Physics 151
April 15, 2005

Roster No.:________________________

Score:____________________________

Midterm Exam #3, Part A

Exam time limit: 50 minutes. You may use calculators and both sides of 2 pages of notes, *handwritten only*. Closed book; no collaboration. For multiple choice questions, circle the one best answer or letter (unless more than one answer is asked for).

Constants & Useful Data: $g = 9.81$ m/s^2

Some Moments of Inertia:

solid sphere: $I = (2/5)\, M R^2$
solid cylinder or disk (rotated about axis of symmetry): $I = (1/2)\, M R^2$
hoop or thin ring (rotated about axis of symmetry): $I = M R^2$
thin rod, rotated about center: $I = (1/12)\, M L^2$
thin rod, rotated about end: $I = (1/3)\, M L^2$

1. a. (2 pts.) A mass $2M$ moving at speed v_0 collides head-on with another mass M initially at rest. The two stick together. If the masses can move only along the x-axis, what is their **final speed** after collision? (Ignore friction.)

A. 0.333 v_0
B. 0.5 v_0
C. 0.667 v_0
D. v_0
E. 1.5 v_0
F. 3 v_0

b. (1 pt.) The collision in part (a) is:

A. **elastic**
B. **inelastic**

2. A 150-gram baseball traveling to the left at 45 m/s is hit by a bat. The ball leaves to the right at high speed.
a. (2 pts.) If the baseball receives an impulse of 17 kg·m/s from the bat, what is the baseball's **final speed**?

A. 52 m/s
B. 68 m/s
C. 75 m/s
D. 89 m/s
E. 98 m/s
F. 120 m/s

b. (2 pts.) If the baseball is in contact with the bat for 0.70 ms, what is the **average force** of the bat on the ball?

A. 390 N
B. 770 N
C. 1300 N
D. 5200 N
E. 8900 N
F. 24,000 N

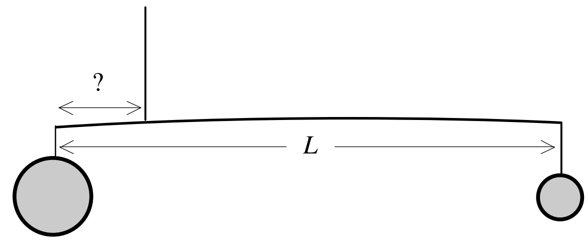
3. Computer hard disks with operating "speeds" of 7200 rpm (revolutions/minute) are now commonly available.
a. (2 pts.) Laptop manufacturers now advertise computers that can sense when they have been dropped. Before the laptop strikes the ground, it "parks" its hard disk by decelerating it from its normal operating speed to a complete stop in just 0.25 s. What is the disk's **angular acceleration** during this time period (assuming that the deceleration is constant)?

A. –80. rad/s^2
B. –180 rad/s^2
C. –500 rad/s^2
D. –1100 rad/s^2
E. –3000 rad/s^2
F. –11,000 rad/s^2

b. (3 pts.) How many **revolutions** does the hard disk complete during the 0.25 s in part (a)?

A. 0.36 rev
B. 2.4 rev
C. 9.6 rev
D. 15 rev
E. 52 rev
F. 180 rev
G. 320 rev
H. 610 rev

4. (2 pts.) An artist constructing a mobile (hanging sculpture) wants to suspend a lightweight rod of length *L* with a 2.0-kg object on one end and a 0.80-kg object on the other. In order for the rod to be balanced, at what **distance from the larger mass** should she suspend the rod? (Ignore the mass of the rod itself; consider only the two masses.)



A. 0.12 *L* D. 0.29 *L*
B. 0.17 *L* E. 0.35 *L*
C. 0.24 *L* F. 0.42 *L*

5. A clock's second hand completes exactly one rotation every minute.

a. (2 pts.) What is its **angular velocity**?

A. 0.10 rad/s D. 6.7 rad/s
B. 0.42 rad/s E. 27 rad/s
C. 1.7 rad/s F. 110 rad/s

b. (1 pt.) In which **direction** does its **angular momentum vector** point?

A. toward the "12" D. toward the "9"
B. toward the "3" E. into the clock face
C. toward the "6" F. out of the clock face

6. (1 pt.) The Earth spins into the east. If every person, animal, car, etc., on the surface of the Earth simultaneously started walking or driving **eastward**, the Earth's **angular speed** would:

A. speed up just a little
B. be unchanged
C. slow down just a little

7. (2 pts.) All of the following are true **EXCEPT** which **one** statement?

