Physics 195 **Midterm 1, Summer 2010** **D. Brownell**

Name:	Circle one: AM PM	Score: /125

There are **five** problems, each of which is equally weighted at 25 points. You may use your calculator plus a single equation sheet handwritten on one side. If you have forgotten either of these tools, shame on you ☺ (I might have spares – come ask). Write your answers only on the colored paper provided for you, one question per sheet. Do not put multiple questions on one sheet. You may use the back of a sheet only if you need more room to work out the question on the front. For the purposes of this quiz, please use $\boldsymbol{g = 10\ \mathrm{m/s^2}}$. Good luck!

1. Shelly plays baseball with her little brother all the time and recently threw the ball 90 meters, her furthest ever, while her brother threw it 120 m. Later Shelly was standing on the edge of the roof of Tioga Hall at UCSD (35 m high which is about 10 stories up) and threw the ball off at a 36.87° angle above the horizon. *(a)* What is the maximum speed that she can throw the ball? *(b)* After she threw the ball from Tioga Hall, how long did the ball stay in the air before hitting the ground? *(c)* How far from the building did the ball land? *(d)* What was the ball's velocity $\mathbf{v}(t)$ (both x and y components) as it hit the ground? *(e)* What was the ball's speed v and angle θ below the horizon at that instant?

2. The *1-D* speed of a particle is given by the function $v(t) = 4t^3 - 8t$. *(a)* Calculate the position and *(b)* the acceleration as <u>functions of time</u>. Assume that $x(0) = 0$. *(c)* Make three separate sketches of the functions $x(t)$, $v(t)$, and $a(t)$, for the interval $t_i = -4$ s to $t_f = 4$ s. Calculate the times for the zeros of the three functions.

3. A hound and a deer are in a chase on a forest green. The deer is running due North at 25 m/s and the hound is headed 53.13° NE at 20 m/s. Assume they are on a collision course. *(a)* What is the velocity of the deer relative to the hound (both speed and direction) when they collide at the origin? *(b)* Now, here's the challenge: If the chase lasted exactly 10 seconds, what were the starting positions (*vectors!*) of the two animals relative to the end point (which is set at the origin), and *(c)* how far apart were they when the hound spotted the deer? *Please draw a sketch for full credit*. (Note: there is **no** acceleration anywhere in this problem.)

4. Here are three position vectors: **A** = (12, –9), **B** = 6 **i** + 8 **j**, and **C** = (20, 143.13°), all in units of meters. Calculate the following: *(a)* $A = |\mathbf{A}|$, $B = |\mathbf{B}|$, and $C = |\mathbf{C}|$ *(b)* **A** – 2**B** *(c)* 4**A** + 3**C** *(d)* **A** • **B** *(e)* **B** • **C** and *(f)* **A** • **C**. *(g)* How do you interpret each of the results in parts (*b*) through (*f*), *i.e.* can you explain the results using pictorial or geometrical arguments?

5. A speeder moving at a constant 90 km/h (about 40 mph), passes a parked (stationary) police car. Since the local speed limit is 72 km/h, the officer decides to chase the speeder to give her a ticket. The police car accelerates uniformly from rest at 5 m/s^2. ***(a)*** How long does it take for the officer to overtake the speeder? ***(b)*** How far does the speeder get before being overtaken by the officer? ***(c)*** What is the officer's speed at that moment? ***(d)*** What's wrong with this "picture" – what is very non-physical at the end of the chase? How could the officer change his motion to make the chase end more realistically?

6. ***<u>Extra Credit</u>***: Identify as many *red herrings* as you can, *i.e.* numerical pieces of information which are not needed for any part of a problem.

Physics 195

Midterm 1, Summer 2010

D. Brownell

(1)

$R=\frac{v_0^2}{g}\rightarrow v_0=\sqrt{Rg}\rightarrow \boxed{v_0=30\text{ m/s}}$

$y_f=y_0+v_0\sin(\theta)t-\frac{1}{2}gt^2\rightarrow 0=35+18t-5t^2$

$\boxed{t=+5\text{ s,}}$ or -1.4 s $\rightarrow$ Choose <+>.

$x_f=v_0(\cos\theta)t\rightarrow \boxed{x_f=120\text{ m}}$

$v_y=v_0\sin\theta-gt=-32$ m/s

$\boxed{\underset{\sim}{\mathbf{v}}_f=(24,-32)\text{ m/s}}\rightarrow \boxed{v_f=40\text{ m/s, and }\theta=-53.13^\circ}$

