MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Department of Physics

Physics 8.01 Fall 2000

EXAM 1
Friday, September 22, 2000
Corrected Version; Blank Spaces Removed

FAMILY (Last) NAME

GIVEN (First) NAME

Student ID Number

Your Recitation (check one) →

R01	MW 1:00	W. Bertozzi	
R02	MW 2:00	W. Bertozzi	
R03	MW 3:00	W. Bertozzi	
R12	TR 1:00	A. Bolton	
R18	TR 9:00	B. Burke	
R19	TR 10:00	B. Burke	
R20	TR 11:00	B. Burke	
R21	TR 2:00	M. Evans	
R22	TR 3:00	M. Evans	
R06	MW 2:00	M. Feld	
R07	MW 3:00	M. Feld	
R08	MW 4:00	M. Feld	
R16	TR 11:00	D. Fernie	
R15	TR 10:00	A.Guth	
R23	TR 11:00	J. Hager	
R24	TR 12:00	J. Hager	
R09	MW 1:00	P. Joss	
R10	MW 2:00	P. Joss	
R11	MW 3:00	P. Joss	
R17	TR 12:00	K. Lee	
R25	TR 1:00	K. Lee	
R26(M)	TR 3:00	McBride/Bove	
R13	TR 2:00	J. Shelton	
R14	TR 3:00	J. Shelton	
R04	MW 1:00	G. Stephans	
R05	MW 2:00	G. Stephans	

Instructions:
1. SHOW ALL WORK. All work must be done in this booklet. Extra blank pages are provided.
2. This is a closed book exam.
3. CALCULATORS, BOOKS, and NOTES are NOT ALLOWED.
4. Do all FOUR (4) problems.
5. Exams will be collected 5 minutes before the hour.

NOTE: In all problems, your answer must be expressed **ONLY** in terms of given symbols. Not all the given symbols will necessarily be needed.

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

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EXAM 1
FORMULA SHEET
Friday, September 22, 2000

Equations introduced in Chapter 1:

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

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

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

Equations introduced in Chapter 2:

$\vec{\mathbf{F}} = m\vec{\mathbf{a}}$	(Newton's second law);
$\vec{\mathbf{F}} = -\frac{GMm}{r^2}\hat{\boldsymbol{r}}$	(the gravitational force between two particles);
$\vec{\mathbf{F}} = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}\hat{\boldsymbol{r}}$	(the electrostatic force between two particles);
$\vec{\mathbf{F}} = -k\vec{\mathbf{x}}$	(Hooke's law);
$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = -\omega^2 x$	(for a particle near a point of stable equilibrium; equation leads to simple harmonic motion);
$x = A\sin\omega t$	(a solution to the above equation; any solution can be written this way if we choose $t = 0$ when $x = 0$);
$\omega = 2\pi f$	(relation between angular frequency and frequency);
$T = \frac{1}{f} = \frac{2\pi}{\omega}$	(period of an oscillator).

1. (Multiple Choice problems; 5 points each part, no partial credit.) If your answer is "none of these", please state which other answer is the closest to being correct. Also explain why it is not correct.

a) A car of mass m is traveling on a horizontal road with constant velocity. The magnitude of this velocity is a. Assuming the local acceleration of gravity is g, the magnitude of the net force on the car is:

i) mg ii) ma iii) $mg + ma$ iv) $ma - mg$ v) $mg - ma$

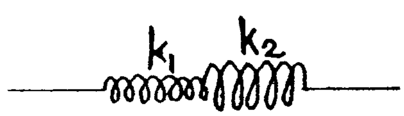
vi) $\frac{ma + mg}{2}$ vii) 0 viii) none of these

b) An astronaut of mass m is a member of the crew of a space shuttle orbiting the earth at an altitude h. If the radius of the earth is R and g is the acceleration due to gravity at the surface of the earth, the magnitude of the gravitational force on the astronaut is:

i) mg ii) $mg\,\frac{R}{R+h}$ iii) $mg\,\frac{(R+h)}{R}$ iv) $mg\,\frac{R^2}{(R+h)^2}$ v) $mg\,\frac{(R+h)^2}{R^2}$

vi) none of these

c) Two springs are connected as shown below:

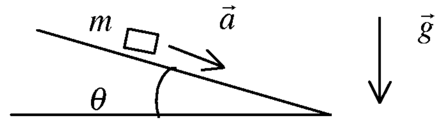


Both obey Hooke's Law. One has spring constant k_1 and the other k_2. The spring constant of the combined system is:

i) $k_1 + k_2$ ii) $k_1\,k_2$ iii) $\frac{k_1\,k_2}{k_1 + k_2}$ iv) $\frac{k_1 + k_2}{k_1\,k_2}$ v) $\frac{k_1 + k_2}{2}$

vi) $2(k_1 + k_2)$ vii) none of these

d) A block of mass m slides down a frictionless slope inclined at an angle θ to the horizontal.

