PHYS 1420 (Fall 2019) - Final Exam (A)

Name:

Student Number:

Instructions–

- **Read all instructions carefully.**
- Clearly write your name and student number above **BEFORE** you start the exam. Also, have your student ID out and on your desk (you may be asked for an invigilator to see it before/during/after the exam).
- Once the test begins, **the instructor and invigilators will not be able to answer questions**. You will need to interpret things as best you can and answer accordingly.
- Calculators can be used for this exam. Use of phones/tablets/computers/smart watches/etc... is not permitted.
- Feel free to use scratch paper (some is included at the back, feel free to detach it). You will not be graded upon what is on the scratch paper, though **you must turn it in with your exam**.
- You are allowed a formula sheet (8.5x11 in) to bring with you. It must be a single hard copy sheet of paper (though you can write on front and back). **You must turn such in with your exam**.
- This test has:
  - 50 T/F questions (Q1)
  - 31 multiple choice (Q2)
  - Six write-in problems (Q3-8)
  - One extra credit problem.

  It is worth 100 points (with 110 total points possible). It is your responsibility to make sure that you have done all the problems!
- **For write-in problems**: Show all work clearly in order to get full credit. Points can be taken off if it is not clear to see how you arrived at your answer (even if the final answer is correct). Sketch all relevant graphs and explain all relevant mathematics. Circle/box your final answers. Please keep your written answers brief; be clear and to the point.
- Make sure to turn your test in as requested at the end of the exam period. Failure to do such can lead to a failing grade.

1. (*25 points*)
For the following questions, circle the appropriate choice T or F (where **T≡True** and **F≡False**). **No explanation in necessary.**

i. *T or F* – The word *Physics* stems from the ancient Greek term meaning "knowledge of space and time".

ii. *T or F* – The notion of change is a lynchpin of physics.

iii. *T or F* – One can obtain both a parabola and hyperbola by slicing a cone.

iv. *T or F* – Einstein's theory of special relativity answers the question *What causes gravity?*.

v. *T or F* – The *average* and *instantaneous* velocity vectors are never the same.

vi. *T or F* – Neglecting air resistance, it takes the same amount of time for a bullet to hit the ground independent of whether you shoot it or drop it.

vii. *T or F* – Assuming no air resistance, a projectile will cover the same horizontal range if the launch angle is 15^o or 65^o.

viii. *T or F* – Uniform motion can be reasonably describes as *unchanging change*.

ix. *T or F* – Weight and mass are equivalent.

x. *T or F* – Newton's third law is relevant to understanding global tidal dynamics.

xi. *T or F* – A rocket is able to move essentially by a reduction of mass.

xii. *T or F* – Drag forces are typically proportional to the cross-sectional area of an object.

xiii. *T or F* – For a fan blade slowing down, the angular velocity and angular acceleration both point in the same direction.

xiv. *T or F* – For a fan rotating in clockwise direction, the angular acceleration vector points in the counter-clockwise direction.

xv. *T or F* – Work can be positive or negative.

xvi. *T or F* – *Tomography* uses a bunch of lower-dimensional projections to build up a higher-dimensional image.

xvii. *T or F* – The gravitational potential energy of a ball does not change as you raise it from the ground to a height of two meters.

xviii. *T or F* – Kinetic energy is proportional to the square of the velocity.

xix. *T or F* – Force is the dot product of pressure and area.

xx. *T or F* – For things moving very fast, Newton's 2nd Law as $F = ma$ is not valid.

xxi. *T or F* – When the net external force on a system is non-zero, the total momentum of the system remains constant.

xxii. T *or* F – In physics, a system is a portion of the physical universe chosen for analysis. Everything outside the system is known as the environment.

xxiii. T *or* F – An "impulse" and "contact time" are the same thing.

xxiv. T *or* F – The center-of-mass for a flat triangular plate will always be somewhere inside the plate.

xxv. T *or* F – It is possible to have a solid object where its center-of-mass is outside the object.

xxvi. T *or* F – If the net force on a system is zero, than the center-of-mass can move due to conservation of (linear) momentum.