5 points each

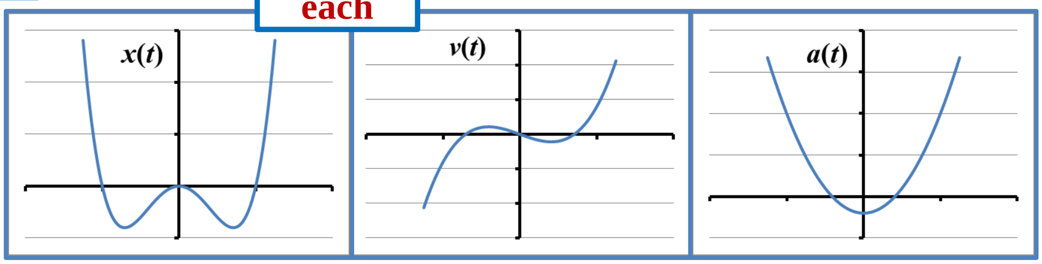
(2)

$\boxed{x(t)=\int v(t)dt+C=t^4-4t^2+\cancel{C}^{\,0}}$

$v(t)=4t^3-8t$

$\boxed{a(t)=\frac{d}{dt}v(t)=12t^2-8}$

5 points each



Zeros:

$x=0$ at $t=0,\pm 2$

$v=0$ at $t=0,\pm\sqrt{2}=\pm 1.414$

$a=0$ at $t=\pm\sqrt{2/3}=\pm 0.8165$

(3)

$\underset{\sim}{\mathbf{v}}_{DG}=(0,25)$ m/s

$\underset{\sim}{\mathbf{v}}_{HG}=20(\cos\theta,\sin\theta)=(12,16)$ m/s

$\underset{\sim}{\mathbf{v}}_{DH}=\underset{\sim}{\mathbf{v}}_{DG}-\underset{\sim}{\mathbf{v}}_{HG}=(-12,9)$ m/s

$v_{DH}=15$ m/s headed 36.87° NW

$\underset{\sim}{\mathbf{x}}_{0D}=-\underset{\sim}{\mathbf{v}}_{DG}t=(0,-250)$ m

$\underset{\sim}{\mathbf{x}}_{0H}=-\underset{\sim}{\mathbf{v}}_{HG}t=(-120,-160)$ m

$\Delta\underset{\sim}{\mathbf{x}}=(120,90)\text{ m}\rightarrow \boxed{\Delta x=150\text{ m apart}}$

5 points each

(4)

$\underset{\sim}{\mathbf{A}}=(12,-9)$, $\underset{\sim}{\mathbf{B}}=(6,8)$, $\underset{\sim}{\mathbf{C}}=(-16,12)$

$\boxed{A=15,\ B=10,\ C=20}$

5 points

$\underset{\sim}{\mathbf{A}}-2\underset{\sim}{\mathbf{B}}=(12,-9)-(12,16)\rightarrow \boxed{\underset{\sim}{\mathbf{A}}-2\underset{\sim}{\mathbf{B}}=(0,-25)\rightarrow \text{3-4-5 right triangle}}$

$4\underset{\sim}{\mathbf{A}}+3\underset{\sim}{\mathbf{C}}=(48,-36)+(-48,36)\rightarrow \boxed{4\underset{\sim}{\mathbf{A}}+3\underset{\sim}{\mathbf{C}}=0\rightarrow \text{ cancels = antiparallel}}$

$\underset{\sim}{\mathbf{A}}\bullet\underset{\sim}{\mathbf{B}}=12\cdot 6-9\cdot 8\rightarrow \boxed{\underset{\sim}{\mathbf{A}}\bullet\underset{\sim}{\mathbf{B}}=0\rightarrow \text{ vectors are perpendicular }=\perp}$

$\underset{\sim}{\mathbf{B}}\bullet\underset{\sim}{\mathbf{C}}=-6\cdot 16+8\cdot 12\rightarrow \boxed{\underset{\sim}{\mathbf{B}}\bullet\underset{\sim}{\mathbf{C}}=0\rightarrow \text{ vectors are perpendicular }=\perp}$

$\underset{\sim}{\mathbf{A}}\bullet\underset{\sim}{\mathbf{C}}=-12\cdot 16-9\cdot 12\rightarrow \boxed{\underset{\sim}{\mathbf{A}}\bullet\underset{\sim}{\mathbf{C}}=-300\rightarrow \text{magnitude}=-A\cdot C=\text{antiparallel}}$

4 points each

(5)

$\boxed{v_s=90\text{ kph}=25\text{ m/s}}\rightarrow x_s=v_st\text{, and }a_p=5\text{ m/s}^2\rightarrow x_p=\frac{1}{2}a_pt^2$

$x_s=x_p\rightarrow v_st=\frac{1}{2}a_pt^2\rightarrow \boxed{t=\frac{2v_s}{a_p}=10\text{ s}}$

$\boxed{x=250\text{ m,}}\ \boxed{v_{fp}=a_pt=50\text{ m/s}=180\text{ kph}=\textit{too fast}!}$

Suggested fix: cop should speed up to 120 kph, then decelerate at a rate which will allow him to end just behind the speeder at exactly her velocity without passing her.

