Physics 195 **Fall 2009** **Problem Set 2**

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

Conceptual Questions: **Place the letter** corresponding to your answer **in the box.**
Limit your explanation to the space provided. Please write legibly.

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1. Is it possible for an object to have a non-zero velocity and a zero acceleration at some time?

$\boxed{A}$

a) Yes, of course.
b) No, of course not.
c) Depends on other information.
Explain

after being accelerated to some final velocity, a could go to zero.
For example - starting at a red light you accelerate from rest to 35 mph and maintain that speed for the next mile...

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2. Is it possible for an object to have traveled a distance greater than zero, yet have a zero displacement?

$\boxed{A}$

a) Yes, of course.
b) No, of course not.
c) Depends on other information.
Explain

since displacement is a vector that depends only on endpoint locations any round trip will result in distance > Ø but displacement of Ø.

Due on or before 9/11

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

3. Is it possible for an object to have a displacement greater than zero, yet have traveled a distance of zero?

$\boxed{B}$

a) Yes, of course.
b) No, of course not.
c) Depends on other information.
Explain

since a zero distance traveled means that the initial and final positions are the same, you cannot have a displacement > $\emptyset$ if $\Delta x = \emptyset$.

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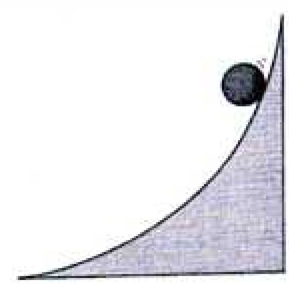
4. As the ball rolls down the hill pictured, its speed will ________ and its downhill acceleration component will __________.



$\boxed{C}$

a) Increase, increase
b) Decrease, decrease
c) Increase, decrease
d) Decrease, increase
e) Decrease, remain constant
f) Increase, remain constant
g) Depends on other information.
Explain

the ball is accelerated the entire time, so it does continuously increase speed, but as the slope of the hill $\to \emptyset$ $g \sin\theta \to \emptyset$ and $a \to \emptyset$

both rocks travel same distance ... ∴ displacement is the same...

$$\Delta y_A = V_{0A}t + \frac{1}{2}g t_A^2 \Rightarrow \Delta y_A(+\hat{y}) = \emptyset + \frac{1}{2}g t_A^2(+\hat{y})$$

$$\Delta y_B(+\hat{y}) = V_{0B} t_B(+\hat{y}) + \frac{1}{2}g t_B^2(+\hat{y})$$

$$\therefore \frac{1}{2}g t_A^2 = V_{0B}t_B + \frac{1}{2}g t_B^2 \; ; \; t_A = t_B + t$$

$$t_A^2 = \frac{2V_{0B}}{g}t_B + t_B^2 \Rightarrow t_A^2 - t_B^2 = \frac{2V_{0B}t_B}{g}$$

$$(t_B+t)^2 - t_B^2 = \frac{2V_{0B}t_B}{g} \Rightarrow t_B^2 + 2tt_B + t^2 - t_B^2 = \frac{2V_{0B}t_B}{g}$$

$$t^2 + 2tt_B - \frac{2V_{0B}t_B}{g} = \emptyset \quad \text{quadratic in } t$$

$a=1 \quad b=2t_B \quad c=-\frac{2V_{0B}t_B}{g}$

$$t = \frac{-2t_B \pm \sqrt{4t_B^2 + 4(1)\left(\frac{2V_{0B}t_B}{g}\right)}}{2}$$

$$t = -t_B \pm \sqrt{t_B^2 + \frac{2V_{0B}t_B}{g}} \Rightarrow -t_B \pm t_B\sqrt{1 + \frac{2V_{0B}}{g t_B}}$$

since $t < \emptyset$ makes no sense - must choose + root ...

