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University of California at Berkeley
Department of Physics
Physics 7A, Spring 1999

Final examination, Prof. Jacobsen
May 19, 5PM to 8PM

You will be given three hours to work this exam. No books are permitted, but you may use a handwritten sheet of notes no larger than one standard sheet of paper.

Your description of the physics involved in a problem is worth significantly more than any numerical answer. Show all work, and take particular care to explain what you are doing.

Write your answers directly on the exam, and if you have to use the back of a sheet, make sure to put a note on the front. Do not use a blue book or scratch paper.

The multiple choice questions are worth one point each for a total of thirty points. The multipart problems are labeled with their point values, which total seventy points. To ensure appropriate partial credit we grade each problem as a whole. The exam total is one hundred points.

Please use g = 10 m/sec^2

sin 45° = 0.707, cos 45° = 0.707, sin 30° = 0.500, cos 30° = 0.866

$$\frac{1}{2}\rho v^2 + yg\rho + P = \text{constant} \quad F = \frac{GM_1M_2}{r^2} \quad \omega = \sqrt{\frac{k}{m}} \quad \omega = \sqrt{\frac{g}{l}} \quad \sum \vec{F} = m\vec{a}$$

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Read the problems carefully.

Try to do all the problems.

If you get stuck, go on the the next problem.

DON'T GIVE UP! Try to remain relaxed and work steadily.

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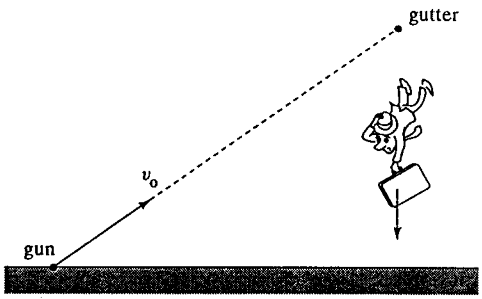
I	
II	
III	
IV	

1) An object is shot from the back of a truck moving at 30 miles per hour on a straight horizontal road. The gun is aimed upward, perpendicular to the bed of the truck. The object falls:
   a) in front of the truck
   b) behind the truck
   c) on the truck
   d) depends on the initial speed of the object
   e) depends on the value of g

2) A physics textbook is suspended on a spring scale in an elevator. Of the following, the scale shows the highest reading when the elevator:
   a) moves upward with increasing speed
   b) moves upward with decreasing speed
   c) remains stationary
   d) moves downward with increasing speed
   e) moves downward with constant speed

3) A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown
   a) upward
   b) downward
   c) neither – they both hit with the same speed

4) Consider the situation depicted here. A gun is accurately aimed at a dangerous criminal hanging from the gutter of a building. The target is well within the gun's range, but the instant the gun is fired and the bullet moves with a speed v0, the criminal lets go and drops to the ground. What happens? The bullet
   a) misses
   b) hits the criminal, regardless of the value of v0
   c) hits the criminal if v0 is large enough



5) A locomotive pulls a series of wagons. Which is the correct analysis of the situation?
   a) The locomotive's force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large while the backward frictional force on the wagons is small.
   b) The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backward on the locomotive.
   c) Because action always equals reaction, the locomotive cannot pull the wagons the wagons pull backward just as hard as the locomotive pulls forward, so there is no motion.
   d) The locomotive gets the wagons to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.
   e) The locomotive can pull the wagons forward only if it weighs more than the wagons.

6) An object is held in place by friction on an inclined surface. The angle of inclination is increased until the object starts moving. If the surface is kept at this angle, the object
   a) slows down.
   b) moves at uniform speed.
   c) speeds up.
   d) none of the above

7) Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has

a) as much kinetic energy as the lighter one.
b) twice as much kinetic energy as the lighter one.
c) half as much kinetic energy as the lighter one.
d) four times as much kinetic energy as the lighter one.
e) impossible to determine

8) A cart on an air track is moving at 0.5 m/s when the air is suddenly turned off. The cart comes to rest after traveling 1 m. The experiment is repeated, but now the cart is moving at 1 m/s when the air is turned off. How far does the cart travel before coming to rest?

a) 1 m
b) 2 m
c) 3 m
d) 4 m
e) 5 m
f) impossible to determine

9) A rock, initially at rest with respect to Earth and located an infinite distance away is released and accelerates toward Earth. An observation tower is built 3 Earth-radii high to observe the rock as it plummets to Earth. Neglecting friction, the rock's speed when it hits the ground is

a) twice
b) three times
c) four times
d) six times
e) eight times
f) nine times
g) sixteen times

its speed at the top of the tower.

