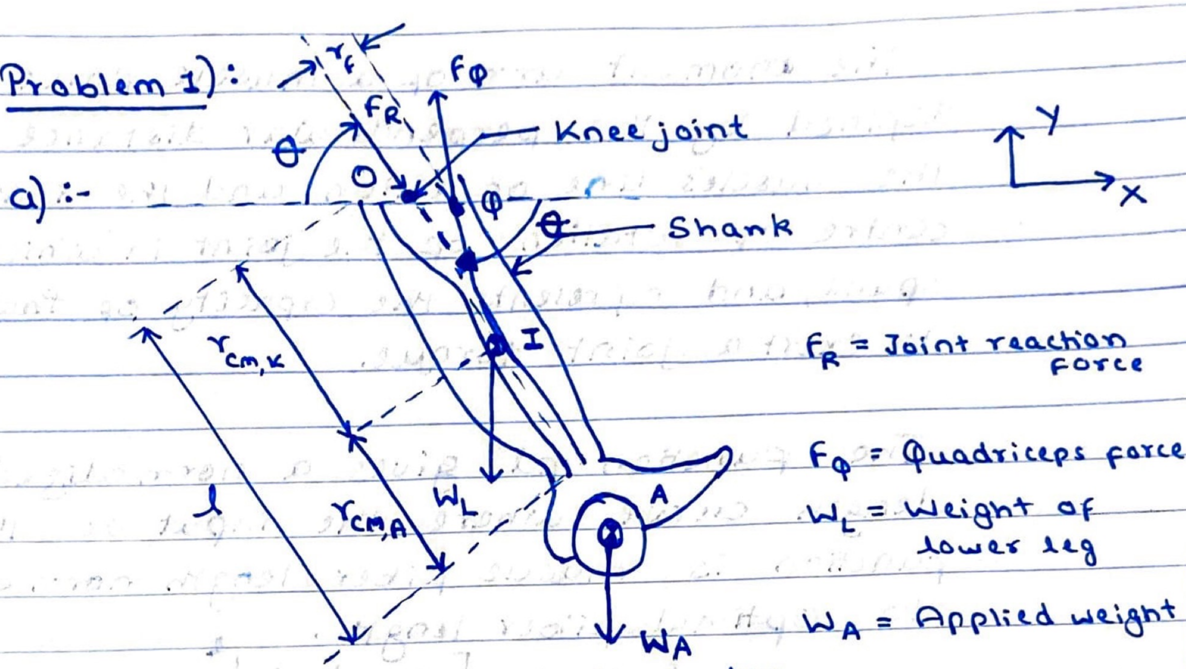
Problem 1):

a) :-



I = Moment of inertia of lower leg
ϕ = Quadriceps insertion
L = COM of lower leg
A = Location of applied weight
θ = Knee flexion angle
$r_{cm,K}$ = Distance b/w COM and knee joint
$r_{cm,A}$ = Distance b/w COM and ankle joint
r_F = Moment arm of quadriceps muscle

Assuming; leg extension exercise without any external weight, i.e. $W_A = 0$

Taking moment about point O we get,

$$\Sigma M = M = (F_\phi \times r_f) - (W_L \times r_{cm,K} \times \sin(\theta - \pi/2))$$

$$\Rightarrow \boxed{M = (F \times r_f) - (m \times g \times r_{cm,K} \times \sin(\theta - \pi/2))}$$

The moment arm of a muscle force is defined by the perpendicular distance between the muscle's line of action and the instantaneous centre of rotation of the joint in which it spans, and represents the capacity of that muscle to exert a joint torque.

The function 'fl' gives a normalized force-length curve, where the input to the function is muscle fiber length normalized to optimal fiber length.

