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LEG PROSTHESIS

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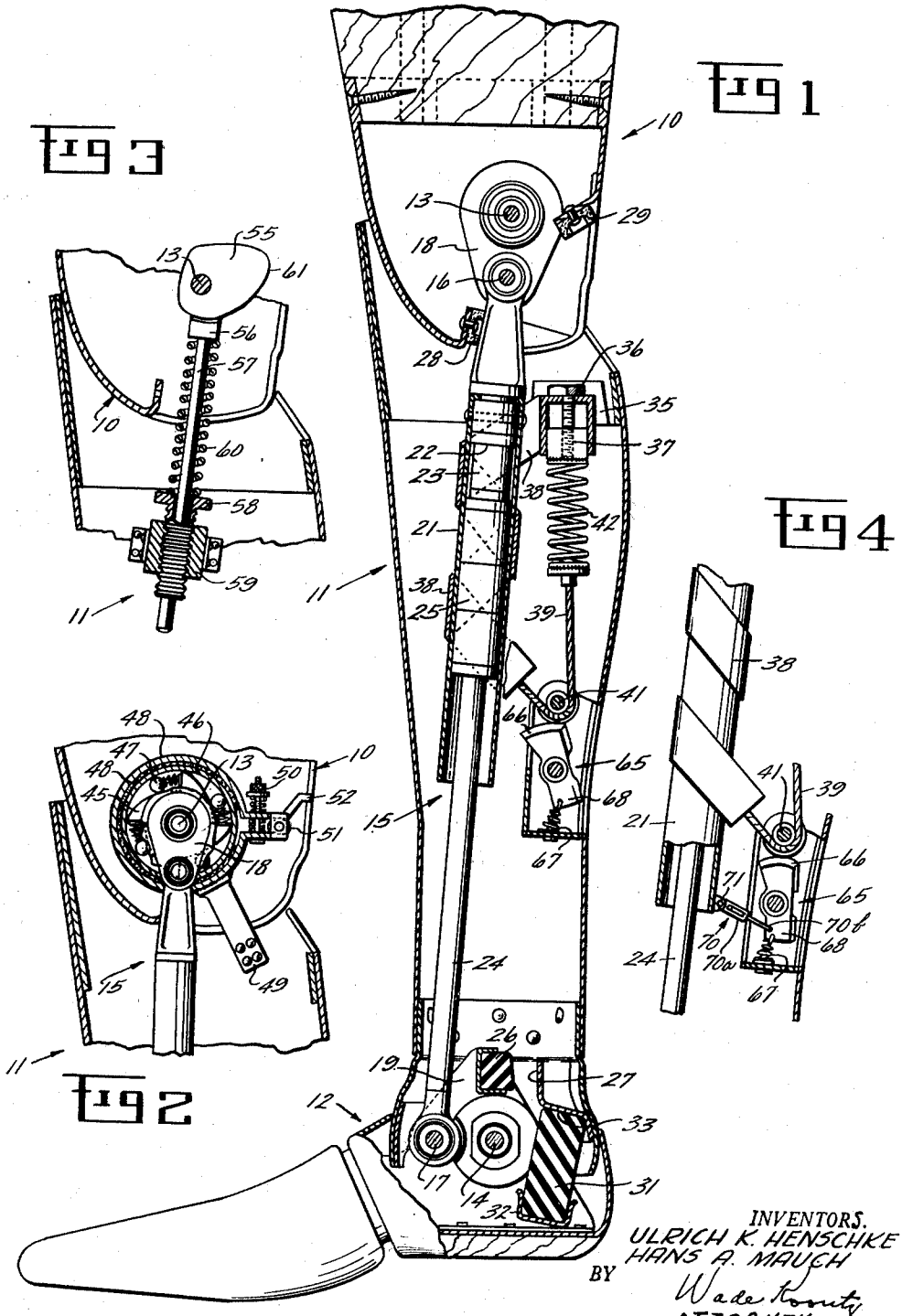

Fig 1

Fig 3

Fig 4

Fig 2

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LEG PROSTHESIS

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to artificial legs for above the knee amputees and more particularly to pantograph and knee brake means for controlling the knee and foot under normal conditions of use.