$$-t_B + t_B\left(1 + \frac{2V_{0B}}{g t_B}\right)^{\frac{1}{2}} \Rightarrow t_B\left[\left(1 + \frac{2V_{0B}}{g t_B}\right)^{\frac{1}{2}} - 1\right]$$

$$\boxed{t = t_B\left[\sqrt{1 + \frac{2V_{0B}}{g t_B}} - 1\right]}$$

$$t = \frac{t_B}{N} \quad \therefore \quad \frac{t_B}{N} = t_B\left[\sqrt{1+\frac{2V_{0B}}{g t_B}} - 1\right]$$

$$\frac{1}{N} + 1 = \sqrt{1+\frac{2V_{0B}}{g t_B}} \qquad \left[\frac{N+1}{N}\right]^2 = 1 + \frac{2V_{0B}}{g t_B}$$

$$\left[\frac{N+1}{N}\right]^2 - 1 = \frac{2V_{0B}}{g t_B} \qquad t_B = \frac{2V_{0B}}{g} \cdot \frac{1}{\left[\frac{N+1}{N}\right]^2 - 1}$$

$$t_B = \frac{2V_{0B}}{g} \cdot \frac{1}{\frac{(N+1)^2 - N^2}{N^2}} \Rightarrow \frac{2V_{0B}}{g} \cdot \frac{N^2}{(N+1)^2 - N^2}$$

$$\rightarrow \frac{2V_{0B}}{g} \cdot \frac{N^2}{N^2 + 2N + 1 - N^2} \Rightarrow \boxed{\frac{2V_{0B}}{g} \cdot \frac{N^2}{2N+1} = t_B}$$

$$H(+\hat{y}) = V_{0B} t_B (+\hat{y}) + \frac{1}{2} g t_B^2 (+\hat{y})$$

$$H = \frac{2V_{0B}^2}{g}\left[\frac{N^2}{2N+1}\right] + \frac{g}{2} \frac{4V_{0B}^2}{g^2}\left[\frac{N^2}{2N+1}\right]^2$$

$$H = \frac{2V_{0B}^2}{g}\left(\frac{N^2}{2N+1}\right)\left[1 + \left(\frac{N^2}{2N+1}\right)\right] \Rightarrow \boxed{\frac{2V_{0B}^2}{g}\left(\frac{N^2}{2N+1}\right)\left(\frac{N^2+2N+1}{2N+1}\right)}$$

d) $$H = \frac{2(10)^2 \frac{m^2}{s^2}}{9.8 \frac{m}{s^2}}\left(\frac{25}{11}\right)\left(\frac{25+10+1}{11}\right) \simeq \boxed{151.8\,m}$$

$$a_{car} = \frac{60\,\frac{miles}{hr} - \emptyset}{4.5s} = \frac{60}{4.5}\,\frac{miles}{hr\cdot sec}$$

$$13.33\,\frac{miles}{hr\cdot s} \times \frac{1hr}{3600s} = \emptyset.\emptyset\emptyset37\,\frac{miles}{s^2} \times \frac{1.6\cdot 10^3 m}{mi} \simeq 5.93\,\frac{m}{s^2}$$

$$\boxed{a_{car} \simeq 5.93\ m/s^2}$$

with $x_f = X$ $x_o = \emptyset$, $V_o = \emptyset$ $a = 5.93\,m/s^2$]- for your car
$x_f = X$ $x_o = \emptyset$ $V_o = 55\,\frac{mi}{hr} \times \frac{1600m}{3600s} \simeq 24.4\,\frac{m}{s}$ $a = \emptyset$]- cycle.

since you will be in same spot when you catch the cyclist...

$$\frac{1}{2}at^2 = V_{om}t \quad \therefore \quad \frac{2V_{om}}{a} = t = \frac{2(24.4)}{5.93} \simeq 8.24s$$

when $t = 8.24s$ you have drawn level w/ cyclist...

