

<i>first (given)</i>
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<i>last (family)</i>
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Name, *printed* as it appears in Canvas

Quiz

3A

- **Print** your name and nine-digit Tech ID *very neatly* in the spaces above.
- Free-response problems are numbered I–III. Show all your work clearly, including all steps and logic. Write **darkly**. Blue or black ink is recommended. Do not make any erasures in your free-response work. Cross out anything you do not want evaluated. Box your answer.
- Multiple-choice questions are numbered 1–7. For each, select the answer most nearly correct, circle it on your quiz, and fill the bubble for your answer on this front page.
- Initial the odd pages in the top margin, in case the pages of your quiz get separated.
- The standard formula sheet is on the back of this page, which may be removed from the quiz form if you wish, but it must be submitted.
- If the page for a free-response problem has insufficient space for your work, ask a proctor for an additional sheet. If you wish this work to be evaluated, put your name on the sheet and make a note on the problem page, so graders will know where to look for your work.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next quiz is administered.

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*Fill in bubbles for your Multiple Choice answers darkly and neatly.*

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|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|   | a                     | b                     | c                     | d                     | e                     |
| 1 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 2 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 3 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 4 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 5 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 6 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 7 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|   | a                     | b                     | c                     | d                     | e                     |

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{\omega} = \frac{d\vec{\theta}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt}$$

$$v_{sf} = v_{si} + a_s \Delta t$$

$$\omega_f = \omega_i + \alpha \Delta t$$

$$s_f = s_i + v_{si} \Delta t + \frac{1}{2} a_s (\Delta t)^2$$

$$\theta_f = \theta_i + \omega_{si} \Delta t + \frac{1}{2} \alpha (\Delta t)^2$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$W = \int \vec{F} \cdot d\vec{s}$$

$$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$$

$$K = \frac{1}{2} m v^2$$

$$K = \frac{1}{2} I \omega^2$$

$$U_g = mgy$$

$$U_s = \frac{1}{2} k (\Delta s)^2$$

$$U_G = -\frac{Gm_1 m_2}{r}$$

$$P = \frac{dE_{\text{sys}}}{dt}$$

$$P = \vec{F} \cdot \vec{v}$$

$$\vec{J} = \int \vec{F} dt = \Delta \vec{p}$$

$$\vec{p} = m\vec{v}$$

$$\vec{r}_{\text{cm}} = \frac{\sum \vec{r}_i m_i}{\sum m_i}$$

$$\vec{r}_{\text{cm}} = \frac{\int \vec{r} dm}{\int dm}$$

$$I = \sum m_i r_i^2$$

$$I = \int r^2 dm$$

$$I = I_{\text{cm}} + Md^2$$

$$\vec{L} = \vec{r} \times \vec{p}$$

$$\vec{L} = I\vec{\omega}$$

$$x = A \cos(\omega t + \phi_0)$$

$$\vec{a}_x = -\omega^2 \vec{x}$$

$$\omega = \sqrt{k/m}$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

### Physical Constants:

Universal Gravitation Constant  $G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$   
 Gravitational Acceleration at Earth's Surface  $g = 9.81 \text{ m/s}^2$

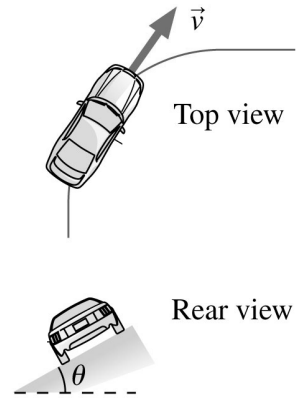
Unless otherwise directed, drag is to be neglected, all problems take place on Earth, use the gravitational definition of weight, and all springs, ropes, and pulleys are ideal.

All derivatives and integrals in free-response problems must be evaluated.

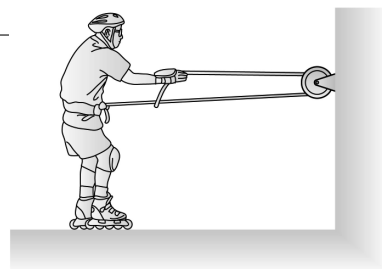
You may remove this sheet from your Quiz or Exam, but it must be submitted

Initial:

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- I. (16 points) Consider a road whose curve has a “reverse bank”, that is, the outside of the curve is lower than the inside, as shown. If the bank angle is  $\theta$  from the horizontal, and the coefficient of static friction between tires and the road is  $\mu_s$ , with what maximum speed can a car travel around a curve of radius  $R$ ? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants. (*On Earth.*)



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1. (6 points) Jorge, with mass  $m$ , wants to test his new skating helmet. He straps on his cheap skates, which have a non-negligible coefficient of rolling friction  $\mu_r$  with the level floor, ties a rope to his waist, passes it around a pulley attached to the wall as shown, and pulls to accelerate from rest. Assuming the rope is horizontal except where it passes around the pulley, describe the resulting thermal energy changes. Note that “Jorge” includes his skates. (*On Earth.*)



