EXSS 323 – Biomechanics of Sport & Exercise Fall 08
Final Exam

Name: _____

Matching (Questions 1-5; *1 point each; 5 points total*):

Each of questions 1-5 consists of a definition. Match each definition with the best answer from the list below it. (*Note: Not all answers will be used and no answer is used more than once*)

1. _____ pulling or stretching force directed normal to a surface
2. _____ concept related to the difficulty with which an object's motion is altered
3. _____ the rate of work production
4. _____ study of the relationship between forces acting on a system and the system's motion
5. _____ a force that is proportional to the deformation of an object

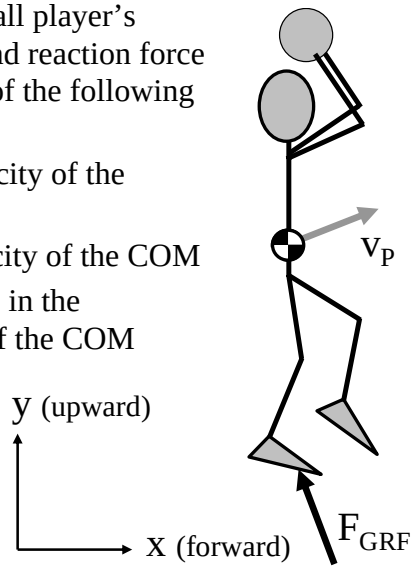
A. Center of Mass
B. Compression
C. Elastic Force
D. Energy
E. Friction Force
F. Impulse
G. Inertia
H. Kinematics
I. Kinetics
J. Momentum
K. Power
L. Shear
M. Tension
N. Torsion
O. Viscous Force
P. Weight

True-False (Questions 6-16; *42 points total*)

In each question, indicate whether each statement is true (T) or false (F)

6. *(5 points)* Which of the following statements about forces acting within the body are true and which are false?
   - ___T ___F : The stress required to fracture a bone increases as the number of loading cycles increases
   - ___T ___F : As a muscle contracts, it produces a torque on the distal limb segment but not on the proximal limb segment at a joint
   - ___T ___F : A viscoelastic tissue, such as ligament, produces more force if stretched quickly than if stretched slowly by the same amount
   - ___T ___F : If a bone is bent by a medially-directed force, it will experience the greatest tension forces at its medial surface
   - ___T ___F : The torque that a muscle can produce at a joint is the same throughout the range of joint motion

7. *(5 points)* During the take-off phase of a jump shot, a basketball player's center of mass (COM) is moving at a velocity v_P and the ground reaction force F_{GRF} acts on the player's foot, as shown in the figure. Which of the following are true and which are false?
   - ___T ___F : F_{GRF} will act to increase the forward (+x) velocity of the COM
   - ___T ___F : F_{GRF} will act to increase the upward (+y) velocity of the COM
   - ___T ___F : F_{GRF} will cause a smaller magnitude of change in the forward velocity than in the upward velocity of the COM
   - ___T ___F : The greater the mass of the player, the greater the effect that a given F_{GRF} will have on the velocity of the COM
   - ___T ___F : To generate the F_{GRF} shown, the player must push downward and forward on the ground



8. *(3 points)* A hockey player is trying to avoid being pushed over sideways by an opponent who is approaching from his right. Which of the following will help him to increase his stability?
   - ___T ___F : Stand up tall to raise his center of mass
   - ___T ___F : Spread his feet farther apart in the mediolateral direction (with both skates on the ice)
   - ___T ___F : Shift his body center of mass to the left

9. *(4 points)* A fall will result in a forearm fracture if the ground reaction force on the hand produces a stress in the bone that exceeds its strength. All else being equal, which of the following would result in smaller average stresses being applied to the bones of the forearm while stopping the body's downward motion after landing on one's hand during a fall?

