PHY1321 PHY1331 Fall 2019 Assignment 9. Due Nov 15, 6:00PM

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1. A hot wheel toy car is send from its "accelerator booth" at the edge of the table. It lands 2 meters away horizontally. Find the angular velocity (in the revolutions per second) of the spinning rollers in the acceleration booth. The table is 1 meter tall. The car's mass is 80g, and the radius of the roller is 5cm.

$y = \frac{1}{2}gt^2$ t= $\sqrt{\frac{2y}{g}} = 0.4517s$ $x = vt$ $v = 4.428\frac{m}{s}$

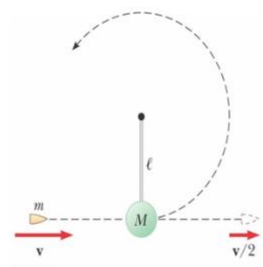
$\omega = \frac{v}{r} = \frac{4.428}{0.05}$=$88.55\frac{rad}{s} = 14.09\, rev/s$

2 A tennis player receives a shot with the ball (0.060 0 kg) traveling horizontally at 50.0 m/s and returns the shot with the ball traveling horizontally at 40.0 m/s in the opposite direction. (a) What is the impulse delivered to the ball by the racquet? (b) What work does the racquet do on the ball?
Assume the initial direction of the ball in the –*x* direction.

(a) Impulse, $\mathbf{I} = \Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = (0.060\,0)(40.0)\hat{\mathbf{i}} - (0.060\,0)(50.0)(-\hat{\mathbf{i}}) = \boxed{5.40\hat{\mathbf{i}}\ \mathrm{N\cdot s}}$

(b) Work $= K_f - K_i = \frac{1}{2}(0.060\,0)\left[(40.0)^2 - (50.0)^2\right] = \boxed{-27.0\ \mathrm{J}}$

3 As shown in , a bullet of mass *m* and speed *v* passes completely through a pendulum bob of mass *M.* The bullet emerges with a speed of *v*/2. The pendulum bob is suspended by a stiff rod of length ℓ and negligible mass. What is the minimum value of *v* such that the pendulum bob will barely swing through a complete vertical circle?



Energy is conserved for the bob-Earth system between bottom and top of swing. At the top the stiff rod is in compression and the bob nearly at rest.

$K_i + U_i = K_f + U_f$: $\frac{1}{2}Mv_b^2 + 0 = 0 + Mg2\ell$ $v_b^2 = g4\ell$ so $v_b = 2\sqrt{g\ell}$

Momentum of the bob-bullet system is conserved in the collision:

$mv = m\frac{v}{2} + M\left(2\sqrt{g\ell}\right)$ $\boxed{v = \frac{4M}{m}\sqrt{g\ell}}$

4 12.A circus trapeze consists of a bar suspended by two parallel ropes, each of length ℓ, allowing performers to swing in a vertical circular arc (Figure P8.12). Suppose a performer with mass *m* holds the bar and steps off an elevated platform, starting from rest with the ropes at an angle θ_i with respect to the vertical. Suppose the size of the performer's body is small compared to the length ℓ, that she does not pump the trapeze to swing higher, and that air resistance is negligible. (a) Show that when the ropes make an angle θ with the vertical, the performer must exert a force

$$mg(3\cos\theta - 2\cos\theta_i)$$

in order to hang on. (b) Determine the angle θ_i for which the force needed to hang on at the bottom of the swing is twice the performer's weight.

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5 A rocket for use in deep space is to be capable of boosting a total load (payload plus rocket frame and engine) of 3.00 metric tons to a speed of 10 000 m/s. (a) It has an engine and fuel designed to produce an exhaust speed of 2 000 m/s. How much fuel plus oxidizer is required? (b) If a different fuel and engine design could give an exhaust speed of 5 000 m/s, what amount of fuel and oxidizer would

$$v = v_e \ln \frac{M_i}{M_f}$$

(a) $M_i = e^{v/v_e} M_f$ $\qquad M_i = e^5 \left(3.00 \times 10^3 \text{ kg}\right) = 4.45 \times 10^5 \text{ kg}$

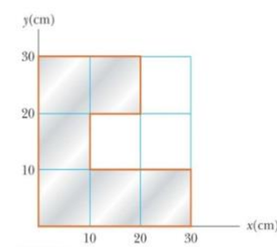
The mass of fuel and oxidizer is

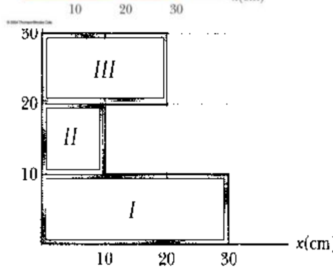
$$\Delta M = M_i - M_f = (445 - 3.00) \times 10^3 \text{ kg} = \boxed{442 \text{ metric tons}}$$

(b) $\Delta M = e^2 (3.00 \text{ metric tons}) - 3.00 \text{ metric tons} = \boxed{19.2 \text{ metric tons}}$

Because of the exponential, a relatively small increase in fuel and/or engine efficiency causes a large change in the amount of fuel and oxidizer required.

