. Consider a 1m long stick of uniform mass 500g. Suppose that zero corresponds to the left end of the stick and that a weight of 50g is added at the 75cm mark. What is the x-coordinate of the center of mass?
a. 47.7 cm b. 50 cm c. 52.3 cm d. 75 cm

4. A very light object (*a*) and a very heavy (*b*) object are sliding along a frictionless surface at the same speed. They slide up a frictionless hill. Which of the following is true, where h is the height the object reaches above the horizontal surface?
a. $h_a > h_b$ b. $h_b > h_a$ c. $h_a = h_b$ d. cannot tell from the information given.

5. Suppose that a bowling ball and a baseball are thrown off of a high building with the same magnitude of the velocity. Let the bowling ball be thrown horizontally while the baseball is thrown upward at an angle θ with respect to the horizontal. Ignoring air resistance, the balls
a. have the same magnitude of the velocity at the bottom
b. $v_{baseball} > v_{bowling\ ball}$
c. $v_{bowling\ ball} > v_{baseball}$
d. cannot tell from the information given?

6. A large truck runs into a small car and pushes it 20 m before stopping. During the collision

a. the truck exerts a larger magnitude force on the car than the car exerts on the truck,
b. the truck exerts a smaller magnitude force on the car than the car exerts on the truck,
c. the truck and car exert equal magnitude forces on each other,
d. the car doesn't actually exert a force on the truck, the truck just keeps on going.

7. Suppose that a ball is dropped from a building. At the point of release it has a gravitational potential energy of U. Just before it hits the ground, it has a kinetic energy of K. ***Taking into account air resistance***, what is the relationship between K and U?

a. $K > U$ b. $K < U$ c. $K = U$ d. cannot tell from the information given.

8. A 1 kg duck is flying horizontally at 20 m/s when seized by a 0.8 kg hawk diving at 30 m/s. The hawk is coming in from behind and makes an angle of 30^o from the vertical just before contact. The magnitude of the velocity of the birds just after contact is

a. 13.2 m/s b. 21.3 m/s c. 31.6 m/s d. 42.6 m/s

9. In the above question, the angle with respect to the horizontal that the birds make is

a. 33^o b. -33^o c. 49^o d. -49^o

10. What is the power of a motor that is required to lift a 2000 kg elevator at a constant rate of 3 m/s?

a. 5.88 kW b. 58.8 kW c. 117.6 kW d.29.4 kW

Useful formulas:

Motion in the x, y or z-directions

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

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

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

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

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

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

Vectors

$$magnitude\ of\ a\ vector = \sqrt{v_x^{\ 2} + v^2_{\ y}}$$

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

Useful Constants

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

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

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

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

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

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

$$U_g = mgh$$

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

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

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

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

Heat

$$T_C = \tfrac{5}{9}\left[T_F - 32\right]$$

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

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

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

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

$$PV = Nk_BT$$

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

$$\Delta Q = mc\Delta T$$

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

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

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

Rotational Motion

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

$$\omega_f = \omega_i + \alpha t$$

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

$$\tau = I\alpha = rF$$

$$L = I\omega$$

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

$$a_r = r\omega^2$$

Fluids

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

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

$$P_d = P_0 + \rho gd$$

$$F_B = \rho gV$$

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

Simple Harmonic Motion/Waves

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

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

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

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

$$v_{max} = \omega A$$

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

$$v = f\lambda$$

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

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