MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01 Spring 2005

WEEKLY QUIZ 2

Friday, February 11, 2005

FAMILY (LAST) NAME

GIVEN (FIRST) NAME

STUDENT ID NUMBER

Please check (✔) your class ☞

	L01	MTW 10:00	Walter Lewin
	L02	MTW 11:00	Walter Lewin
	L03	MTW 2:00	Min Chen
	L04	MTW 3:00	Min Chen

INSTRUCTIONS:

1. The FORMULA SHEET is in the back of this exam. You may tear it off. There is also an extra BLANK PAGE in case you need it.
2. This is a closed book exam. CALCULATORS, BOOKS, and NOTES are NOT ALLOWED.
3. Unless otherwise stated, to earn full credit you must show a valid DERIVATION and/or EXPLANATION of your answer, and you must express it in terms of the GIVEN VARIABLES.

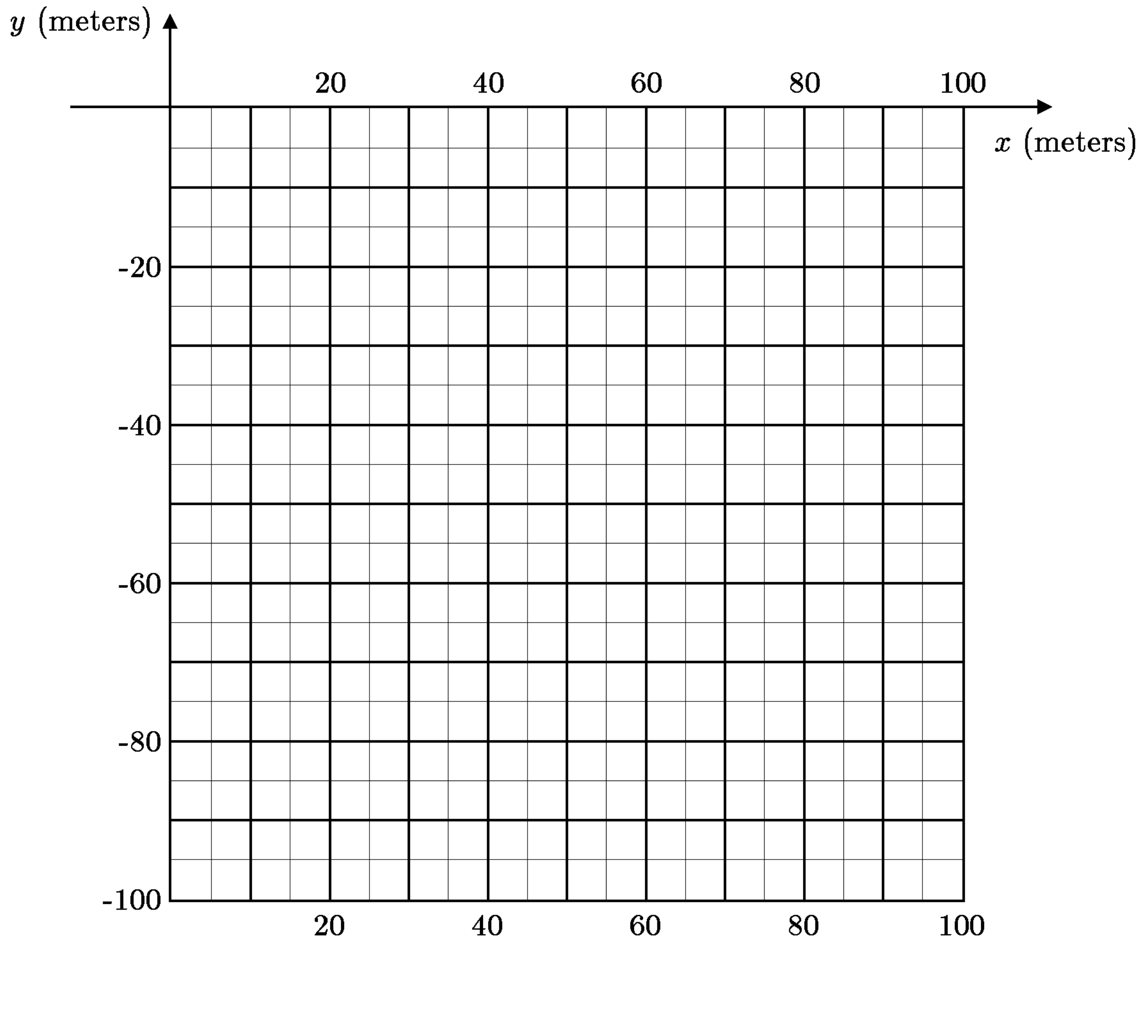
Problem	**Maximum**	**Score**	**Grader**
1	25		
2	25		
3	25		
4	25		
TOTAL	100		

Name ______________________

Problem 1: Short answer questions (*25 points*)

(a) A simple trajectory (*10 points*)

A ball is thrown from a cliff, with an initial velocity that is exactly horizontal, with a magnitude of 20 meter/second. It travels under the influence of gravity, and for numerical simplicity we use the approximate value $g = 10$ meter/second^2 for the acceleration of gravity. Use a coordinate system in which the ball is thrown from [0, 0, 0], and travels initially in the positive x-direction. Ignoring all frictional effects, indicate the trajectory followed by the ball by putting a dot on the following graph at the location of the ball at $t = 1$, 2, 3, and 4 seconds.



