AP PHYSICS C  JANUARY 2008

DIRECTIONS: Please PRINT your name, school, area, and which test you are taking on the scantron. For each statement or question, completely fill in the appropriate space on the answer sheet. Use the letter preceding the word or phrase or sketch which best completes the statement or answers the question. Unless otherwise stated assume ideal conditions including no friction with the air. Sketches are not to scale.

1. A two-stage model rocket is fired vertically up from the position \( y(0) = 0 \). The first stage burns for the first four seconds accelerating the rocket upward, then detaches and falls freely to the ground. Which of the graphs represents the motion of the first stage of the rocket as a function of time?
   a. 1  b. 2  c. 3  d. 4  e. none of these is correct

2. The rocket described in the previous problem accelerates from rest at \( 4 \text{ m/s}^2 \) while the first stage is burning. After the four second burn, the first stage falls freely to the ground. What is the speed of the burned-out first stage right before it hits the ground?
   a. 24 m/s  b. 16 m/s  c. 8 m/s  d. 4 m/s  e. none of these is correct

3. The coordinate of a particle in meters is given by \( x(t) = 12t - 3.0t^2 \), where the time \( t \) is in seconds. The particle is momentarily at rest at \( t = \)
   a. 2.0 sec  b. 4.0 sec  c. 5 sec  d. 8 sec  e. 10 sec

4. An ice cube slides down a ramp without friction. It starts from rest and slides the distance \( d \) during the first second of its motion. How far does it slide during the next one-second long interval of time? (Give the answer is in terms of the given distance \( d \).)
   a. \( d/2 \)  b. \( d \)  c. \( 2d \)  d. \( 3d \)  e. \( 4d \)

5. The force generated by the spring in a paintball rifle is shown as a function of the compression distance \( x \). The spring in the rifle is compressed 20 cm before firing. What is the change in the kinetic energy of the paint ball as it leaves the barrel?
   a. 5 J  b. 7.5 J  c. 15 J  d. 20 J  e. 40 J

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6. Assume that a paint ball leaves the barrel with the kinetic energy of 10 J and that air resistance can be neglected during the ball's flight. The barrel of the rifle makes a 37° angle to the horizontal. What is the kinetic energy of the paint ball at its highest point?
   a. 3.6 J  b. 5.0 J  c. 6.4 J  d. 0 J  e. need to know the mass of the ball

7. A marble rolls off horizontally from a table and lands a distance x horizontally from its initial position (as shown). If the initial horizontal velocity of the marble doubles its horizontal distance from the table is going to
   a. double  b. triple  c. quadruple  d. remain the same  e. not enough information

8. A marble of a mass m is released into a bowl from the edge. What is the magnitude of the normal force applied onto the marble at the instant it passes through the bottom of the bowl? (Neglect friction for this problem)
   a. mg/2  b. mg  c. 2mg  d. 3mg  e. 4mg

9. A person is riding a spinning amusement park ride with her back to the wall as shown. Determine the minimum coefficient of static friction needed so that the person does not slide down the wall when she is moving at a speed v. The radius of the ride is R.
   a. \( \frac{v^2}{gR} \)  b. \( \frac{gR}{v^2} \)  c. \( \frac{gR}{v} \)  d. \( \frac{v^2}{R} \)

10. Assume that an x-y coordinate system is associated with an ice hockey ring and its origin is at the center of the ring. What is the change in kinetic energy of a hockey puck that moves from the origin to a point (4m, -3m) being pushed by the stick with a force \( F = (20N)i + (10N)j \)?
    a. 11J  b. 20J  c. 50J  d. 110J  e. need to know the mass of the puck

Questions #11 – 12 refer to the potential energy graph shown to the left. The graph shows the potential energy of an interaction of two small objects as a function of their relative position. Here \( r \) corresponds to the distance between the objects measured in angstroms (1Å = 1 × 10⁻¹⁰ m)

11. Which of the following positions is a point of stable equilibrium?
    a. \( r = 0.5 \) Å  b. \( r = 1.0 \) Å  
    c. \( 0.5 \) Å < \( r < 2.5 \) Å  d. \( r > 3 \) Å  
    e. there is no point of stable equilibrium
12. Which of the following graphs best represents the conservative force of interaction between these objects as a function of their relative position?