5 points each

Red herrings: (1) 10 stories high, 120 m distance, (2) 1-D, (5) 40 mph, 72 kph speeds

Physics 195 **Midterm 1, Summer 2010** **D. Brownell**

Name: Francesco Meli	lab: B (1:15pm)	Score: 104 /125

There are **five** problems, each of which is equally weighted at 25 points. You may use your calculator plus a single equation sheet handwritten on one side. If you have forgotten either of these tools, shame on you ☺ (I might have spares – come ask). Write your answers only on the colored paper provided for you, one question per sheet. Do not put multiple questions on one sheet. You may use the back of a sheet only if you need more room to work out the question on the front. For the purposes of this quiz, please use **$g = 10\ m/s^2$**. Good luck!

1. Shelly plays baseball with her little brother all the time and recently threw the ball 90 meters, her furthest ever, while her brother threw it 120 m. Later Shelly was standing on the edge of the roof ~~of Tioga Hall at UCSD~~ (35 m high which is about 10 stories up) and threw the ball off at a 36.87° angle above the horizon. *(a)* What is the maximum speed that she can throw the ball? *(b)* After she threw the ball from Tioga Hall, how long did the ball stay in the air before hitting the ground? *(c)* How far from the building did the ball land? *(d)* What was the ball's velocity *v(t)* (both *x* and *y* components) as it hit the ground? *(e)* What was the ball's speed *v* and angle θ below the horizon at that instant?

2. The *1-D* speed of a particle is given by the function $v(t) = 4t^3 - 8t$. *(a)* Calculate the position and *(b)* the acceleration as functions of time. Assume that $x(0) = 0$. *(c)* Make three separate sketches of the functions $x(t)$, $v(t)$, and $a(t)$, for the interval $t_i = -4$ s to $t_f = 4$ s. Calculate the times for the zeros of the three functions.

3. A hound and a deer are in a chase on a forest green. The deer is running due North at 25 m/s and the hound is headed 53.13° NE at 20 m/s. Assume they are on a collision course. *(a)* What is the velocity of the deer relative to the hound (both speed and direction) when they collide at the origin? *(b)* Now, here's the challenge: If the chase lasted exactly 10 seconds, what were the starting positions (*vectors!*) of the two animals relative to the end point (which is set at the origin), and *(c)* how far apart were they when the hound spotted the deer? *Please draw a sketch for full credit.* (Note: there is **no** acceleration anywhere in this problem.)

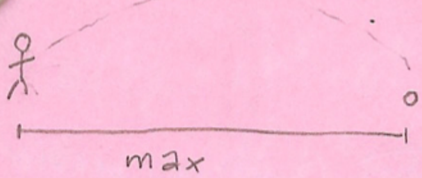
+4

4. Here are three position vectors: **A** = (12, –9), **B** = 6 **i** + 8 **j**, and **C** = (20, 143.13°), all in units of meters. Calculate are the following: *(a)* $A = |\mathbf{A}|$, $B = |\mathbf{B}|$, and $C = |\mathbf{C}|$ *(b)* **A** – 2**B** *(c)* 4**A** + 3**C** *(d)* **A** • **B** *(e)* **B** • **C** and *(f)* **A** • **C**. *(g)* How do you interpret each of the results in parts (*b*) through (*f*), *i.e.* can you explain the results using pictorial or geometrical arguments?

5. A speeder moving at a constant 90 km/h (about 40 mph) passes a parked (stationary) police car. Since the local speed limit is 72 km/h, the officer decides to chase the speeder to give her a ticket. The police car accelerates uniformly from rest at 5 m/s^2. *(a)* How long does it take for the officer to overtake the speeder? *(b)* How far does the speeder get before being overtaken by the officer? *(c)* What is the officer's speed at that moment? *(d)* What's wrong with this "picture" – what is very non-physical at the end of the chase? How could the officer change his motion to make the chase end more realistically?

6. ***Extra Credit***: Identify as many *red herrings* as you can, *i.e.* numerical pieces of information which are not needed for any part of a problem.

Problem number 1



$\theta = 45°$
$x_0 = 0\,m$
$y_0 = 0\,m$
$x_f = 90\,m$
$y_f = 0\,m$
$v_{x0} = \cos\theta\, v_0$
$v_{y0} = \sin\theta\, v_0$
$a_y = g = -10\,\frac{m}{s^2}$
$t = ?$
$v_{fy} = ?$
$v_{fx} = v_{0x}$

22

$v_{fy} = v_{0y} - gt$ [3]

$y_f = y_0 + v_{0y}t - \frac{gt^2}{2}$ [2]

$x_f = x_0 + v_{0x}t - \cancel{\frac{gt^2}{2}} = v_{0x}t$ [2]

