Rules: This exam is to be completed by you unaided by textbook, web, notes, homework solutions, friends etc.... (You are of course encouraged to use a calculator.) The one external aid you may use during the exam is the unannotated 'Course Guide:' the formulas, definitions, etc that I recorded there may help you recall how to work a problem. If, during the exam, you think you need an additional formula or hint, ask me (via personal chat) and I may be willing to provide it. Remotes will enable video, have audio available but muted and be on screen 100% of the time. Questions may be asked via personal chat. You should also use the Hands Up feature to draw my attention to your question.

Clearly the above will hardly deter the determined cheater. Your personal integrity is the only real deterrent to cheating. To engage that, sign the below statement just before you turn in the exam.

In answering these questions I have not aided any other student or used any external aids other then the unannotated 'Course Guide'.

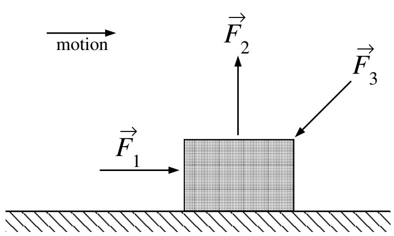
Name: ________________________________

Circle the letter of the single best answer. Each question is worth 1 point

Physical Constants:

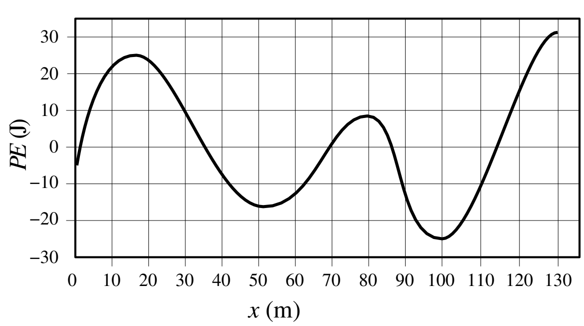
Earth's free-fall acceleration $= g = 9.80$ m/s^2

1. Three forces of equal magnitude but different direction act on a block as shown below. The block moves 3 m to the *right*. Rank the work done by each force. (The work done by force $\vec{F}_1$ is W_1, etc.)



A. $W_1 > W_2 > W_3$
B. $W_2 > W_3 > W_1$
C. $W_3 > W_1 > W_2$
D. $W_3 > W_2 > W_1$

2. An object moving along the x axis experiences a varying potential energy, PE, as shown below. (All forces acting on the particle are conservative and are included in this potential energy.) If the object is at $x = 50$ which of the below is the smallest kinetic energy that would allow the object to get over the hump at $x = 80$?



A. 10 J
B. 15 J
C. 20 J
D. 25 J

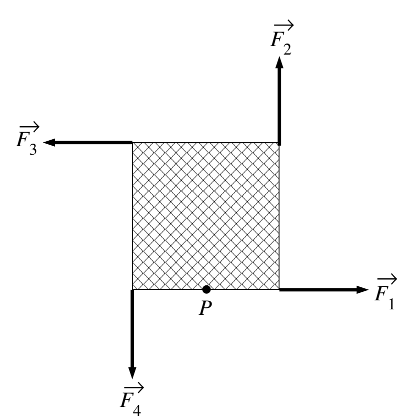
3. On a flat curvy road, without peddling, a bicyclist goes around a corner with speed hardly diminished. This is an example of *approximate*:

A. conservation of energy
B. conservation of momentum
C. both of the above
D. none of the above

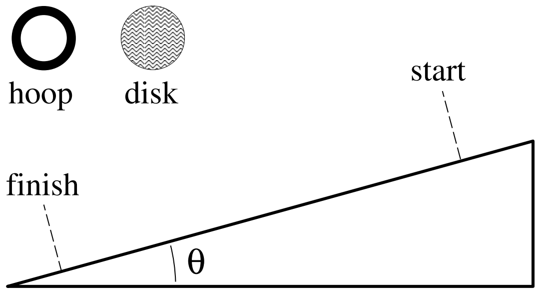
4. A small table cloth is placed on a table, and a glass of wine is placed on top of the table cloth. Dr. Science pulls (horizontally) the cloth very rapidly from underneath the glass and the glass (only slightly disturbed by the process) ends up at rest on the table top. This can be explained by: the quicker the pull,

A. the smaller the force on the glass.
B. the smaller the impulse to the glass.
C. the larger the momentum of the cloth.
D. the smaller the coefficient of friction.

5. Four forces of equal magnitude but with directions as shown below act at the corners of a square. The square has a fixed pivot point P. Rank (from least to greatest) the torque produced by these forces about the pivot point. We define a positive torque as one in the counterclockwise direction. Note: negative numbers are smaller than any positive number. (The torque produced by $\vec{F}_1$ is denoted τ_1, etc.)