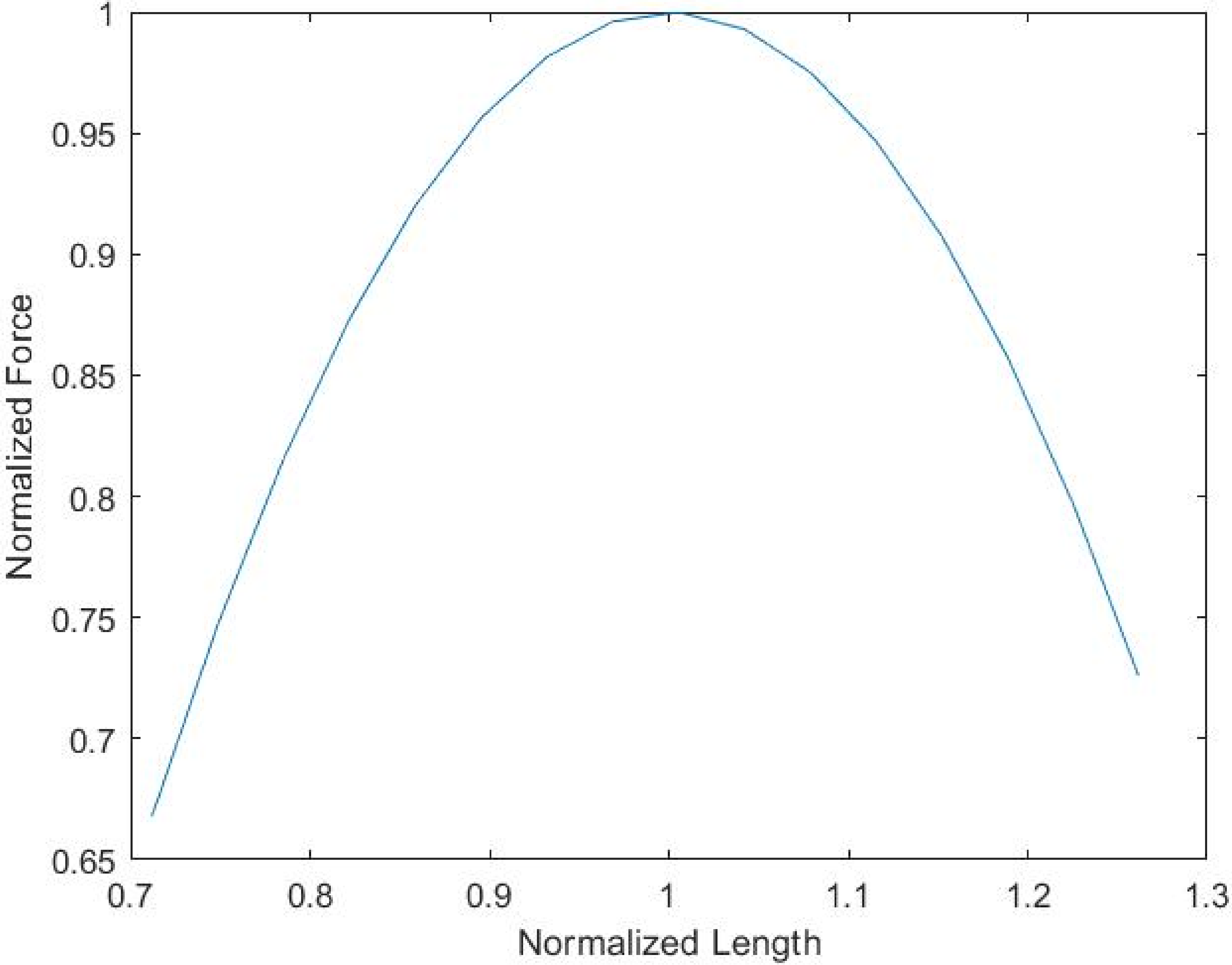
$$f = 1 - \left[\frac{x - l_{opt}}{w \times l_{opt}}\right]^2$$

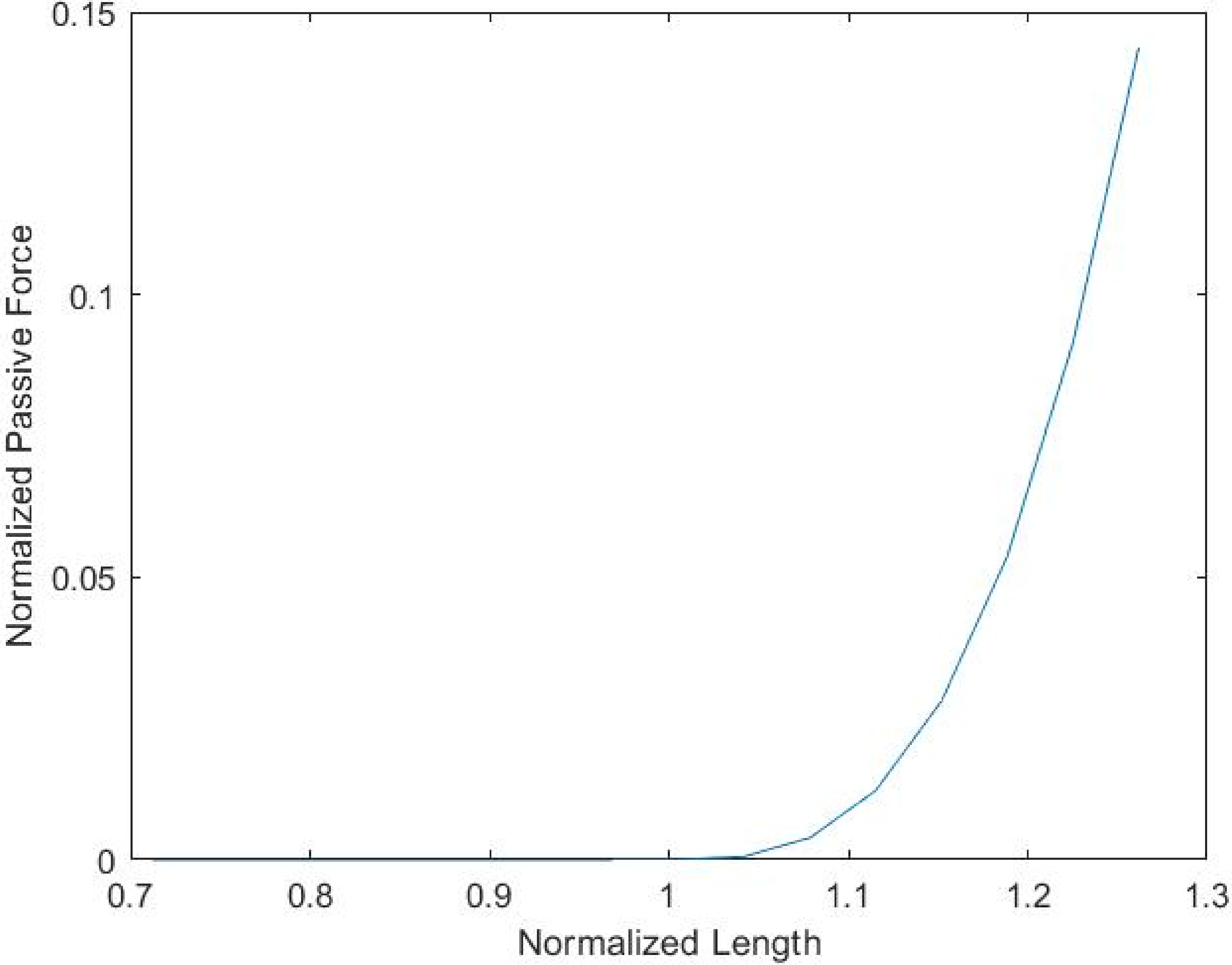
This equation represents a parabolic curve, where w ~~as~~ sets the width of the parabola.

