Western University
Faculty of Health Sciences
School of Kinesiology

KIN2241b – "Biomechanics"

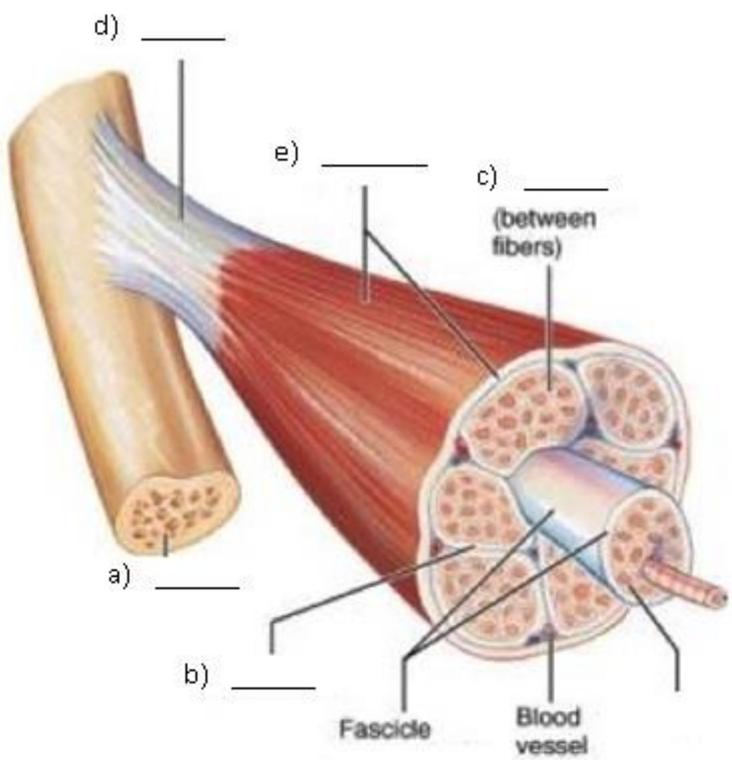
EXAMPLE FINAL EXAM

Cheating:	University policy states that cheating on an examination is a scholastic offense. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.

Short answers

Answer the following questions with one or two sentences unless otherwise stated:

10 marks 1. Identify the connective tissue structures of skeletal muscle below:



a) Bone
b) Perimysium
c) Endomysium
d) Tendon
e) Epimysium

5 marks 2. Explain the difference between a diarthrodial joint and an amphiarthrodial joint. Give examples of each. Which of the two types is also known as a synovial joint?

A diarthrodial joint is a synovial joint such as the elbow joint. This joint has a joint capsule, synovial fluid lubricating the contact surfaces that are covered in articular cartilage. These joints allow for the greatest range of motion of the connecting segments.

An amphiarthrodial joint is a fibrous or cartilaginous joint, such as between vertebrae or between a rib and the sternum. There is a small but significant range of motion allowed by the joint made possible by the fibrous connective tissue that joins the bones.

5 marks 3. In the diagram of the discus in flight below,

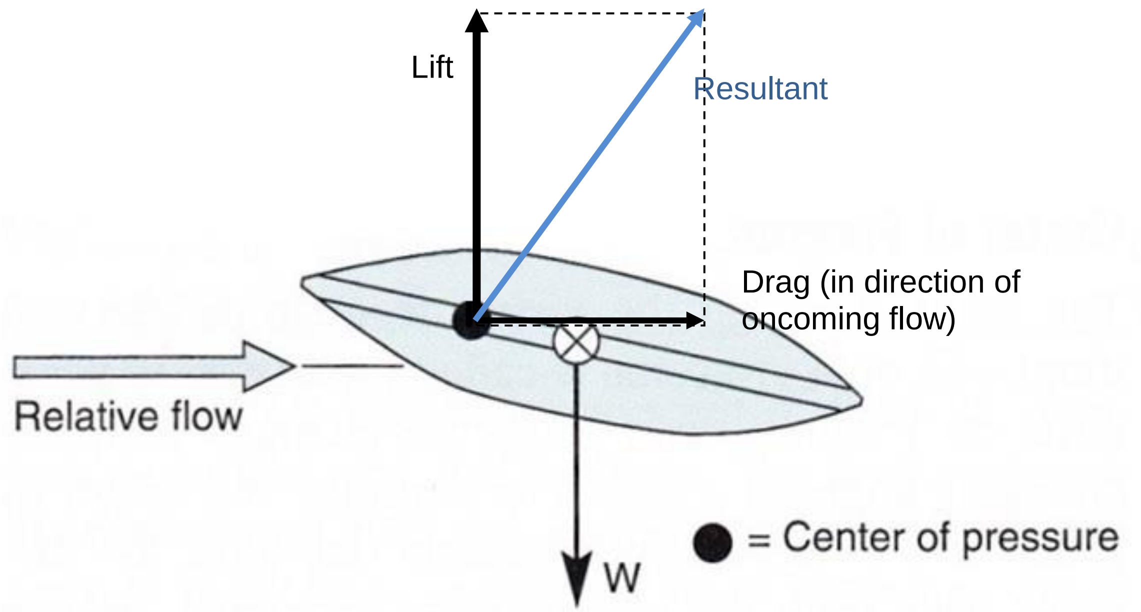
a) What does the center of pressure represent?

