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: _____

Physical Constants

$\sigma = 5.6704 \times 10^{-8}\ \mathrm{W \cdot m^{-2} \cdot K^{-4}}$
$R = 8.3145\ \mathrm{J/(K \cdot mol)}$
$N_A = 6.0221 \times 10^{23}$
$k_B = 1.3806 \times 10^{-23}\ \mathrm{J/K}$
$1\ \mathrm{atm} = 1.01325 \times 10^5\ \mathrm{Pa}$
$g = 9.80 \mathrm{m/s^2}$

Properties of H_2O

$L_v = 2256\ \mathrm{J/g}$
$c_w = 4.186\ \mathrm{J/(g \cdot K)}$
$L_f = 334\ \mathrm{J/g}$
$c_i = 2.09\ \mathrm{J/(g \cdot K)}$
$\rho_w = 1000\ \mathrm{kg/m^3}$
$\eta = 1 \times 10^{-3}\ \mathrm{Pa \cdot s}$

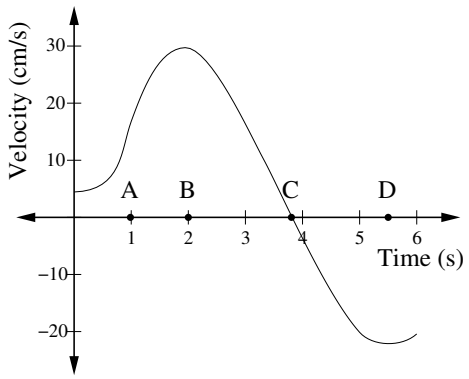
Unless stated otherwise, circle the letter of the single best answer. Each answer is worth 1 point.

1. How many of the below numbers display exactly 3 significant digits?

   - 0.090
   - 70.0
   - 0.72
   - 5.02
   - 0.63×10^4
   - 720.
   - 720
   - 0.720
   - 7210
   - 7.20×10^{14}

   A. five
   B. six
   C. seven
   D. none of the above

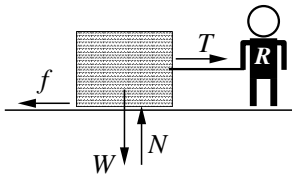
2. The below graph displays the velocity, v, of an object moving on a straight line as a function of time. Circle the labeled time when the particle has the maximum acceleration.



3. Romeo throws a pebble at Juliet's window. It bounces off; no harm done. Bluto throws a brick at Olive Oyl's window. It crashes through breaking the window.

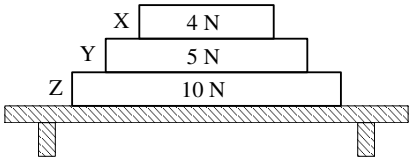
   A. The pebble's force on the window is less than the window's force on the pebble, so no harm is done.
   B. The brick's force on the window is greater than the window's force on the brick, so the window breaks.
   C. Both of the above.
   D. None of the above.

4. Rhonda pulls a box of mass m across a horizontal surface at a constant velocity v by pulling horizontally on a rope with tension T. Other forces ($W = mg$: gravity, N: normal force, f: friction) also act in the directions indicated. Which of the following relations among the force magnitudes must be true?



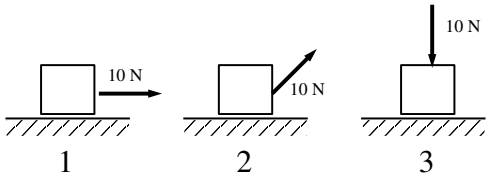
   A. $T = f$ and $N = W$
   B. $T > f$ and $N > W$
   C. $T > f$ and $N = W$
   D. $T > f$ and $N < W$

5. Three books (X, Y, and Z) rest on a table. The weight (i.e., mg) of each book is indicated. The force of book Z on book Y is:



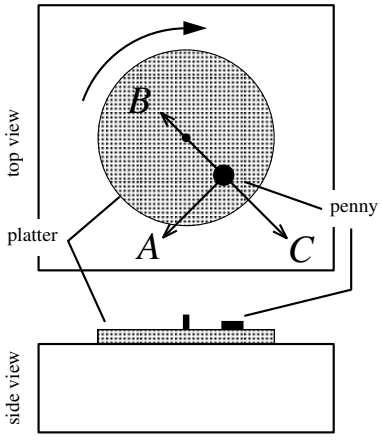
A. zero
C. 9 N up
B. 5 N up
D. 19 N up

6. A crate rests on a horizontal surface and a man pulls on it with a 10 N force. He applies the force in several different directions but the frictional force keeps the crate from moving. Below are displayed three attempts to move the crate. Rank the situations shown according to the magnitude of the frictional force exerted by the surface on the crate, least to greatest.



A. $2 < 3 < 1$
C. $2 < 1 < 3$
B. $3 < 2 < 1$
D. $3 < 1 < 2$

7. A penny is placed on the rotating platter of a turntable; it remains in place due to static friction. Circle the below letter that best describes the direction of this frictional force.

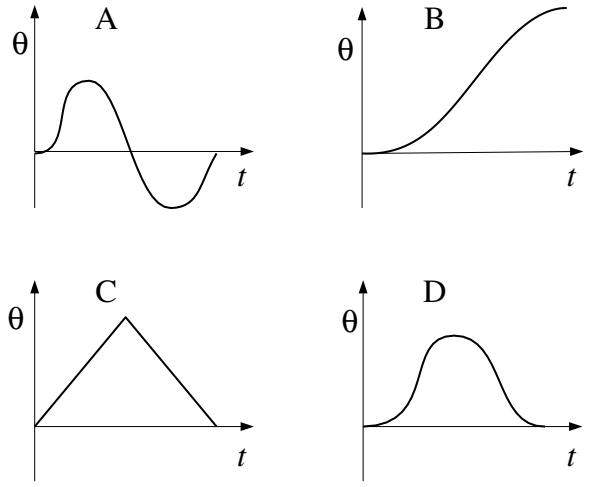


D. none of the above

8. A golf ball is fired at a very massive bowling ball which initially was at rest. The golf ball bounces back elastically. Compared to the post collision bowling ball, the post collision golf ball has:

A. more momentum but less kinetic energy
B. more momentum and more kinetic energy
C. less momentum and less kinetic energy
D. less momentum but more kinetic energy

9. Starting from rest, a record player is turned on so the platter spins up to its usual speed. A short time later the record player is turned off, so the platter slows and comes to rest. Which of the below graphs of angle vs. time best displays this motion?



10. Consider the moment of inertia of a racket rotated about different axes:

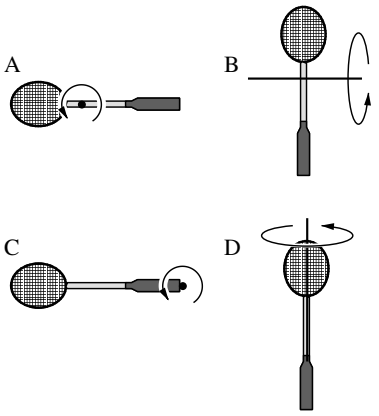
    A. an axis through its center of mass and perpendicular to its face

    B. an axis through its center of mass and in the plane of its face

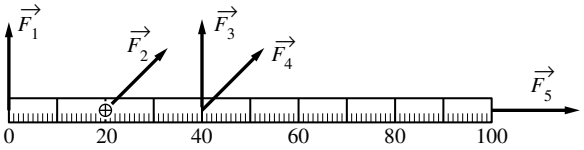
    C. an axis located at the handle's end

    D. an axis parallel its shaft.

    Which rotation axis has the smallest moment of inertia?



11. The meter stick shown below rotates about a pivot point at the 20 cm mark (shown below marked $\bigoplus$). Five forces act on the stick. The magnitudes of these forces are the same but the directions and points of application vary as shown below. Rank (from least to greatest) the torque produced by these forces about the pivot point. We define a positive torque as one in the counter-clockwise direction. (The torque produced by $\vec{F}_1$ is denoted τ_1, etc.)