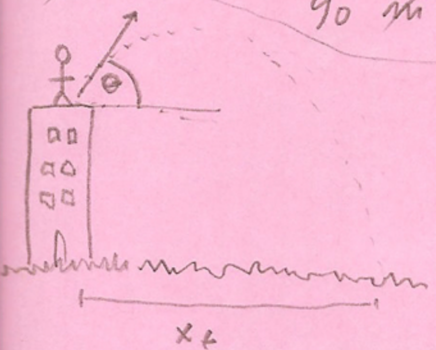
$$\boxed{t = \frac{x_f}{v_{0x}} = \frac{x_f}{\cos\theta\, v_0}}$$

$$y_f = y_0 + \frac{\sin\theta\, v_0 \cdot x_f}{\cos\theta\, v_0} - \frac{g x_f^2}{\frac{\cos^2\theta\, v_0^2 \cdot 2}{\cancel{2}}}$$

$\theta_{max} = 45°$, so $\cos^2\theta = \frac{1}{2} = 0.5$

$$\tan\theta \cdot 90\,m - \frac{10\,\frac{m}{s^2} \cdot 8100\,m^2}{1\,\cancel{(0.25)}\, v_0^2} = 0 \qquad \frac{324.000\,\frac{m^3}{s^2}}{v_0^2} = 90\,m$$

$$v_0 = \sqrt{\frac{\cancel{324.000}\ 81000\,\frac{m^{3}}{s^2}}{90\,m}} = \boxed{\cancel{60}\ 30\,\frac{m}{s}} \text{ (a)}$$



$\theta = 36.87°$
$x_0 = 0\,m$
$y_0 = 35\,m$
$x_f = ?$
$y_f = 0\,m$
$48\,\frac{m}{s} = v_{x0} = \cos\theta\, v_0$
$36\,\frac{m}{s} = v_{y0} = \sin\theta\, v_0$
$a_y = -10\,\frac{m}{s^2}$
$t = ?$
$v_{fx} = v_{0x}$
$v_{fy} = ?$

$v_{fy} = v_{0y} - gt$ [2]

$x_f = v_{0x}t$ [2]

$y_f = y_0 + v_{0y}t - \frac{gt^2}{2}$ [1]

$$-5\,\frac{m}{s^2}t^2 + 36\,\frac{m}{s}t + 35\,m = 0$$

$$t_{1,2} = \frac{-36\,\frac{m}{s} \pm \sqrt{1296\,\frac{m^2}{s^2} + 700\,\frac{m^2}{s^2}}}{-10\,\frac{m}{s^2}} = \frac{-36\,\frac{m}{s} \pm 44.68\,\frac{m}{s}}{-10\,\frac{m}{s^2}} = \begin{cases} \cancel{-0.868\,sec} \\ \boxed{8.068\,sec} \text{ (b)} \end{cases}$$

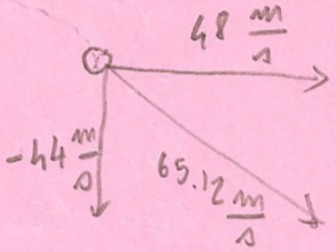
ok.

$x_f = v_{0x} t =$

$= 48 \frac{m}{s} \cdot 8.068\ s = \boxed{387.264\ m}$ (c) ok.

$v_{yf} = v_{0y} - gt = 36 \frac{m}{s} - 10 \frac{m}{s^2} \cdot 8.068 \cancel{s} = \boxed{-44 \frac{m}{s}}$ (negative because the ball goes down) ok.

$\boxed{v_{xf} = v_{x0}}$ (d)



$v_f = \sqrt{v_{fx}^2 + v_{fy}^2} = \boxed{65.12 \frac{m}{s}}$ (e) ok

$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \boxed{-42.5^\circ}$ ok.

blem number 2

$v(t) = 4t^3 - 8t$

$x(t) = \int (4t^3 - 8t)\,dt = \boxed{t^4 - 4t^2} + C$ (a) → What is C?

$a(t) = \frac{d[v(t)]}{dt} = \boxed{12t^2 - 8}$ (b)

$t^2(t^2 - 4) = 0$

zeros:

$t_1 = 0$

$t_1 = -2$

$t_3 = 2$

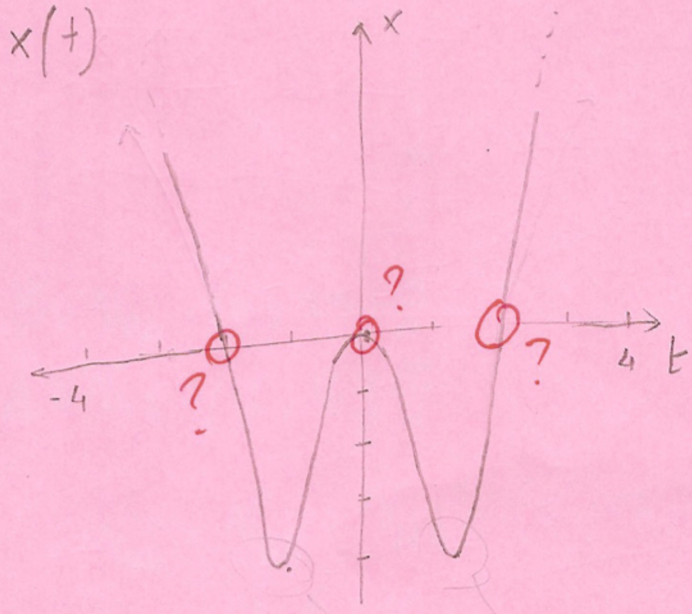
← zeros

$\boxed{x(t) = t^4 - 4t^2}$

$t^2 = v$

$x(v) = v^2 - 4v$

$= v(v-4) = 0$ (x-intercepts)