A. $\tau_1 = \tau_2 = \tau_3 = \tau_4$
B. $\tau_1 < \tau_2 = \tau_4 < \tau_3$
C. $\tau_1 < \tau_2 = \tau_3 = \tau_4$
D. $\tau_4 < \tau_1 < \tau_2 < \tau_3$



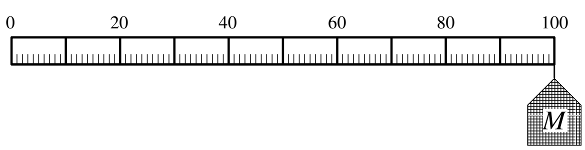
6. A solid disk made of wood and a hoop made of metal have exactly the same mass and radius. When the two objects "race" (roll without slipping down an inclined plane) the disk always wins. Consider the following statements about (1) the magnitude of the static frictional force (f) between the inclined plane and the rolling object, (2) the finish-line value of the total kinetic energy (K) and (3) the moment of inertia "about" the center of mass (I). (For example, K_{hoop} denotes the total kinetic energy of the metal hoop when it crosses the finish-line.)

   - $f_{\text{disk}} < f_{\text{hoop}}$
   - $K_{\text{disk}} < K_{\text{hoop}}$
   - $I_{\text{disk}} < I_{\text{hoop}}$

   How many of these statements are true?

   A. none
   B. one
   C. two
   D. three

7. A 400 g mass M hangs from one end of a uniform 100 g meter stick. The system will be balanced if the fulcrum is placed:

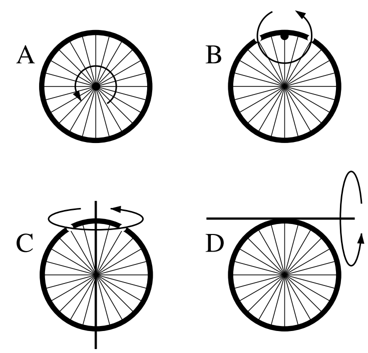


   A. at the 50 cm mark.
   B. at the $66\frac{2}{3}$ cm mark.
   C. at the 75 cm mark.
   D. at the 90 cm mark.

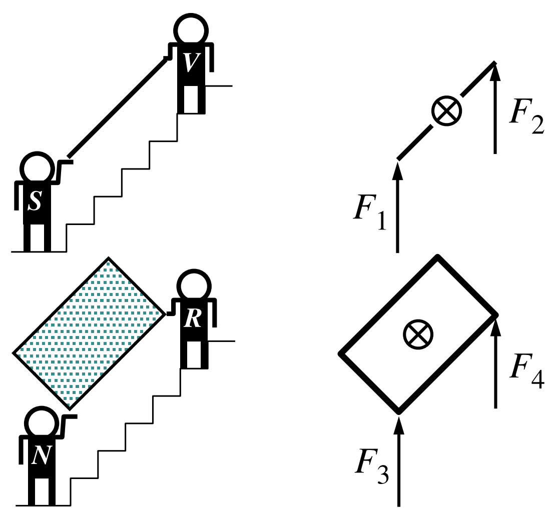
8. Consider the rotational moment of inertia of a bicycle wheel rotated about different rotation axes:

   A. its usual axle
   B. about a parallel axis on the edge
   C. a diameter
   D. an axis parallel to a diameter, but on an edge.

   Which rotation axis has the smallest rotational inertia?

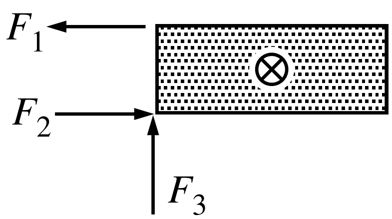


9. Moving into their upstairs apartment, Venus and Serena enlist Roger and Novak to help. Roger and Novak carry a 38" × 75" mattress that weighs 50 lbs. Venus and Serena carry an equal length steel exercise bar that also weighs 50 lbs. Rank the lifting force that each must provide. (The center of gravity of each item is located at the symbol: ⊗.)



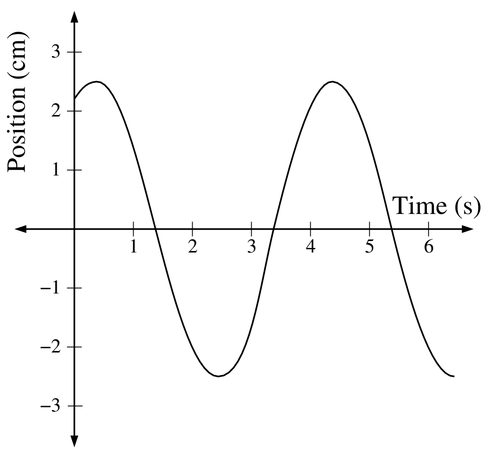
   A. $F_4 < F_1 = F_2 < F_3$
   B. $F_4 < F_1 < F_2 < F_3$
   C. $F_4 = F_2 < F_1 = F_3$
   D. $F_1 = F_2 = F_3 = F_4$

10. As shown below a 50 lb rectangular sign hangs outside of a shop supported by the three forces that act in the directions shown below. Rank the magnitude of these forces. (The center of gravity of the sign is located at the symbol: $\otimes$.)