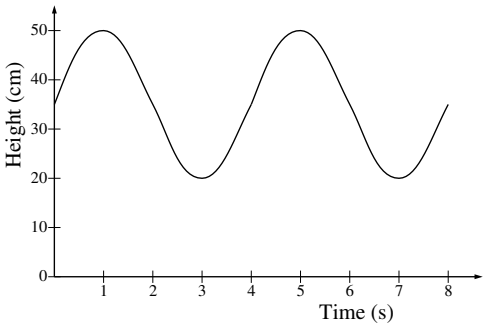
    A. $\tau_1 < \tau_2 = \tau_5 < \tau_4 < \tau_3$

    B. $\tau_1 < \tau_2 < \tau_4 < \tau_3 < \tau_5$

    C. $\tau_1 < \tau_2 = \tau_4 < \tau_3 < \tau_5$

    D. $\tau_2 = \tau_5 < \tau_4 < \tau_1 = \tau_3$

12. A baby bounces up and down in a Baby Doorway Jumper. Her height above the floor is plotted below. What is the oscillation amplitude (A) and frequency (f) of her motion?



    A. $A = 50$ cm, $f = 4$ Hz

    B. $A = 35$ cm, $f = 2$ Hz

    C. $A = 30$ cm, $f = 1$ Hz

    D. $A = 15$ cm, $f = .25$ Hz

13. In the context of chapter 16, which of the below best describes *resonance*.

    A. the reverberation of music played in a confined space.

    B. the phenomenon of nodes clashing with antinodes

    C. the phenomenon of driving a system at its natural frequency.

    D. the opposite of dissonance

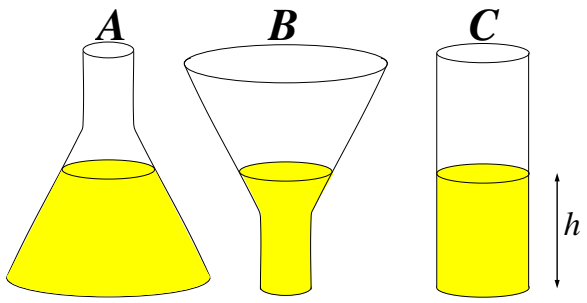
14. A small obstruction plugs the exit from a bicycle tire pump. In a (failed) attempt to force the obstruction out, a force F_A is applied to the handle while a force F_B holds the obstruction in place. Compare these forces:

    A. $F_A > F_B$ by Pascal's principle

    B. $F_A = F_B$ by Newton's law

    C. $F_A < F_B$ because the obstruction is not moved

15. As shown below three different shape containers are filled with water to exactly the same water-level, h. (Of course, because of the different shapes the total amount of water differs.) Circle the letter of the container with the smallest pressure at its bottom.



D. none of the above

16. Two objects of the same volume are placed in water. Object A floats and Object B sinks. The greater buoyant force is on

A. Object A

B. Object B

C. both are same

17. When you increase the temperature of honey it seems to flow faster, this is because:

A. the density of the honey decreases

B. the pressure on the honey increases

C. the tension on the honey is increased

D. the viscosity of the honey is reduced

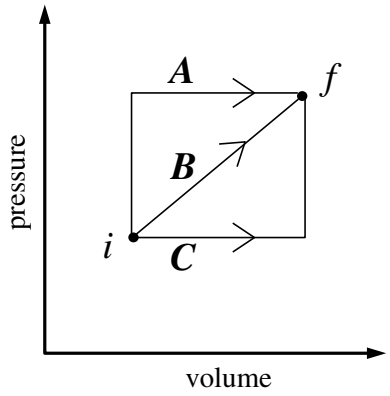
18. Neon and helium are both monoatomic gases under 'normal' room conditions (say $P = 1$ atm, $T = 20°$C), but neon has a molecular weight about 5 times that of helium. Which atom would have more kinetic energy on average?