xxvii. T *or* F – A rotating rod with an axis of rotation (perpendicular to the rod) about one end has a higher moment of inertia than if the axis of rotation was through the center of the rod.

xxviii. T *or* F – A frame of reference is inertial if it is in uniform motion (which also includes being at rest).

xxix. T *or* F – Suppose $y = k/x^2$ where k is a constant. Than y is proportional to $1/x^2$.

xxx. T *or* F – A hoop and a disk (both of radius R and mass M) are placed at the top of an incline of height H. The hoop will "win the race" to the bottom.

xxxi. T *or* F – Standing on the balls of your feet, the tension in your Achilles tendon is nearly four times your weight.

xxxii. T *or* F – Angular acceleration and radial acceleration are the same thing.

xxxiii. T *or* F – For an object undergoing angular acceleration, the applied force and corresponding torque point in different directions.

xxxiv. T *or* F – Work done for rotational motion is $W = \int \tau \, d\theta$ where τ is the applied torque and θ is the angular displacement.

xxxv. T *or* F – The equation $\tau = dL/dt$ (where τ is the applied torque and L is angular momentum) is equivalent to the statement *The time rate of change of angular momentum of a particle is equal to the torque acting on it*.

xxxvi. T *or* F – A non-living thing such as a pollen grain moves around by the same fundamental mechanism as a bacteria such as *E. coli*.

xxxvii. T *or* F – Diffusion is the result of random thermal agitations.

xxxviii. T *or* F – In diffusion, solute moves *down a concentration gradient* because of solute-solute interactions (or "crowding").

xxxix. T *or* F – Diffusion is the main physical mechanism underlying *conduction*.

xl. T *or* F – The "scallop theorem" indicates that a microscopic swimmer with a single "hinge" won't be able to move anywhere (i.e., it is subject to reciprocal motion).

xli. T *or* F – Changes in pressure is how sound energy propagates.

xlii. T *or* F – A gas is a fluid and thus both are nearly incompressible.

xliii. T *or* F – The natural frequency for a harmonic oscillator is k/m where k is the *stiffness* and m is the *mass*.

xliv. T *or* F – Something oscillating at 3 MHz has a period of 0.33 μs.

xlv. T *or* F – Resonance exhibits a full cycle phase shift as the driving frequency progresses through the natural frequency of the system.

xlvi. T *or* F – A general definition of a wave is when *a condition of some kind is transmitted from one place to another by means of a medium, where the medium itself is transported*.

xlvii. T *or* F – A compressional wave can be regarded as longitudinal wave.

xlviii. T *or* F – Standing waves arise by virtue of interference between waves traveling in opposite directions.

xlix. T *or* F – For an object undergoing uniform circular motion, there is a non-zero acceleration pointing in a direction tangent to the motion.

l. T *or* F – Static friction is typically larger than kinetic friction.

2. (*30 points*)
For the following questions, clearly **circle the most appropriate** choice. **Choose only one** (answers with more than one circle answered will be marked wrong). No explanation in necessary.

i. Approximately how many neurons are in the human brain?

A. 10^3

B. 10^6

C. 10^{11}

D. 10^{15}

E. 10^{25}

ii. The "wave equation" is best given by what equation below?

A. $\ddot{x} + \gamma\dot{x} + \omega_o^2 x = 0$

B. $\frac{\partial^2 B}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 B}{\partial t^2}$

C. $Ae^{x^2/t}$

D. $\frac{\partial^2 B}{\partial x^2} = \frac{1}{c^2}\frac{\partial B}{\partial t}$

E. $\frac{\partial B}{\partial x} = D\frac{\partial B}{\partial t}$

iii. Assume the function describing the position of an object with respect to time is a parabola. Which best describes the associated function for the acceleration (as a function of time) for that object?

A. A straight line with positive slope

B. A parabola

C. A hyperbola

D. A straight line with negative slope

E. A flat line

iv. Assume vector $\mathbf{A} = \hat{x} + \hat{y}$ and $\mathbf{B} = \hat{x} - \hat{y}$. Then $2\mathbf{A} - \mathbf{B}$ is (using compact component notation):

A. [1 1]

B. [2 1]

C. [3 1]

D. [1 3]

E. [3 3]

v. A plane flying horizontally at constant speed drops an aid package. Assuming air resistance is not negligible, the plane will be where when the package hits the ground?