6 A uniform piece of sheet steel is shaped as shown. Compute the *x* and *y* coordinates of the center of mass of the piece.





$$x_{CM} = \frac{x_1 M_1 + x_2 M_2 + x_3 M_3}{M} = \frac{15.0 \text{ cm} \left(\frac{1}{2} M\right) + 5.00 \text{ cm} \left(\frac{1}{6} M\right) + 10.0 \text{ cm} \left(\frac{1}{3} M\right)}{M}$$

$$x_{CM} = \boxed{11.7 \text{ cm}}$$

$$y_{CM} = \frac{\frac{1}{2} M (5.00 \text{ cm}) + \frac{1}{6} M (15.0 \text{ cm}) + \left(\frac{1}{3} M\right)(25.0 \text{ cm})}{M} = 13.3 \text{ cm}$$

$$y_{CM} = \boxed{13.3 \text{ cm}}$$

7 A 90.0-kg fullback running east with a speed of 5.00 m/s is tackled by a 95.0-kg opponent running north with a speed of 3.00 m/s. If the collision is perfectly inelastic, (a) calculate the speed and direction of the players just after the tackle and (b) determine the mechanical energy lost as a result of the collision. Account for the missing energy.

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(a) First, we conserve momentum for the system of two football players in the *x* direction (the direction of travel of the fullback).

$$(90.0\ \text{kg})(5.00\ \text{m/s}) + 0 = (185\ \text{kg})V\cos\theta$$

where θ is the angle between the direction of the final velocity *V* and the *x* axis. We find

$$V\cos\theta = 2.43\ \text{m/s} \qquad (1)$$

Now consider conservation of momentum of the system in the *y* direction (the direction of travel of the opponent).

$$(95.0\ \text{kg})(3.00\ \text{m/s}) + 0 = (185\ \text{kg})(V\sin\theta)$$

which gives, $V\sin\theta = 1.54\ \text{m/s}$ (2)

Divide equation (2) by (1) $\tan\theta = \dfrac{1.54}{2.43} = 0.633$

From which $\boxed{\theta = 32.3°}$

Then, either (1) or (2) gives $V = \boxed{2.88\ \text{m/s}}$

(b) $$K_i = \frac{1}{2}(90.0\ \text{kg})(5.00\ \text{m/s})^2 + \frac{1}{2}(95.0\ \text{kg})(3.00\ \text{m/s})^2 = 1.55\times10^3\ \text{J}$$

$$K_f = \frac{1}{2}(185\ \text{kg})(2.88\ \text{m/s})^2 = 7.67\times10^2\ \text{J}$$

Thus, the kinetic energy lost is $\boxed{783\ \text{J into internal energy.}}$

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P8.12 (a) The force needed to hang on is equal to the force F the trapeze bar exerts on the performer.

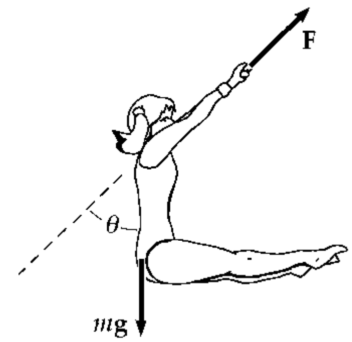

FIG. P8.12

From the free-body diagram for the performer's body, as shown,

$$F - mg\cos\theta = m\frac{v^2}{\ell}$$

or

$$F = mg\cos\theta + m\frac{v^2}{\ell}$$

Apply conservation of mechanical energy of the performer-Earth system as the performer moves between the starting point and any later point:

$$mg(\ell - \ell\cos\theta_i) = mg(\ell - \ell\cos\theta) + \frac{1}{2}mv^2$$

Solve for $\frac{mv^2}{\ell}$ and substitute into the force equation to obtain $F = \boxed{mg(3\cos\theta - 2\cos\theta_i)}$.

(b) At the bottom of the swing, $\theta = 0°$ so

$$F = mg(3 - 2\cos\theta_i)$$
$$F = 2mg = mg(3 - 2\cos\theta_i)$$

which gives

$$\theta_i = \boxed{60.0°}.$$