The function 'flp' gives a normalized passive force-length curve for muscle, where input is fiber length normalized to optimal fiber length

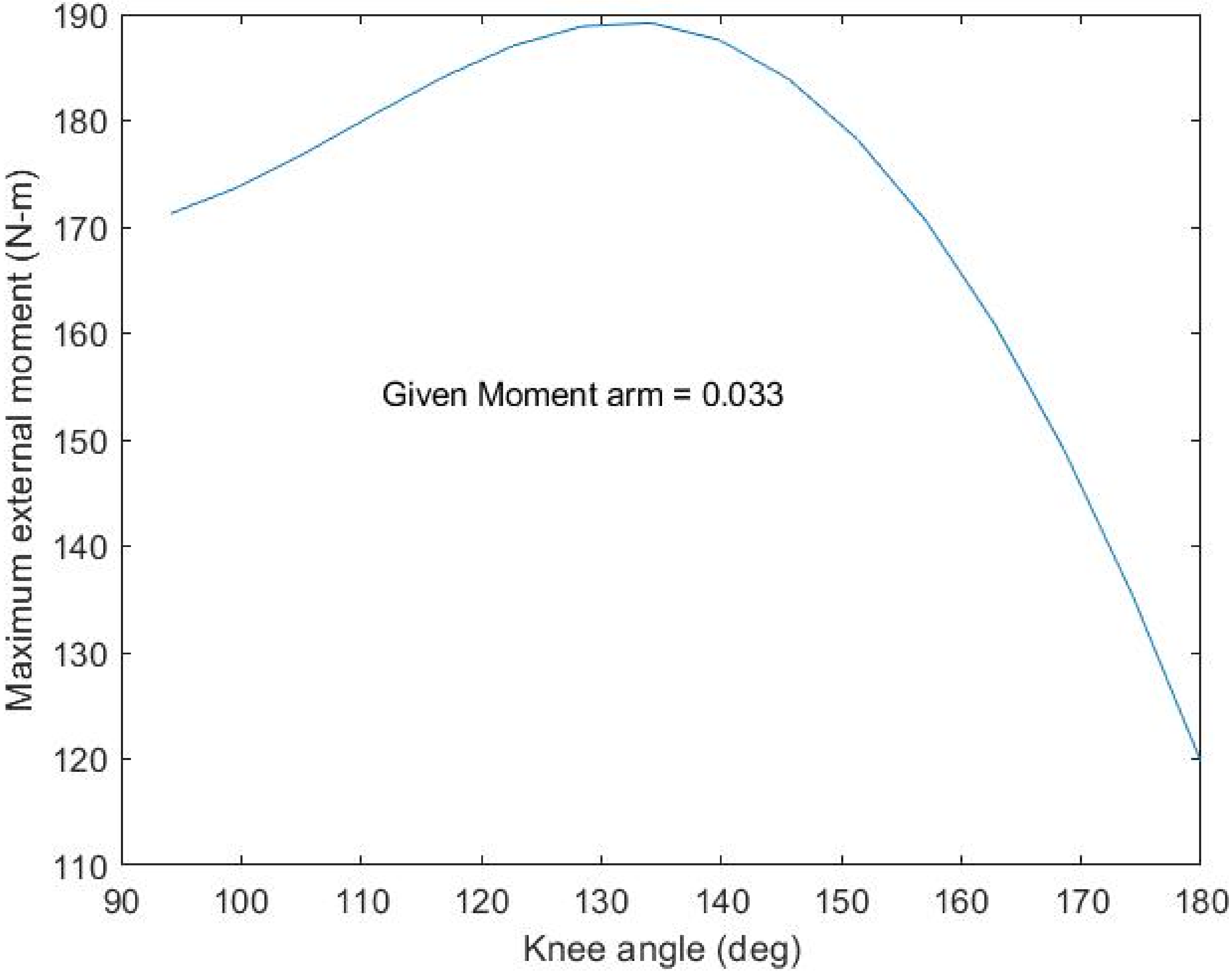
$$f = 8(x-1)^3$$

Here the function ~~as~~ is modelled as a cubic but it can also be modeled as an exponential. In the equation, one is subtracted from fiber length to calculate strain from peak isometric. Titin plays an important role in development of passive muscle force. Titin is situated at the end of the sarcomere which ~~is~~ connects thick filament to the Z-discs.