A. Neon

B. Helium

C. they would have the same average kinetic energy

19. As shown in the diagram below, a gas is taken reversibly from an initial state i to a final state f by three possible paths. Which path results in the greatest heat Q being added to the gas.?



A. A

B. B

C. C

D. they all have the same heat.

20. As shown in the same diagram (above), a gas is taken reversibly from an initial state i to a final state f by three possible paths. Which path results in the greatest change in entropy (ΔS)?

A. A

B. B

C. C

D. they all have the same ΔS.

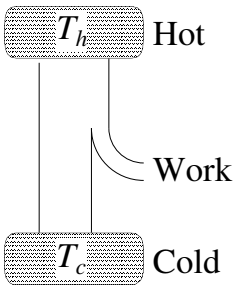
21. The below is a schematic diagram of a refrigerator. Consider the *signs* of the entropy change of the cold reservoir (ΔS_c), the entropy change of the hot reservoir (ΔS_h), and the sign of the work (W). Which of the below is correct

    A. $\Delta S_c > 0$, $\Delta S_h > 0$, $W > 0$

    B. $\Delta S_c > 0$, $\Delta S_h > 0$, $W < 0$

    C. $\Delta S_c < 0$, $\Delta S_h > 0$, $W < 0$

    D. none of the above



22. An ice cube (object A) is placed in a glass of warm water (object B). Eventually the two are in thermal equilibrium. Compare the entropy change of the ice (ΔS_A) to the entropy change of the water (ΔS_B).

    A. $|\Delta S_A| < |\Delta S_B|$

    B. $|\Delta S_A| > |\Delta S_B|$

    C. $|\Delta S_A| = |\Delta S_B|$

    D. not enough information is given to know

23. How many of the following statements are true?

    - If a process is reversible $\Delta S = 0$.
    - If you dissolve salt in water ($\mathrm{NaCl} \longrightarrow \mathrm{Na^+ + Cl^-}$) the entropy of the universe increases.
    - Since $\Delta G = \Delta H - T\Delta S$ composites must break apart at sufficiently high temperature even if the composite is strongly held together

    A. none

    B. one

    C. two

    D. all three

24. How many of the following statements are true?

    - Since a gram of ice (at 0°C) contracts a bit when it melts into water (also at 0°C) the change in internal energy upon melting ΔU must be a bit more than the latent heat of fusion.
    - Since a gram of liquid water (at 100°C) hugely expands when it becomes a gas (also at 100°C) the change in internal energy upon boiling ΔU must be a bit less than the latent heat of vaporization.
    - Since melting is a reversible process the change in entropy of the ice on melting must be zero,