— Problem 1 continues on the next page —

Name

Problem 1, continued

(b) (*10 points*) If $\vec{\mathbf{a}} = (2\text{ m})\,\hat{\boldsymbol{\imath}} - (4\text{ m})\,\hat{\boldsymbol{\jmath}} + (4\text{ m})\,\hat{\boldsymbol{k}}$ and $\vec{\mathbf{b}} = (3\text{ m})\,\hat{\boldsymbol{\imath}} - (2\text{ m})\,\hat{\boldsymbol{k}}$, find:

(i) (*2 points*) $\vec{\mathbf{a}} + \vec{\mathbf{b}} =$

(ii) (*2 points*) $\vec{\mathbf{a}} - \vec{\mathbf{b}} =$

(iii) (*2 points*) $\vec{\mathbf{a}} + 2\vec{\mathbf{b}} =$

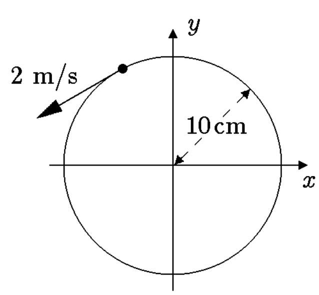
(iv) (*2 points*) $|\vec{\mathbf{a}}| =$

(v) (*2 points*) Construct a unit vector in the direction of $\vec{\mathbf{a}}$.

(c) (*5 points*) Suppose that a particle is moving in a circle of radius 10 cm, at a speed of 2 m/s.

(i) (*3 points*) What is the magnitude of the acceleration?

(ii) (*2 points*) On the diagram below, draw an arrow showing the direction of the acceleration when the particle is at the position shown by the dot.



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Problem 2: Tracing the flight of bees (*25 points*)

At time $t = 0$, three bees are located at the origin of a coordinate system. From that time onward, the first bee travels at a constant velocity $[0, 0, v_a]$. The second bee has an initial velocity $[v_b, 0, 0]$, and accelerates with a uniform acceleration $[0, a, 0]$. The third bee flies at a constant velocity, and collides with the second bee at time $t = t_f$. Note that $[x, y, z]$ has the same meaning as $x\hat{\boldsymbol{\imath}} + y\hat{\boldsymbol{\jmath}} + z\hat{\boldsymbol{k}}$; you may express your answers in either notation.

(a) (*6 points*) Find the displacement vector $\vec{\mathbf{r}}_1(t)$ which describes the position of the first bee as a function of time, valid for times $t > 0$.

(b) (*6 points*) Find the displacement vector $\vec{\mathbf{r}}_2(t)$ which describes the position of the second bee as a function of time, valid for $t > 0$.

(c) (*6 points*) Find the velocity vector $\vec{\mathbf{v}}_2(t)$ of the second bee as a function of time (for $t > 0$).

(d) (*7 points*) With what ***speed*** v_3 does the third bee travel?

Be sure to express all your answers in terms of the given variables, v_a, v_b, a, and t_f.

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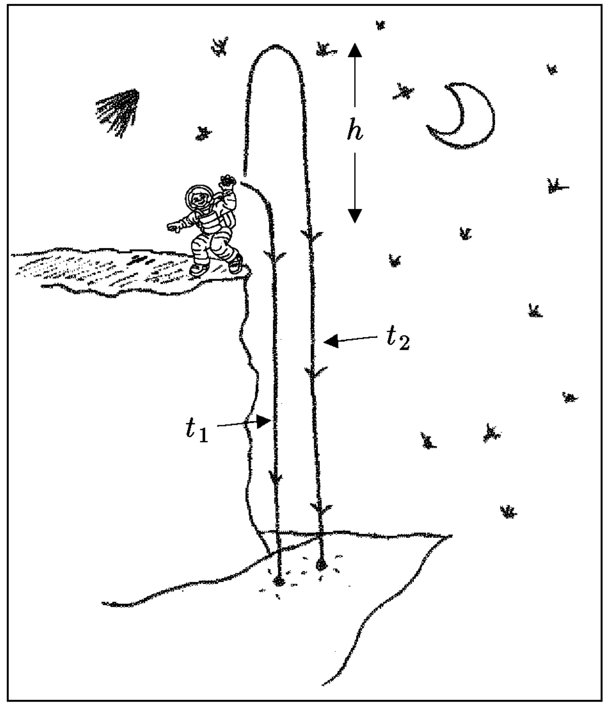
Problem 3: Vertical trajectories on an exotic planet (*30 points*):

A crewman on the starship Enterprise is on shore leave on a distant planet. He drops a rock from the top of a cliff and observes that it takes time t_1 to reach the bottom. He now throws another rock vertically upwards so that it reaches a height h above the cliff before dropping down the cliff face. The second rock takes a total time t_2 to reach the bottom of the cliff, starting from the time it leaves the crewman's hand. The planet has a very thin atmosphere which offers negligible air resistance. How high is the cliff, and what is the value of g on this planet?



