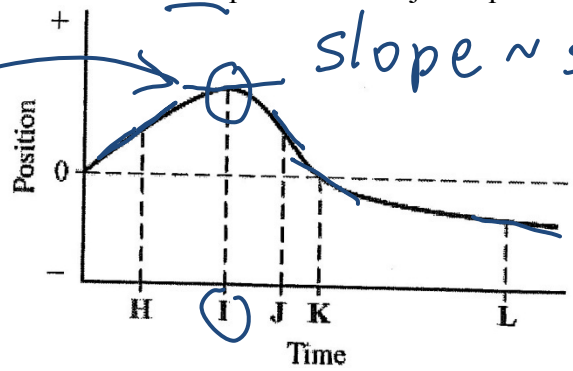
1. The plot below shows the position of an object as a function of time. The letters H-L represent particular moments of time. At which moment in time is the speed of the object equal to zero?

A. H
B. I
C. J
D. K
E. L

slope = zero here.

slope ~ speed.



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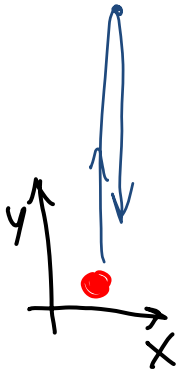
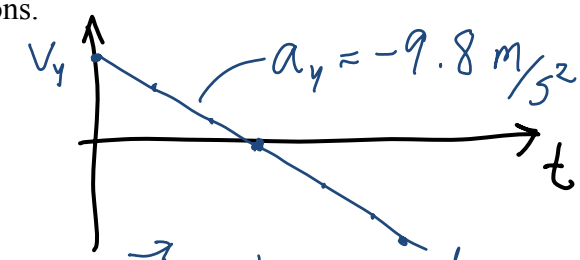
2. A hockey-ball is thrown vertically upward and then comes back down. During the ball's flight up and down, its velocity and acceleration vectors are
   A. always in opposite directions.
   B. always in the same direction.
   C. first in opposite directions and then in the same direction.
   D. first in the same direction and then in opposite directions.





$\vec{a}$ always down

$\vec{v}$ first up, then down

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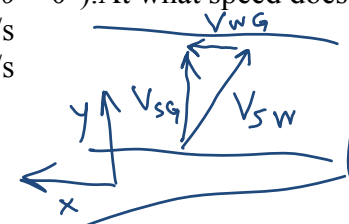
3. You want to swim straight across a river that is 66 m wide. You find that you can do this if you swim at $\theta = 18°$ upstream at a constant velocity of 1.5 m/s relative to the water. The angle is measured from the line that is perpendicular to the river bank (directly upstream is $\theta = 90°$ and directly across the river is $\theta = 0°$).At what speed does the river flow?

A. 0.14 m/s
B. 0.46 m/s
C. 1.1 m/s
D. 1.4 m/s
E. 14 m/s



S = swimmer
W = water
G = ground.

$$\vec{V}_{SG} = \vec{V}_{SW} + \vec{V}_{WG}$$

$V_{WG} = ?$ $\vec{V}_{SW} = 1.5\ m/s$, $\theta = 18°$

$(V_{SW})_x$

θ

V_{SW}

$(V_{SG})_x = 0$

$$(V_{SG})_x = 0 = (V_{SW})_x + \underbrace{(V_{WG})_x}_{= V_{WG} \cdot \sin\theta}$$

$$\sin\theta = \frac{(V_{SW})_x}{V_{SW}} \qquad |V_{WG}| = (V_{SW})_x = V_{SW} = (15\ m/s)(\sin 18)$$

4. You measure the distance between two trees to be 54.0 ± 0.5 m. Your friend, Bob, runs as fast as he can from the first tree to the second tree, touches it, and then runs all the way back to the first tree. You measure the time for his trip there and back to be 17.0 ± 0.2 s. Which of the following is a good estimate for Bob's average running speed over these 17 seconds?
   A. 6.35 ± 0.048 m/s
   B. 6.4 ± 0.1 m/s
   C. 6.35 ± 0.25 m/s
   D. 6.4 ± 0.5 m/s
   E. 6.4 ± 2.5 m/s

$$V = \frac{2d}{t} = 6.4\ m/s$$

$$2d = (54 \pm 0.5)2 = 108 \pm 1\ m$$

$$\Delta V = V\sqrt{\left(\frac{\sigma(2d)}{2d}\right)^2 + \left(\frac{\sigma t}{t}\right)^2}$$

$$= 6.4\sqrt{\left(\frac{1}{108}\right)^2 + \left(\frac{0.2}{17}\right)^2} = 0.0958\ldots \sim 0.1\ m/s$$

