DIRECTIONS: Only students in AP Physics C should be taking this exam. Please Print your name, Phy C, date, and school 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. Each question is worth 4 points. Use 9.8 m/s² as the value of the acceleration due to gravity. Unless otherwise stated assume ideal conditions including no friction with the air. Sketches are not to scale.

Some additional facts... \( I_{sphere} = \frac{2}{5} mR^2 \quad I_{hoop} = mR^2 \quad I_{cylinder} = \frac{1}{2} mR^2 \)

The following description is used for items 1 through 7.

Given a “point mass” of 3.00 kg traveling in a circle with a constant radius of 1.50 meters. The initial motion is counter-clockwise as seen from above. The angular velocity is given by the following equation:

\[ \omega = -t^4s^{-4} + 5t^3s^{-3} + 10ts^{-2} \quad \text{The t represents the time and } \omega \text{ is given in radians per second.} \]

1. The net torque was a maximum at approximately _____ seconds.
   A) 5.6 B) 4.1 C) 2.1 D) 1.7 E) 0

2. When the angular velocity was 56.0 radians per second the tangential velocity was approximately _____ m/s.
   A) 168 B) 84 C) 37 D) 22 E) 15

3. During the first 4 seconds the mass traveled through an angle of approximately _____ radians.
   A) 28 B) 56 C) 112 D) 123 E) 310

4. When the object’s tangential velocity was 15.0 m/s, its angular momentum was approximately _____ kg-m²/s.
   A) 30 B) 34 C) 45 D) 56 E) 68

5. The maximum angular velocity was approximately _____ radians/s.
   A) 4.14 B) 6.53 C) 22.6 D) 56.1 E) 9030

6. The torque at \( t=6.0 \) seconds was approximately _____ Nm.
   A) 57 B) 108 C) 171 D) 162 E) 256

7. The direction of the torque described in the previous problem...
   A) is in the same direction as the motion of the mass.
   B) is opposite to the direction of the motion of the mass.
   C) cannot be determined from the information available here.
The following description and table are for items 8 through 10.

A sphere, a hoop, and a cylinder are arranged next to each other at the top of a ramp inclined at 40° to the horizontal. The objects all begin from rest at the same height, H, above the bottom and roll without slipping. At the bottom of the ramp they go a short horizontal distance to a second ramp inclined at 60° to the horizontal and roll up the second ramp without slipping. No work is done against friction.

The table gives the mass, radius, and moment of inertia of the three objects. The letters are used for identification in the questions below.

<table>
<thead>
<tr>
<th>Object</th>
<th>Shape</th>
<th>m in kg</th>
<th>R in m</th>
<th>I in kg·m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>sphere</td>
<td>3.0</td>
<td>0.6</td>
<td>0.43</td>
</tr>
<tr>
<td>B</td>
<td>hoop</td>
<td>2.0</td>
<td>0.5</td>
<td>0.50</td>
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<tr>
<td>C</td>
<td>cylinder</td>
<td>1.0</td>
<td>0.4</td>
<td>0.080</td>
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</tbody>
</table>

8. Rank the objects according to the order in which they arrive at the bottom of the first ramp. The first to arrive should be listed first.


9. Rank order the objects according to the height to which they rise on the second ramp. The object which rises highest is listed first.

A) A, B, C  B) A, C, B  C) B, A, C  D) One of the previous answers is correct but in reverse order.  E) None of the above are correct...all ascend to the same height.

10. The ratio of the maximum velocity of the sphere, A, to the maximum velocity of the cylinder, C, (v_{sphere}/v_{cylinder}) is approximately ________.

A) 0.87  B) 0.93  C) 1.00  D) 1.04  E) 1.07

The following description is used for items 11 through 13.

Given a uniform solid disk (a thin solid cylinder) free to rotate about a vertical axis perpendicular to the circular face of the disk at its center. The thickness of the disk is 0.020 m. Its radius is 0.40 m. The moment of inertia of the disk about the vertical axis is 1.0 kg·m². The rotation of the disk is described by its position in radians given by \( \Theta = 2t^2 - 10t + 8 \) where \( t \) is in seconds.