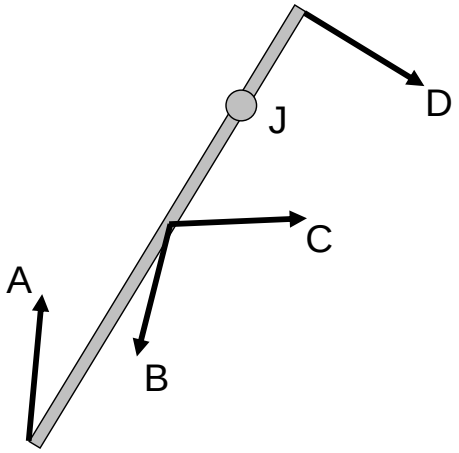
___T ___F : A smaller downward velocity of the body at the instant the hand contacts the ground

___T ___F : Keeping the elbow rigid after contact to minimize the time required to stop the body's downward motion

___T ___F : A smaller body mass of the individual who is falling

___T ___F : Contacting the ground with both hands instead of just one

10. *(5 points)* Four forces (A – D) act about a joint center (J). Based on the figure to the right, which of the following are true and which are false? *Reminder: The magnitude of a torque is its absolute value.*



___T ___F : Force A produces a clockwise torque about J

___T ___F : Force B has a smaller moment arm about J than force C has

___T ___F : If forces B and D are equal, the magnitude of the torque produced by force B about J is larger than that of the torque produced by force D about J

___T ___F : If the magnitudes of the torques produced by forces A and D about J are equal, then force A is larger than force D

___T ___F : Forces B and C produce torques in opposite directions about J

11. *(4 points)* A punter is trying to increase the distance of his punts. During the kicking motion, the punter keeps his knee extended and rotates his kicking limb towards the ball by flexing the hip. Other factors being equal, which of the following changes would help to increase the velocity of the ball after impact?

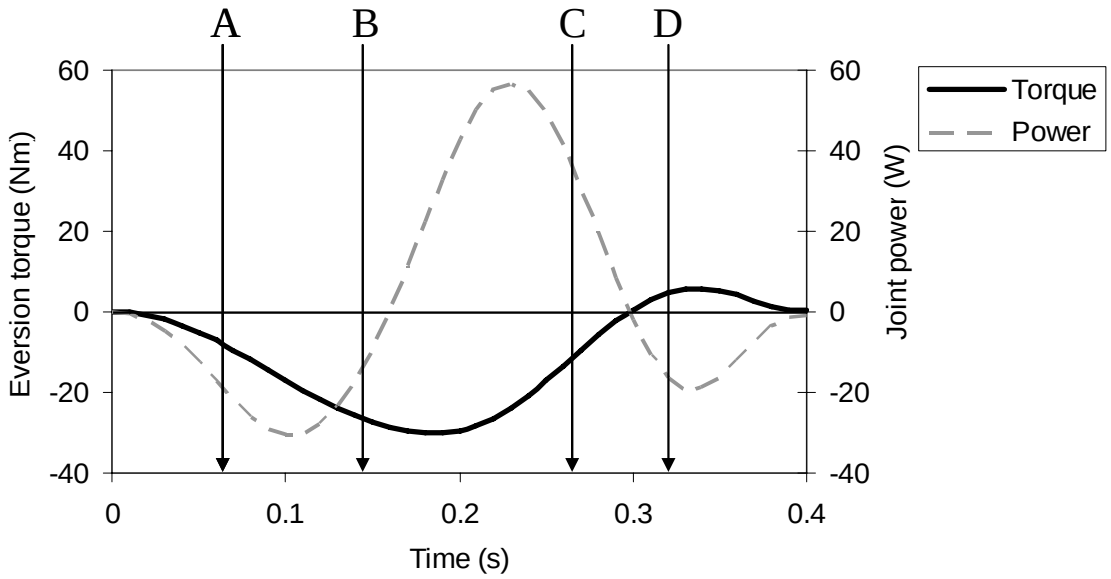
___T ___F : Apply a greater average hip flexion torque for the same period of time during the kicking motion

___T ___F : Apply the same average hip flexion torque for a smaller period of time during the kicking motion

___T ___F : Increase the mass of the kicking limb without changing the angular velocity of the kicking limb at impact

___T ___F : Wear a shoe with a smaller coefficient of restitution between the shoe and ball

12. *(4 points)* The graph below shows the ankle eversion torque and the corresponding joint power during the stance phase of running. Based on this graph, which of the following statements are true and which are false?