minimum parabola

20

$v(t) = 0$

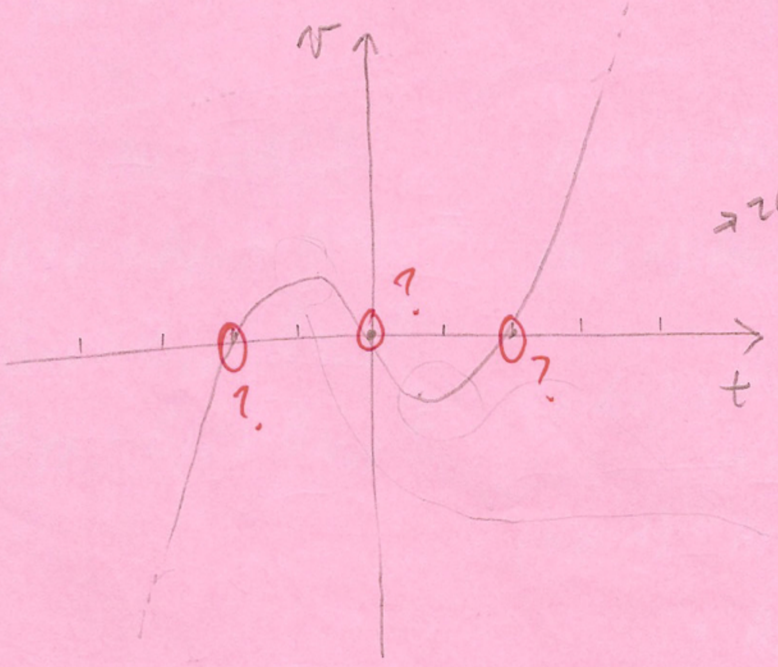
$4t^3 - 8t = 0$

$t(4t^2 - 8) = 0$

$\boxed{t = \pm\sqrt{2}}$

$x(-\sqrt{2}) = -4$

$x(\sqrt{2}) = 4$



$\boxed{v(t) = 4t^3 - 8t} = t\underbrace{(4t^2 - 8)} = 0$

→ zeros

zeros:

$t_1 = 0$

$t_2 = 2$

$t_3 = -2$ X

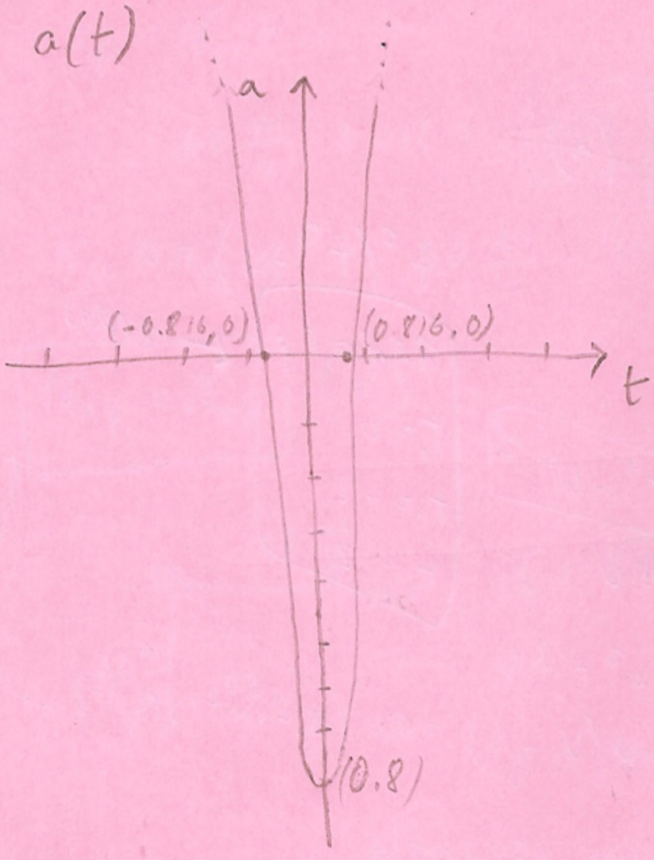
$t_2 = -\sqrt{2}$, $t_3 = +\sqrt{2}$

max - min

$a(t) = 0 = 12t^2 - 8$

$t = \sqrt{\frac{8}{12}} = \sqrt{\frac{2}{3}} = \pm 0.816$

$a(t)$



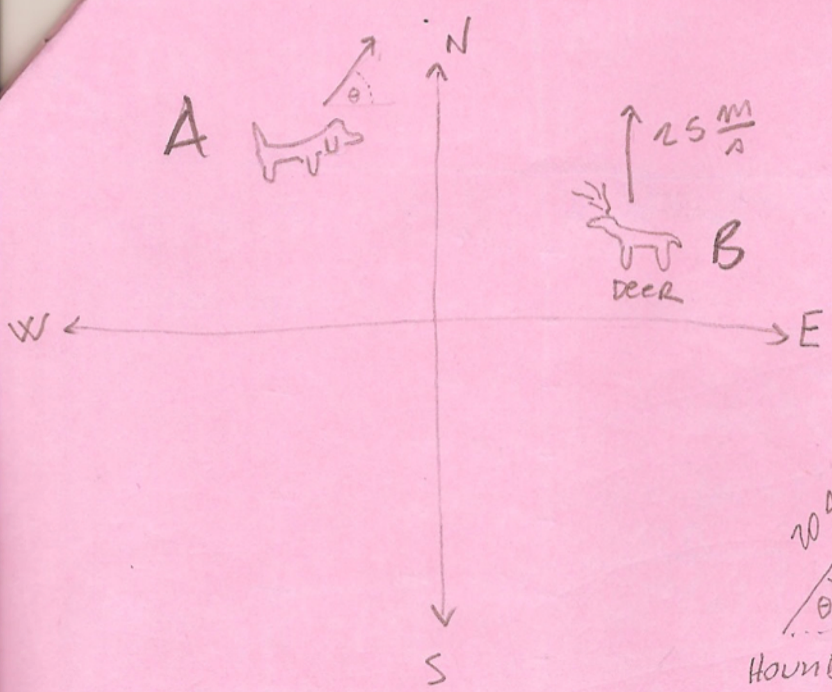
$$\boxed{a(t) = 12t^2 - 8}$$

$12t^2 - 8 = 0$

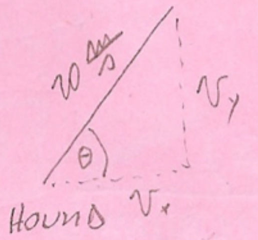
→ zeros

$$\boxed{t = \pm 0.816}$$

lem number 3



20



$\theta = 53.13°$

$\sin\theta = \frac{V_y}{20 \frac{m}{s}}$

$V_y = \sin\theta \cdot 20 \frac{m}{s} = 16 \frac{m}{s}$

$V_x = \cos\theta \cdot 20 \frac{m}{s} = 12 \frac{m}{s}$

$B \Rightarrow V_{DG} = (0, 25) \frac{m}{s}$

$A \Rightarrow V_{HG} = (12, 16) \frac{m}{s}$

$V_{DH} = V_{DG} - V_{HG} = (0 - 12, 25 - 16) \frac{m}{s} = (-12, 9) \frac{m}{s}$

magnitude V_{DH}:

$\sqrt{(-12)^2 + 9^2} = 15 \frac{m}{s}$

$$\boxed{\text{Position final } A = \text{Position final } B}$$

$V_x = \cos\theta\, V$

$V_y = \sin\theta\, V$

a) $Ax_f = \cancel{Ax_0 + AV_{0x}t}$

b) $Ay_f = Ay_0 + AV_{0y}t$

c) $Bx_f = Bx_0 + BV_{0x}t$

d) $By_f = By_0 + BV_{0y}t$

(a & c) $Ax_0 + AV_{0x}t = Bx_0 + BV_{0x}t$

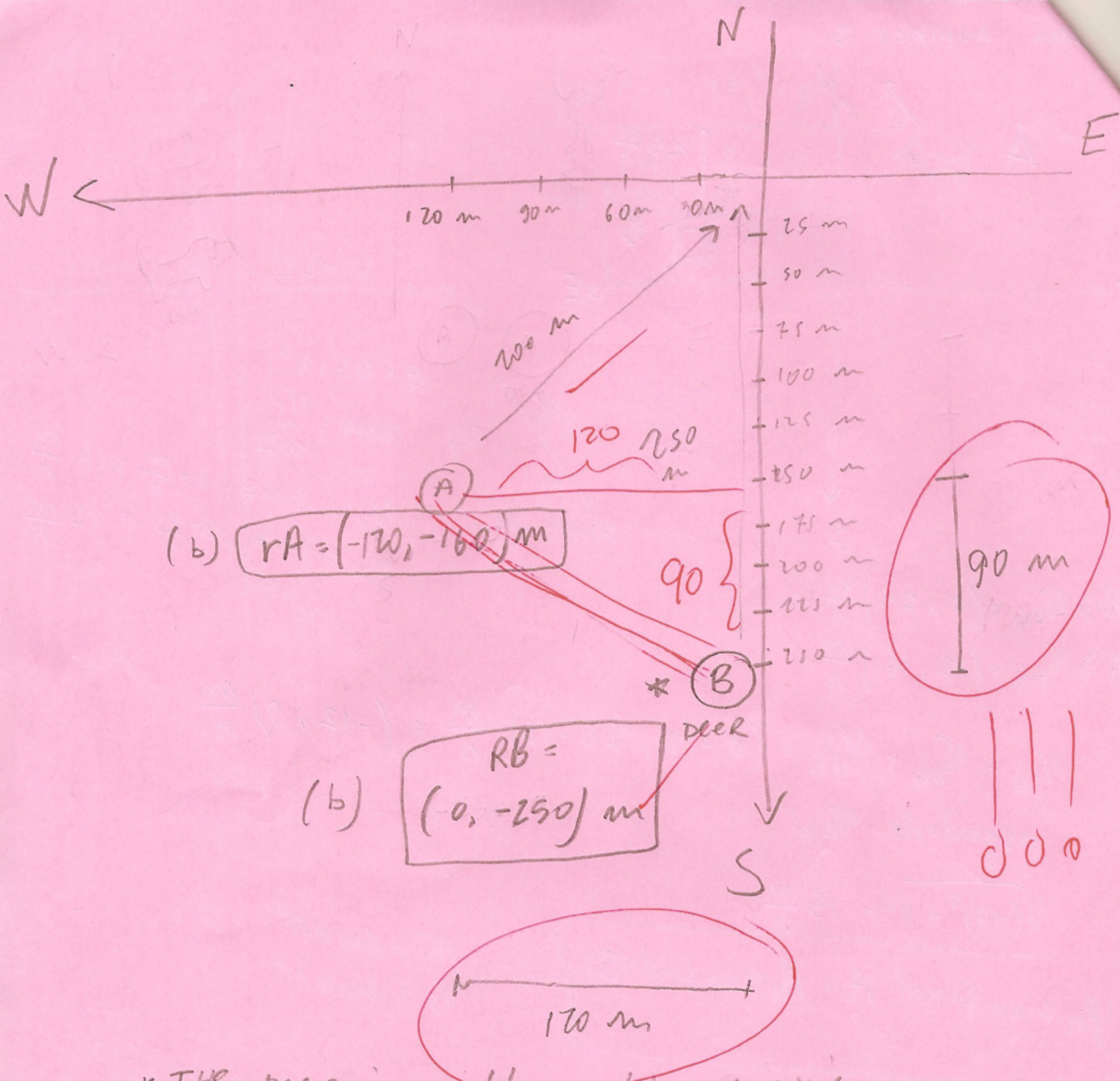
(b & d) $Ay_0 + AV_{0y}t = By_0 + BV_{0y}t$

(a & c) $= Ax_0 + 12 \frac{m}{s} 10s = Bx_0$

$Ax_0 - Bx_0 = |-120 \text{ m}| = 120 \text{ m}$

(b & d) $= Ay_0 + A\,16 \frac{m}{s} \cdot 10s = By_0 + 25 \frac{m}{s} \cdot 10s$

$= Ay_0 - By_0 = |90 \text{ m}| = 90 \text{ m}$



(b) $\boxed{rA = (-120, -160)\ m}$

(b) $\boxed{RB = (0, -250)\ m}$

* THE deer is right on the y-AXIS.

(c) = THE deer is 150 m apart from the start.
$25\ \frac{m}{s} \cdot 10\ s = 550$ m. it goes just north.
= THE HOUND is 200 m away from the starting point.

$\sqrt{\cancel{160^2 + 120^2}} = \cancel{100}$ m $150 = \sqrt{120^2+90^2}$

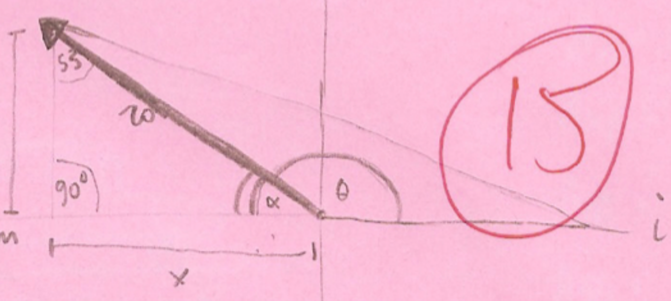
blem 4

$A = (12, -9) = (12i - 9j)\,m$

$B = (6, 8) = (6i + 8j)\,m$

$C = (-16.77, 12.64) = (-16.77i, 12.64j)\,m$

$= (20, 143.13°)$



15

$\sin 53° = \frac{x}{20}$

$x = \sin 53°\ 20 = \cancel{16.77}$

$y = \cos 53°\ 20 = \cancel{12.64}$

NO! the angle is 53.13°, 40

$\cancel{\theta = 143°}$

$\cancel{\alpha = 37°}$

$x = 16$ and $y = 12$ exactly!

