KEY

Digipen Institute of Technology

PHY 115 Midterm Exam

Name: ______________________________

Date: 2/19/2014

Total Points: 30

Please show your work. Numerical answers with no supporting work will receive partial credit.

Please box your numerical answers.

1. [4 pts.] One light-year (ly) is the distance that light travels in one year in a vacuum. The speed of light in vacuum is approximately 3.0 x 10^8 m/s.

The binary star system of Sirius A and Sirius B, the brightest in the night sky, is located about 8.58 light-years from Earth. Using two significant figures, express this distance in miles.

1 mile = 1.6 x 10^3 m. yr = year

$$1\,yr = 1\,\cancel{yr} * \frac{365\,\cancel{days}}{1\,\cancel{yr}} * \frac{24\,\cancel{h}}{1\,\cancel{day}} * \frac{3.6*10^3 s}{1\,\cancel{h}} = 3.154 \times 10^7 s$$

Dist. that light travels in 1 yr (in m) $= 3.0\times10^8 m/s * \frac{3.154\times10^7 s}{yr} = 9.462\times10^{15} m/yr$

Miles in 1 yr: $9.462\times10^{15}\cancel{m} * \frac{1\,mile}{1.6*10^3\cancel{m}} = 5.91\times10^{12}$ miles
(= 1 ly in miles)

$$\Rightarrow 8.58\,ly = \underbrace{5.91\times10^{12}\frac{miles}{\cancel{ly}}}_{=1\,ly\text{ in miles}} * 8.58\,\cancel{ly} = 5.07\times10^{13} miles \approx \boxed{5.1\times10^{13}\,miles}$$

2. [4 pts.] Sirius A is larger than the Sun, and has a radius of 1.2 x 10^6 km. On the other hand, Sirius B is smaller (in volume) than the Earth, and has a radius of 5.9 x 10^3 km. Interestingly, Sirius B has a density that is much higher than the Earth's density, but this information is not relevant to this problem.

Estimate how many stars with the same radius of Sirius B would fit inside Sirius A. *Hint:* the volume *V* of a sphere is SB SA

$V = \frac{4}{3}\pi R^3,$

where *R* is the radius of the sphere.

n = # of SB that would fit in SA

$$n = \frac{V_{SA}}{V_{SB}} = \frac{\cancel{\frac{4}{3}\pi}(1.2*10^6\,km)^3}{\cancel{\frac{4}{3}\pi}(5.9\times10^3 km)^3} =$$

$$n = \frac{(1.2)^3\times10^{18}\,km^3}{(5.9)^3\times10^9\,km^3} \simeq 8.4\times10^6 \approx$$

$\boxed{8\times10^6 \text{ SB in SA}}$

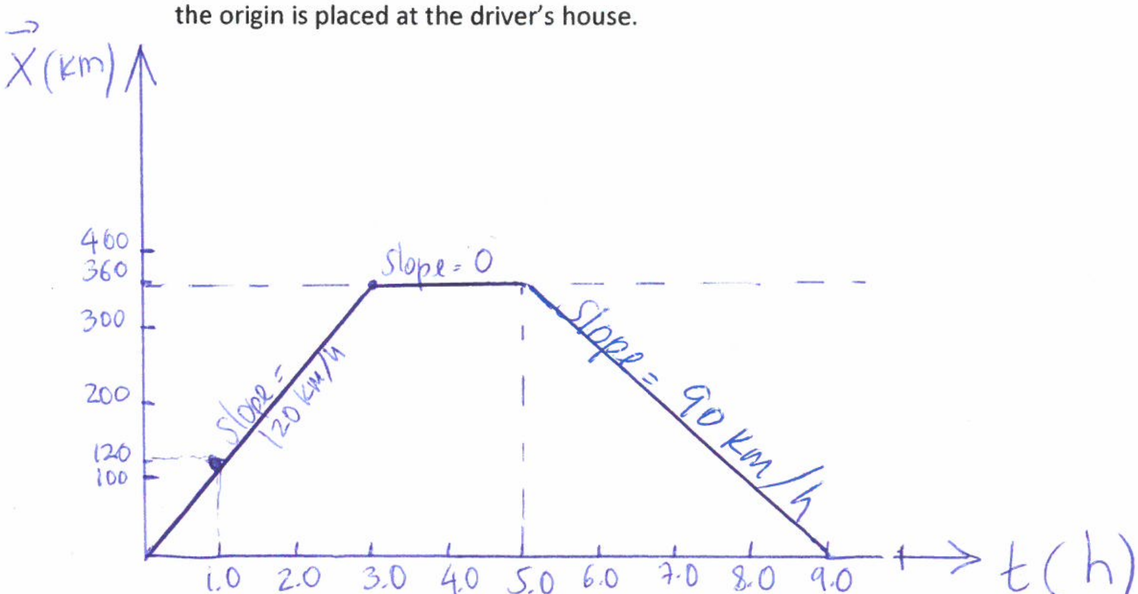
3. A Pontiac GTO travels 360 km due north, starting from the driver's house, at a constant velocity of 120 km/h. Subsequently, there is a 2.0-hour break in which the car is at rest at a service area, as the driver is dealing with a mechanical problem. After this 2.0-hour interval, the driver goes back to his house, moving due south at a constant speed of 90 km/h. The entire motion of the GTO is one-dimensional.