![Graphs a, b, c, d]

13. A missile is shot from ground level at 60° above horizontal with an initial speed V. At the highest point of its trajectory the missile explodes into two unequal pieces. The mass of the smaller piece is ¼ of the mass of the larger piece. The smaller piece lands at exactly the launch point. What is the speed of the larger piece immediately after the explosion? Give the answer in terms of the initial speed V.

For questions # 14 and 15 consider the following:
A cucumber man of a mass m jumps into a garden pond. His initial speed in the water is \( v_0 \) and the drag force in the water is proportional to his speed at any time during the plunge with a proportionality coefficient \( b \).

14. What is the terminal velocity achieved by the cucumber man?
   a. mg  b. 3m/b  c. 3b/m  d. mb  e. mg/b
15. Assuming the cucumber’s initial speed is greater than his terminal speed, which of the following graphs correctly represents the speed of the cucumber man as a function of time?

![Graphs of speed vs. time]

16. A mountain climber (mass $m$) is repelling pulling on a rope making an angle $\alpha$ with the vertical. If the maximum tension in the rope is $T$, what is the minimum coefficient of friction between the climber’s feet and the rock?

\[
\begin{align*}
T - mg & = \frac{mg}{T} \\
mg = T\cos\alpha & = \frac{T\sin\alpha}{T} \\
mg - T & = \frac{mg - \tan\alpha}{T}
\end{align*}
\]

a. $T\cos\alpha$  
 b. $T$  
 c. $T\sin\alpha$  
 d. $mg - T$  
 e. $mg - \tan\alpha$

17. Sergey Bubka was the first pole-vaulter to achieve a 6-m height. Assume that he has negligible horizontal velocity at the top of his jump and falls 5 meters onto the mats below. What is Sergey’s stopping acceleration if the mats compress by 0.8 meters when he falls? (The answers are in terms of the acceleration due to gravity $g$)

a. 0.75g  
 b. 2.25g  
 c. 4.5g  
 d. 6.25g  
 e. 8g

18. At a certain instant of time, a car negotiating a turn changes its direction at a rate of 2 m/s² while slowing down at 1 m/s². What is the angle between the car’s instantaneous velocity and its instantaneous acceleration? (Report the angle from 0 to 180°)

a. 63°  
 b. 117°  
 c. 37°  
 d. 143°  
 e. 180°

19. Two identical pucks collide elastically on a frictionless air hockey table. Puck #1 is originally at rest. After collision, puck #1 moves at 30° to the original direction of puck #2. What is the final speed of puck #2 in terms of its original speed $v_0$?

a. $v_0/2$  
 b. $3v_0/4$  
 c. $\sqrt{3}v_0/2$  
 d. $\sqrt{2}v_0/2$  
 e. $3v_0/2$

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20. Abe, Bob, and Cory caught identical unhappy fish. The fishing contest judge holds the scale in his 
hand while weighing their catch. For Abe, he moves the scale steadily upward at 2 m/s. For Bob, 
he accidentally drops the scale while taking the reading. For Cory, the judge moves the scale with 
an upward acceleration of 2 m/s². Rank the reading on the scale for each person’s fish.
a. Abe=Bob>Cory  b. Abe=Bob<Cory  c. Cory=Abe>Bob  d. Abe>Bob>Cory  
e. Bob<Abe<Cory

![Image of a scale with a fish]

21. The force applied by a golf club on the ball is shown as a function of 
time. The change of momentum of the golf ball is determined by the 
a. slope of this graph  
b. the area under the graph  
c. the maximum value of the force shown  
d. the minimum value of the force shown  
e. … can not be determined from this graph

![Image of a force vs. time graph]

22. The graph shows the acceleration of a 
person as a function of time during a real 
bungee jump. At t=0 the person is standing 
on the platform, ready to jump. At what 
times does the person’s **downward** velocity 
reaches **local maxima**? Choose the best 
approximate answers.  
a. 3 sec, 9 sec, 15.5 sec  
b. 4.5 sec, 10.5 sec, 17 sec  
c. 2.2 sec, 8 sec, 14 sec  
d. 2 sec, 6 sec, 12 sec  
e. … cannot be determined from the acceleration vs. time graph

(Note: the acceleration graph is adapted from a Vernier® LoggerPro® lab experiment)
The figure shows a wedge of mass M with the base angle of 30° free to slide on a horizontal surface and two blocks of masses m₁ and m₂ attached by a string passing over a pulley. All surfaces including the wedge, the blocks, and the table are frictionless, and friction should be ignored in the following questions.