A. In front of it

B. Atop it

C. Behind it

D. Can't determine based upon the information given

E. None of the above

vi. A hoop of radius R rolls without slipping along a horizontal plane with constant speed v. What is the acceleration of different points on the hoop's circumference?

A. g

B. v/R

C. vR

D. v^2/R

E. None of the above (can't say without specifying some additional quantity)

vii. Which force deals with holding sub-atomic particles together?

A. Gravity

B. Electrostatic force

C. Weak nuclear force

D. Strong nuclear force

E. Gluon force

viii. At an altitude of 3.2×10^5 m, the acceleration due to Earth's gravity is approximately (in $\mathrm{m/s^2}$)

A. 0

B. 9.7

C. 9.81

D. 0.05

E. 1

ix. If you drop a bowling ball, a spoon, and book at the same time from the same height, do they fall at the same rate?

A. No, because of drag.

B. No, heavier objects fall faster.

C. This is a trick question

D. Yes, as the acceleration due Earth's gravity is the same for all cases.

E. It depends upon where you are.

x. You just kicked a ball and it is rolling away from you. Which forces are NOT acting on the ball?

A. You (from the kick)

B. Friction

C. Centripital

D. Gravity

E. Normal (from the ground)

xi. Let y be proportional to the reciprocal of the square of x. Then the best function describing y would be:

A. $y = 1/x$

B. $y = 1/x^2$

C. $y = c/x^2$ (where c is a constant)

D. $y = 1/\sqrt{x}$

E. None of the above

xii. A falling sphere and a falling (end down) cylinder both have the same radius. The drag coefficient for the sphere is:

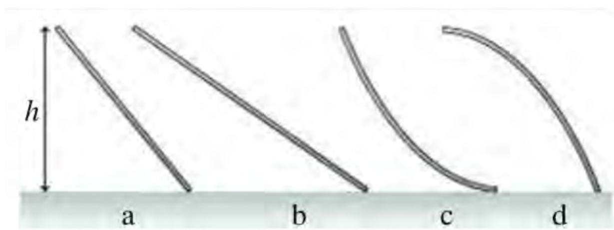
A. Larger than that of the cylinder

B. Smaller than that of the cylinder

C. The same as than that of the cylinder

D. Impossible to tell given the information provided

xiii. Consider a ball placed at the top (at height h above the ground) of four different frictionless ramps as shown below. Upon rolling down (initially from rest) each ramp, once the ball reaches the ground it will



A. Have the same speed, but will take different times to reach the bottom

B. Have different speeds, but take the same amount of time to reach the bottom

C. Have different speeds and will take different times to reach the bottom

D. Have the same speed and take the same amount of time to reach the bottom

E. Can not determine from the information given

xiv. Consider a falling object whose motion is described by the differential equation $m\ddot{x} = mg - k\dot{x}$. Eventually the object would reach what speed (before it hits the ground)?

A. 0

B. mg/k

C. mg

D. It will grow without bound.

E. None of the above.

xv. Suppose you have a solid object with integrable cross-sectional area $A(x)$ and it extends along the x-axis from a to b. Then the volume of the object is given by:

A. $\int_a^b A(x)\,dx$

B. $A^2\,dx$

C. $A(x)(b-a)$

D. $\sum A(x)$

E. None of the above

xvi. For an elastic collision

A. Energy is conserved, but momentum is not conserved

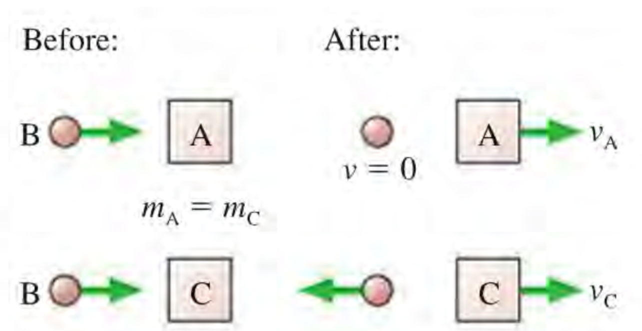
B. Energy is conserved and momentum is conserved

C. Kinetic energy is not conserved, but potential energy is conserved

D. Energy is not conserved, but momentum is conserved

E. Energy is not conserved, nor is momentum

xvii. Objects A and C are made of different materials (see figure below), with different "springiness," but they have the same mass and are initially at rest. When ball B collides with object A, the ball ends up at rest. When ball B is thrown with the same speed and collides with object C, the ball rebounds to the left. Compare the velocities of A and C (v_A and v_C respectively) after the collisions.



