

TRENT UNIVERSITY
Forensic Science-Physics 102H
FINAL EXAMINATION

Duration: 3 hours

Friday December 15, 2006
7:00 - 10:00 p.m., DNA B110

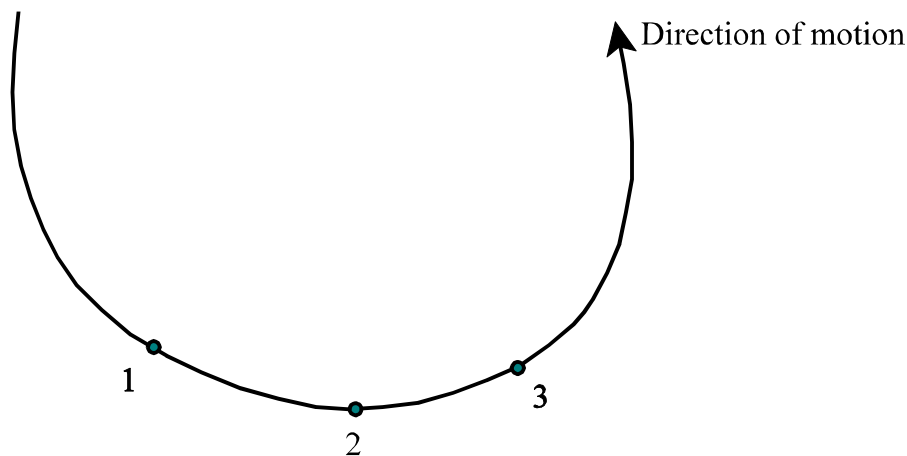
Attempt **all** parts of question 1, and do only **3** of the remaining 5 questions. Question 1 is worth 40%; the rest are worth 20 % each. The parts of question 1 are of approximately equal value.

A sheet of basic formulae and physical constants is attached. Calculators may be used, but must not contain any physics formulae before the start of the exam. Other physical aids (string, etc.) are allowed for visualization of the problems, but no other written material is permitted. **The majority of marks will be given for a clear exposition of your solutions, including relevant sketches.**

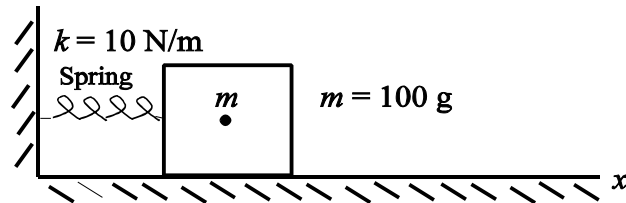
Hand in this page with your other answers.

Name _____

1. (a) A midway-ride passenger is suing the operator for allowing the ride to exceed its maximum rated speed. A bystander's video camera has captured the positions of the rider during the critical time, as sketched below, where points 1, 2 and 3 are the positions at successive frames of the video. The frames of the video are 0.1 s apart, and in the figure 1.0 cm represents 0.5 m on the ride. (i) Determine graphically the velocity of the person between points 1 and 2, and between 2 and 3, and (ii) use these and the definition of average acceleration, $\bar{a} = \Delta \vec{v} / \Delta t$, to obtain the average acceleration between points 1 and 3. Show all your work. The human body can begin to suffer damage for accelerations of about 4 times that of free fall (g). Does the claimant have a case?

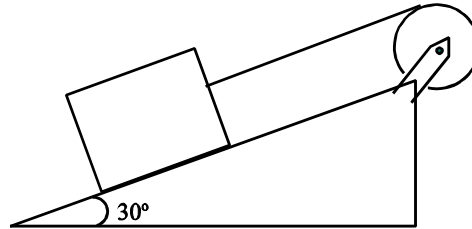


- (b) A spy satellite is in a circular geosynchronous orbit around the Earth; that is, it rotates at the same angular velocity of the Earth so it always stays above the same spot. What is the radius of its orbit?
- (c) A solid disk of mass 200 g and radius 10.0 cm is rotating horizontally on a frictionless turntable with a frequency of 2.0 Hz. A wad of gum of mass 10.0 g is dropped vertically near the rim of the disk, where it sticks. (i) What is the final frequency of the turntable? (ii) What is the speed of the gum?
- (d) A block of mass 100 g is connected to a spring of spring constant 10 N/m as shown below. The block is pulled to the right from its equilibrium position by 5 cm and released at time $t = 0$ s.
- (i) What are the frequency and period of oscillation of the block?
(ii) Sketch the form of the block's displacement as a function of time, putting numerical scales on both axes.
(iii) What is the position of the block 0.5 s after it is released?