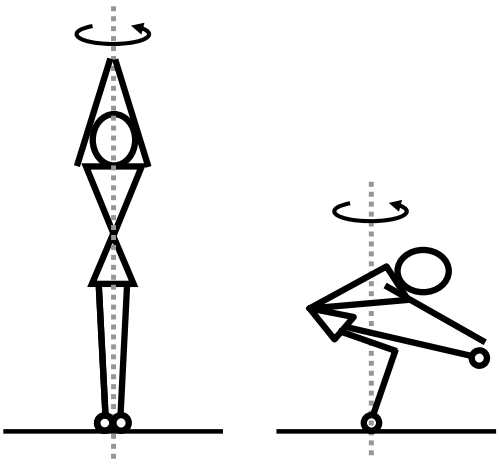
___T ___F : The inverters are the dominant muscle group at time A

___T ___F : The ankle is inverting at time B

___T ___F : The inverters are contracting concentrically at time C

___T ___F : The everters are being used to generate power at time D

13. *(3 points)* A figure skater is on the ice and is spinning about her longitudinal axis in the position shown on the left. While continuously spinning, she changes her body position to the one shown on the right. Assume that there is no friction or other shear force between her skates and the ice during the spin.



In changing from the initial body position to the new body position…

___T ___F : …her moment of inertia about the axis of rotation increases

___T ___F : …her angular momentum about the axis of rotation increases in magnitude

___T ___F : …the angular velocity at which she spins increases in magnitude

14. *(4 points)* A softball pitcher rotates her pitching limb about the shoulder. She uses a torque at the shoulder to control the rotation of the limb and uses her fingers to apply the needed centripetal force to the ball. All else being equal, which of the following are true and which are false?

___T ___F : If she keeps her elbow flexed instead of fully extended, the same net shoulder torque will result in a greater angular acceleration of the pitching limb

___T ___F : Once her pitching limb is rotating, its rotation will slow down anytime that the net torque acting on the limb is zero

___T ___F : The faster her arm rotates, the greater the force she must apply to the ball with her fingers

___T ___F : At a given angular velocity of her pitching limb, keeping her elbow flexed instead of fully extended will reduce the force she must apply to the ball with her fingers

15. *(3 points)* A football lineman is blocking an opponent by applying a force to the opponent. All else being equal, which of the following are true and which are false?

___T ___F : To cause the opponent to turn to the lineman's right as the opponent moves forward, a portion of the force that the lineman applies to the opponent must be directed to the lineman's left

___T ___F : To absorb the most power from the opponent, the lineman should apply a force to the opponent in the direction exactly opposite to that in which the opponent is moving

___T ___F : If the lineman and opponent push against each other but neither player moves, the lineman is doing no work

16. *(2 points)* While trying to execute a double play, a baseball player jumps straight up into the air and throws the ball directly towards first base using a sidearm motion. At the time he jumps into the air, his body is not rotating. After he's in the air, he begins to rotate his throwing arm clockwise. Which of the following are true and which are false?

___T ___F : As he rotates his throwing arm, the rest of his body will rotate clockwise

___T ___F : After he releases the ball while in the air, the player's center of mass will be traveling directly away from first base

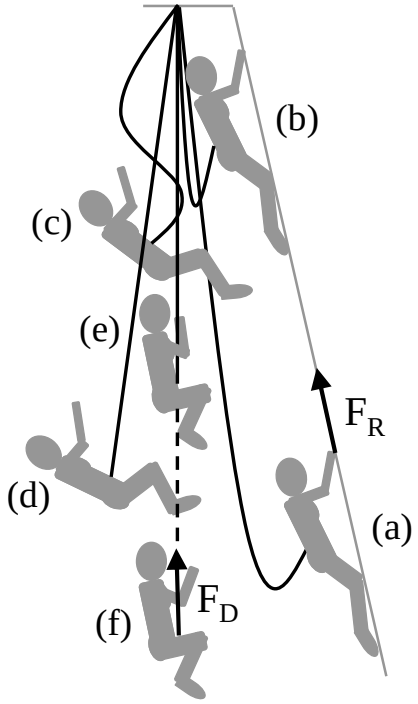
Multiple Choice (Questions 17-19, *5 points*)

A rock climber is attempting a difficult ascent, using a dynamic (i.e. elastic) rope for fall protection:

a. She climbs *slowly* (F_R = force acting on the climber from the rock)
b. Near the top of the climb, she loses her grip
c. She falls *rapidly*
d. Her rope stretches and stops her fall
e. She comes to rest hanging from the rope
f. Her climbing partner uses the rope to lower her *slowly* back to the ground (F_D = force acting on the climber from the dynamic rope)

The force acting in the dynamic rope is greatest at event d.

