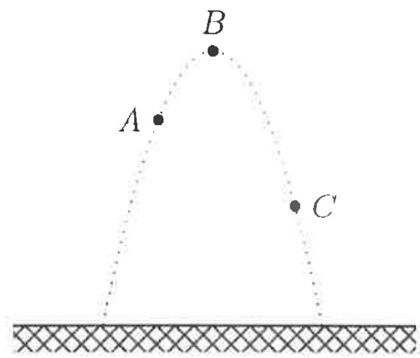
Name:
Date:
PH 105 Section:

Problem 1

A boy throws a ball upward. Compare the magnitudes of the gravitational accelerations at three points along the path of the ball. Point A is before the ball reaches the top on the way up, Point B is at the top, and Point C is after it has passed the top and on the way down.



(a) The magnitudes of the acceleration relative to A are related as
1. $a_A < a_B$
2. $a_A = g$

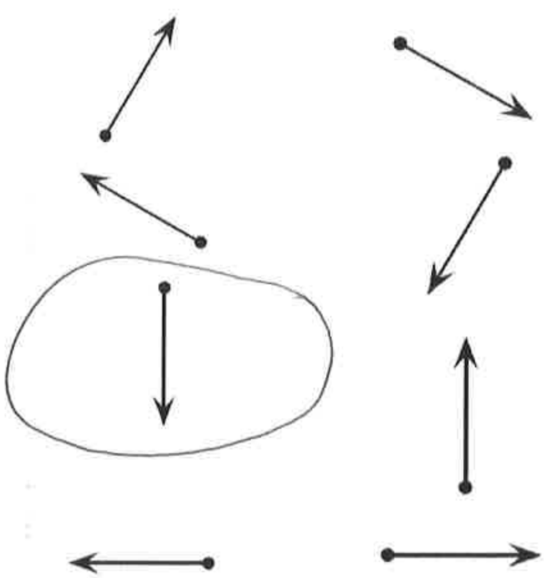
(b) The magnitudes of the acceleration relative to B are related as
1. $a_B = a_A$
2. $a_B = 0$
3. $a_B > a_C$

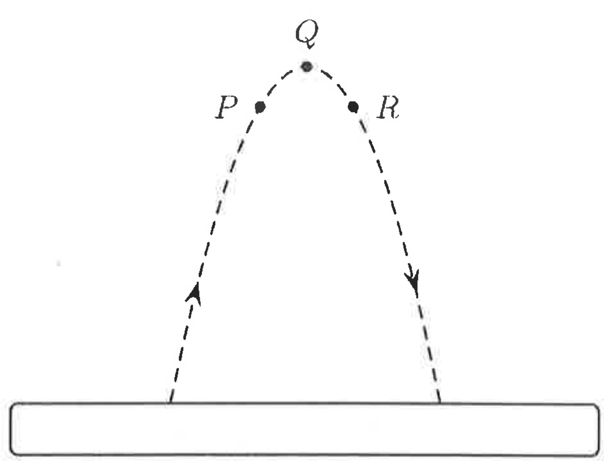
(c) The magnitudes of the acceleration relative to C are related as
1. $a_C = a_B = a_A$
2. $a_C < a_B$ and $a_A < a_B$

Problem 2

A ball is thrown and follows the parabolic path shown. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground. Which of the following diagrams best indicates the direction of the acceleration on the ball at Point R?

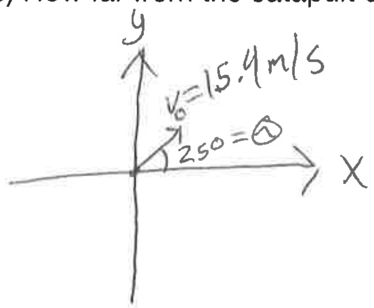
(a) The ball is in free fall and there is no acceleration at any point on its path, or
(b) Circle the correct arrow:





Problem 3

A Knight of the Round Table fires off a vat of burning pitch from his catapult at 15.4 m/s, at 25° above the horizontal. (a) How long is it in the air? (b) What is the horizontal component of the velocity? (c) How far from the catapult does it land?



