1. You are a physiotherapist assessing the rehabilitation of an athlete after an injury to the quadriceps muscle group of his left thigh. Using a Kin-Com isokinetic machine you test the strength of both legs at low angular velocities. The torque (moment of force) in Nm exerted against the machine for four angles of flexion are shown in the table below. Zero degrees is full extension.

- Mass of individual = 70 kg
- % of mass in combined foot and shank segment = 6.1%
- Location of centre of gravity of combined foot and shank segment = 0.3m from knee joint axis.
- Distance from quadriceps tendon insertion on tibial tuberosity to knee axis of rotation = 0.09m.
- Angle of pull of quadriceps is 30° from longitudinal axis of tibia (assume this is constant throughout range of motion).
- Assume the contact point between the Kin-Com and the subject is at 0.25 m from the knee axis and that the force exerted between the Kin-Com and the shank is always perpendicular to the longitudinal axis of the shank.
- The torque values in the table are absolute with no regard to direction. You can draw your free body diagram with the subject facing either left or right. The answer provided assumes the subject is facing left as in the picture above.
- Ignore the low angular velocity of the segment and assume situation is static.

<table>
<thead>
<tr>
<th>Angle</th>
<th>External Torque Right</th>
<th>External Torque Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>40°</td>
<td>180</td>
<td>150</td>
</tr>
<tr>
<td>60°</td>
<td>250</td>
<td>230</td>
</tr>
<tr>
<td>90°</td>
<td>120</td>
<td>100</td>
</tr>
</tbody>
</table>

a. Draw a free body diagram of the shank (tibia and fibula only) at 40° of flexion. Try to draw the length of your force vectors realistically. [8]

b. What is the muscle moment of the left quadriceps group at the 60° angle? [5]

c. What is the force produced by the left quadriceps and the joint reaction force on the tibia at the 60° angle? (Ignore the influence of the patella). [12]

d. What is the strength ratio of the left (injured) leg compared to the right (non-injured) leg at the four angles given? [4]
e. Can you make any suggestion as to which of the quadriceps muscles in the left leg may be more affected by the injury? [2]

2. In order to make a bicycle helmet that does not overload the neck extensor muscles during prolonged cycling, a manufacturer contracts you to determine the maximum mass the helmet should be for an average size male (70 kg). Assume that the neck extensors can be modelled as one muscle (a single equivalent muscle) with the following parameters.

Maximum voluntary contraction force (MVC) = 3600 N  
Moment arm of neck extensors = 0.04 m  
Line of action of muscle = 35 degrees from horizontal.

The following anthropometric parameters will be needed:

- Head/neck length (C7 to crown) = 0.28 m
- Head/neck centre of mass (from C7) = 60% of segment length
- Head/neck mass = 8% of total body mass
- Angle of head/neck segment = 55° from right horizontal
- Helmet centre of mass = 0.24 m from C7 along head/neck axis

a) The literature tells you that static contractions maintained for more than one hour should not exceed 5% of MVC. What is the maximum tension you want to permit in the muscle in your model? [2]

b) Draw an appropriate free body diagram of the situation. [5]

c) What helmet mass would you recommend that the manufacturer not exceed? [6]

d) Calculate the compressive force at C7 along the segments mechanical axis if the subject wore a helmet of 0.4 kg (Hint: you have to sum components of the vector forces acting on this model that produce compressive forces). [7]

3. The figure opposite shows a student's head bent over her biomechanics book. The head weighs 5 kg and is supported by the muscle force $F_m$ exerted by the neck extensor muscles and by the joint contact force $F_c$ exerted at the atlantooccipital joint. Given that the magnitude of $F_m$ is 60 N and that it is directed 35° below the horizontal (-35°), find the magnitude and direction of $F_c$. [3] If the cervical spine is aligned parallel to the line of action of $F_m$, what is the compressive and shear force acting on the joint? [2]
4. a) The figure opposite shows the quadriceps ($F_Q$) and patella ($F_T$) tendons as they attach to the patella. If the tension in the quadriceps and patella tendons is 1500 N (it must obviously be the same as it is due to the quadriceps muscle force) what is the magnitude and direction of the resultant contact force $F_C$ exerted on the patella by the femur? [4]

b) Explain briefly from a biomechanical perspective (resolution of vectors) why deep knee bends (knee angle $<$90-100°) are not recommended, especially when you are weight training or carrying a heavy load. [3]

5. The diagram opposite is a model of the biceps curl shown in question 2 (upper arm, forearm, hand and barbell are shown). The forces due to segment and load weights are shown along with the force in the elbow flexors.

a) We normally do not know the muscular force. In this case what is the NET force you would calculate at the elbow? [2]

b) What is the real joint reaction force in this example? Assume there is no antagonist elbow extensor activity. [6]

6. Using the standard anthropometry given.

a) Calculate the mass of the total arm (hand, lower and upper arm). [1]

b) Calculate the horizontal distance from the shoulder to the centre of gravities of the three segments. [3]

b) Calculate the moment at the shoulder in this position (torque due to the arms mass and location). [4]

d) Which muscles would be resisting this moment to maintain static equilibrium? [3]