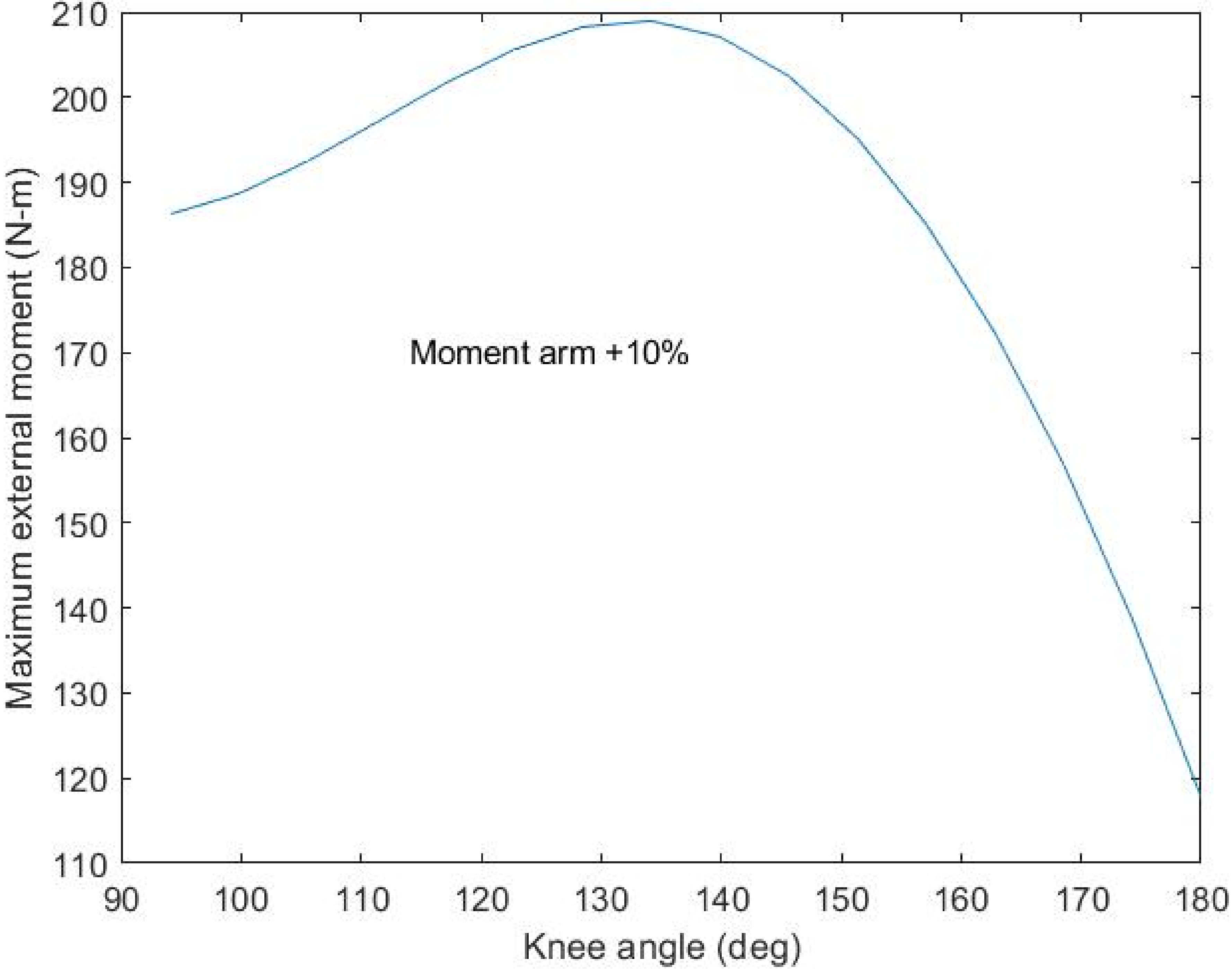

Normalized Force
Normalized Length
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.7
0.8
0.9
1
1.1
1.2
1.3