11. In the time interval \( t=0 \) to \( t=2.0 \) s, the disk rotated through an angle of approximately ___ radians.

A) 4  B) 8  C) 12  D) 16  E) 20

12. The disk is at rest when \( t = ____ \) s.

A) 0  B) 2.5  C) 5  D) 8  E) 1 or 4

13. The torque required to produce this motion...

A) starts at zero and increases.  B) starts at 4 Nm and increases.  C) remains constant at 4 Nm.  D) reverses direction at \( t = 2.5 \) s.  E) starts at a positive value and decreases at a constant rate.
14. A student investigates the behavior of a common frictionless spring and block simple harmonic oscillator. Using the same block she checks combinations of springs using a single spring, two springs attached in parallel to the block (side by side), and two springs with the second attached at the end of the first. All springs are identical with exactly the same length and spring constant. The sketch shows the letters identifying the spring arrangements used.

Rank order the springs in order of period with the highest value first. (That means the longest period would occur with the spring arrangement listed first.) The equal (=) sign indicates a tie.


The following description is used for items 15 through 18.

The position of the mass attached at the end of a spring behaving as a simple harmonic oscillator is given by

\[ x = 6.0 \text{cm} \times \sin \left( \frac{4 \pi \text{s}^{-1}}{2} t - \frac{\pi}{2} \right) \]

15. The value of \( x \) at \( t = 0 \) is approximately ____ cm.

A) 6.0  B) 0.16  C) 0  D) -0.16  E) -6.0

16. The period of this motion is approximately ____ seconds.

A) 0.5  B) 1.0  C) 2.0  D) 6.3  E) 12

17. The magnitude of the velocity of the mass at \( t = 1.2 \) seconds is approximately ____ m/s.

A) 7.7  B) 2.2  C) 0.73  D) 0.44  E) 0.060

18. The maximum value of the acceleration is ____ m/s².

A) 0.73  B) 2.2  C) 7.7  D) 9.5  E) 160

19. A spring with force constant \( k = 10 \text{ N/m} \) is used in an experiment in which blocks of various mass are attached to the spring which is then stretched to the same amplitude and released. The resulting period is recorded. During the analysis of the data it is discovered a plot of \( T^2 \) as a function of \( m \) yields a straight line. The slope of the line is approximately ____ s²/kg.

A) 0.25  B) 0.39  C) 2.0  D) 2.5  E) 3.9

20. A simple pendulum of length \( L \) is constructed using a massless rod with a point mass \( m \) at one end and pivoted at the other. The rod exhibits simple harmonic motion as it swings from a maximum angular displacement \( \Theta_1 \) to the left through its vertical equilibrium position to \( \Theta_2 \) on the right and back. The tension in the rod when the pendulum is at \( \Theta_2 \) is given by

A) \( mgL \sin \Theta_2 \)  B) \( mgL \cos \Theta_2 \)  C) \( mgL(1 - \cos \Theta_2) \)  
D) \( mg \sin \Theta_2 \)  E) \( mg \cos \Theta_2 \)
21. Given a frictionless hollow hemisphere (like a bowl) of radius R. A point mass is held against the inside of the hemisphere a distance h above the lowest point and released. Which of the following will give the period in seconds of the oscillatory motion which results?

A) \( \frac{R}{g} \)  \quad B) \( \frac{2\pi}{R} \)  \quad C) \( \frac{1}{2\pi} \sqrt{\frac{g}{R}} \)  \quad D) \( 2\pi \sqrt{\frac{R}{g}} \)  \quad E) \( 2\pi \sqrt{\frac{g}{R}} \)

The following description is used for items 22 and 23.

A 22\textsuperscript{nd} century monitoring probe is to be placed between a newly discovered pair of asteroids which are designated A and B. The distance between them is d. The mass of A is M and B is 2M. The mass of the probe is m.

22. At what point x, measured from A, should the probe be placed so that the net gravitational force on it from the asteroids is zero?