A. $F_3 < F_1 = F_2$
B. $F_1 < F_2 < F_3$
C. $F_1 < F_3 < F_2$
D. none of the above

11. The position of a particle undergoing simple harmonic motion is displayed as a function of time below. The frequency f of the particle is most nearly:



A. 4 s
B. 2 s
C. 0.25 Hz
D. 0.5 Hz

12. For the above simple harmonic motion, the amplitude of the motion is most nearly:

A. 1.5 cm
B. 2.5 cm
C. 4 s
D. 5 cm

The following questions are worth 12 pts each

Record your steps! (Grade based on method displayed not just numerical result)

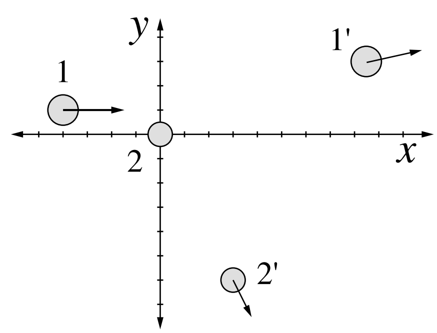
13. Particles 1 and 2 collide in space where no external forces are present. Particle 1 moves parallel to the x^+ axis and collides with particle 2 which was at the origin. The below table lists the mass (in kg), a pre-collision (unprimed) and a post-collision (primed) position (in m) and velocity (in m/s) in (x, y) notation.

object	mass	pre-collision		post-collision	
m_1	3	$\vec{r}_1 = (-4, 1)$	$\vec{v}_1 = (5, 0)$	$\vec{r}'_1 = \left(\frac{17}{2}, 3\right)$	$\vec{v}'_1 = \left(\frac{9}{2}, 1\right)$
m_2	1	$\vec{r}_2 = (0, 0)$	$\vec{v}_2 = (0, 0)$	$\vec{r}'_2 = (3, -6)$	$\vec{v}'_2 = \left(\frac{3}{2}, -3\right)$

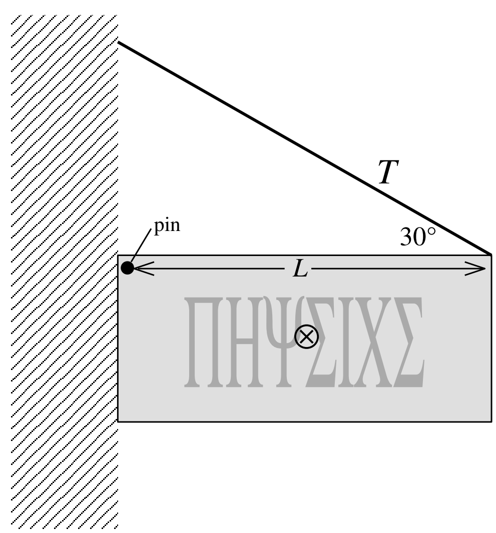
A. Calculate the x and y components of momentum in the pre-collision state and in the post-collision state. Any sign of the presence of an external force?

B. Calculate the total kinetic energy in the pre-collision state and in the post-collision state. Is the collision elastic?

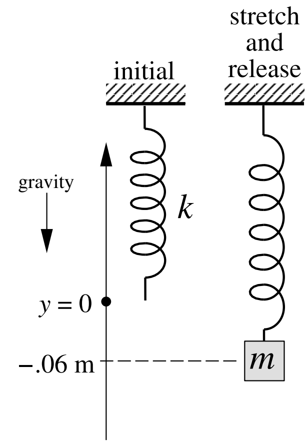
C. Calculate the x and y components of the pre-collision velocity of the center of mass.



14. A uniform sign of mass 20 kg hangs from the side of a building; ⊗ marks the location of the sign's center of mass right in the center of the sign. The sign is held in place by forces at a pin (as shown) and a cable with tension T. The length of the sign (L) is not given as it should cancel. Using the pin as the origin draw/label (directly on the diagram) $r_\perp$ for T and $r_\perp$ for the force of gravity on the sign. Find the tension T in the cable.



15. A spring (spring constant $k = 250$ N/m) is hanging from the ceiling. A mass ($m = 0.35$ kg) is attached to the spring, pulled down 6 cm, and then released. What is the velocity of the mass when it rises to 1 cm above the initial (relaxed, unattached) spring-end position (i.e., at $y = +.01$ m)?



16. A spool has a large radius $R = 5$ cm and an inner radius of $r = 1$ cm. A string is wrapped around the inner radius and, after passing over a massless, frictionless pulley, is attached to a hanging mass $M = 0.75$ kg. The large radius section rubs against the surface acting like a brake with total frictional force 0.6 N. The spool's total moment of inertia is $0.004\ \mathrm{kg \cdot m^2}$. Find the acceleration of the falling mass. Begin by drawing a free body diagram of M showing all the forces acting on it and a free body diagram of the spool showing all the torques on it.