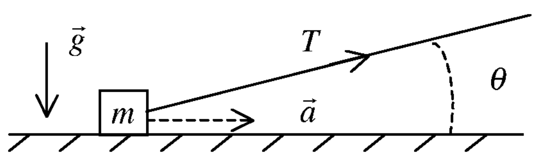


The magnitude of the acceleration of the block is observed to be a. From this observation you can conclude that the magnitude of the local acceleration due to gravity is:

i) $ma\sin\theta$ ii) $ma\cos\theta$ iii) $\dfrac{ma}{\sin\theta}$ iv) $\dfrac{ma}{\cos\theta}$ v) $a\sin\theta$

vi) $a\cos\theta$ vii) $\dfrac{a}{\sin\theta}$ viii) $\dfrac{a}{\cos\theta}$ ix) none of these

e) A large mass m, at the end of a rope, is pulled on level ice. The mass of the rope and the friction between the mass and the ice are negligible. The rope makes an angle θ to the horizontal. If the mass has an acceleration $\vec{\mathbf{a}}$ and the acceleration due to gravity is $\vec{\mathbf{g}}$, the tension T in the rope is:

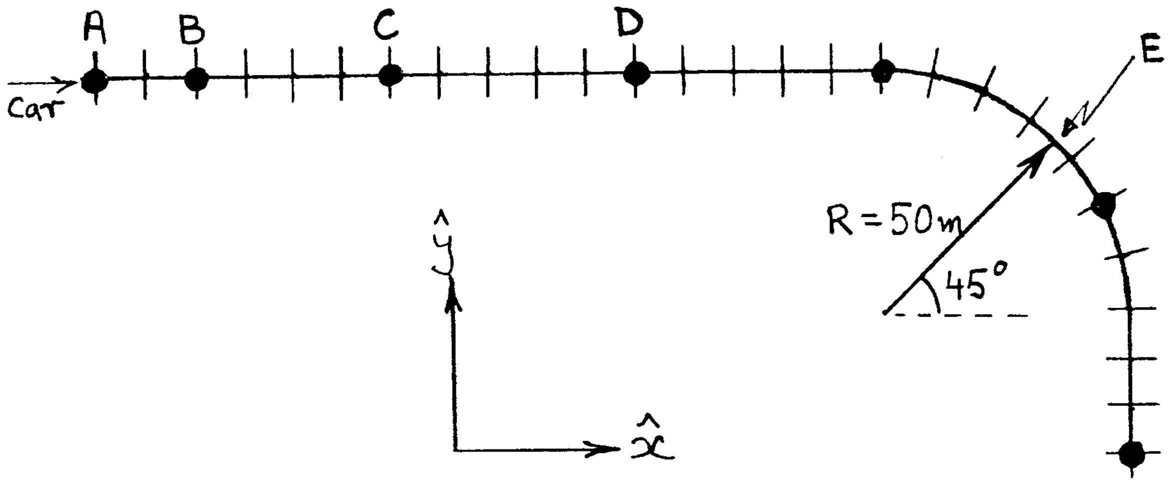


i) $\dfrac{ma}{\cos\theta}$ ii) $\dfrac{ma}{\sin\theta}$ iii) $ma\cos\theta$ iv) $ma\sin\theta$ v) $mg\sin\theta$

vi) $mg\cos\theta$ vii) $\dfrac{ma}{\cos\theta} + mg\sin\theta$ viii) none of these

2. (25 points)

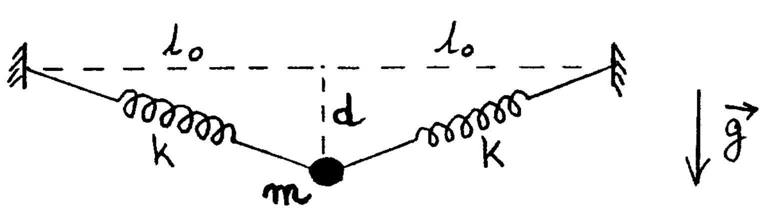
The figure below illustrates a stretch of a horizontal road. The markers (+—+) indicate distance along the road separated by 10 m. At A a car enters the stretch of road. It accelerates uniformly up to point C, and then continues moving at constant speed. The dots show the position of the car at one second intervals. Using the coordinate system shown, write down expressions for the velocity and acceleration of the car at points B, D, and E.



3. (25 points)

A mass m is stationary, supported from two identical massless springs as shown. Each spring obeys Hooke's Law and has unstretched length ℓ_0 and constant k. Suddenly the left spring breaks. Immediately after the spring breaks, the mass accelerates with acceleration $\vec{\mathbf{a}}$.

a) On the diagram show the direction of $\vec{\mathbf{a}}$. Explain in words, or by calculations, what is the direction of $\vec{\mathbf{a}}$ and how you established it.



b) Write an expression for the magnitude of $\vec{\mathbf{a}}$.

4. (25 points)

   A toy train moves due north at a constant speed V along a straight track which is parallel to the wall of a room. The wall is to the east of the track at a distance d. There is a toy dart gun on the train with its barrel fixed in a plane perpendicular to the motion of the train. The gun points at an angle θ to the horizontal. There is a vertical line drawn on the wall, stretching from floor to ceiling, and the dart gun is fired at the instant when the line is due east of the gun. If the dart leaves the gun at speed W relative to the gun, derive an expression for the distance by which the dart misses the vertical line. That is, find how far north or south of the vertical line is the point at which the dart hits the wall. Assume that the dart hits the wall without first bouncing off the floor or ceiling.