a. **[3 pts.]** For the entire round trip, including the break, what is the average speed of the GTO in km/h?

$$\text{Avg. speed} = \frac{\text{total dist. traveled}}{\text{total time elapsed}}$$

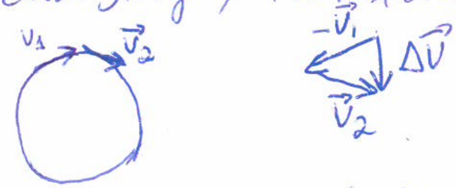
$$= \frac{360\text{ km} + 0\text{ km} + 360\text{ km}}{\frac{360\text{ km}}{120\text{ km/h}} + 2.0\text{ h} + \frac{360\text{ km}}{90\text{ km/h}}} = \frac{720\text{ km}}{9.0\text{ h}} = \boxed{80\text{ km/h}}$$

b. **[4 pts.]** Make a position versus time graph for the motion of the GTO for the entire round trip, including the break. The time should be given in hours, and the position should be expressed in km. Assume that the origin is placed at the driver's house.



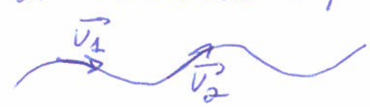
c. **[4 pts.]** Briefly describe a way in which the GTO, while moving in a path that is **not** straight, can have a constant speed, yet a nonzero acceleration. Please use full sentences. A diagram must be part of your explanation.

a) If the GTO follows a circular path at a constant speed, the direction of the velocity will be continuously changing, therefore $\frac{\Delta\vec{v}}{\Delta t} \neq 0$, so $\vec{a}_{AVG} \neq 0$. In this case, the centripetal acceleration is equal to the average acceleration.