The center of pressure is where the lift and drag forces act on the object.

b) Draw the two forces that act at the center of pressure noting the direction of on-coming air flow.

c) What rotational effect will this have on the discus?

Since the center of pressure is in front of the center of mass and the lift is acting upward, the tendency is for the lift and drag apply a clockwise torque to the discus



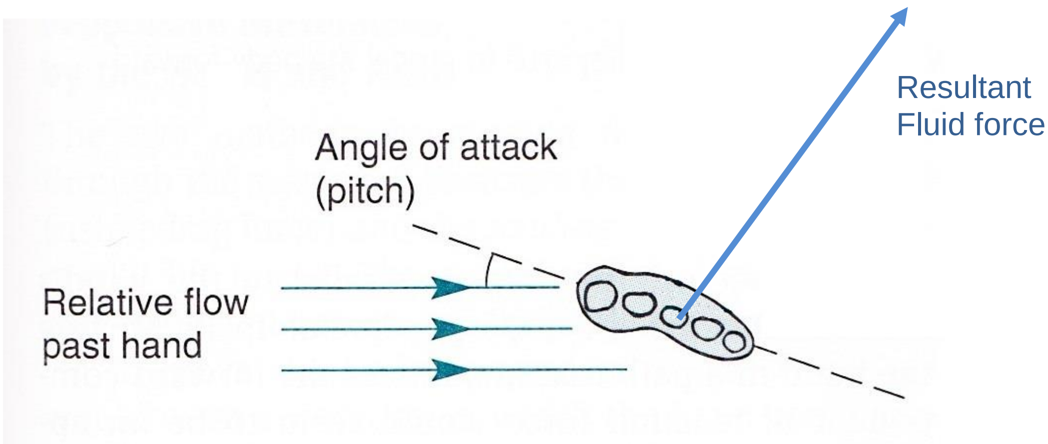
5 marks 4. What are the three types of drag acting on a body moving through water? How do you reduce each one?

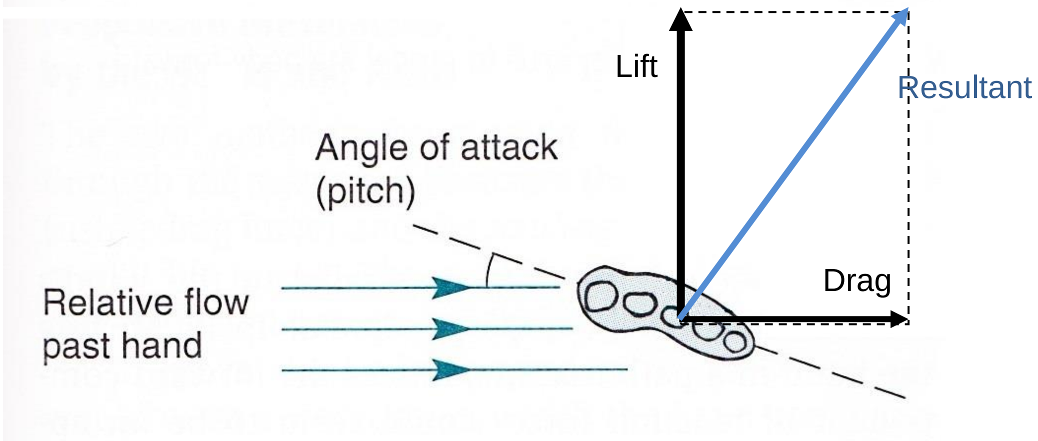
Skin drag is the energy lost by dragging along a boundary layer of slower moving water with the body. It can be reduced by wearing a swim suit with a special rough texture to minimize boundary layer thickness.

Profile drag is the energy lost to having a zone of low pressure behind the body. It can be reduced by minimizing the cross-sectional area presented to the on-coming flow and by maximizing the streamlining of the body. This is done with proper swimming technique.

Wave drag is the energy lost to creating waves on the surface of the water. This is reduced by minimizing splashing and proper swimming technique.

5 marks 5. Copy the diagram of a hand skulling through water shown below into your answer booklet. Note the direction of on-coming water flow and the resultant fluid force. Draw the drag force vector and the lift force vector onto your diagram.