A. $v_A > v_C$

B. $v_A < v_C$

C. $v_A = v_C$ (but non-zero)

D. $v_A = v_C = 0$

E. Can not determine given the provided information

xviii. Consider a rigid object of total mass M rotating at angular velocity ω. The furthest point away of the object relative to the axis of rotation is at a distance R. The associated kinetic energy of the object is then:

A. $\frac{1}{2}M\omega^2$

B. $\frac{1}{2}M(\omega R)^2$

C. $\frac{1}{2}M(\omega/R)^2$

D. Can not determine from the provided information

xix. Two spheres have the same radius R and masses M. Sphere A has uniform density δ, in contrast to sphere B which is a "thin spherical shell" (i.e., the center is mostly hollow and most of the mass is concentrated near R). Both are rotating at constant angular velocity ω. In terms of moments of inertia:

A. $I_A > I_B$

B. $I_B > I_A$

C. $I_A = I_B$

D. $I_A + I_B = 1$

E. Can not determine from the provided information

xx. Consider a bar of length L and mass M free to move about an axis through one end of the bar (and perpendicular to the bar). A force $\bar{F}$ is applied to the bar *in the same plane as the bar* and is constant in magnitude and direction relative to the bar (i.e., the vector difference between $\bar{F}$ and the radius vector $\hat{r}$ of the bar is constant). This force causes the bar to accelerate in the counter-clockwise when viewed from the top looking down. The corresponding angular torque vector points in which direction?

A. Up

B. Down

C. Along the radius of the bar (i.e., $\hat{r}$)

D. In the same direction as $\bar{F}$

E. Can not determine from the provided information

xxi. Which of the following is equal to $\cos(x + \pi)$?

A. $\cos(x - \pi)$

B. $\cos(x + 3\pi)$

C. $-\sin(x)$

D. All of the above

E. None of the above

xxii. For angular momentum (L) to not be conserved, one must have

A. $dL/dt = 0$

B. Net internal torque is zero

C. Non-zero net external torque

D. Moment of inertia is constant

E. None of the above

F. All of the above

xxiii. *Active movement* chiefly refers to:

A. You use energy to move yourself around

B. The medium you are in moves you around

C. You have a bias as a random walker

D. Your motion is not random

E. None of the above

xxiv. A basic mechanism for heat transfer is:

A. Conduction

B. Convection

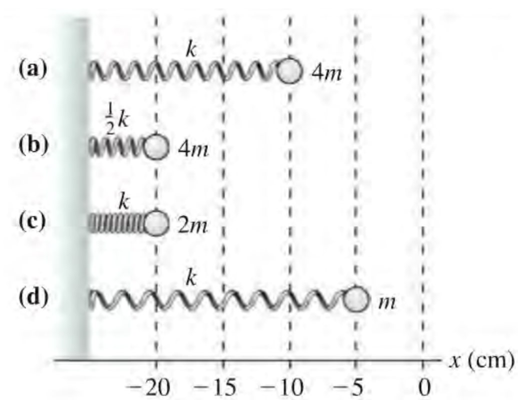
C. Radiation

D. Evaporation

E. None of the above

F. All of the above

xxv. The four springs shown below have been compressed from their equilibrium position at $x = 0$ cm. When released, the attached mass will start to oscillate. Rank in order, from highest to lowest, the maximum speeds of the masses.



A. $a = b = c = d$

B. $a > b = c > d$

C. $b > a > c > d$

D. $c > b > a = d$

E. $d > c > b > a$

xxvi. Consider a large ensemble of random 1-D walkers that are independent of one another and have equal probability of stepping left or right.