$|A| = \sqrt{12^2 + (-9)^2} = \boxed{15\ m\ (a)}$

$|B| = \sqrt{6^2 + 8^2} = \boxed{10\ m\ (a)}$

$|C| = \boxed{20\ m\ (a)}$

$A - 2B = [12 - (6 \cdot 2), -9 - (2 \cdot 8)] = (0, -25) = \boxed{0i - 25j\ m}$ (b)

$4A + 3C = [(12 \cdot 4) - (-16.77 \cdot 3), (-9 \cdot 4) - (12.64 \cdot 3)] =$

$= (48 - 50.31), (-36 - 37.92) = (-2.31, -73.92)\,m$

$= \boxed{(-2.31i, -73.92j)\,m}$ (c)

$A \cdot B = (12 \cdot \cancel{8})\ +\ (-9 \cdot \cancel{6}) = \boxed{\cancel{42}}\,m$? $\emptyset$

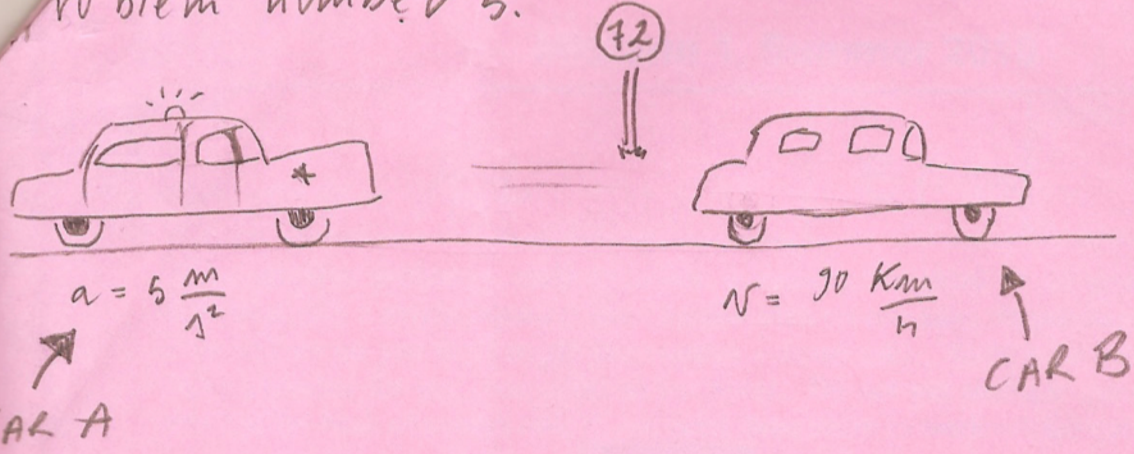
6 8

$B \cdot C = (6 \cdot 12.64) - (8 \cdot (-16.77)) = \cancel{\boxed{210}}\,m$?

$C \cdot A = ((-16.77) \cdot (-9)) - (12.64 \cdot 12) = \cancel{\boxed{0.75}}\,m$?

~~(b) & (c) are simply the hypotenuse of the triangle.~~

Problem number 5.



$A_{x_0} = 0\ m$

$A_{x_f} = ?$

$A_{v_0} = 0 \frac{m}{s}$

$A_{v_f} = ?$

$A_a = 5 \frac{m}{s^2}$

$B_{x_0} = 0\ m$

$B_{x_f} = ?$

$B_{v_0} = 90 \frac{Km}{h} = 25 \frac{m}{s}$

$B_{v_f} = 25 \frac{m}{s}$

$B_a = 0 \frac{m}{s^2}$

$t = ?$

(a) $\Rightarrow A_{x_f} = B_{x_f}$

$$x_f = x_0 + v_0 t + \frac{a t^2}{2}$$

$$\frac{A_a t^2}{2} = B_{v_0} t$$

$$\frac{A_a t^2}{2} - B_{v_0} t = 0$$

$$t\left(\frac{A_a}{2} t - B_{v_0}\right) = 0$$

$t = 0$

$$t = \frac{B_{v_0} \cdot 2}{A_a} = \frac{\overset{10}{\cancel{50}} \frac{m}{\cancel{s}}}{\cancel{5} \frac{m}{s^2}} = \boxed{10 \text{ seconds}} \text{ (a)}$$

23

$$B_{x_f} = B_{v_0} t$$

$$= 25 \frac{m}{\cancel{s}} \cdot 10 \cancel{s} = \boxed{250\ m} \text{ (b)}$$

$$A_{v_f} = A_{v_0} + A_a t$$

$$= 5 \frac{m}{s^2} \cdot 10 s = 50 \frac{m}{s} = \boxed{180 \frac{Km}{h}} \text{ (c)}$$

more like $8 \frac{''}{\text{o}}$

Considering the speed limit ($72 \frac{Km}{h}$), it is a joke to think of a police car riding at $180 \frac{Km}{h}$. the police car should decrease his acceleration at like 5 seconds and then ~~accelerate~~ at $\frac{m}{s^2}$!

they must Decelerate at