10 marks 6. Consider the diver at the moment of takeoff from a 3 m spring board. Assume that at the moment the diver leaves the board, their center of mass is 3.6 m above the surface of the water.

a) If the takeoff velocity has a magnitude of 7 m/s and is angled at 20º with respect to vertical as shown, calculate the vertical and horizontal components of takeoff velocity

$v_{vertical} = 7x\cos(20^o)=6.6$ m/s
$v_{horizontal} = 7x\sin(20^o)=2.4$ m/s

b) What is the maximum height above the water that the diver reaches?

Maximum height is $(v_{vertical})^2 / (2 \times g) + 3.6$
$=(7x\cos(20^o)^2)/(2 \times 9.81) + 3.6$
$=(6.6)^2/(19.62) + 3.6$
$=43.3/19.62 + 3.6$
$=2.2+3.6 = 5.8$ m

c) If the diver's mass is 76 kg and radius of gyration is 1.23 m, what is the mass moment of inertia (I) of the diver at takeoff?

Mass moment of inertia = $I = mk^2 = 76x(1.23)^2 = 115$ kgm^2

d) If, at the moment of takeoff, the diver starts a forward somersault about their mediolateral axis with an angular velocity of 10 deg/s, what does their angular velocity become during the diver when they assume a tight tuck position with a radius of gyration of 0.45 m?

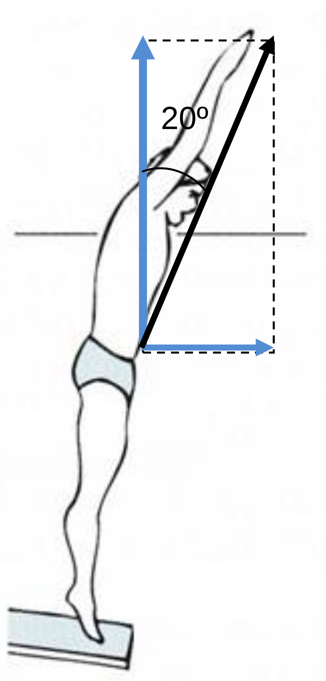
Once in the air, the angular momentum, L, is constant. So at takeoff,

$L = Ix\omega_{takeoff} = mk^2\omega_{takeoff} = 115 \times 10 = 1150$ kgm^2/s

During the tight tuck, when the radius of gyration is 0.45,

$L = 1150 = 76x(0.45)^2 \times \omega_{tuck} = 15.39$

So, $\omega_{tuck} = 1150 / 15.36 = 74.7$ deg/s



Long answers

Answer the following questions with 4 to 5 sentences and with diagrams written in your answer booklet where applicable:

15 marks 7. Consider the lever and spring device in the diagram below. The lever rotates about the axis at the bottom. The lever is in a vertical position at the instant shown. Spring 1 pulls horizontally to the left and is attached 50 cm from the axis. Spring 2 pulls to the left and down at an angle of 60º to the lever and is attached 25 cm from the axis. Spring 3 pulls to the right at an angle of 45º to the lever and is attached at 30 cm from the axis.

a) If spring 1 pulls with 100 N, spring 2 with 130 N and spring 3 with 200 N, what is the net torque acting at the axis?

The counter clockwise (CCW) torque is

100x(0.50) + 130sin(60)x(0.25)

=50.0+28.15=78.15 Nm (CCW)

The clockwise (CW) torque is

200sin(45)x(0.30)=42.4 Nm (CW)

So the net torque is

78.15-42.4=35.7 Nm (CCW)

b) If someone were to pull on the lever as shown (i.e. at a right angle to the lever) with a force of 90 N to the right, how far from the axis should they pull in order to make the net torque at the axis zero?

The pull from the hand needs to create a CW torque of 35.7 Nm to balance make the net torque equal zero. So:

90x(distance)=35.7

Distance=35.7 Nm / 90 N = 0.40 m = 40 cm

c) If someone were to pull on the lever as shown with a force of 200 N, how far from the axis should they pull in order to make the net torque 10 Nm clockwise?

The pull from the hand needs to create a CW torque of 35.7+10 Nm to make the net torque equal to 10 Nm CW. So:

200x(distance)=35.7+10

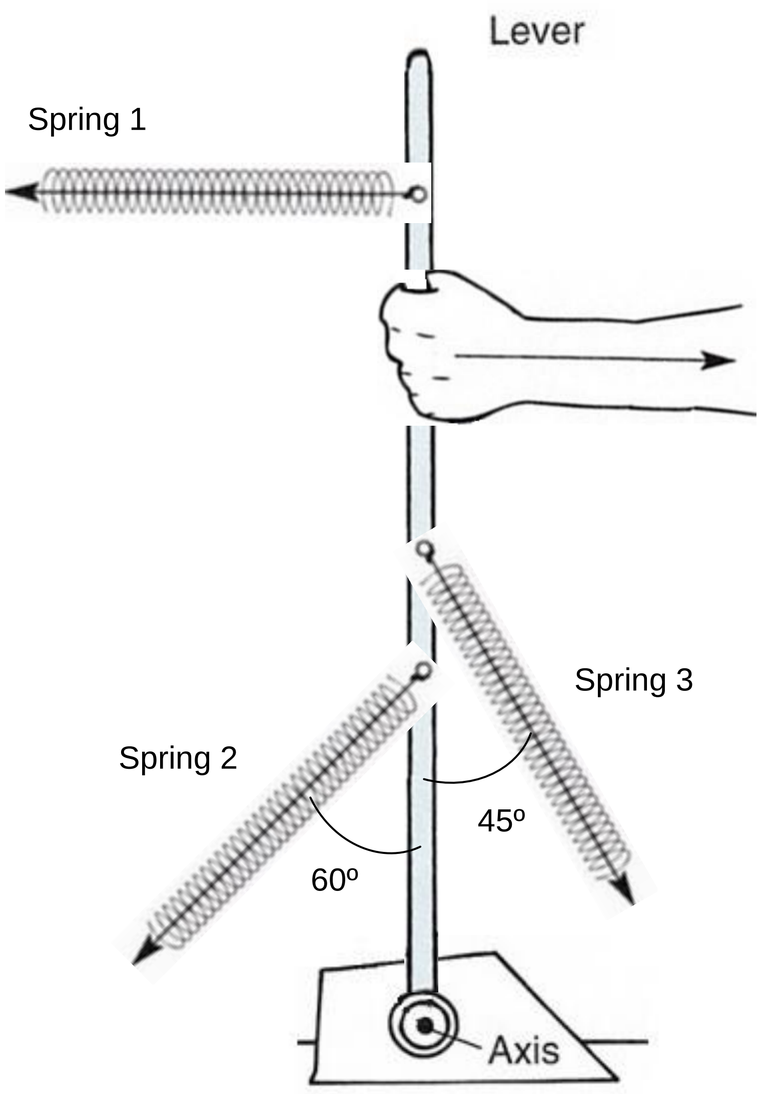
Distance=45.7 Nm / 200 N = 0.23 m = 23 cm

d) What is the net force tending to stabilize or dislocate the axis in part c)?

To find the net stabilizing or dislocating force acting on the axis, we need to find the components of the three springs and the hand along the lever. So:

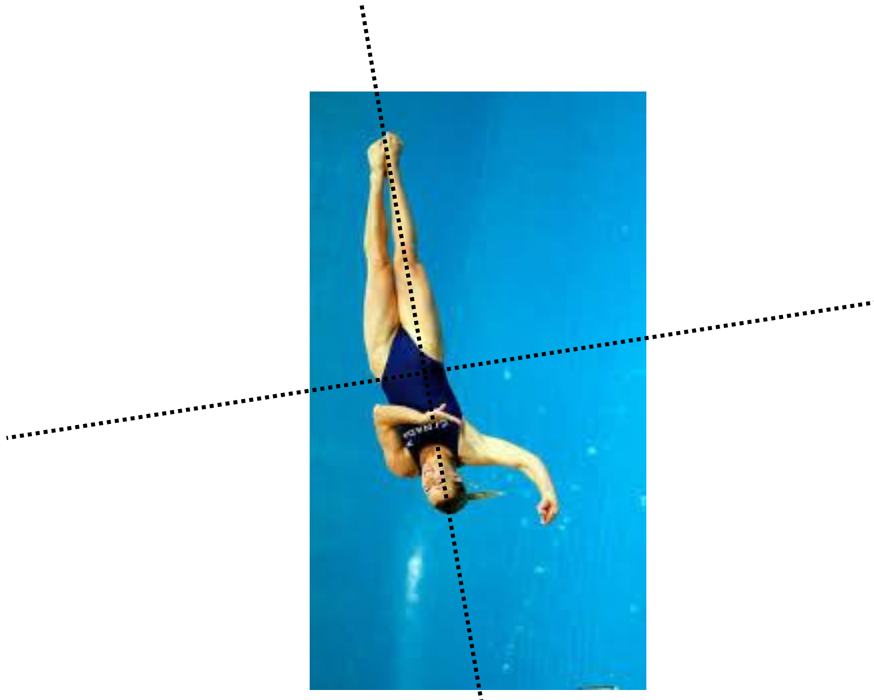
If stabilizing (i.e. force components directed toward the axis) is positive, and dislocating (i.e. force components directed away from the axis) is negative, then