In the course of the last decades, it was often tried to improve artificial legs by simulation of movement not only of the normal knee joint, but also of the normal ankle. For this purpose, it was suggested to couple the ankle movement with the knee movement by a pantograph, or an equivalent kinetic arrangement, which consists of the knee joint and the ankle joint of the prosthesis and of two other fulcrums, one of them located in the foot part and the other in the thigh part of the prosthesis. Contrary to expectations, this arrangement did not succeed in practice. This is due to the fact that an extraordinary variety of movements is possible with the pantograph, depending on the chosen arrangement, and that it is extremely difficult to find a solution out of this variety which is most suitable to simulate the movement of the natural ankle in dependence upon the bending of the knee joint. The main disadvantages of the device of this kind, suggested until now, lay in the fact that the stability of the prosthesis for stretched knee joint and for the shifting of the body's weight on the ball of the foot was so much impaired that amputees voiced their open disapproval of such artificial limbs. The reduction of the stability is due to the fact that the pantograph used exerts not only torque moments from the knee joint to the ankle but also in the reverse direction creating, during the standing on the ball of the foot and for unsuitable arrangements of the fulcrums of the pantograph, torque moments in the knee joint which tend to bend the knee and thus jack-knife the prosthesis.

It is also well known that the leg prosthesis with artificial knee joint can be considerably improved in function if the lower leg is not pivoted freely in the knee joint, but if certain friction or spring forces are provided during the bending of the knee which control the movement of the lower leg. Such devices were constructed in different types and the intended improvements were achieved to a certain degree. An optimal simulation of the function of the normal leg, however, was not achieved. That is, the course of the movements of the artificial leg could not be controlled in such a way that in all types of gait,

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short and slow steps, short and quick steps, long and slow steps, long quick steps, an optimal approach to the natural pattern was accomplished without disadvantages in other common positions of the prosthesis, as for example, while bent in the sitting position.

The present invention aims at achieving the simulation of natural leg movement by producing a pantograph wherein the advantages of natural ankle movement are accomplished without disadvantages and optimum knee movement is achieved by utilization of a knee brake in cooperation with the pantograph. The basic idea of the present invention is the choice of the fulcrum in the thigh part in such a way that it is in relation to the knee joint in or nearly its dead point when the prosthesis is straight and by this choice of the fulcrum in the thigh part forces of any magnitude can be exerted on the ball of the foot without creating torque moments in the knee joint. This is due to the fact that these forces act in an arrangement, according to the invention, upon the upper or the lower dead point of the knee joint and thus do not create torque moments. The fulcrum point in the thigh and foot parts are connected by a cylindrical element which is operatively associated with a spring biased friction member that is arranged to exert forces against the bending of the knee several times stronger than the straightening effect. These forces, by the arrangement of the fulcrum point of the pantograph, become zero in the sitting position of the prosthesis. Very favorable results are realized in these principles in that sudden rising of the lower leg towards the rear, after it leaves the ground, is avoided by the relatively strong resistance opposing knee bending during the forward movement of the artificial leg; and that in the next phase the same forces do not pull the lower leg, or shank, forward too quickly and too violently.

It would appear that one disadvantage in the prosthesis of the present invention lies in the fact that there are positions of the prosthesis in which the pantograph has undesirable effects. This is chiefly the case in the sitting position of the prosthesis because the foot would be dorsalflexed. In order to avoid this, provisions are made according to the invention which make possible the required horizontal of the foot part of the prosthesis in the sitting position as an exception of the proper action of the pantograph. This is accomplished by a change of the length of the elements which connect the fulcrum in

the foot with the fulcrum in the thigh after overcoming a certain minimum friction. By this arrangement, amputees are able to keep the sole of the foot of the artificial leg in its whole length on the floor while sitting down. For this purpose, it is only necessary to keep a certain fraction of the body weight on the artificial leg during the sitting down exercise in order to cause a change of length of the pantograph members against the friction forces thus avoiding the rising of the toes on the floor. The same change of these elements occurs during normal walking while stepping with the heel first contacting the ground floor.

There are times when the forces exerted to control the operation of the knee brake are undesirable and disadvantageous, as for example, when bicycling. The present invention also provides a means to disable the knee brake in order to permit the knee joint to work freely. In this manner, the amputee will not have to overcome the friction and spring forces of the knee brake which would normally require considerable physical effort.

It is a primary object of this invention to provide an artificial leg for above the knee amputees that permits normal use of the leg with little effort.

It is another object of this invention to provide an artificial leg for above the knee amputees that produces related foot and knee movement simulating normal movement of a physical leg.

It is still another object of this invention to provide an artificial leg for above the knee amputees having means to exert forces opposing knee bending that are greater than the forces exerted during knee straightening and wherein the stretching effect becomes zero in the sitting position of the prosthesis.

It is a further object of this invention to provide an artificial leg for above the knee amputees having pantograph means for producing relative ankle and knee movement and a knee brake means operatively associated with the pantograph to exert forces opposing knee bending that are greater than the forces exerted during knee straightening.