$$\Delta X_{you} = \frac{1}{2}(5.93\,m/s^2)(8.24s)^2 \simeq \boxed{201.5m\,(+\hat{x})}$$

$$v_f = V_o + at \Rightarrow (5.93\,m/s^2)(+\hat{x})(8.24s) \simeq \boxed{48.86\,\frac{m}{s}}$$

you - $V_o = 31.1\,m/s\,(+\hat{x})$ them $V_o = 6.67\,m/s\,(+\hat{x})$
you - $a_{min} = ?\ m/s^2(-\hat{x})$ them $a = \emptyset$
you $X_o = \emptyset$ them $X_o = 400m\,(+\hat{x})$

during the $\frac{1}{2}$ second of foot movement, your car travels a distance $x_f = x_o + V_o t = \emptyset + 15.5m\,(+\hat{x})$ and their car travels a distance $x_f = 400 + V_o t$
$X_{f_T} = 403.34m\,(+\hat{x})$

$\therefore$ the distance b/t the cars $= 403.3m - 15.5m$

$$= \boxed{387.8m}$$

simplest way to proceed is to transform to the FOR of your vehicle ... in that reference frame

you are @ x_0 they are @ 387.8m ($+\hat{x}$)

you are moving towards them with a relative velocity of $31.1\,m/s(+\hat{x}) - 6.67\,m/s(+\hat{x}) = 24.4\,m/s(+\hat{x})$

$v_f^2 = v_0^2 + 2a\Delta x$ then within this FOR...

$\emptyset = (24.4\,m/s)^2 - 2a(387.8m) \Rightarrow a_{min} \simeq \emptyset.7695$

$$\boxed{a_{min} = 7.7\cdot10^{-1}\,m/s^2(-\hat{x})}$$

$$0 = v_f = \underbrace{\cancel{}}_{}\overset{24.4\,m/s(+\hat{x})}{} + 7.7\cdot10^{-1}\tfrac{m}{s^2}(-\hat{x})t \qquad \therefore t = \frac{24.4\frac{m}{s}}{7.7\cdot10^{-1}\,m/s^2} \simeq 31.71s$$

so - it takes you 31.7 sec to slow down - and in this time...

$x_f = x_0 + v_0t - \frac{1}{2}at^2 \Rightarrow$ with $x_0 = \emptyset$ $v_0 = 31.1$

$x_f = \emptyset + 31.1\frac{m}{s}(31.7s) - \frac{1}{2}(.77\,m/s^2)(31.71s)^2$

$985.9m - 386.9m = 598.97 \sim \boxed{599m}$

oops - sorry - almost forgot... you traveled 15.5m before you started to slow down ...

total displacement = $\boxed{614.5m}$

$t_{fall} + t_{sound} = t$

distance traveled by rock = distance traveled by sound...

~~$\frac{1}{2} g t_{fall}^2 = V_{sound} t_{sound} = V_s t$~~ oops.

$\frac{1}{2} g t_{fall}^2 = V_{sound} t_{sound}$ $\quad t_{sound} = t - t_{fall}$

$\frac{1}{2} g t_f^2 = V_s (t - t_f) = V_s t - V_s t_f$ and so

$\frac{1}{2} g t_f^2 + V_s t_f - V_s t = \emptyset$ $\quad$ with $\frac{1}{2} g = 4.91 \frac{m}{s^2}$, $V_s = 340 \frac{m}{s}$

$V_s t = 2210\ m$

$4.91 t_f^2 + 340 t_f - 2210 = \emptyset$ $\quad t_f = \frac{-340 \pm \sqrt{340^2 + 4(4.91)(2210)}}{9.81}$

$t_{fall} \sim 5.99s$ $\therefore$ $t_{sound} \sim \emptyset.5s$

a) well is $V_s t_s$ m deep $\simeq \boxed{170\ m}$

b) $v_f = v_0 + g t_{fall} = \emptyset + 9.81 \frac{m}{s^2}(6s) \simeq \boxed{58.9\ m/s}$