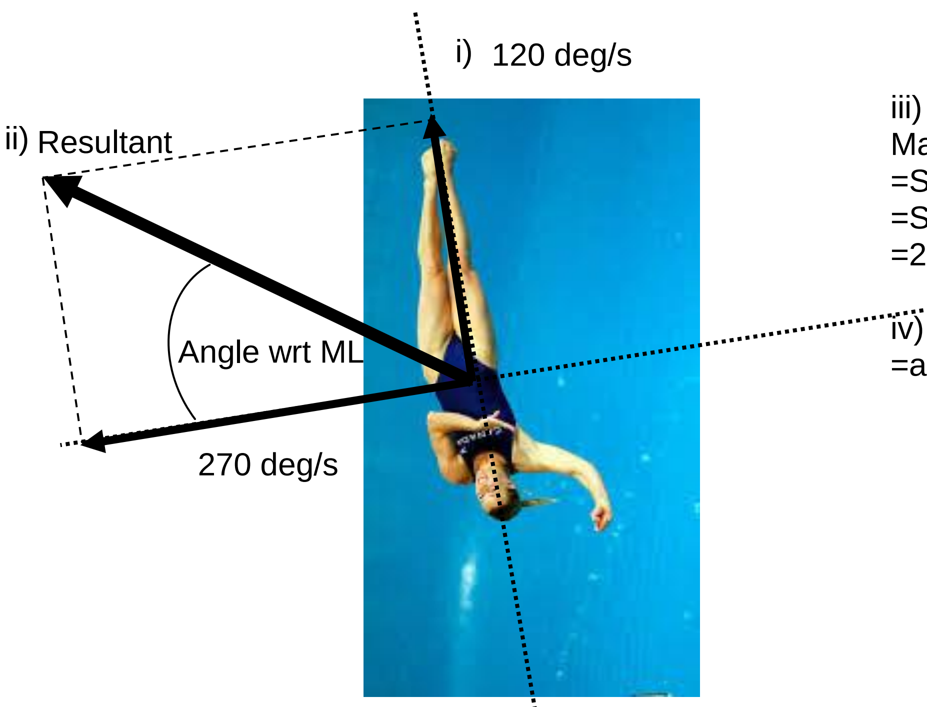
+100cos(0)+130cos(60)+200cos(45)+200cos(0)
=0 + 65 +141.4 + 0
=206.4 N tending to stabilize the axis



10 marks

8. a) A diver is somersaulting forward about her medio-lateral (ML) axis at 270 deg/sec and spinning about her long axis at 120 deg/sec with her left shoulder coming forward. Do the following: i) draw the two angular velocity components about the correct axes and in the proper directions according to the right hand rule, ii) draw the resultant angular velocity vector, iii) calculate the magnitude of the resultant angular velocity and, iv) calculate the angle of the resultant vector with respect to the ML axis.