    A. none

    B. one

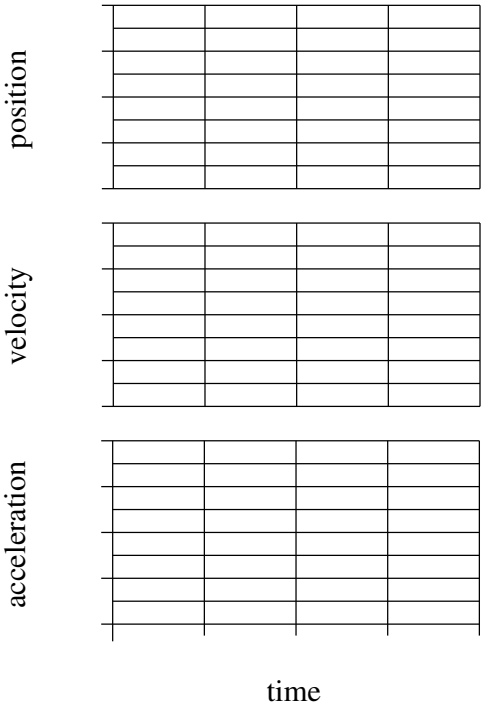
    C. two

    D. all three

The following questions are worth 12 pts each

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

25. You throw a ball straight up; it rises 20 m, and then returns to exactly where you released it. Use the supplied right graph paper to sketch three graphs of the entire up-and-back motion: position (height) vs. time, velocity vs. time, and acceleration vs. time. Note that the supplied grids lack scales! You will need to calculate some typical values in order to make appropriate scales for your graphs; the same time scale should be used for all three grids. I suggest finding the total time of flight, and the maximum velocity during the flight, but feel free to calculate anything that will provide accurate values for your scales. As usual, make a drawing of the scene displaying the origin and direction of the axis you're using for position. Just to make graphing easy, you can use $g = 10$ m/s^2 for this problem.

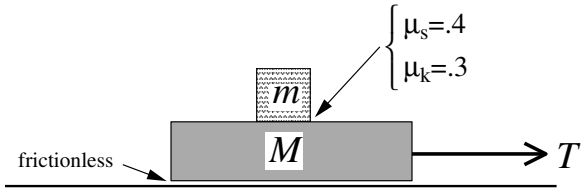


26. A large slab ($M = 10$ kg) sits on frictionless surface. A block ($m = 1$ kg) rests on top of the slab. The surface between the slab and the block has a coefficient of static friction of $\mu_s = 0.4$ and a coefficient of kinetic friction $\mu_k = 0.3$. The slab is pulled with a horizontal force T. If T is sufficiently small the block+slab will move together as one object; if T is larger, there will be slippage and the slab will accelerate faster than the block (and the block will eventually fall off the back of the slab).

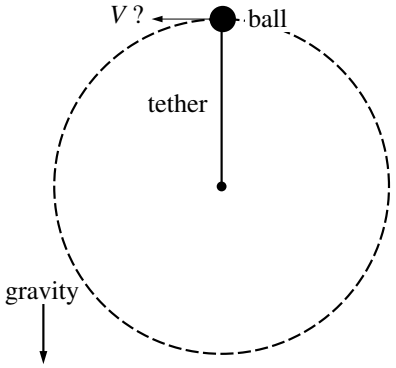
    A. Draw free body diagrams for each mass separately. Show and name all forces acting each mass. Show the direction of the acceleration (if there is any).

    B. *For each mass separately* and for both the x and y directions, write down the equations that follow from Newton's second law ($F_{\text{net}} = ma$).

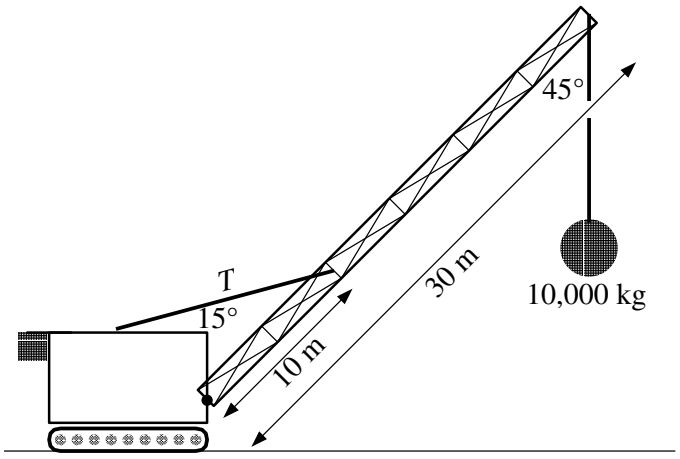
    C. Report the maximum acceleration of the block (m) that is possible without slipping.



27. A ball (of mass 0.1 kg) is attached to a tether and swung around in a vertical circle of radius 1 m. When the ball is at the top of the circle (as shown) the tension in the tether is 0.62 N. Draw a free body diagram showing/naming all the forces acting on the ball and the direction of any resulting acceleration. Find the speed of the ball at that time.