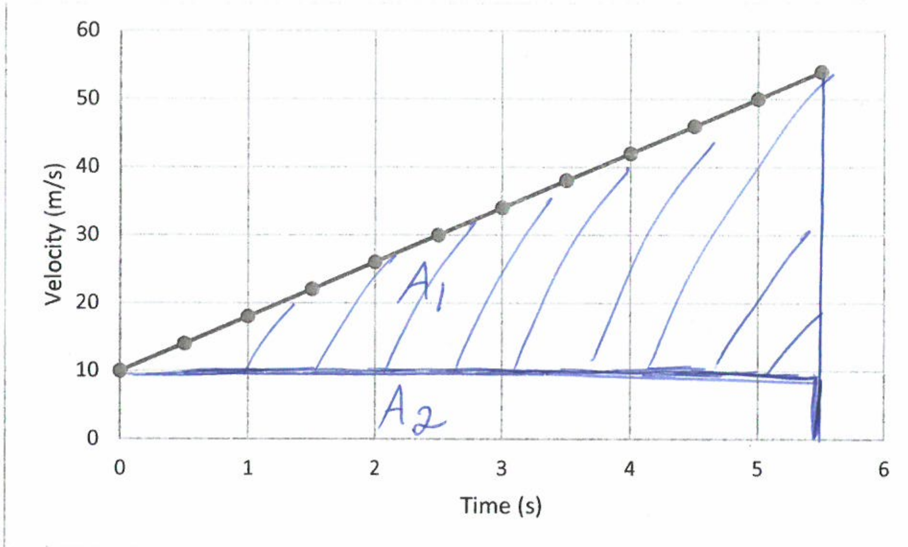


$\vec{v}_2 - \vec{v}_1 = \Delta\vec{v} \neq 0$

b) If the GTO follows a curved or sinusoidal path at a constant speed, $\Delta\vec{v}$ is also $\neq 0$ and $\vec{a}_{AVG} \neq 0$.



4. The graph below represents the 1-D motion of a remote-controlled toy airplane in the first 5.5 seconds of motion. The airplane moves in the positive direction. At 5.5 s, the velocity of the airplane is equal to 54 m/s as shown in the graph.



a. **[3 pts.]** What is the acceleration of the toy airplane during this 5.5 s time interval?

$$\vec{a} = \text{slope} = \frac{54\ m/s - 10\ m/s}{5.5\ s} = \boxed{8.0\ m/s^2\ \hat{x}}$$

Since the airplane speeds up in the positive direction.

b. **[4 pts.]** What is the total displacement of the airplane during this 5.5 s time interval?

METHOD 1: use the area under the curve

$\Delta\vec{x}$ = total area = total displacement = $A_1 + A_2$

= area of triangle + area of rectangle =

$$= \frac{1}{2} * 5.5\,\cancel{s} * 44\ m/\cancel{s} + 5.5\,\cancel{s} * 10\frac{m}{\cancel{s}} = 121\,m + 55\,m = 176\,m \approx \boxed{1.8\times10^2\,m}$$

METHOD 2: use this kinematic equation:

$$\Delta\vec{x} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2 = 10\frac{m}{s} * 5.5s + \frac{1}{2} * (8.0\,m/s^2) * (5.5s)^2$$

$$= 55\,m + 121\,m \approx \boxed{1.8\times10^2\,m}$$

5. Socrates, a super-powered soccer player, kicks a ball straight upwards from an initial height of 1.0 m above the flat ground, with speed of 30 m/s. Socrates's super powers allow him to play soccer in a vacuum, therefore you can ignore air resistance and wind to answer the questions below. Please assume that the magnitude of the acceleration due to gravity is 9.8 m/s^2.

a. **[4 pts.]** What is the maximum height (relative to the ground) reached by the ball?

@ peak height: $V = 0$

y

$\vec{v}_{0y} = 30\,m/s\,\hat{y}$

$y_0 = +1.0\,m$

$\vec{g} = -9.8\,m/s^2$

$V^2 = V_0^2 + 2(-9.8\,m/s^2)\Delta y$

But $\vec{V} = 0$ (velocity at max. height)

$\Delta y = \dfrac{-V_0^2}{2(-9.8\,m/s^2)}$

$V_0 = 30\,m/s$

$\Rightarrow \Delta y = -\dfrac{9.0\times10^2\,m^2/s^2}{-19.6\,m/s^2} = 45.9\,m \approx 46\,m$

$y = \Delta y + y_0 = 46\,m + 1.0\,m = \boxed{47\,m}$

b. **[+4 pts.]** EXTRA-CREDIT - Make a position versus time graph for the upward motion of the ball.

To reach max. height, the time is $t = \dfrac{\cancel{V}^{0} - V_0}{-9.8\,m/s^2} = -\dfrac{30}{-9.8}\,s \approx \boxed{3.1\,s}$

$\vec{y} = \vec{y}_0 + \vec{v}_0 t + \frac{1}{2}\vec{g}t^2$

$t(s)$	$\vec{y}(m)$
0	1.0
0.50	$\approx$ 15
1.0	$\approx$ 26
1.5	$\approx$ 35
2.0	$\approx$ 41
2.5	$\approx$ 45
3.0	$\approx$ 47