A) \( x = (\sqrt{2} - 1)d \)  \quad B) \( x = \left( \frac{1}{2} + \frac{1}{\sqrt{2}} \right)d \)  \quad C) \( x = \frac{1}{\sqrt{2}}d \)  \quad D) \( x = \frac{d}{2} \)  \quad E) \( x = \frac{d}{3} \)

23. The potential energy of the monitoring probe when it is between the asteroids an equal distance from each (at \( x = d/2 \)) is given by

A) \( -\frac{Gmm}{d} \)  \quad B) \( -\frac{4Gmm}{d} \)  \quad C) \( -\frac{Gmm}{6d} \)  \quad D) \( -\frac{6Gmm}{d} \)  \quad E) \( -\frac{Gmm}{4d} \)

24. Given two blocks. Block Q has a mass of 4.0 kg and rests on top of block P which has a mass of 16.0 kg. Block P rests on a horizontal frictionless surface. It is attached to a horizontal “massless” spring with a spring constant of 300 N/m. The opposite end of the spring is attached to a fixed support. The coefficient of static friction between the two blocks is 0.50. The blocks are displaced and execute simple harmonic motion. The maximum displacement of block P such that block Q does not slide relative to block P is approximately ____ m.

A) 0.41  \quad B) 0.33  \quad C) 0.26  \quad D) 0.22  \quad E) 0.070

25. Given a uniform metal rod 6.0 meters in length with a weight of 1000 N. A load of 2000 N is attached at the upper end. A cable is attached to the rod 4.0 meters from the lower end. The cable makes an angle of 53 degrees with the rod. The rod is inclined at 30 degrees with the horizontal. A force F is applied to the rod at a point 1.0 m from the lower (left) end so that the rod is in translational and rotational equilibrium.

The tension in the cable is approximately ____ N.

A) 7700  \quad B) 4300  \quad C) 4000  \quad D) 3300  \quad E) 2500
# PHYSICS FORMULAE UPDATED 12-29-04

<table>
<thead>
<tr>
<th>MECHANICS</th>
<th>ELECTRICITY AND MAGNETISM</th>
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<tbody>
<tr>
<td>( v = \Delta x / \Delta t ) ( \Delta x = \text{displacement} ) (change of position) ( E = k \frac{q_1 q_2}{r^2} ) ( E = \text{electric field intensity} )</td>
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<td>( a = \Delta v / \Delta t ) ( a = \text{average acceleration} ) ( E = \frac{F}{q} ) ( I = \text{electric current} )</td>
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<tr>
<td>( v_f = v_i + at ) ( v = \text{average velocity} ) ( k = \text{electrostatic constant} )</td>
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<td>( \Delta x = v_i t + \frac{1}{2} at^2 ) ( v_i = \text{initial velocity} ) ( V = \frac{W}{q} = Ed ) ( P = \text{Power} )</td>
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<td>( 2a \Delta x = v_f^2 - v_i^2 ) ( v_f = \text{final velocity} ) ( I = \frac{\Delta q}{\Delta t} ) ( q = \text{charge} )</td>
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<td>( \Sigma F = ma ) ( F = \text{force} ) ( R = \text{resistance} )</td>
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<td>( W = mg ) ( F_f = \text{force of friction} ) ( V = IR ) ( V = \text{electric potential difference} )</td>
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<td>( F_k = G \frac{m_1 m_2}{r^2} ) ( F_N = \text{normal force} ) ( P = VI = I^2 R = \frac{V^2}{R} ) ( W = \text{Work} )</td>
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<td>( \rho = mv ) ( F_g = \text{gravitational force} ) ( \text{SERIES CIRCUIT} )</td>
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<td>( F \Delta t = m \Delta v ) ( \mu = \frac{F_f}{F_N} ) ( \rho = \text{momentum} )</td>
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<tr>
<td>( G = \text{Universal Gravitational Constant} ) ( \mu = \text{coefficient of friction} )</td>
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<td>( r = \text{distance between center of masses} ) ( W = \text{weight} )</td>
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<tr>
<th>ENERGY</th>
<th>MOTION IN 2-D</th>
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<tr>
<td>( W = F \Delta x ) ( h = \text{height} ) ( a_c = \frac{v^2}{r} ) ( a_c = \text{centripetal acceleration} )</td>
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<tr>
<td>( P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv ) ( k = \text{spring constant} ) ( F_c = m \frac{v^2}{r} ) ( F_c = \text{centripetal force} )</td>
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<tr>
<td>( PE_g = mgh ) ( KE = \text{kinetic energy} ) ( 1 \text{rev} = 2\pi rad = 360^\circ )</td>
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<td>( KE = \frac{1}{2} mv^2 ) ( PE_g = \text{gravitational potential energy} ) ( \tau = Fxr ) ( \tau = \text{Torque} )</td>
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<tr>
<td>( PE_s = \text{potential energy stored in a spring} ) ( P = \text{power} )</td>
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<td>( F = -kx ) ( W = \text{work} )</td>
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<td>( P = \frac{\Delta E}{\Delta t} = KE ) ( x = \text{change in spring length from the equilibrium position} )</td>
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NJSLS Physics Formula Sheet. Updated 12-29-04
**Physics Formulae Updated 12-29-04**