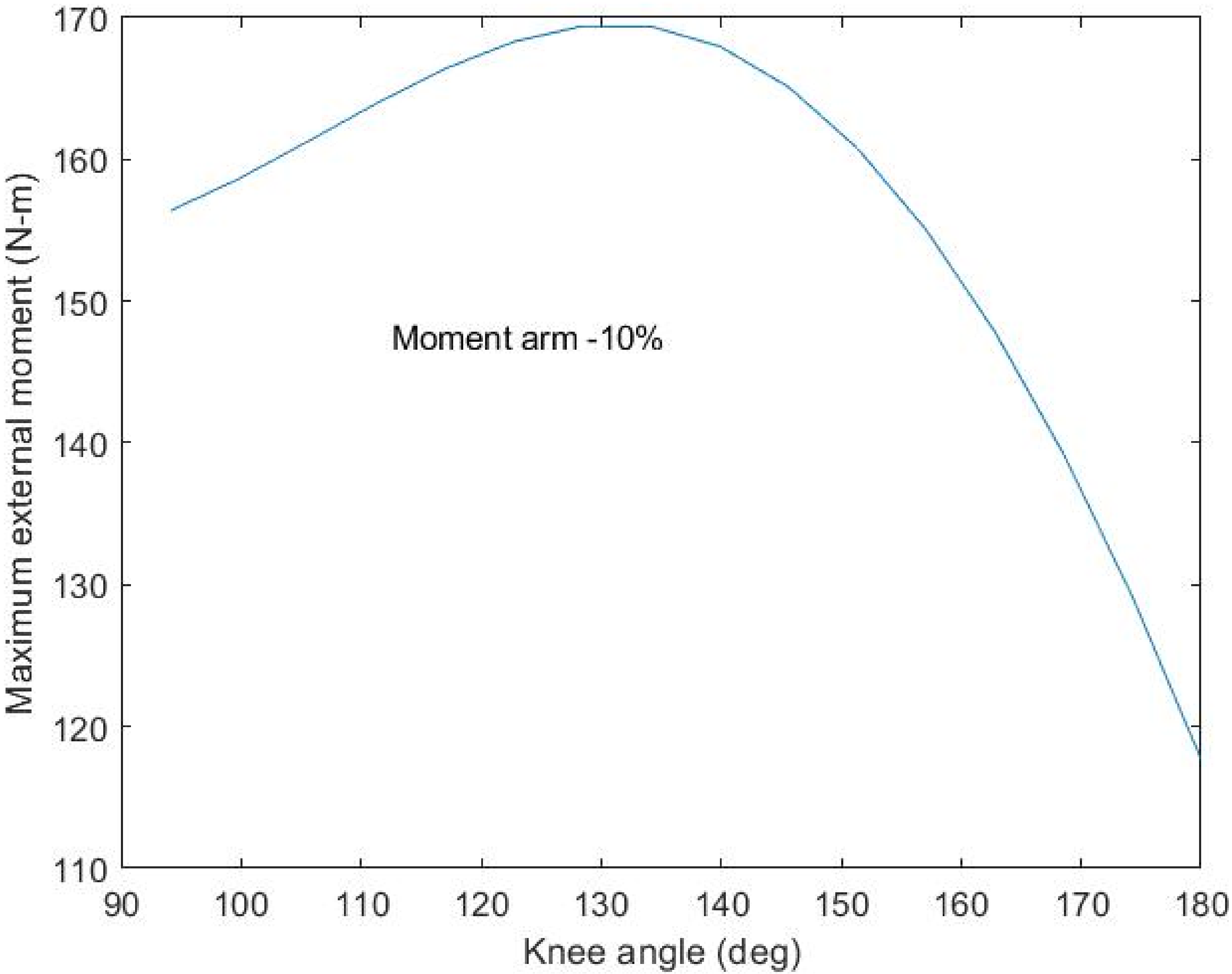

0.15
0.1
0.05
0
Normalized Passive Force
0.7
0.8
0.9
1
1.1
1.2
1.3
Normalized Length

Problem 1b):