10) An astronaut floating weightlessly in orbit shakes a large iron anvil rapidly back and forth. She reports back to Earth that

a) the shaking costs her no effort because the anvil has no inertial mass in space.
b) the shaking costs her some effort but considerably less than on Earth.
c) although weightless, the inertial mass of the anvil is the same as on Earth.

11) A car accelerates from rest. In doing so the car gains a certain amount of momentum and Earth gains

a) more momentum.
b) the same amount of momentum.
c) less momentum.
d) The answer depends on the interaction between the two.

12) Consider two carts, of masses m and 2m,at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the momentum of the light cart is

a) four times
b) twice
c) equal to
d) one-half
e) one-quarter

the momentum of the heavy cart.

13) Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the time intervals to stop them compare?

a) It takes less time to stop the ping-pong ball.
b) Both take the same time.
c) It takes more time to stop the ping-pong ball.

14) Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the distances needed to stop them compare?

a) It takes a shorter distance to stop the ping-pong ball.
b) Both take the same distance.
c) It takes a longer distance to stop the ping-pong ball.

15) A person attempts to knock down a large wooden bowling pin by throwing a ball at it. The person has two balls of equal size and mass, one made of rubber and the other of putty. The rubber ball bounces back, while the ball of putty sticks to the pin. Which ball is most likely to topple the bowling pin?

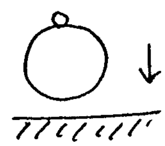
a) the rubber ball
b) the ball of putty
c) makes no difference
d) need more information

16) A compact car and a large truck collide head on and stick together. Which vehicle undergoes the larger acceleration during the collision?

a) car
b) truck
c) Both experience the same acceleration.
d) Can't tell without knowing the final velocity of combined mass.

17) A small rubber ball is put on top of a volley-ball, and the combination is dropped from a certain height. Compared to the speed it has just before the volleyball hits the ground, the speed with which the rubber ball rebounds is

a) the same.
b) twice as large.
c) three times as large.
d) four times as large.
e) none of the above



18) A figure skater stands on one spot on the ice (assumed frictionless) and spins around with her arms extended. When she pulls in her arms, she reduces her rotational inertia and her angular speed increases so that her angular momentum is conserved. Compared to her initial rotational kinetic energy, her rotational kinetic energy after she has pulled in her arms must be

a) the same.
b) larger because she's rotating faster.
c) smaller because her rotational inertia is smaller.

19) An object hangs motionless from a spring. When the object is pulled down, the sum of the elastic potential energy of the spring and the gravitational potential energy of the object and Earth.

a) increases.
b) stays the same.
c) decreases.

20) A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, two people sit on the swing, the natural frequency of the swing is

a) greater.
b) the same.
c) smaller.

21) A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, the person stands on the swing, the natural frequency of the swing is

a) greater.
b) the same.
c) smaller.

22) By shaking one end of a stretched string, a single pulse is generated. The traveling pulse carries

a) energy.
b) momentum.
c) energy and momentum.
d) neither of the two.

23) Two identical pulses of opposite amplitude travel along a stretched string and interfere destructively. Which of the following is/are true?

a) There is an instant at which the string is completely straight.
b) When the two pulses interfere, the energy of the pulses is momentarily zero.
c) There is a point on the string that does not move up or down.
d) There are several points on the string that do not move up or down.

24) Imagine holding two bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is

a) larger
b) the same as
c) smaller

than the force required to hold brick A in place.