28. The boom of a crane has a mass of 3,000 kg distributed uniformly along its 30 m length. The boom is inclined at 45° and supports a 10,000 kg ball at its far end. The boom is supported by the tension T in a cable that is inclined, as shown, at 15° and connects to the boom 10 m from its end. A pin at the bottom of the boom connects the boom to the hub of the crane. Using the pin as the origin, draw directly on the diagram the moment arm ($r_\perp$) of the cable tension. Calculate the cable tension T.



29. You have an unpowered grindstone (a disk; $I = \frac{1}{2}MR^2$; with mass 90 kg and radius 0.35 m) that is initially turning at 90 rpm, and you press a steel ax against it with a radial force of 20 N.

    A. Assuming the kinetic coefficient of friction between steel and stone is 0.20, calculate the torque and resulting angular (de)acceleration of the grindstone. (Assume friction from the ax is the only torque acting on the grindstone.)

    B. How many turns will the stone make before coming to rest?

30. Water flowing at 0.3 m/s through a horizontal rubber tube of diameter 1 cm is used to model blood flow. An obstruction is introduced into a small section of the tube which reduces the tube diameter to .6 cm.

    A. Calculate the fluid's speed through the tube section with the obstruction. (

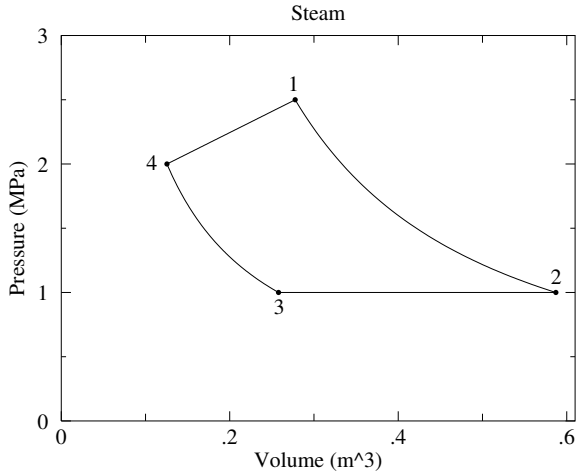
    B. Calculate the pressure difference between: upstream of the obstruction and inside of the obstruction.

    C. Which is greater: the pressure in the obstruction or the pressure upstream of the obstruction?

31. Consider the following cycle using 1 kg of water vapor (which is <u>not</u> an ideal gas). Starting (#1) at a pressure of 2.5 MPa, volume 0.2777 m^3, and temperature 1232°C:

- $1 \rightarrow 2$: The steam expands adiabatically to a volume of 0.5871 m^3; pressure of 1 MPa.
- $2 \rightarrow 3$: In a constant-pressure (a.k.a., isobaric) process, the volume is compressed to 0.2579 m^3.
- $3 \rightarrow 4$: An isothermal compression (at 300°C) reduces the volume to 0.1255 m^3
- $4 \rightarrow 1$: A straightline process returns to the initial state.

The below graph displays this cycle. The below table reports state variables at the labeled points. The questions focus on the heat, Q, added (+) or removed (–) from the steam during these steps often calculated using the work. (Note that when calculating work, you are likely to be using units of J, whereas the below table uses kJ.) Please report the proper sign for these Qs!



point	Volume (m^3)	Pressure (MPa)	Temperature (°C)	U (kJ)	Entropy (kJ/K)
1	0.2777	2.5	1232	4531	8.912
2	0.5871	1.0	1000	4051	8.912
3	0.2579	1.0	300	2793	7.123
4	0.1255	2.0	300	2773	6.766

A. Find the heat Q added to the steam during the process $1 \rightarrow 2$

B. Find Q for the process $2 \rightarrow 3$. (Hint: use work; careful with sign & units!)

C. Use ΔS to find Q in the isothermal compression $3 \rightarrow 4$

D. Which table entries show that the gas is not ideal? Explain!

(Flip page for final problem)

32. In an insulated container, 250 g of water at 35°C is mixed with 75 g of ice at −20°C. The final state consists of 100% liquid water. Calculate the final (equilibrium) temperature of this system.