A. On average, they do not move anywhere.

B. Their spatial distribution forms a Gaussian.

C. The mean displacement is zero.

D. None of the above

E. All of the above

xxvii. Reynolds number can be best described as a

A. Ratio of mass over volume (i.e., a density)

B. Ratio of inertial forces over viscous forces

C. Ratio of viscous forces over inertial forces

D. Proportional to viscosity

E. Large for small swimmers (e.g., bacteria)

xxviii. A frog eardrum

A. Behaves like a simple harmonic oscillator

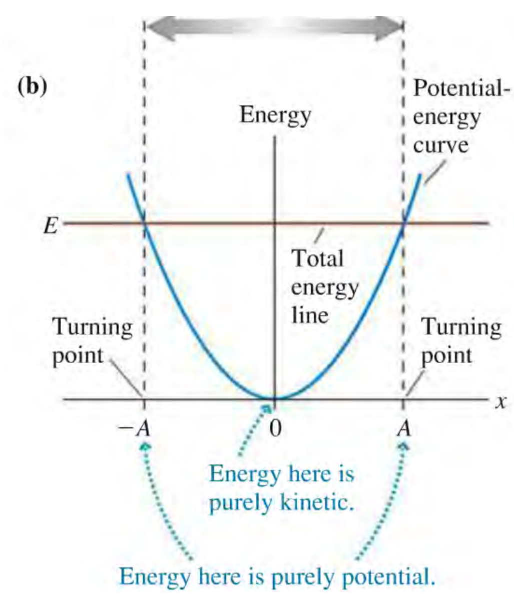
B. Exhibits standing waves

C. Exhibits traveling waves

D. Acts like a piston (i.e., all points move in phase)

E. None of the above

xxix. Consider the energy diagram shown for a simple harmonic oscillator. The kinetic energy (KE) will be a maximum at



A. $x = A$

B. $x = 0$

C. $x = -A$

D. KE is constant and does not depend upon x

E. None of the above

xxx. Euler's formula states $Ae^{i\theta} = a + ib$. If $\theta = \pi/2$, where would you be in the complex plane?

A. $[a, b] = [A, 0]$

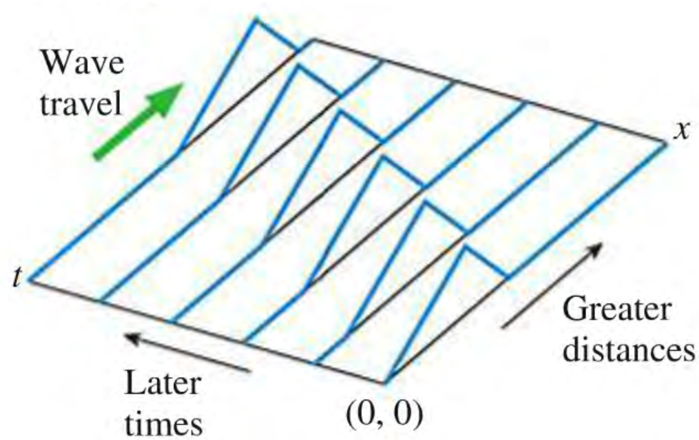
B. $[a, b] = [0, A]$

C. $[a, b] = [A/2, 0]$

D. $[a, b] = [-A, 0]$

E. Can not determine from the provided information

xxxi. Consider the wave shown below. This can best be described by:



A. Some function $f(x, t) = f(x - ct)$

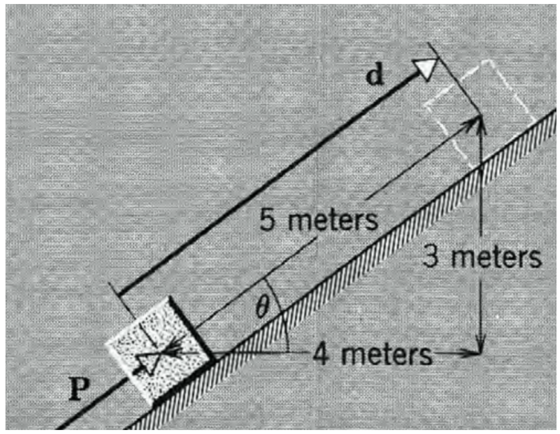
B. Some function $f(x, t) = f(x + ct)$

C. $A \sin(kx - \omega t)$

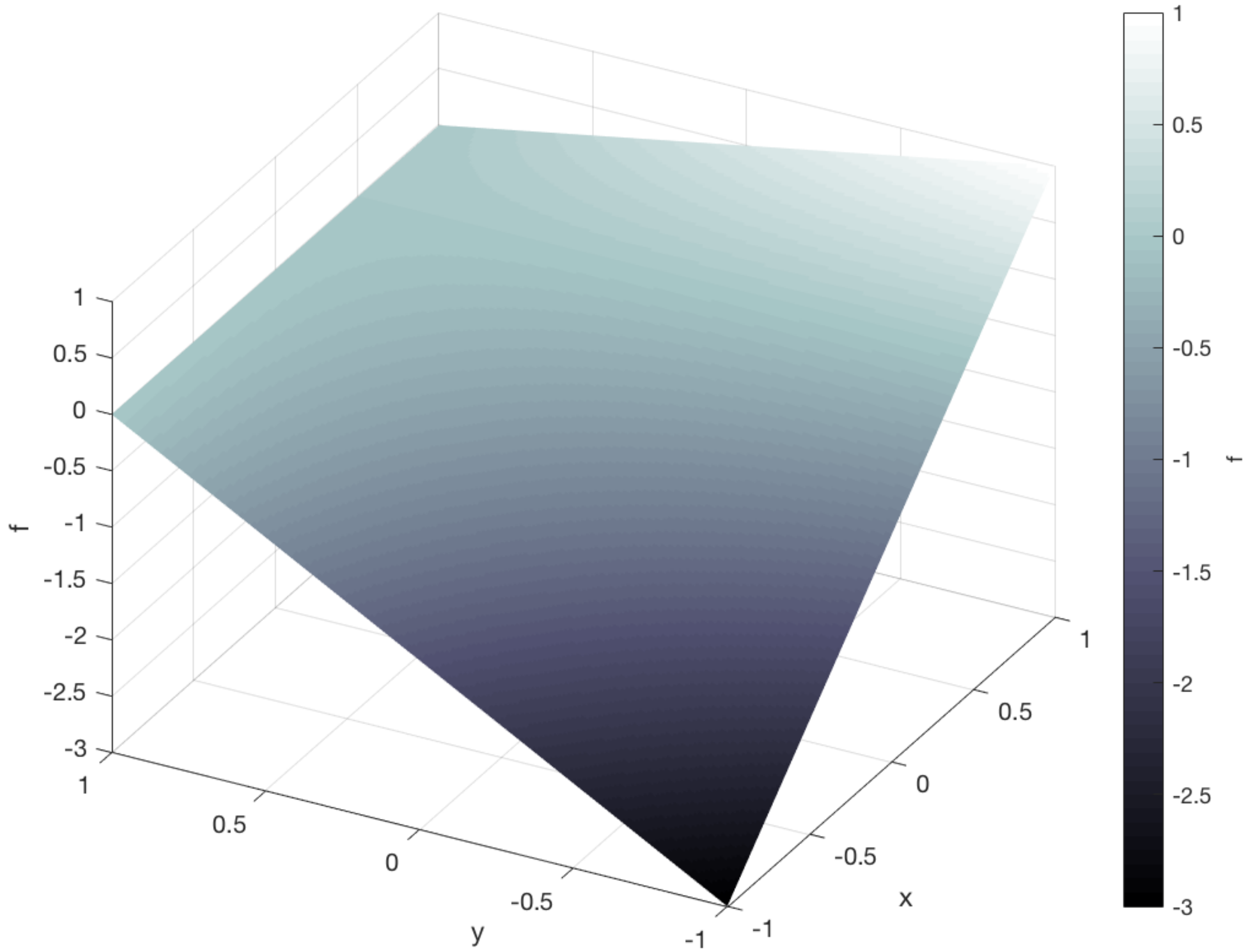
D. It is a standing wave

E. None of the above

3. (*8 points*) A block of mass 10.0 kg is to be raised from the bottom to the top of an incline 5.00 meters long and 3.00 meters off the ground at the top. Assuming frictionless surfaces, **determine how much work must be done by a force parallel to the incline pushing the block up at constant speed**. Assume that the acceleration due to gravity is $g = 9.80\,m/s^2$. Make sure to clearly explain your answer!