$a_y = -g$

$a_x = 0$

(a) $y = y_0 + V_{0y} t + \frac{1}{2} a_y t^2$

for $y = 0$, $0 = 0 + (V_0 \sin\theta)\, t - \frac{1}{2} g t^2$

$\Rightarrow \frac{1}{2} g t = V_0 \sin\theta$

$\Rightarrow t = \frac{2 V_0 \sin\theta}{g} = 1.33\ s$

(b) $V_x = V_{0x} + a_x t = V_{0x} = V_0 \cos\theta = 13.96\ m/s$

(c) $X = X_0 + V_{0x} t + \frac{1}{2} a_x t^2$

$\Rightarrow X = V_{0x} t$

$= (13.96\ m/s)(1.33\ s)$

$= 18.57\ m$

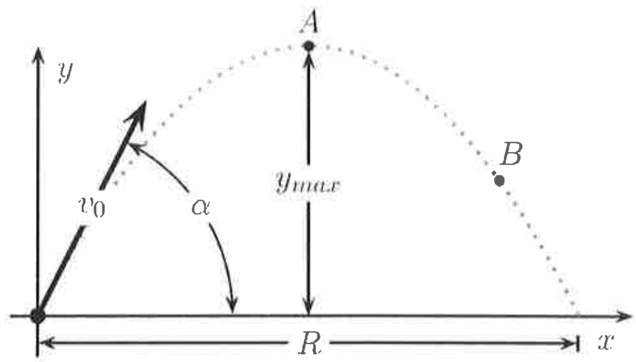
Problem 4

A projectile is fired with an initial speed v_0 at $t = 0$. The angle between the initial velocity v_0 and the horizontal plane is α.

(a) What is the time t_{max} it takes for the projectile to reach its maximum height?

(b) Given $v_0 = 23$ m/s and $\alpha = 30°$, what is the speed of the projectile when it reaches its maximum height $y = y_{max}$ (i.e., at Point A in the figure)?

(c) Find the speed of the projectile, on its way down, at the height $y = y_{max}/2$ (i.e., at Point B in the figure).



(a) $V_y = V_{oy} + a_y t$

$= V_o \sin\alpha - gt$

$V_y = 0 \Rightarrow t_{max} = \dfrac{V_o \sin\alpha}{g}$

(b) $\vec{V}(t_{max}) = V_y(t_{max})\hat{j} + V_x(t_{max})\hat{i}$

$V_y(t_{max}) = 0$

$V_x = V_{ox} + a_x t = V_{ox} = V_o \cos\alpha = 19.92\ m/s$

$V = \sqrt{V_x^2 + V_y^2} \Rightarrow V(t_{max}) = V_x(t_{max}) = 19.92\ m/s$

(c) $V_B = \sqrt{V_{Bx}^2 + V_{By}^2}$

$V_{Bx} = 19.92\ m/s$

$y = y_0 + V_{oy}t + \frac{1}{2}a_y t^2 \Rightarrow y_{max} = V_{oy}t_{max} - \frac{1}{2}g\,t_{max}^2$

$= \dfrac{V_{oy}^2}{g} - \dfrac{1}{2}g\left(\dfrac{V_{oy}^2}{g^2}\right)$

$= \dfrac{V_{oy}^2}{2g}$

$V_y^2 = V_{oy}^2 + 2a_y(y - y_0)$

$\Rightarrow V_{yB}^2 = V_{Ay}^2 + 2(-g)(y_B - y_A)$

$\Rightarrow V_{By}^2 = 0 - 2g\left[\dfrac{y_{max}}{2} - y_{max}\right] = g \cdot y_{max} = \dfrac{V_{oy}^2}{2}$

$\Rightarrow V_{By} = V_{oy}/\sqrt{2}$

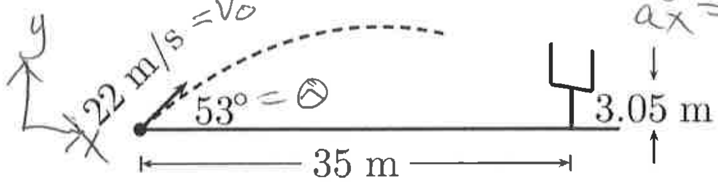
$\therefore V_B = \sqrt{(19.92\ m/s)^2 + (66.125\ m/s)}$

$= 21.52\ m/s$

Problem 5

A place kicker must kick a football from a point 35 m (about 38 yd) from the goal, and the ball must clear the crossbar, which is 3.05 m high. When kicked, the ball leaves the ground with a speed of 22 m/s at an angle of 53° to the horizontal. (a) By how much does the ball clear or fall short of clearing the crossbar? (b) To determine if the ball approaches the crossbar while still rising or while falling, what is its vertical velocity at the crossbar?