### Heat Energy
- \( Q = mc\Delta T \)  
- \( Q = mL_f \)  
- \( Q = mL_v \)  
- \( \Delta L = \alpha L_o \Delta T \)  
- \( c = \text{specific heat} \)  
- \( L_f = \text{latent heat of fusion} \)  
- \( L_v = \text{latent heat of vaporization} \)  
- \( Q = \text{amount of heat} \)  
- \( \Delta T = \text{change in temperature} \)  
- \( \alpha = \text{coefficient of linear expansion} \)  
- \( L_o = \text{original length} \)  

**Wave Phenomena**
- \( T = \frac{1}{f} \)  
- \( v = f\lambda \) OR \( v = \nu\lambda \)  
- \( n = \frac{c}{v} \)  
- \( n_i \sin \theta_i = n_r \sin \theta_r \)  
- \( \sin \theta_c = \frac{1}{n} \)  
- \( c = \text{speed of light in a vacuum} \)  
- \( d = \text{distance between slits} \)  
- \( f = v = \text{frequency} \)  
- \( L = \text{distance from slit to screen} \)  
- \( n = \text{index of absolute refraction} \)  
- \( T = \text{period} \)  
- \( v = \text{speed} \)  
- \( x = \text{distance from central maximum to first-order maximum} \)  
- \( \lambda = \text{wavelength} \)  
- \( \theta = \text{angle} \)  
- \( \theta_c = \text{critical angle relative to air} \)  

### Geometric Optics
- \( \frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \)  
- \( f = \text{focal length} \)  
- \( d_i = \text{image distance} \)  
- \( d_o = \text{object distance} \)  
- \( h_i = \frac{d_i}{d_o} \)  
- \( h_o = \frac{d_i}{d_o} \)  
- \( h_i = \text{image size} \)  
- \( h_o = \text{object size} \)  

### Electromagnetic Applications
- \( F = Bqv \)  
- \( F = BLI \)  
- \( V = BLv \)  
- \( N_p = V_p \)  
- \( N_s = V_s \)  
- \( V_p I_p = V_s I_s \) (ideal)  
- \( \text{efficiency} = \frac{V_s I_s}{V_p I_p} \)  
- \( B = \text{magnetic field strength} \)  
- \( I_p = \text{current in primary} \)  
- \( I_s = \text{current in secondary} \)  
- \( N_p = \text{number of turns in primary coil} \)  
- \( N_s = \text{number of turns in secondary coil} \)  
- \( V_p = \text{voltage of primary} \)  
- \( V_s = \text{voltage of secondary} \)  
- \( L = \text{length of conductor} \)  
- \( V = \text{electric potential difference} \)  

### Additional Formulæ:
- \( x = \text{Acos(} \omega t + \phi \text{)} \)  
- \( n\lambda = \text{osin}\theta \)  
- \( E_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 \)  

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

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

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

NJSI Physics Formula Sheet.  
Updated 12-29-04
AP PHYSICS "C" TEST - FEBRUARY, 2005

Answer Key

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NEXT TEST - MARCH 10, 2005

TOPICS: electrostatics and electric circuits