DO NOT CARRY OUT THE ALGEBRA for this problem, but instead write down a set of equations that could be solved to obtain the answer.

CLEARLY ENCLOSE IN BOXES the set of equations that needs to be solved. (5 points will be taken off for any irrelevant boxed equation, so don't box everything!)

BE SURE TO DEFINE any variables you introduce into the discussion, beyond the variables t_1, t_2, h, and g, which have already been defined.

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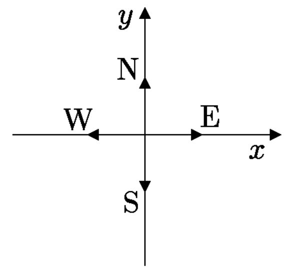
Problem 4: Flying in the wind (*25 points*)

For this problem we will use a coordinate system in which the compass directions — North, South, East, and West — are oriented with respect to the x- and y-axes as shown on the right. Suppose that an airplane is traveling due north, at a speed v_{air} relative to the air. There is a wind blowing uniformly toward the west, at a speed v_{wind}.



(a) (*6 points*) What is the velocity $\vec{\mathbf{v}}_{\text{ground}}$ of the plane relative to the ground? Express your answer as a vector of the form $\vec{\mathbf{v}}_{\text{ground}} = ?\hat{\boldsymbol{\imath}} + ?\hat{\boldsymbol{\jmath}}$.

(b) (*6 points*) What is the speed of the plane relative to the ground?

(c) (*6 points*) What is the angle of the plane's ground velocity relative to north? Be sure to specify if the angle is east of north or west of north.

(d) (*7 points*) Keeping the same speed relative to the air, v_{air}, the pilot turns the plane at just the right angle so that its velocity relative to the ground is due north. What is the ground speed (i.e., magnitude of the velocity relative to the ground) of the plane?

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QUIZ 2
FORMULA SHEET
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For motion in one dimension:

$$v_{\rm av} = \frac{\Delta x}{\Delta t} \qquad \text{Average velocity;}$$

$$v = \frac{\mathrm{d}x}{\mathrm{d}t} \qquad \text{Instantaneous velocity;}$$

For motion in three dimensions:

$$\vec{\mathbf{v}} = \frac{\mathrm{d}\vec{\mathbf{r}}}{\mathrm{d}t}\,; \qquad \vec{\mathbf{a}} = \frac{\mathrm{d}\vec{\mathbf{v}}}{\mathrm{d}t} = \frac{\mathrm{d}^2\vec{\mathbf{r}}}{\mathrm{d}t^2}\,; \qquad \vec{\mathbf{r}}(t_1) = \vec{\mathbf{r}}_0 + \int_0^{t_1} \vec{\mathbf{v}}\,\mathrm{d}t\,; \qquad \vec{\mathbf{v}}(t_1) = \vec{\mathbf{v}}_0 + \int_0^{t_1} \vec{\mathbf{a}}\,\mathrm{d}t\ .$$

For *constant* acceleration $\vec{\mathbf{a}}$, if $\vec{\mathbf{r}} = \vec{\mathbf{r}}_0$ and $\vec{\mathbf{v}} = \vec{\mathbf{v}}_0$ at time $t = 0$, then

$$\vec{\mathbf{v}}(t) = \vec{\mathbf{v}}_0 + \vec{\mathbf{a}}t$$

$$\vec{\mathbf{r}}(t) = \vec{\mathbf{r}}_0 + \vec{\mathbf{v}}_0 t + \frac{1}{2}\vec{\mathbf{a}}t^2\ .$$

For one-dimensional motion with constant acceleration a:

$$v^2 = v_0^2 + 2a(x - x_0)\ .$$

For circular motion at constant speed v:

$$a = \frac{v^2}{r}\ ,$$

where r is the radius of the circle, and the acceleration is directed towards the center of the circle.

If an object has position $\vec{\mathbf{r}}$ and velocity $\vec{\mathbf{v}}$, its position and velocity relative to an observer with position $\vec{\mathbf{r}}_0$ and velocity $\vec{\mathbf{v}}_0$ are given respectively by

$$\vec{\mathbf{r}}' = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0\ , \qquad \vec{\mathbf{v}}' = \vec{\mathbf{v}} - \vec{\mathbf{v}}_0\ .$$

Average velocity and acceleration are given by

$$\vec{\mathbf{v}}_{\rm average} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t}\ , \qquad \vec{\mathbf{a}}_{\rm average} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t}\ .$$