Answer questions 17-19 based on the picture to the right.



17. *(3 points)* Which event (a – e) corresponds to each of the following?

___ Gravitational potential energy (= potential energy due to gravity) is at its maximum
___ Kinetic energy is at its maximum
___ Strain energy is at its maximum

Pick the best answer for each. The same event may appear more than once, or not at all.

18. *(1 point)* _____ Which force does positive work on the climber?

A. F_R while she is climbing (event a)
B. F_D while she is being lowered (event f)
C. Both of the above

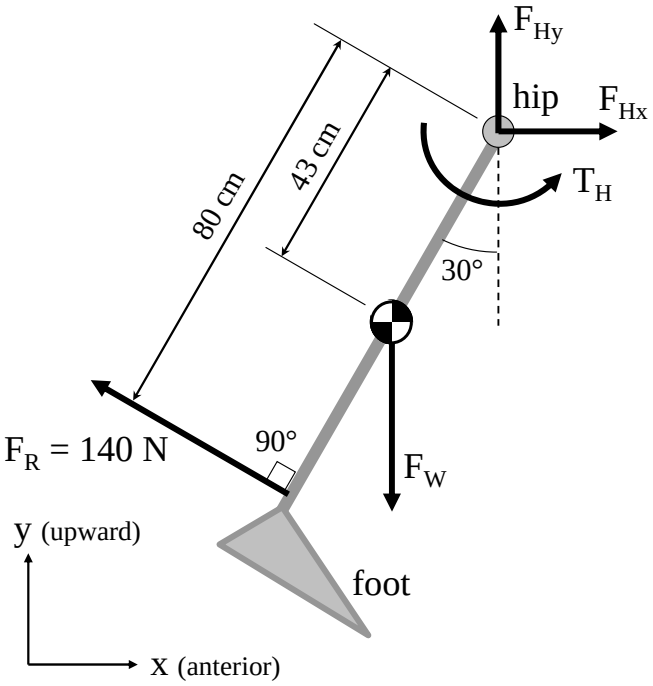
19. *(1 point)* _____ Which force does negative work on the climber?

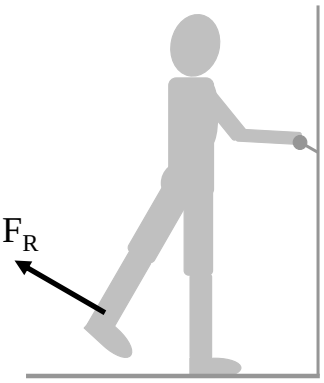
A. F_R while she is climbing (event a)
B. F_D while she is being lowered (event f)
C. Both of the above
D. None of the above

<u>Problem Solving</u> (Questions 20-23; *53 points total*)

Show your work for all parts in questions 20 – 23, including all formulas used. Answers will not receive any points unless the associated work is shown.

20. *(23 points total)* A person stands with the hip extended 30º and performs an isometric contraction against an applied resistance of 140 N, as shown in the figure on the right. A diagram of the forces and torques acting on the person's lower limb is shown in the figure on the left. The mass of the lower limb is 12.0 kg. The lower limb is not moving and will continue not to move.





F_H = resultant hip force
T_H = resultant hip torque
F_R = resistance force
F_W = lower limb weight

Answer the following questions:

a. *(9.5 points)* What are the *magnitude* and *direction* of the **resultant hip force** (F_H)?

b. *(10.5 points)* What are the *magnitude* and *direction* of the **resultant hip torque** (T_H)? You **must** say whether the resultant torque is acting *clockwise* or *counterclockwise*.

c. *(2 points)* _____ Based on your answers to parts (a) and (b), which of the following is true during this exercise?