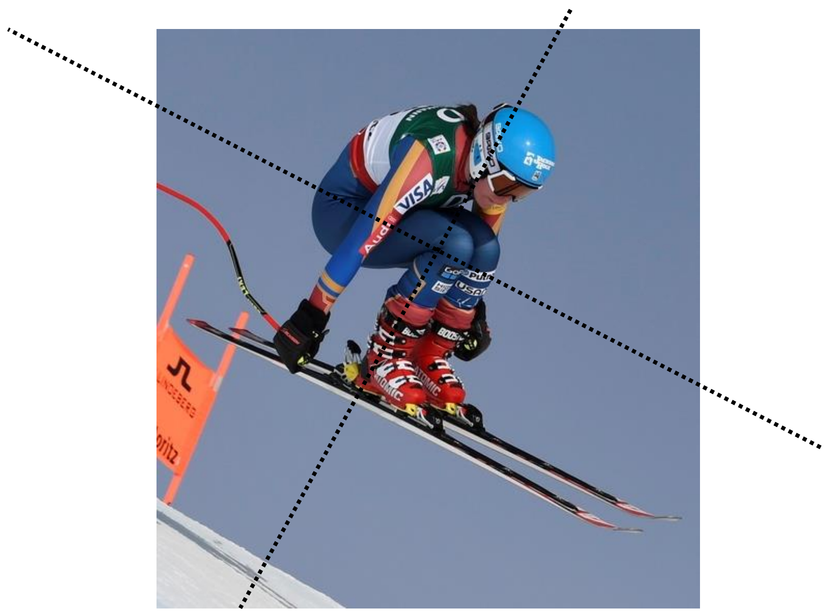


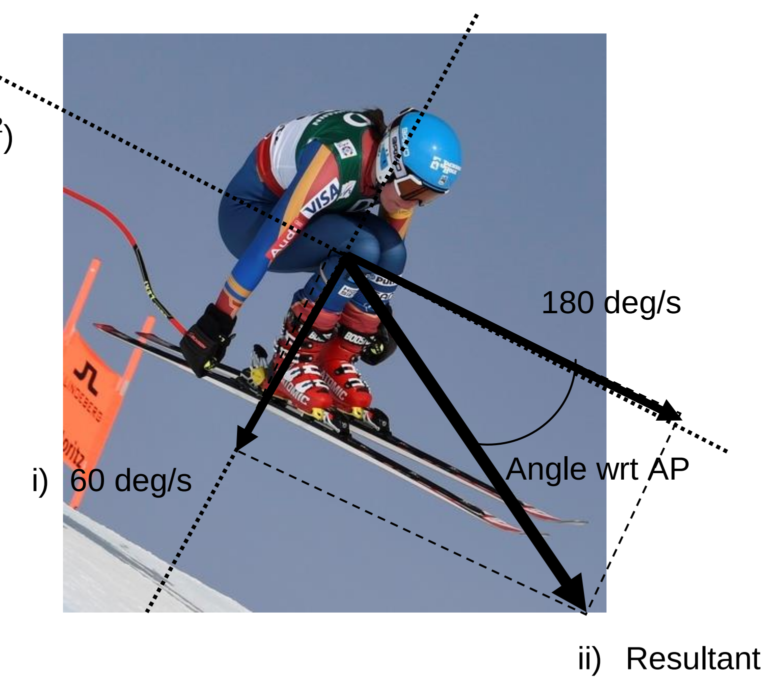


iii)
Magnitude=SQRT((120)^2+(270)^2)
=SQRT(14400+72900)
=SQRT(87300)
=295.5 deg/sec

iv) Angle wrt ML axis
=arctan(120/270)=24 degrees

b) A ski racer becomes airborne during a race. He rotates to his right about his anterio-posterior (AP) axis at 180 deg/s and about his longitudinal axis 60 deg/s with his left shoulder moving forward. Do the following: i) draw the two angular velocity components about the correct axes and in the proper directions according to the right hand rule, ii) draw the resultant angular velocity vector, iii) calculate the magnitude of the resultant angular velocity and, iv) calculate the angle of the resultant vector with respect to the AP axis.

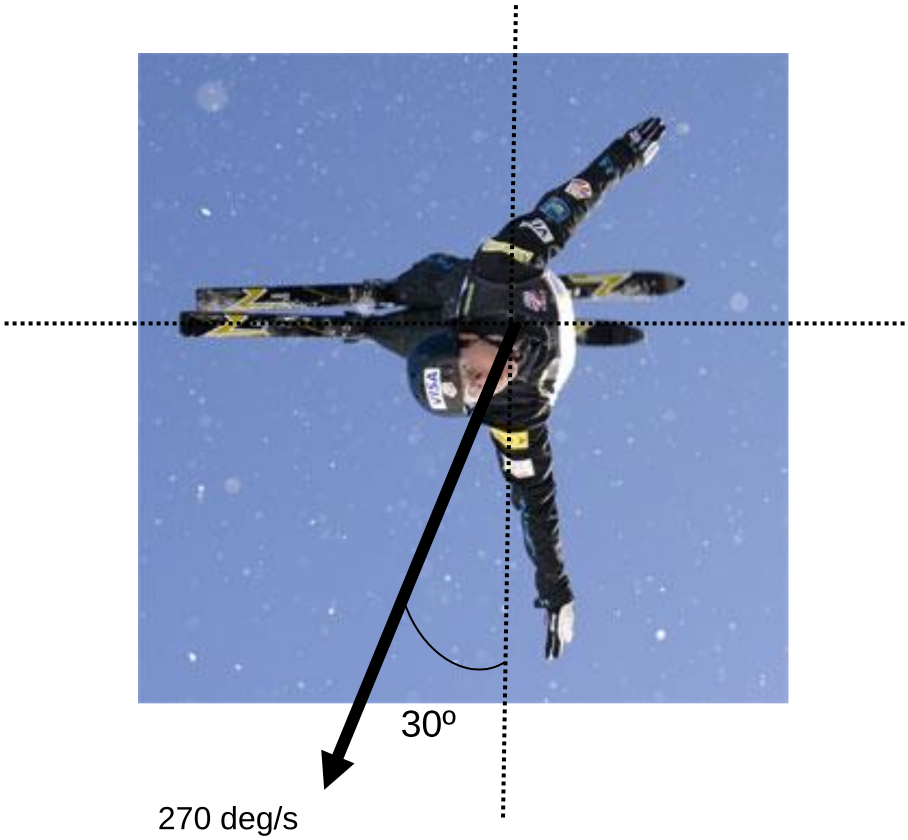




iii) Magnitude=SQRT($(180)^2+(60)^2$)
=SQRT(32400+3600)
=SQRT(36000)
=190 deg/sec