- (a) Jorge’s thermal energy increases by  $\mu_r mgd$ .
- (b) Jorge’s thermal energy increases by  $\mu_r mgd$ , and the floor’s thermal energy decreases by  $\mu_r mgd$ .
- (c) The floor’s thermal energy increases by  $\mu_r mgd$ .
- (d) Jorge’s thermal energy increases by  $\mu_r mgd/2$ , and the floor’s thermal energy increases by  $\mu_r mgd/2$ .
- (e) The floor’s thermal energy and Jorge’s thermal energy increase by a combined total of  $\mu_r mgd$ .
- II. (16 points) In Jorge’s excitement, he pulls harder and harder as he moves. In fact, if he starts at the origin and  $+x$  is to the right, the magnitude of his force depends on position according to

$$F = F_0 \left( \frac{x}{d} \right)^2$$

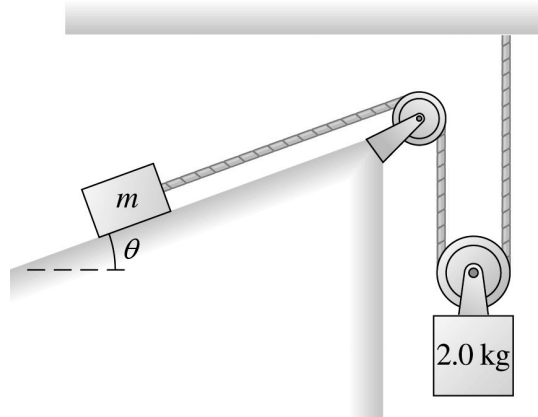
where  $F_0$  is a constant and  $d$  is his initial distance from the wall. With what speed does he strike the wall? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.

Initial:

2. (6 points) The block of mass  $m$  accelerates up a frictionless ramp. Describe the tension in the vertical portion of the rope farthest to the right, attached to the ceiling. (*On Earth.*)

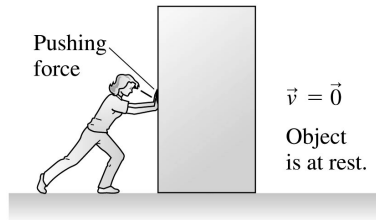
- (a) It is more than 19.6 N.
- (b) It is 19.6 N.
- (c) It is between 9.8 N and 19.6 N.
- (d) It is less than 9.8 N.
- (e) It is 9.8 N.

III. (16 points) In the problem above, the frictionless ramp makes an angle  $\theta = 26^\circ$  with the horizontal, and the block of mass  $m$  slides up it with an acceleration magnitude  $1.7 \text{ m/s}^2$ . What is the value of the mass  $m$ ?



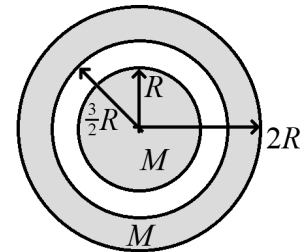
3. (8 points) Sugi pushes on the crate which, due to static friction, remains at rest on level ground. Which of these is a “force pair”, in the sense of Newton’s Third Law, for this situation? (*On Earth.*)

- (a) The crate’s gravitational force on the Earth, and the crate’s normal force on the Earth.
- (b) The Earth’s gravitational force on the crate, and the crate’s normal force on the Earth.
- (c) Sugi’s push force on the crate, and the Earth’s friction force on the crate.
- (d) The Earth’s gravitational force on the crate, and the Earth’s normal force on the crate.
- (e) Sugi’s push force on the crate, and the crate’s push force on Sugi.



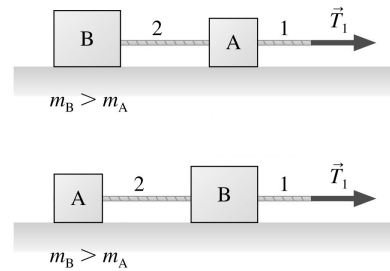
4. (8 points) Imagine a very strange planet, made of two concentric pieces. The inner piece is solid, with mass  $M$  and radius  $R$ . The outer piece is hollow, with mass  $M$ , inner radius  $3R/2$ , and outer radius  $2R$ . What is the acceleration due to gravity at the inner surface of the outer piece (that is, at radius  $3R/2$ )?

- (a)  $2GM/R^2$
- (b)  $\frac{1}{2}GM/R^2$
- (c)  $\frac{8}{9}GM/R^2$
- (d)  $\frac{4}{9}GM/R^2$
- (e)  $GM/R^2$



Initial:

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5. (8 points) Blocks  $A$  and  $B$  are connected by rope 2 and pulled along a frictionless surface by tension  $T_1$ . The mass of block  $B$  is greater than the mass of block  $A$ . The tension  $T_1$  may be applied to block  $A$ , as in the upper illustration, or it may be applied to block  $B$  as in the lower illustration. Compare the tension magnitude in the connecting rope 2 for these two situations. (*On Earth.*)



- (a) The tension in rope 2 is greater when  $T_1$  is applied to block  $A$ .  
(b) The tension in rope 2 is greater when  $T_1$  is applied to block  $B$ .  
(c) The tension in rope 2 is the same in the two situations.  
(d) The tension in rope 2 is different in the two situations, but in which it is greater cannot be determined from the information provided.

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6. (8 points) Two spheres,  $A$  and  $B$ , are made of the same material, have the same radius, and have the same drag coefficient. Sphere  $B$  is hollow, though, so it has half the mass of sphere  $A$  (that is,  $M_B = M_A/2$ ). Each is falling through the air at its own terminal speed. Compare the rate of thermal energy increase of sphere  $A$  and the air, to that of sphere  $B$  and the air. (*On Earth, do NOT neglect drag!*)
- (a)  $P_A = \sqrt{2}P_B$   
(b)  $P_A = 4P_B$   
(c)  $P_A = 2P_B$   
(d)  $P_A = 4\sqrt{2}P_B$   
(e)  $P_A = 2\sqrt{2}P_B$

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7. (8 points) The Ferris Wheel rotates counter-clockwise with constant angular speed. At a particular instant, there is a car directly to the right of the hub, marked with an asterisk. What is the direction of the force exerted by the seat on a person riding in that car at that instant? (*On Earth.*)

- (a) Upward and to the right.
- (b) Upward and to the left.
- (c) To the left.
- (d) To the right.
- (e) Upward.