5. A satellite uses an infrared radiometer to indirectly measure the surface temperature of the ocean off the coast of British Columbia. The temperature is measured 5 times in the same week, and the measurements reported are 10.40, 10.35, 10.31, 10.56, and 10.43, all in degrees Celsius (°C). The estimated mean of these five measurements is 10.41°C. What is the error in this estimated mean?
   A. 0.005°C
   B. 0.01°C
   C. 0.04°C
   D. 0.1°C
   E. 0.25°C

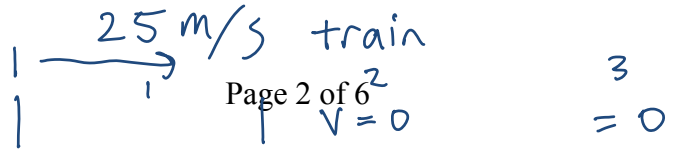
$$\sigma = \sqrt{\frac{1}{N-1}\sum_i (x_i - \bar{x})^2}$$

$$= \left[\frac{1}{4}\left[(10.40-10.41)^2 + (10.35-10.41)^2 + (10.31-10.41)^2 + (10.56-10.41)^2 + (10.43-10.41)^2\right]\right]^{1/2}$$

$$\sigma = 0.0956°C \Leftarrow \text{error in one meas.}$$

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{5}} = 0.0427°C$$

6. A car and a train move together along straight, parallel paths with the same constant cruising speed of 25 m/s. Initially they are side-by-side.Suddenly, the car driver notices a red light ahead and slows down with constant acceleration of −5.0 m/s^2 until it stops. The car remains stopped for 15 seconds. The light turns green, and the car begins to speed up with a constant acceleration of +5.0 m/s^2 until it reaches its original speed of 25 m/s. During the same time interval, the train continues to travel at the constant speed 25 m/s. How far behind the train is the car after it has reached its original speed again?
   a. 130 m



b. 250 m
c. 380 m
d. 500 m
e. 630 m

$v_0 = 25\ m/s$
$v_f = 0$
$a_1 = -5\ m/s^2$
$t_1 = \frac{\Delta v}{a} = \frac{25}{5}$
$t_1 = 5s$
$d_1 = \bar{v}\, t_1$
$= \left(\frac{v_0 + v_f}{2}\right) t_1$
$\left(\frac{25+0}{2}\right) 5$
$d_1 = 62.5m$

$t_2 = 15s$
$d_2 = 0$

v_0
$v_f = 25 m/s$
$a_3 = +5 m/s^2$
$t_3 = \frac{\Delta v}{a} = 5s$
$d_3 = \bar{v}\, t_3$
$= \left(\frac{0+25}{2}\right) 5s$
$d_3 = 62.5m.$

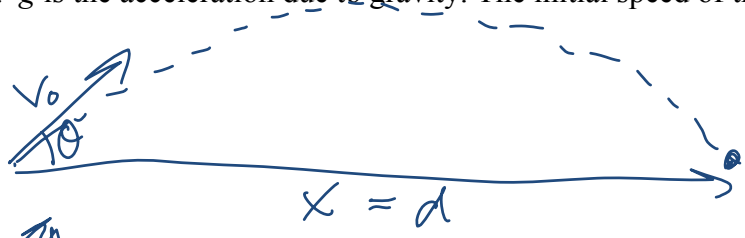
$d_{car} = d_1 + d_2 + d_3 = 62.5m + 0 + 62.5m$
$d_{car} = 125m$

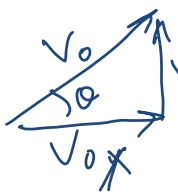
$d_{train} = v(t_1 + t_2 + t_3)$
$= 25 m/s\,(5 + 15 + 5)$
$d_{train} = 625m$