iv) Angle wrt AP axis
=arctan(60/180)=18.4 degrees

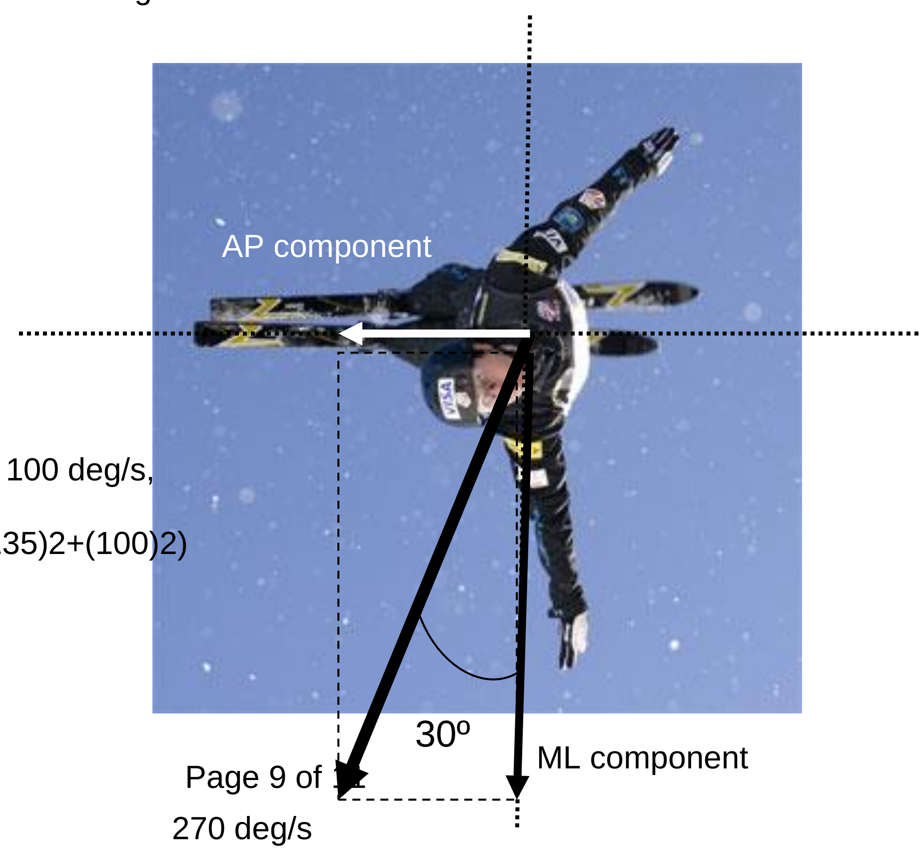
c) An aerial skier is rotating at 270 deg/sec with the resultant angular velocity vector shown. Do the following: i) draw the two angular velocity components about the AP and ML axes, ii) calculate the magnitude of the angular velocity about the ML axis, iii) calculate the magnitude of the angular velocity about the AP axis, iv) if the skier is also twisting about his longitudinal axis at 100 deg/s, what is the magnitude of the overall angular velocity of the skier?



ii) ML comp= 270 cos (30)
=233.8 deg/s

iii) AP comp=270 sin (30)
=135 deg/s

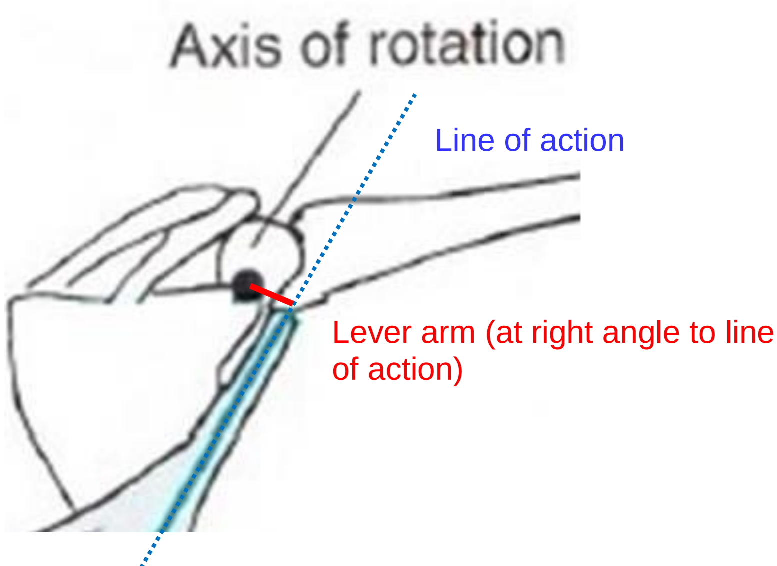
iv) if longitudinal component is 100 deg/s, then
magnitude=SQRT((233.8)2+(135)2+(100)2)
=SQRT(54662+18225+10000)
=287.9 deg/s



15 marks 9. In the figure below the humerus bone of the upper arm is acted upon by the force of the teres minor muscle. The forces each have the same magnitude but act in different directions.

a) What is the primary action that this muscle performs at the glenohumeral joint?
Shoulder ad-duction

b) In your answer booklet, draw the lever arm of this muscle about the joint center of rotation, See diagram below