23. For this question, assume that the wedge cannot move horizontally. What should be the ratio of m₂/m₁ so that the blocks remain in equilibrium?
   a. 0.5   b. 0.75   c. 1   d. 1.5   e. 3

24. Now the wedge is free to move pulled by a horizontal force F such that blocks m₁ and m₂ do not slide relative to M. Mass m₂=m₁=1 kg and the mass of the wedge M=2 kg. Determine the magnitude of the acceleration of m₂
   a. 1.6 m/s²  b. 3.5 m/s²  c. 4.2 m/s²  d. 5.8 m/s²  e. 6.4 m/s²

25. For the situation described in question #24, choose the correct free body diagram for m₂.

   a.  
   b.  
   c.  
   d.  
   e.  

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### Heat Energy

- \( Q = mc\Delta T \)  
- \( Q = mL_f \)  
- \( Q = mL_v \)  
- \( \Delta L = \alpha L_o \Delta T \)  

### Wave Phenomena

- \( c = \text{speed of light in a vacuum} \)  
- \( d = \text{distance between slits} \)  
- \( f = \nu = \text{frequency} \)  
- \( L = \text{distance from slit to screen} \)  
- \( n = \text{index of absolute refraction} \)  
- \( n_i \sin \theta_i = n_r \sin \theta_r \)  
- \( T = \frac{1}{f} \)  
- \( \nu = f \lambda \text{ or } V \lambda \)  
- \( \lambda = \frac{xd}{L} \)  
- \( \sin \theta_i = \frac{1}{n} \)

### Geometric Optics

\[
\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}
\]

- \( f = \text{focal length} \)  
- \( d_i = \text{image distance} \)  
- \( d_o = \text{object distance} \)  
- \( h_i = \text{image size} \)  
- \( h_o = \text{object size} \)  

### Electromagnetic Applications

- \( F = Bqv \)  
- \( F = BIL \)  
- \( V = BLv \)  
- \( N_p = \frac{V_p}{V_S} \)  
- \( N_S = \frac{V_S}{V_{S_s}} \) (ideal)  
- \( V_{p_s}I_{p_s} = V_{S_s}I_s \)  
- \( \text{efficiency} = \frac{V_{S_s}I_s}{V_p I_p} \)  
- \( B = \text{magnetic field strength} \)  
- \( I_p = \text{current in primary} \)  
- \( I_s = \text{current in secondary} \)  
- \( N_p = \text{number of turns in primary coil} \)  
- \( N_S = \text{number of turns in secondary coil} \)  
- \( V_p = \text{voltage of primary} \)  
- \( V_s = \text{voltage of secondary} \)  
- \( L = \text{length of conductor} \)  
- \( V = \text{electric potential difference} \)

Additional Formulae:

- \( x = \cos(\theta t + \phi) \)  
- \( n = \sin \phi \)  
- \( E_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 \)

\[
\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}} = 2\pi f
\]

\[
y = A \sin \left[ 2\pi \left( \frac{x}{\lambda} - ft \right) \right]
\]

\[
\frac{1}{f} = (n - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)
\]