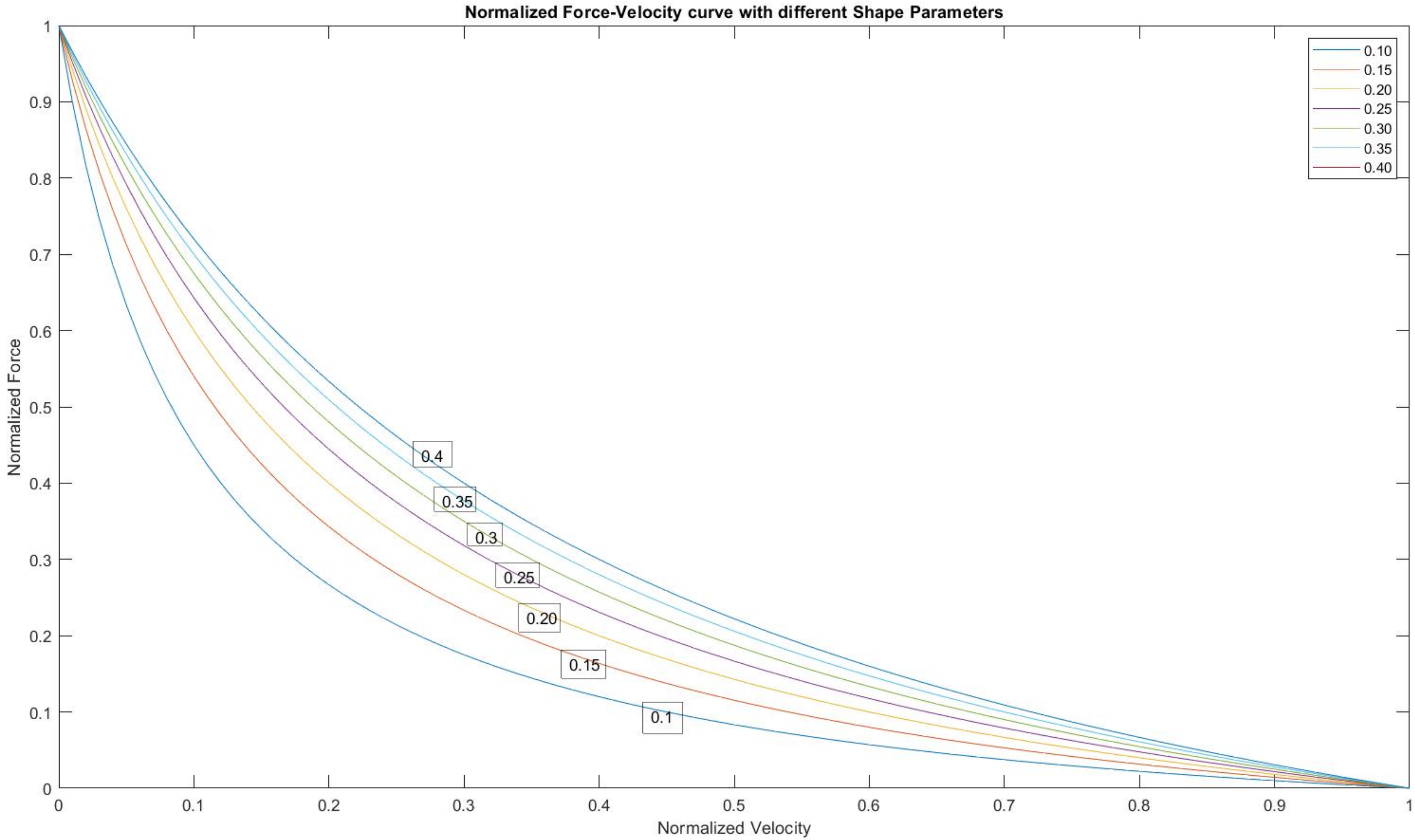
Given Moment arm = 0.033
Maximum external moment (N-m)
Knee angle (deg)
190
180
170
160
150
140
130
120
110
90
100
110
120
130
140
150
160
170
180


Maximum external moment (N-m)
210
200
190
180
170
160
150
140
130
120
110
90
100
110
120
130
140
150
160
170
180
Knee angle (deg)
Moment arm +10%


Moment arm -10%
Maximum external moment (N-m)
Knee angle (deg)
170
160
150
140
130
120
110
90
100
110
120
130
140
150
160
170
180