25) When a hole is made in the side of a container holding water, water flows out and follows a parabolic trajectory. If the container is dropped in free fall, the water flow

a) diminishes.
b) stops altogether.
c) goes out in a straight line.
d) curves upward.

26) Two cups are filled to the same level with water. One of the two cups has ice cubes floating in it. Which weighs more?

a) The cup without ice cubes.
b) The glass with ice cubes.
c) The two weigh the same.

27) Two cups are filled to the same level with water. One of the two cups has plastic balls floating in it. If the density of the plastic balls is less than that of ice, which of the two cups weighs more?

a) The cup without plastic balls.
b) The cup with plastic balls.
c) The two weigh the same.

28) A lead weight is fastened on top of a large solid piece of Styrofoam that floats in a container of water. Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down so that the weight is now suspended underneath it,

a) the arrangement sinks.
b) the water line is below the top surface of the Styrofoam.
c) the water line is still flush with the top surface of the Styrofoam.

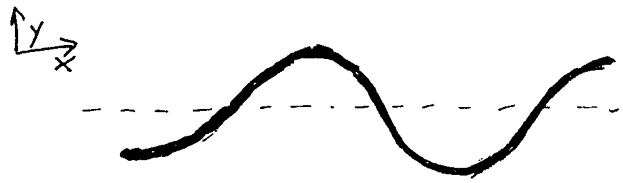
29) Consider an object that floats in water but sinks in oil. When the object floats in water, half of it is submerged. If we slowly pour oil on top of the water so it completely covers the object, the object

a) moves up.
b) stays in the same place.
c) moves down.

30) Two hoses, one of 20-mm diameter, the other of 15-mm diameter are connected one behind the other to a faucet. At the open end of the hose, the flow of water measures 10 liters per minute. Through which pipe does the water flow faster?

a) the 20-mm hose
b) the 15-mm hose
c) The flow rate is the same in both cases.
d) The answer depends on which of the two hoses comes first in the flow.

I) (20 points) Wave motion



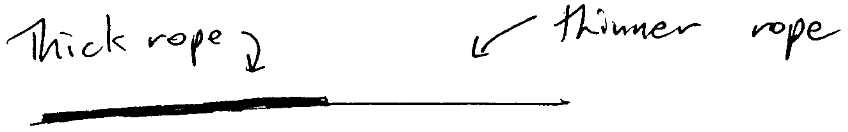
A sinusoidal wave is travelling to the right on an infinitely long, thick rope. Ignore the ends of the rope for now. The picture above is a snapshot of the wave at a particular time we'll call **t**=0. Note that the directions of the **x** and **y** axes are specified. The rope is under a tension **T**, is made of stuff with a density ρ, and has a radius **r**.

f) Write the equation describing this wave in terms of its amplitude y_m, frequency ω and wave velocity **v**. Please indicate on the diagram above where you consider the **x**=0 point to be.

g) What is the wave velocity, in terms of the variables given in the first paragraph?

h) In what direction is energy moving? What is the total energy transferred in one second (e.g. the power moving along the string)?

i) Imagine putting a mark on the string at the **x**=0 point you indicated above. What is the velocity and position of that mark as a function of time? Both direction and magnitude must be specified.



Now we consider instead that the thick rope described above is attached to a thinner rope at one end. This thin rope has radius **r**/10, and is made of the same stuff with density ρ. The wave of parts a-d travels down the thick rope and onto the thin one.

j) What is the tension in the thinner rope? Please be sure to explain your reasoning.