A. As a spinning ice skater pulls her arms and legs inward, her angular speed increases.
B. As a spinning ice skater pulls her arms and legs inward, her angular momentum remains constant.
C. Examples of gyroscopes include spinning toy tops, bicycle wheels, and the Earth itself.
D. A large rate of precession is a desirable quality in industrial and navigational gyroscopes.

8. (2 pts.) **Why** does a bicycle at rest fall over easily, while a bicycle in motion does not? (In fact, the faster the bicycle is going, the more stable it becomes!)

A. Spinning wheels have greater *angular momentum* than stationary wheels.
B. Spinning wheels have greater *moment of inertia* than stationary wheels.
C. Spinning wheels have greater *torque* than stationary wheels.
D. Spinning wheels have a greater *rate of precession* than stationary wheels.

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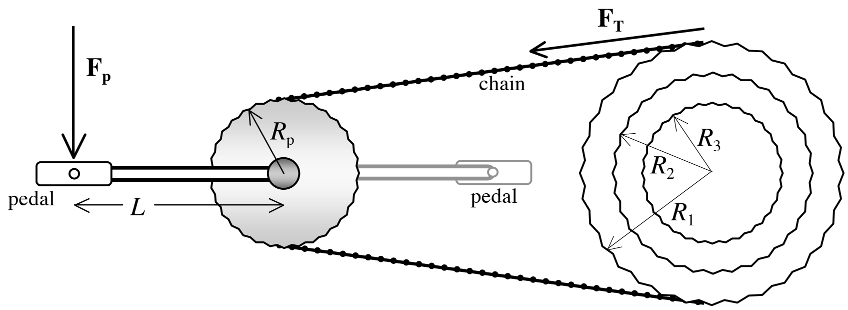
Midterm Exam #3, Part B

Show your work on free-response questions. Be sure to use **proper units** and **significant figures** in your final answers.

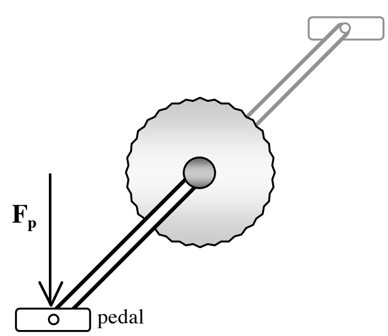
1. This is a simplified diagram of a "three-speed" bicycle's gears: the chain wraps from the front pedal-gear (attached to the pedals) to one of a set of three concentric rear gears (attached to the rear wheel).



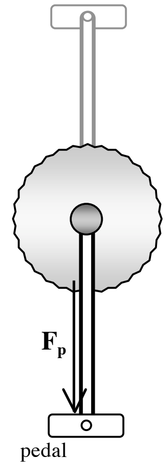
a. (5 pts.) Suppose the pedal's arm has length $L = 0.18$ m, and at present is positioned horizontally, as shown. If a 55-kg rider stands with all her weight ($\mathbf{F_p}$) on one pedal, then how much **torque** does she create on the pedal-gear? Show your work.

b. (2 pts.) If the same rider stands on the same pedal after the pedal-arm has revolved 45° (one-eighth of a turn) from horizontal, then how much **torque** does she exert?

A. zero
B. 0.25 times the torque in part (a)
C. 0.50 times the torque in part (a)
D. 0.71 times the torque in part (a)
E. 0.87 times the torque in part (a)
F. the same torque as part (a)



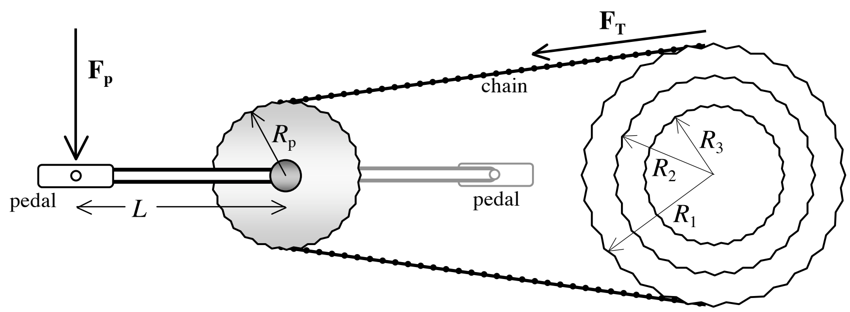
(1. cont'd.)



c. (2 pts.) If the same rider stands on the same pedal after the pedal-arm has revolved 90˚ (one-quarter of a turn) from horizontal, then how much **torque** does she exert?