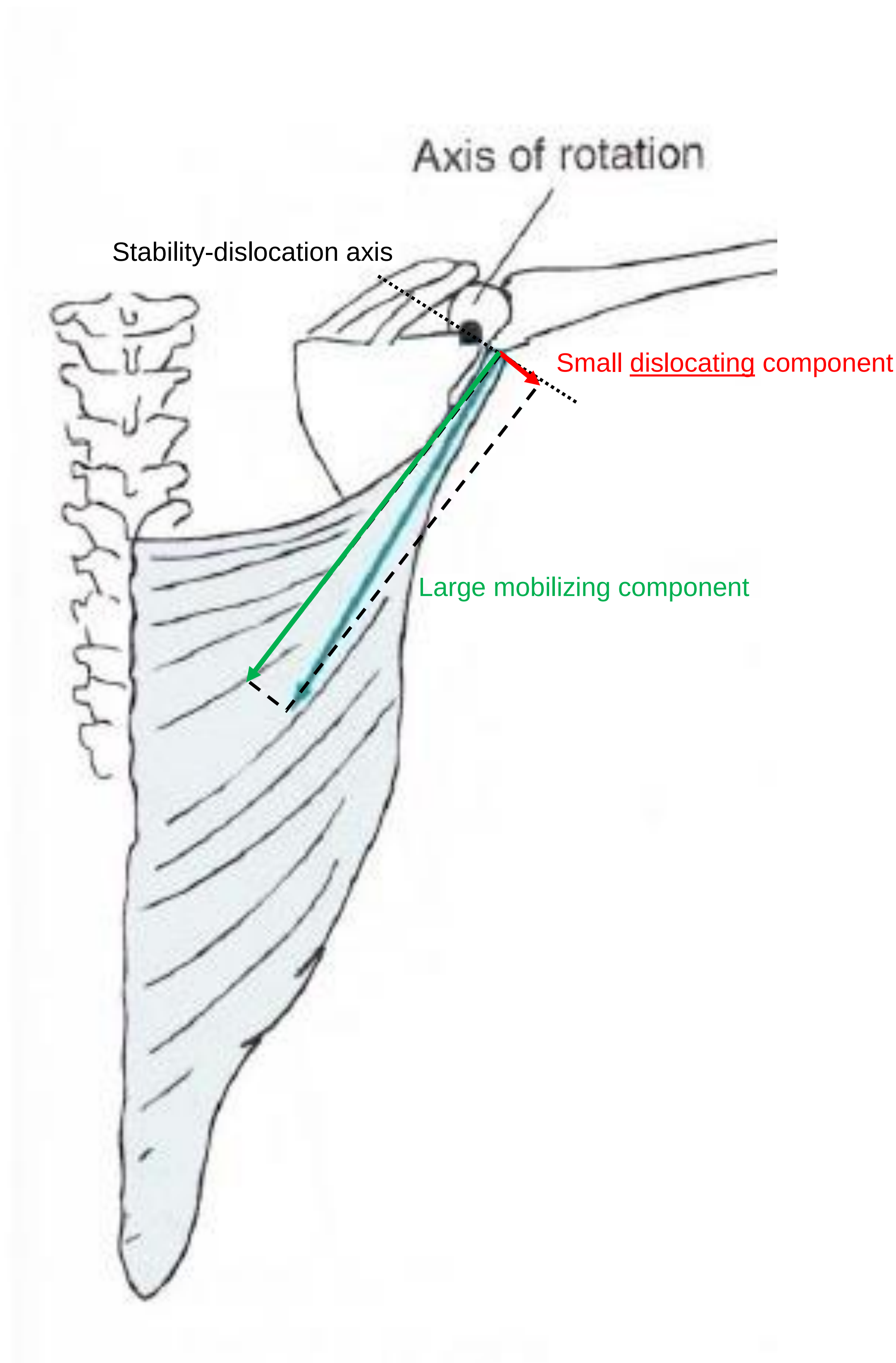


c) If the lever arm is 1.5 cm and the muscle force is 500 N, then what is the magnitude of torque acting at the joint axis?
Torque=500N x 0.015 m = 7.5 Nm

d) Draw the stabilizing component of the muscle force,
See diagram below

e) Draw the mobilizing component of the muscle force,
See diagram below

f) If the distance between the point of attachment of the muscle and the axis of rotation of the joint is 2.0 cm, what is the magnitude of the mobilizing component of the muscle force?
Torque=7.5 Nm (from part c) also = $F_{mobilizing}$ x distance from P to axis
So, 7.5 Nm = $F_{mobilizing}$ x 0.02 m
Or $F_{mobilizing}$ = 7.5/0.02 = 375 N


Axis of rotation
Stability-dislocation axis
Small dislocating component
Large mobilizing component