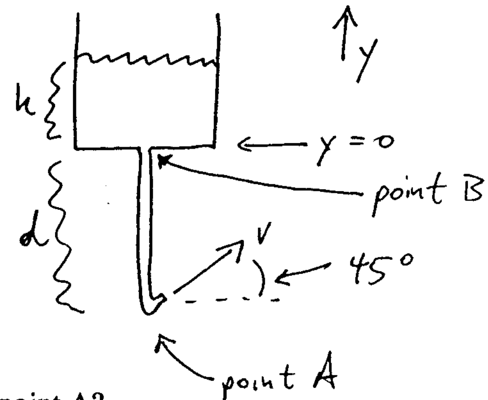
k) What is the frequency of the wave in the thinner rope? Please be sure to explain your reasoning.

l) What is the amplitude of the wave in the thinner rope? Please be sure to explain your reasoning.

m) What is the wavelength of the wave in the thinner rope? Please be sure to explain your reasoning.

n) What is the velocity of the wave in the thinner rope? Please be sure to explain your reasoning.

II) (20 points) The simple fountain



A simple fountain is drawn at right. It consists of a can, kept full of water to a constant height **h** by an industrious grad student (not shown), and a hose. The hose has radius **r**, and droops down to a maximum depth **d** before turning upward at the point labeled "A". The tank is open to the air at the top, and the hose is open to the air at its end. Ignore friction, viscosity and all other defects; this is a problem about the idealized flows we've discussed in class. Note that the y=0 line has been labelled; please use that to simplify grading.

a) What is the velocity **v** of the water stream that emerges at point A?

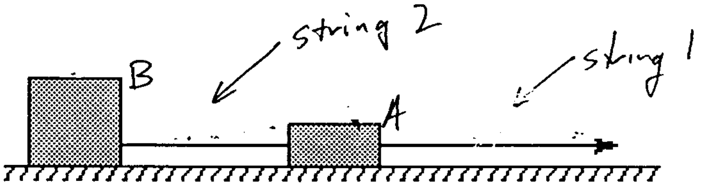
b) How much water flows out of the hose per second?

c) At point "B", how much water flows past in the hose each second?

d) What is the pressure at point B?

e) Sketch the path that the stream of water makes. Be sure to carefully indicate how high it goes and how far it goes.

III) (10 points) Two blocks

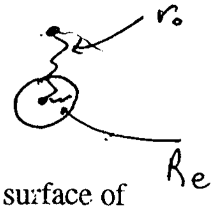


In the situation above, a person pulls a string attached to block A, which is in turn attached to another, heavier block B via a second string. Be sure to explain your answers.

a) Which block has the larger acceleration?

b) How does the force of string 1 on block A compare with the force of string 2 on block B?

c) How does the force of string 1 on block A compare with the force of string 2 on block A?



IV) (20 points) Various orbits

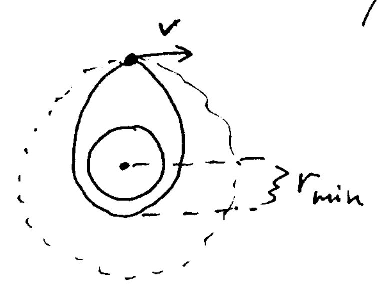
In this problem, we consider a satellite that starts at a certain distance $\mathbf{r_0}$ from the surface of the Earth. The earth has radius $\mathbf{R_e}$ and mass $\mathbf{M_e}$. Please make sure the grader can understand both your answer to each question, and how you're justifying it.

a) In this part, the satellite is placed at $\mathbf{r_0}$ with zero velocity. It falls straight down to the surface of the Earth at $\mathbf{R_e}$. What is the satellite's velocity when it hits the surface?

b) In this part, the satellite is placed at $\mathbf{r_0}$ with exactly the right velocity to enter a circular orbit. What is that velocity $\mathbf{v_{circular}}$? Both direction and magnitude are required.

15/15

c) In this part, the satellite is placed at $\mathbf{r_0}$ with a non-zero velocity $\mathbf{v}$ parallel to the surface of the earth (see figure). Unfortunately, that velocity is less than the velocity for a circular orbit. In terms of $\mathbf{v}$ and other quantities, what is $\mathbf{r_{min}}$, the minimum distance from the center of the Earth?



d) For the situation of part c, with the orbit that drops to a lower height, what is the speed of the satellite at its lowest point? Please express your answer in terms of $\mathbf{v}$, $\mathbf{r_{min}}$ and/or $\mathbf{r_0}$.