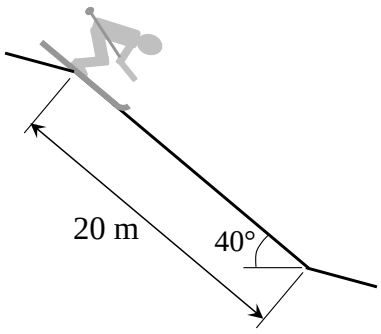
   A. The hip flexors must be active

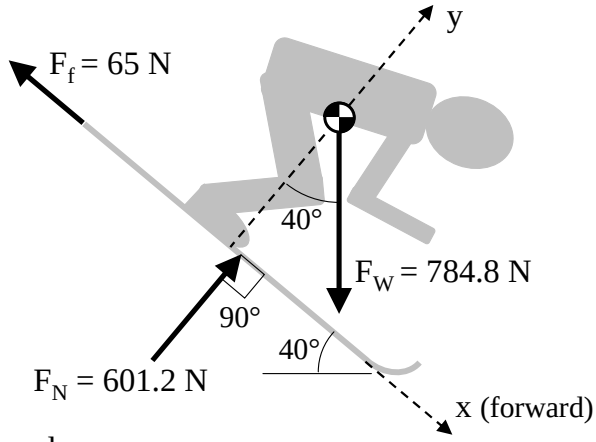
   B. The hip extensors must be active

d. *(1 point)* Is the following true or false during this exercise?

   ___T ___F : The active muscle group in part (c) contributes to the resultant hip force (F_H) **and** the resultant hip torque (T_H)

21. *(10 points total)* An 80 kg skier starts down a short, steep section of a run. This section of the run is 20 m long and angled at 40° from the horizontal, as shown in the left figure. Ignoring air resistance, the three external forces acting on the skier are shown in the figure on the right.





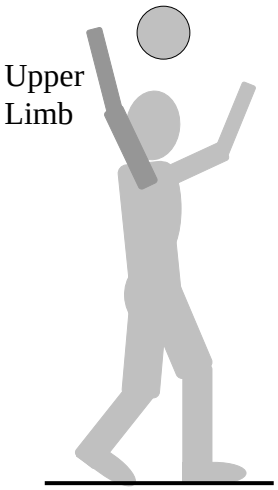
F_W = weight of skier
F_N = normal force from ground
F_f = friction force from ground

Important Note! In parts (a) and (b), "forward" refers to the x direction shown above.

a. *(6 points)* What is the *magnitude* of the **acceleration** of the skier in the forward direction during this steep section of the run? *Hint*: It may help to spin your paper so the skis are horizontal.

b. *(4 points)* Based on the answer to part (a), if the skier is moving forward at 13 m/s at the start of this steep section of the run, what will the *magnitude* of his forward **velocity** be at the end of this 20 m section?

22. *(12 points)* A volleyball player is serving the ball. Starting when her upper limb is moving *counterclockwise* at 250 deg/s (= 4.36 rad/s), she applies a constant net torque to the limb at the shoulder for 300 ms. At the end of this period, her upper limb is moving *clockwise* at 480 deg/s (= 8.38 rad/s).



The inertial properties of her upper limb are:

- Mass of the limb: 4.0 kg
- Distance from the shoulder to the limb's center of mass: 33 cm
- Radius of gyration of the limb about the shoulder: 39 cm

a. *(3 points)* What is the **mass moment of inertia** of her upper limb?

b. *(5 points)* What are the *magnitude* and *direction* of the **angular impulse** on the upper limb due to the net torque applied at the shoulder?

c. *(1 point)* In which **direction** was the net torque that was applied to the upper limb at the shoulder?

___Clockwise

___Counterclockwise

d. *(3 points)* Based on the angular impulse computed in part (b), what is the *magnitude* of the constant net **torque** that the player applied to the upper limb at the shoulder?

23. *(8 points)* A 90 kg cyclist-and-bicycle are turning while traveling at a constant 6.3 m/s. As they make the turn, they apply a normal force to the road that is equal to their weight. The coefficient of static friction between the bicycle tires and the road is 0.85 and the coefficient of kinetic friction is 0.8.

a. *(7 points)* If all of the centripetal force on the cyclist-and-bicycle comes from friction between the tires and the road, what is the smallest **radius** of turn they can make *without slipping sideways*?

b. *(1 point)* In part (a), in which direction does the friction force from the road onto the tires act?

___Outward, away from the center of the turn

___Inward, towards the center of the turn

Unit conversion:	1 ft = 0.3048 m	1 radian = 57.3 degrees
	1 m = 100 cm	1 s = 1000 ms
Constants:	magnitude of acceleration due to gravity = 9.81 m/s^2 = 32.2 ft/s^2	