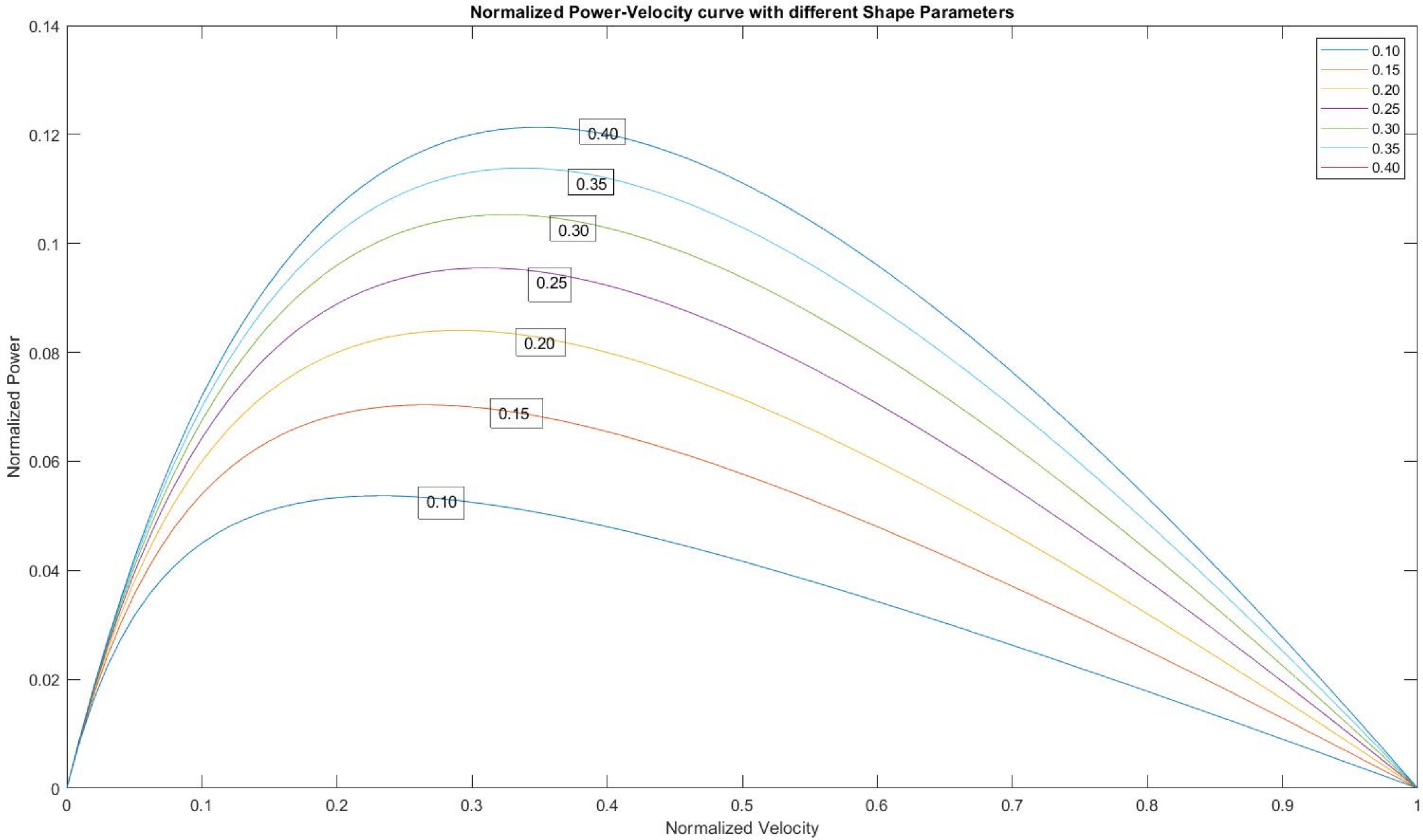
c) :- A quasi-static load is time dependent but is slow enough that we can neglect inertial effects. However, for a non-quasi-static load, which is also time dependent, inertial effects cannot be ignored. For non-quasi-static or dynamic situation, velocity is not assumed to be zero and we have to consider the effect of velocity on maximum moment curve. Muscles which have larger moment arms experience higher contraction velocities. Therefore, muscle with large moment arms will shorten at higher velocity, lowering active muscle force impacting moment developed by muscle. Muscle moment depends on both muscle force and moment arm and therefore lower contraction velocities will generate more force leading to higher maximum moment curve. The inertial loads provide dynamic information on each body segment and the effect of the inertial forces and moments becomes more important as the speed of locomotion increases. Dynamic extension may cause postactivation potentiation which Improves muscle performance after previous contraction. This results in improvement in strength and power as compared to quasi-static extension. Thus, dynamic extension enhances muscle moment causing improved muscular performance of the stretched muscle group. The relation between force-velocity helps us to understand the effect of contraction velocity on muscle moment curve.

Problem 2a):



Normalized Force-Velocity curve with different Shape Parameters
Normalized Force
Normalized Velocity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.4
0.35
0.3
0.25
0.20
0.15
0.1

Problem 2b):


Normalized Power-Velocity curve with different Shape Parameters
Normalized Power
Normalized Velocity
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Problem 2):-

b) :- From the plot (a), it can be seen that, as shape parameter 'af' increases, the force-velocity curve shift upwards. This means that for a velocity, with higher shape parameter muscle generate force. We get higher muscle fiber force for same velocity with higher shape parameter. Also, as shape parameter increases the curve tends to become more linear.

From the plot (b), we can see that, as shape parameter 'af' increases, the power-velocity curve shift upwards as well as towards right. As shape parameter increases, we get maximum power as compared to the previous value and also the velocity at which we get the maximum power shift towards right i.e. at higher contraction velocity than the previous curve with lower shape parameter.

Shape parameter may be a quantity which is analogous to musculotendon structure of a particular individual. Higher shape parameter may be analogous to an individual's ~~general~~ musculotendon architecture generating more force and power compared to other individual with lower shape parameter.

c):- By using different shape parameter values, the muscle force as well as the muscle moment changes. As the shape parameter increases, the muscle fiber force increases. Therefore, higher shape parameter gives higher force generation capacity of muscle fiber.

Also, as shape parameter increases the power capability of muscle fiber increases. From the earlier plots, it can also be seen that the muscle needs higher contraction velocity to generate maximum power with higher shape parameter. This gives more strength and performance because of higher shape parameters while stretching or other exercises.

As, muscle moment depends on muscle fiber force as well as on moment arm, it also experiences change in its values as shape parameter changes. As we discussed earlier, higher shape parameter gives higher force generation leading to increase in muscle moment while extension. Therefore, as shape parameter increases, we could see maximum muscle moment while running or other activities at the knee joint.

Problem 3):

a) :- "Clean and Jerk"

The joint moves through a range of motion at a constant angular velocity of 100°/sec. And for this case, the winning muscle is which produces most force at the instant that it reaches optimal fiber length.