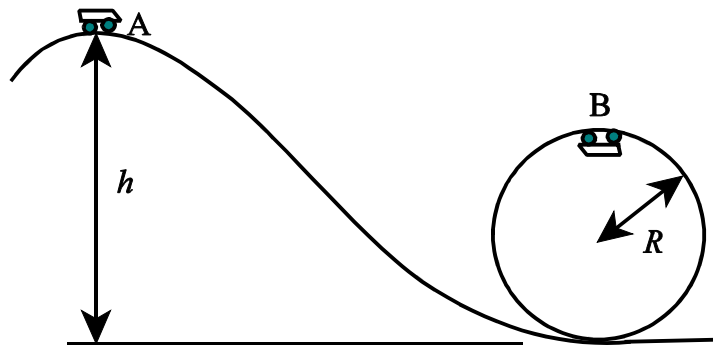
- (e) In 1993 MacDonald's restaurant lost a law suit to a claimant who was burned by coffee served at a temperature of 82°C . If 20 g of milk at 20°C is added to a 200-g cup of coffee at 82°C , is the final temperature of the coffee below the safe limit of 71°C ? Assume the specific heat capacity of coffee is the same as for water, and the specific heat capacity of the milk is 20% greater than for water.
2. The velocity of a bullet as it leaves a rifle's muzzle is measured using a ballistic pendulum. The 5.0-g bullet is fired into a stationary, 400-g block of wood suspended from a 3.0-m long string, where it stays. The block swings sideways, to a maximum angle for the string of 40° to the vertical. Show that the muzzle velocity of the bullet was 300 m/s.
3. The rifle in question 2 is suspected of firing the bullet that killed a person standing on a small hill 5.0 m above the height of the rifle and 200 m away horizontally. A video of the suspected killer shows him aiming the rifle in the general direction of the victim with the rifle barrel at an angle of 5° above the horizontal when the shot was fired. Calculate the height that the rifle bullet would have at the horizontal position of the victim. Is the person videotaped a legitimate suspect? Ignore air resistance.

4. A light cord is wrapped several times around the cylinder in the figure below, and attached to the 4.0-kg block on the slope. The block is released from rest and slides down the plane, causing the cylinder to rotate. The cylinder has a mass of 5.0 kg and a radius of 10.0 cm, and the coefficient of kinetic friction between the block and the plane is 0.20. The axle of the pulley is frictionless. How far does the block slide down the plane in the first second after release?



5. The design code for a loop-the-loop roller coaster, as sketched below, states that the minimum force that the car seat must exert on a passenger when upside-down at the top of the loop is 30% of the body weight of the person.

- (a) Draw the free-body diagram of a *person* in the car at the top of the loop.
- (b) What is the 3rd-law "reaction" forces for each of the forces shown in (a)? That is, state (i) what causes the reaction force, (ii) what it is acting on, and (iii) its direction.
- (c) How high (h) must the starting point A be, for the roller coaster to satisfy the legal requirement, if the radius of the loop is $R = 8$ m? Assume the roller coaster is frictionless, and the height of the car itself is much less than R .



6. A small, 2-person submarine with an internal volume of 3.0 m^3 is rated by its manufacturer to withstand a net external pressure of 500 atmospheres. The internal air pressure of the submarine is normally kept at 1.0 atmosphere. The submarine starts to leak at an ocean depth of 4.5 km. The area of the hole in the submarine wall is 1.0 cm^2 and the density of sea water is 1030 kg/m^3 .

(a) Is the manufacturer or the user to blame for the failure at this depth?

(b) What is the velocity of the stream of water entering the submarine?

(c) How long does it take for the submarine to be half full of water?