$a_y = -g$
$a_x = 0$



$x = \cancel{x_0}^{0} + V_{0x} t + \frac{1}{2} \cancel{a_x}^{0} t^2$

$\Rightarrow x = V_{0x} t = V_0 \cos\theta \, t$

to reach cross bar,

$t = \dfrac{x}{V_0 \cos\theta} = \dfrac{35\,m}{22\,m/s \cos 53°} = 2.64\,s$

$y = \cancel{y_0}^{0} + V_{0y} t + \frac{1}{2} a_y t^2$

$\Rightarrow y = V_0 \sin\theta \, t - \frac{1}{2} g t^2$

at crossbar,

$y = (17.57\,m/s)(2.64\,s) - \frac{1}{2}(9.81\,m/s^2)(2.64\,s)^2$

$= 12.26\,m$

(a) height above is

$12.26\,m - 3.05\,m = \boxed{9.2\,m}$

(b) $V_y = V_{0y} + a_y t$

$= V_0 \sin\theta - g t$

at cross bar,

$V_y = 17.57\,m/s - (9.81\,m/s^2)(2.64\,s) = -8.33\,m/s$

$\therefore$ ball is falling

Problem 6

Calculate the speed of a ball tied to a string of length 1.3 m making 1.6 revolutions every second.

$f = 1.6\ \text{rev/s}$

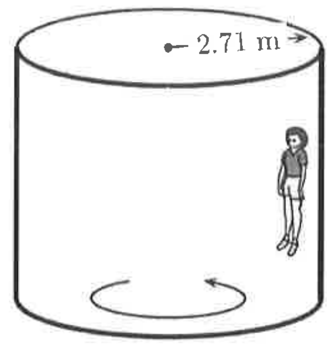
$r = 1.3\ \text{m}$

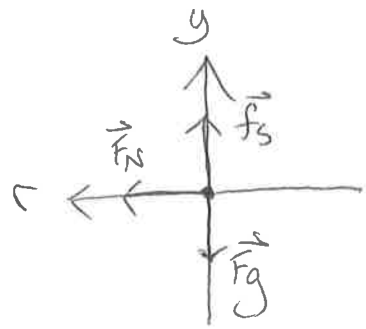
$$T = \frac{1}{f} = \frac{1}{1.6\ \text{rev/s}} = 0.625\ \text{s}$$

$$v = \frac{2\pi r}{T} = \frac{2\pi(1.3\ \text{m})}{0.625\ \text{s}} = 13.07\ \text{m/s}$$

Problem 7

In a popular amusement-park ride, a cylinder of radius 2.71 m is set in rotation at an angular speed of 4.04 rad/s, as shown in the figure. The floor then drops away, leaving the riders suspended against the wall in a vertical position. What minimum coefficient of friction between a rider's clothing and the wall of the cylinder is needed to keep the rider from slipping?





$$F_{net,y} = f_s - F_g = m\cancel{a_y}^{\,0} = 0$$

$$\Rightarrow f_s = F_g = mg$$

$$F_{net,r} = F_N = ma_r = m\frac{v^2}{r} = mr\omega^2$$

$$f_s = \mu_s F_N = \mu_s m r\omega^2$$

$$\therefore mg = \mu_s m r \omega^2$$

$$\Rightarrow \mu_s = \frac{g}{r\omega^2}$$

$$= \frac{9.81\,\mathrm{m/s^2}}{(2.71\,\mathrm{m})(4.04\,\mathrm{rad/s})^2}$$

$$= 0.22$$

Problem 8

At what minimum speed must a roller coaster be traveling when upside down at the top of a circle so that the passengers will not fall out? Assume a radius of curvature of 7.4 m.

$$\vec{F}_{net,r} = m\vec{a}_r = m\frac{v^2}{r}\hat{r}$$

↑ radial

$$F_{net,r} = F_N + F_g = F_N + mg$$

$$\Rightarrow F_N + mg = m\frac{v^2}{r}$$

$$\Rightarrow F_N = m\left(\frac{v^2}{r} - g\right)$$

$$F_N = 0 \Rightarrow \frac{v^2}{r} - g = 0$$

$$\Rightarrow v = \sqrt{rg}$$

$$= \sqrt{(7.4\,m)(9.8\,m/s^2)}$$

$$= 8.5\,m/s$$