$d_{train} - d_{car} = 625 - 125 = 500m$

7. A baseball is hit at angle θ above the horizontal, and is caught at the height from which it was hit, a horizontal distance, d, away. g is the acceleration due to gravity. The initial speed of the ball when it is leaving the bat is

A. $\sqrt{\frac{gd}{2\sin\theta\cos\theta}}$
B. $\sqrt{\frac{gd}{2\sin\theta}}$
C. $\sqrt{\frac{gd}{\sin\theta\cos\theta}}$
D. $\sqrt{gd\tan\theta}$
E. $\sqrt{gd\sin(2\theta)}$





$v_{0y} = v_0 \sin\theta$, $v_{0x} = v_0 \cos\theta$

x	y
$a_x = 0$	$a_y = -g$
$v_x = v_{0x} = \frac{x}{t} = \frac{d}{t}$	By symmetry, half-way point, $v_y = 0$.
$v_0 \cos\theta = \frac{d}{t}$	$a_y = \frac{\Delta v_y}{\Delta t} = \frac{0 - v_{0y}}{(t/2)}$
→ solve for t, so we can eliminate it. $t = \frac{d}{v_0 \cos\theta}$	

$$-g = \frac{-v_0 \sin\theta}{(t/2)}$$

set equal

$$t = \frac{2 v_0 \sin\theta}{g}$$

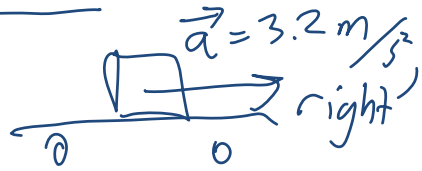
$$\frac{d}{v_0 \cos\theta} = \frac{2 v_0 \sin\theta}{g}$$

$$gd = 2 v_0^2 \sin\theta \cos\theta$$

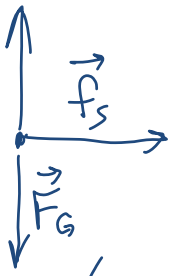
$$v_0 = \sqrt{\frac{gd}{2 \sin\theta \cos\theta}}$$

8. A box of mass 450 kg is in the back of a truck. The truck is accelerating to the right at 3.2 m/s^2. The box does not slide. What is the magnitude of the force of static friction on the box?
   a. 700 N
   b. 1400 N
   c. 4400 N
   d. less than 440 N
   e. not enough information to determine

$\mu_s = ?$ ....



f.b.d.



$$(\vec{F}_{Net})_x = \vec{f}_s = ma_x$$

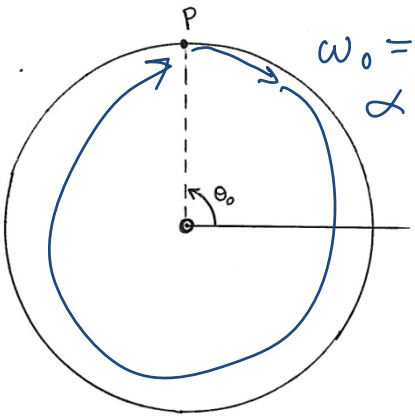
$$f_s = ma = (450\ kg)(3.2\ m/s^2) = 1440\ N$$

2 sig figs.

FREE-FORM PART A (4 points)

The position of a point P on a wheel is described by an angle θ, measured counterclockwise relative to a horizontal line, which passes through the wheel axle. At time $t = 0$, the point P is at its highest point, with an initial angular position of $\theta_0 = +\pi/2$, as shown in the figure. The initial angular velocity is $\omega_0 = -2.0\pi$rad/s (the wheel is initially turning clockwise). The wheel is connected to a motor which causes it to have a constant angular acceleration of $\alpha = +0.40$ rad/s^2. At what time $t_1 > 0$ does the point P first pass this highest point again? [Please write your final answer in the box provided, and express your answer to 2 significant figures.]

don't care about ω_f, need t

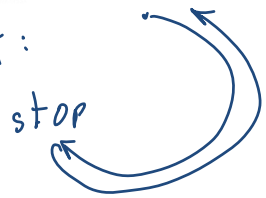


$\omega_0 = -2\pi \text{ rad/s}$

$\alpha = +0.4 \text{ rad/s}^2$

when is P at top again?