A. zero
B. 0.25 times the torque in part (a)
C. 0.50 times the torque in part (a)
D. 0.71 times the torque in part (a)
E. 0.87 times the torque in part (a)
F. the same torque as part (a)

Original diagram repeated:

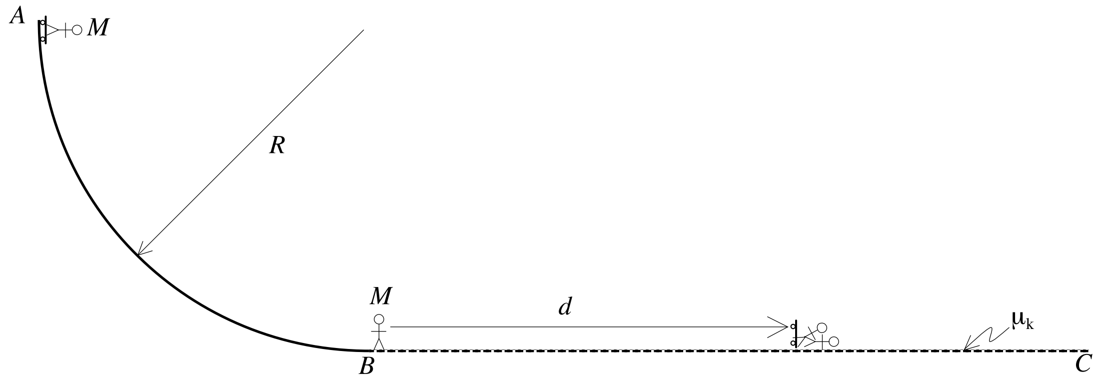


d. (1 pt.) The pedal-gear pulls on the chain, creating some amount of tension in the chain. That tension ($\mathbf{F_T}$) then exerts a torque on one of the three rear-wheel gears, as chosen by the rider. If the rider wants to create the *greatest possible torque on the rear wheel* (for, say, climbing a steep hill), **which rear-wheel gear** should she choose?

A. the largest radius, R_1
B. the smallest radius, R_3
C. the gear radius doesn't matter; the torque exerted on the rear wheel would be the same using any R

e. (2 pts.) Suppose that the rider keeps the pedals turning at a constant angular speed ω_p. If the taut chain wraps around both the pedal gear R_p and the rear-wheel gear R_1 without slipping (as shown above), what is the constant **angular speed** of the rear wheel?

A. ω_p
B. $(R_p/R_1)\ \omega_p$
C. $(R_1/R_p)\ \omega_p$
D. $(R_p/R_1)^2\ \omega_p$
E. $(R_1/R_p)^2\ \omega_p$
F. $[(R_p+R_1)/R_p]\ \omega_p$



2. The above diagram represents a ramp at a skateboard park: a quarter-circle arc of radius R (segment AB) joined to a horizontal section (segment BC). A skateboarder of mass M starts from rest at point A, rolls frictionlessly down arc AB, and collides with his friend (also same mass M) who is standing on the ground at rest at point B. The two people stick together in the collision. They fall over and together slide distance d along the horizontal surface before coming to a stop. The coefficient of kinetic friction along the horizontal segment is μ_k.

Express each of your final answers below in terms of the variables M, R, μ_k, and g, and show your work. *Simplify your final answers* to their most compact algebraic form.

a. (4 pts.) What is the **speed** of the skateboarder when he arrives at the bottom of the arc, at point B (but *just before* he collides with his friend)?

b. (4 pts.) What is the **speed** of the combined skateboarders *immediately after* they collide?

(2. cont'd.) Express each of your final answers below in terms of the variables *M*, *R*, μ_k, and *g*, and show your work. *Simplify your final answers* to their most compact algebraic form.

c. (3 pts.) How much **kinetic energy** is lost in the inelastic collision?

d. (5 pts.) Find an expression for **distance *d*** in terms of the other variables (M, R, μ_k, and g).