4. (*5 points*) A multivariable function $f(x, y)$ is shown in the figure below. Based upon the information provided, **specify the mostly likely form of the function**. Make sure to provide a brief/clear justification.



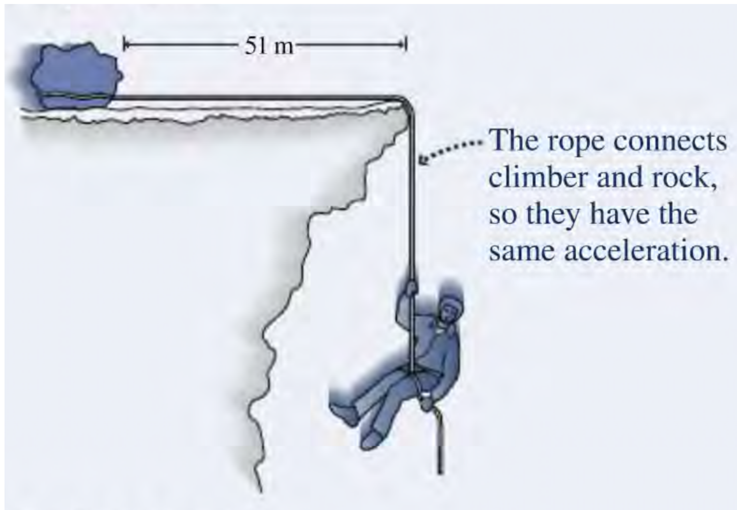
5. (*8 points*) Consider the one-dimensional diffusion of a solute n from a point source in space and time, where n_o is the number of moles of solute per unit area placed at $x = 0$ at $t = 0$.

a. Write an expression for the concentration $c_n(x,t)$ for $t > 0$. Make sure to note any other relevant constants not mentioned above.

b. Briefly indicate how your expression is related to the "diffusion equation" (i.e., $\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2}$).

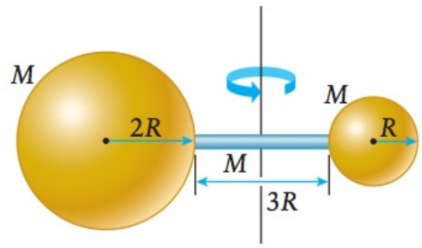
c. From your answer in part a, determine an expression for $\frac{\partial c}{\partial t}$.

6. (*8 points*) A 73-kg climber finds himself dangling over the edge of an ice cliff, as shown in the figure below. Fortunately, he's roped to a 940-kg rock located 51 m from the edge of the cliff. Unfortunately, the ice is frictionless, and the climber accelerates downward. **Determine both his acceleration AND how much time he has before the rock goes over the edge**. Neglect the rope's mass.



7. (*8 points*) Jumbo, a 4.8-t elephant, stands near one end of a 15-t railcar at rest on a frictionless horizontal track. Here t stands for *tonne*, or metric ton, which is equal to 1000 kg. Jumbo walks 19 m toward the other end of the car. **How far does the car move and in which direction?**

8. (*8 points*) Consider two uniform, solid spheres. One has a mass M and radius R, while the other has mass M and a radius $2R$. They are connected by a thin, uniform rod of length $3R$ and mass M (see figure below). **Find the moment of inertia about the axis through the center of the rod**. [*Hint: The parallel-axis theorem will likely be useful here.*]



Extra Credit (10 Points):

A load of mass m falls from height h on to a scale-pan suspended from a spring whose spring constant is k (see figure below). The mass remains on the pan (i.e. its impact on the bottom of the scale-pan may be considered perfectly inelastic). The pan begins to oscillate. **Find the amplitude of the scale-pan's oscillation**, assuming that the pan's weight may be neglected.