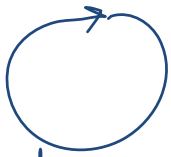
Either A:



$\Delta\theta = 0$

or

B:



$\Delta\theta = 2\pi$ ..

When does it stop?

$\alpha = \frac{\Delta\omega}{\Delta t}$, $\Delta t_{stop} = \frac{|\omega_0|}{\alpha}$

$\Delta t_{stop} = \frac{2\pi \text{ rad/s}}{0.4 \text{ rad/s}^2} = 15.7 \text{ s}$

$\Delta\theta = \bar{\omega} \cdot \Delta t_{stop} = \left(\frac{2\pi + 0}{2}\right) 15.7$

$= 24.6 \text{ rad} \rightarrow 4 \text{ 2 turns!}$

$\rightarrow$ case B: $\Delta\theta = 2\pi$

$\theta_f - \theta_0 = -2\pi$

use

$\theta_f = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\frac{\alpha}{2} t^2 + \omega_0 t + (\theta_0 - \theta_f) = 0$

Quadratic, with $x \rightarrow t$

$a \rightarrow \alpha/2$

$b \rightarrow \omega_0$

$c \rightarrow \theta_0 - \theta_f$

$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$t = \frac{-\omega_0 \pm \sqrt{\omega_0^2 - 2\alpha(\theta_0 - \theta_f)}}{\alpha}$

Set $\theta_0 - \theta_f = 2\pi$ (all the way around.

$t = \frac{2\pi \pm \sqrt{(2\pi)^2 - 0.8(2\pi)}}{0.4}$

$t = \frac{2\pi \pm 5.8696}{0.4} = 30.4 \text{ s}$

first time $\rightarrow$ or 1.034 s

$\boxed{t_1 = 1.0 \text{ s}}$

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FREE-FORM PART B (4 points)

In the Practicals a student uses the computer-based ultrasonic motion sensor to measure distance versus time for a cart. The cart has low-friction wheels and is on a straight 2.2-metre aluminum track that is tilted at some angle. The cart is released from rest at time $t = 2.7$ s, and distance data is collected at a rate of about 10 measurements per second until $t = 9.1$ s. Over this time, the distance increases from 57 cm up to 200 cm as the cart slowly rolls down the slope. A polynomial function of t is fit to the data:

$$\text{Distance (cm)} = a0 + a1\, t + a2\, t^2$$

Where t is the time in seconds, and a0, a1 and a2 are the fit coefficients. The fit is shown below. The best fit gives:

- a0 = 64 ± 0.31 cm
- a1 = −10.95 ± 0.11 cm/s

- a2 = 2.8792 ± 0.0094 cm/s^2

From this fit, what would you conclude is the acceleration of the cart? [Please write your final answer in the box provided, and include the error in your estimate.]

$$x_f = \underset{a0}{x_0} + \underset{a1}{v_0} t + \underset{a2}{\tfrac{1}{2} a t^2}$$

$\frac{1}{2} a = a2$

$a = 2(2.8792 \pm 0.0094)\ cm/s^2$

value: 5.7584

error: 0.0188 ← 1 or 2 sig figs.

most precise specified.

10ths place of error → 10th place of value.

$a = 5.76 \pm 0.02\ cm/s^2$

or

$5.758 \pm 0.019\ cm/s^2$

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FREE-FORM PART C (4 points)

A tow rope pulls a skier up a snow-covered hill at a constant speed. Draw the free-body diagram of the skier. Please choose the forces from the following list of six possibilities, and use the symbols given when you label the force vectors. Not all of these forces may actually be acting on the skier. Please draw the free-body diagram within the box provided below.

- Gravitational force: $\vec{F}_G$
- Spring force: $\vec{F}_{sp}$
- Tension: $\vec{T}$
- Normal force: $\vec{n}$
- Static friction: $\vec{f}_s$
- Kinetic friction: $\vec{f}_k$