NJSSL Physics Formula Sheet.
<table>
<thead>
<tr>
<th>MECHANICS</th>
<th>ELECTRICITY AND MAGNETISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v = \frac{\Delta x}{\Delta t}$</td>
<td>$F_e = k \frac{q_1 q_2}{r^2}$</td>
</tr>
<tr>
<td>$a = \frac{\Delta v}{\Delta t}$</td>
<td>$E = \frac{F}{q}$</td>
</tr>
<tr>
<td>$v_f = v_i + at$</td>
<td>$v = \frac{W}{q} = Ed$</td>
</tr>
<tr>
<td>$\Delta x = v_i t + \frac{1}{2} at^2$</td>
<td>$I = \frac{\Delta q}{\Delta t}$</td>
</tr>
<tr>
<td>$2ax = v_f^2 - v_i^2$</td>
<td>$V = IR$</td>
</tr>
<tr>
<td>$\Sigma F = ma$</td>
<td>$P = VI = I^2R = \frac{V^2}{R}$</td>
</tr>
<tr>
<td>$W = mg$</td>
<td>$W = \text{Work}$</td>
</tr>
<tr>
<td>$F_g = G \frac{m_1 m_2}{r^2}$</td>
<td>$\mu = \frac{F_f}{F_N}$</td>
</tr>
<tr>
<td>$\rho = mv$</td>
<td>$G = \text{Universal Gravitational Constant}$</td>
</tr>
<tr>
<td>$F_{\Delta t} = m\Delta v$</td>
<td>$\rho = \text{momentum}$</td>
</tr>
<tr>
<td>$\mu = \frac{F_f}{F_N}$</td>
<td>$\mu = \text{coefficient of friction}$</td>
</tr>
<tr>
<td>$r = \text{distance between center of masses}$</td>
<td>$W = \text{weight}$</td>
</tr>
<tr>
<td>$h = \text{height}$</td>
<td>$k = \text{spring constant}$</td>
</tr>
<tr>
<td>$h = \text{height}$</td>
<td>$KE = \text{kinetic energy}$</td>
</tr>
<tr>
<td>$P = mgh$</td>
<td>$PE_g = \text{gravitational potential energy}$</td>
</tr>
<tr>
<td>$\frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$</td>
<td>$KE = \frac{1}{2}mv^2$</td>
</tr>
<tr>
<td>$P_{E_g} = mgh$</td>
<td>$PE_s = \text{potential energy stored in a spring}$</td>
</tr>
<tr>
<td>$F = -kx$</td>
<td>$P = \text{power}$</td>
</tr>
<tr>
<td>$PE_s = \frac{1}{2}kx^2$</td>
<td>$W = \text{work}$</td>
</tr>
<tr>
<td>$x = \text{change in spring length from the equilibrium position}$</td>
<td>$x = \text{change in spring}$</td>
</tr>
</tbody>
</table>

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = ...$

$V_T = V_1 + V_2 + V_3 + ...$

$R_T = R_1 + R_2 + R_3 + ...$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ...$

$V_T = V_1 = V_2 = V_3 = ...$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...}$

MOTION IN 2-D

$a_c = \frac{v^2}{r}$

$a_c = \text{centripetal acceleration}$

$F_c = m \frac{v^2}{r}$

$F_c = \text{centripetal force}$

$1\text{ rev} = 2\pi\text{ rad} = 360^\circ$

$\tau = Fxr$

$\tau = \text{Torque}$

NJSI Physics Formula Sheet.
### Physics C: For all students taking Physics C. All exams are based on calculus.

**JANUARY**: kinematics in one and two dimensions; Newton's laws including resistance forces and dynamics of circular motion; vector algebra (mostly assumed as needed); energy and its conservation including potential energy and conservative forces, momentum and its conservation including two-dimensional situations

**FEBRUARY**: angular mechanics including rotational equilibrium, rotational dynamics, rotational energy, and angular momentum; oscillatory motion including kinematics, dynamics, energy, and damping; gravitation including kinematics and dynamics of planetary motion, angular momentum, and energy as applied to gravitation

**MARCH**: electrostatics including electrostatic forces, electrostatic field, electrostatic field flux and Gauss's Law; electrostatic potential and potential energy; dc electrical circuits including multi-loop circuits and power; capacitors, dielectrics, and circuits with capacitors

**APRIL**: Magnetic Fields and Forces including the applications of the Lorenz force, the Law of Biot-Savart, Ampere's Law, magnetic field flux and Faraday's Law, Lenz's Law for electromagnetic induction; magnetic materials, applications of electromagnetic induction, and circuits with inductors

**TESTING DATES FOR THE NEW JERSEY SCIENCE LEAGUE**

- **THURSDAY, JANUARY 10, 2008**
- **THURSDAY, FEBRUARY 14, 2008**
- **THURSDAY, MARCH 13, 2008**
- **THURSDAY APRIL 10, 2008**

Each area may select a date in April, other than the first week, for all schools in the area to take the exam.

No area may take the April exam during the first week of April.