APA 4311
Sample Midterm Examination

1. (a) Compute the **radius of gyration** of the swing phase thigh at frame 12 about its centre of gravity.
(b) Compute same thigh's **moment of inertia** about its centre of gravity for the same frame.

Total body mass: 70.0 kg
Camera frame rate: 60.0 frames/second

	P	R	K
thigh	0.100	0.400	0.600
leg	0.050	0.450	0.500
foot*	0.020	0.500	0.650

P = segment mass as fraction of total body mass
R = distance to centre of gravity from proximal end as proportion of segment length
K = radius of gyration about centre of gravity as proportion of segment length
* foot's endpoints as ankle and ball

2. Using the anthropometric information and marker coordinates, compute the **segmental and total centres of gravity** of the right (swing phase) limb at frame number 13.

3. Using the tables provided, compute the **linear velocity** of the toes marker of the (swing phase) limb at frame number 13.

4. Using the following tables, compute the **angular acceleration** of the leg of the (stance phase) limb at frame number 13.

	Marker: / Frame:		Hip	Knee	Ankle	Heel	Ball	Toes	Thigh angle	Leg angle	Foot angle
	11	X	110.8	107.5	76.7	68.1	78.2	88.9	84.8	42.9	133.7
		Y	104.3	68.3	34.8	32.4	21.7	18.6			
Right	12	X	113.6	111.6	79.4	70.6	79.3	89.3	86.7	39.0	125.5
		Y	104.1	68.0	36.7	35.6	23.4	18.7			
Limb	13	X	116.3	116.0	82.5	73.7	81.0	90.0	89.5	35.0	118.2
		Y	104.0	67.9	40.7	41.9	27.5	19.4			
(swing)	14	X	119.0	120.5	86.0	77.3	83.3	91.6	92.4	31.5	112.6
		Y	103.9	67.9	40.7	41.9	27.5	19.4			
	15	X	121.6	125.0	89.8	81.2	86.4	94.0	95.5	28.6	109.1
		Y	103.9	68.1	42.6	44.5	29.5	20.1			
	11	X	114.9	129.4	134.8	129.6	145.2	157.5	113.4	94.5	178.6
		Y	107.5	74.2	27.0	19.5	19.2	21.0			
Left	12	X	117.2	131.3	134.9	129.5	145.2	157.5	112.9	92.1	178.2
		Y	108.1	74.1	27.0	19.5	19.0	20.7			
Limb	13	X	119.3	133.1	135.0	129.5	145.1	157.5	112.0	90.1	178.1
		Y	108.6	74.6	27.1	19.5	19.0	20.5			
(stance)	14	X	121.5	134.6	135.1	129.5	145.1	157.6	111.0	88.3	178.1
		Y	109.0	74.7	27.1	19.5	19.0	20.5			
	15	X	134.7	136.0	135.2	129.5	145.1	157.7	109.7	86.7	178.3
		Y	109.4	74.7	65.9	27.2	19.1	20.5			

Solutions

1. $length_{thigh} = [(113.6-111.6)^2 + (104.1-68.0)^2]^{0.5} = 36.16$ cm
   (a) $k_{cg} = length_{thigh} \times K_{cg} = 21.7$ cm $= 0.217$ m
   (b) $I_{cg} = m_{thigh} (k_{cg})^2 = 0.330$ kg.m^2

2. $x_{thigh} = x_{prox} + R_{prox.} \times (x_{dist} - x_{prox}) = 116.2$ cm
   $y_{thigh} = y_{prox} + R_{prox.} \times (y_{dist} - y_{prox}) = 89.6$ cm
   $x_{leg} = 100.9$ cm
   $y_{leg} = 55.7$ cm
   $x_{foot} = 81.8$ cm
   $y_{foot} = 34.1$ cm

   $P_{limb} = P_{thigh} + P_{leg} + P_{foot} = 0.02 + 0.05 + 0.10 = 0.17$
   $x_{limb} = (1.0/P_{limb}) \times [(x_{thigh} \times P_{thigh}) + (x_{leg} \times P_{leg}) + (x_{foot} \times P_{foot})]$
   $y_{limb} = (1.0/P_{limb}) \times [(y_{thigh} \times P_{thigh}) + (y_{leg} \times P_{leg}) + (y_{foot} \times P_{foot})]$
   $x_{limb} = (1.0/0.17) \times [(116.2 \times 0.10) + (100.9 \times 0.05) + (81.8 \times 0.02)] = 107.6$ cm
   $y_{limb} = (1.0/0.17) \times [(89.6 \times 0.10) + (55.7 \times 0.05) + (34.1 \times 0.02)] = 73.1$ cm

3. $v_x = (x_{14} - x_{12}) / 2t$
   $v_y = (y_{14} - y_{12}) / 2t$
   $v_x = (91.6 - 89.3) / (2/60) = 69.0$ cm/s
   $v_y = (19.4-18.7) / (2/60) = 21.0$ cm/s
   $\underline{\mathbf{v}} = (0.690, 0.210)$ m/s **or** 0.721 m/s at 16.93 deg

4. $\alpha = [\theta_{11} - (2 \times \theta_{13}) + \theta_{15}] / 4t^2$
   $\alpha = [94.5 - (2 \times 90.1) + 86.7] / 4 \times (1/60)^2 = 900$ deg/s^2 **or** 15.71 rad/s^2