We know that, for muscle moment,

$$\Sigma M_A = F_i^{GRF} l_i - W_{foot} c - F_i^M r_i = 0$$

A → Ankle joint

$$\text{and} \quad F_i^M = \frac{F_i^{GRF} l_i - W_{foot} \cdot c}{r_i}$$

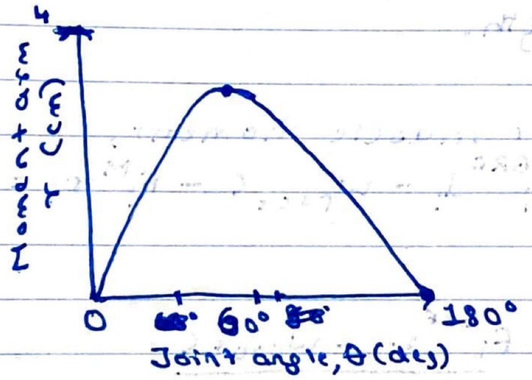
$\therefore$ If r_i is small, F_i^M is large.

Therefore, in this case, Franz will win because he has the smaller moment arm which will allow ~~to~~ him to contract force faster than Hans and also the force will be maximum at optimal fiber length for Franz.

→

b):-

"60° Torque-off": It is given that each joint is fixed at 60° and the winning muscle is that which produces the largest torque during an isometric contraction. We have to assume that each muscle is at optimal fiber length when the joint is at 60°.



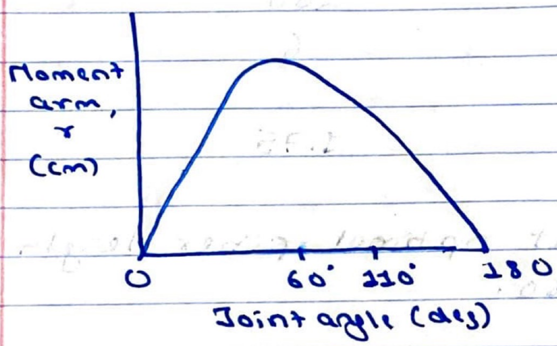
Moment arm and joint angle reaches a peak in the middle of the range of motion.

Since we are operating before the optimal fiber length, the muscle fiber force starts to increase in this region. And we also the relation $r = \frac{dl^{MT}}{d\theta}$ where r is moment arm.

Larger r means larger displacement of muscle fiber length. Therefore, a larger displacement ~~from~~ a ~~before~~ at optimal fiber length means a large gain in force and therefore Hans will win as he have larger r value and therefore higher force and higher torque.

c) :-

"110° Torque-off". It is given that each joint is fixed at 110° and the winning muscle is that which produces the largest torque during an isometric contraction.



In this case, as we are operating after the optimal fiber length, the muscle fiber force starts to decrease in this region.

Larger r means smaller displacement of muscle fiber length. Therefore, a larger displacement after optimal fiber length will lead to large drop in force. Thus, Franz will be the winner as he has lower r value giving him higher force and higher torque.

d):-

"60° Torque-off" re-match:

	Hans	Franz
Fmax (N)	150	200
Optimal fiber Length (cm)	9	6
Moment arm (cm)	2	1.75

Each muscle is at optimal fiber length when the joint is at 60°.

∴ For Hans, $(\text{Torque})_{\text{Hans}} = 150 \times 9 = 1350$ N.cm

For Franz, $(\text{Torque})_{\text{Franz}} = 200 \times 6 = 1200$ N.cm

∴ Hans will still win 60° Torque off match.

e)

"110° Torque-off" rematch:
From the above data,

$(\text{Torque})_{\text{Hans}} = 150 \times 2 = 300$ N.cm

$(\text{Torque})_{\text{Franz}} = 200 \times 1.75 = 350$ N.cm

∴ Franz will still win 110° Torque off challenge.

f):- The human body have redundant muscles to support other muscles that have the same function in our body. Our body has redundant anatomical degree of freedom (DOF) which are present at muscles and joints. Also, we have redundant kinematic DOF i.e. movement which can have different velocities and accelerations but will still achieve same goal. If both the muscles i.e. Hans and Franz were working on a same function in our body, they would be supporting that action, even if one fails.

Problem 4):

"Built for speed: musculoskeletal structure and sprinting ability"

Limitation: In the article it is given that short moment arms lead to increased storage of elastic energy in the Achilles' tendon and reduce metabolic energy consumption, however there was no link established between heel length and running performance. The authors did not count for sarcomeres, they cannot draw conclusions about the optimal fibre lengths of the subjects. Their ~~author also~~ approach did not include the multiplanar nature of natural ankle complex rotations. Fascicle lengths measured by the approach may not be indicative of muscle fibre lengths. Also, fascicle paths does not approxi- ~~mated~~ mates by straight lines in the plane of ultrasound image. Fibre thickness effects were not accounted in the approach. In their experimental study, training methods and muscle composition did not considered for many factors. The simple planar nature and lack of hip and knee joints made it ill-suited for examination of the effects of foot rotation and potential benefits of shorter lower legs. Also, the experimental study was conducted on 12 sprinters and 12 height-matched non-athletes which could not be generalized for total sample population.
It is also difficult to find the bony region on the body to account less for error due to fat.