A still further object of this invention is to provide an artificial leg for above the knee amputees in which a pantograph has a fulcrum point on the foot part approximately in line with the pivotal point of the knee and fulcrum point of the thigh when the leg is in a straight position to avoid transmission of torques placed on the foot part to be placed on the knee joint through an element connecting the fulcrum points, the connecting element consisting of two members impositively retaining the element at a predetermined length to permit ankle movement in one direction without influencing the knee joint, and a knee brake interconnecting the pantograph element to control the operation of the knee joint in the manner of a normal leg.

It is still a further object of this invention to provide an artificial leg for above the knee amputees having a pantograph including an element connecting the ankle and knee joints at fulcrum points, the fulcrum point of the knee joint being eccentric to the pivotal point of the knee, and a friction element resiliently biased around the pantograph element and anchored to the leg shank in the manner to exert a frictional resistance to knee bending which is greater than the stretching force exerted during knee straightening whereupon simulated ambulatory motion of a normal physical leg is accomplished.

It is still another object of this invention to provide an artificial leg having a pantograph for producing relative ankle and knee movement with a knee brake operatively related to the pantograph to control the knee joint in a manner corresponding to natural knee action wherein a knee brake disabling means is associated with the knee brake to selectively render the knee brake inoperative to permit free operation for bicycling, or the like.

These and other objects and advantages will become more apparent as the description proceeds when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a sectional view of an artificial leg with parts shown therein in accordance with this invention;

Fig. 2 is a sectional view of a modification of a knee brake constructed in accordance with this invention;

Fig. 3 is another form of knee brake shown partly in section; and

Fig. 4 is a view partly in section of the knee brake lock and related parts with parts included to provide automatic actuation of the knee brake lock.

Referring now more particularly to Fig. 1, there is shown an artificial leg having a thigh part 10, a shank part 11 and a foot part 12. The shank part 11 is journaled to the thigh part 10 at 13 constituting a knee joint and the foot part 12 is journaled to the shank part at 14 constituting an ankle joint.

A pantograph arrangement producing relative ankle and knee movement is accomplished by connecting the thigh part 10 to the foot part 12 through a connecting element 15 which is pivotally connected at the fulcrum points 16 and 17. The fulcrum point 16 is established by a plate or yoke 18 that is in fixed relation with respect to the thigh part 10 and may, as shown in the preferred form, be the journal portion of the thigh part. The fulcrum point 17 is fixed by a member 19 made integral with the foot on which is one pivotal element forming the fulcrum point 17 and which at the same time provides a support for the ankle joint 14. The fulcrum point 17 rotates in an arc forward of the ankle joint 14 while the fulcrum point 16 rotates through substantially 90 degrees, the initial straight leg position bringing the points 13, 16 and 17 into alignment producing a position of the leg in which the foot, having a shoe thereon, would be flat on the floor with the leg in the upright position.

The connecting element 15 consists of an upper cylindrical component 21 closed at one end 22 and having a resilient element, as a rubber or a spring, 23 therein, and a rod part 24 having a piston 25 thereon operable within the cylindrical component and engageable with the resilient element 23. Upon the knee being bent from the straight position, the foot 12 can be rotated in the ankle joint 14 to raise it with respect to the shank 11 until a resilient bumper as rubber 26 supported by the foot element 19 strikes a stop 27 formed in the shank 11, and any further bending of the knee pulls the piston 25 outwardly away from the bumper 23. The knee rotation is limited by stops 28 and 29 fixed on the thigh part 10 engageable with the connecting element 15. The rotation of the foot 12 in the ankle joint 14 is limited in its counter-clockwise direction by a

resilient member 31, as a rubber block or a spring confined between a cup 32 within the heel of the foot 12 and a support 33 in the shank 11. Extreme pressures applied on the heel or toe portions of the foot 12, as may be expected in the normal use of the leg, will be cushioned by the resilient members 31 and 23 respectively.

Fixed within the shank 11 near the upper end is a bracket 35 rotatably supporting a cap screw 36 threadedly engaging a nonrotatable, reciprocal nut 37. A strap 38 has one end angularly secured to the bracket 35 and wrapped about one and one-half times over the cylindrical component 21 of the connecting element 15. The other end of the strap 38 is connected to the nut 37 by a spring 42 and a cord 39 passing over a pulley 41 mounted on the shank 11. The tension of the strap 38 is adjustable by the cap screw 36 to increase or decrease the friction between the strap and the surface of the cylindrical component 21. Upon knee bending, the cylindrical component 21 will move forward in the shank stretching the spring 42 and causing, additional to the spring force, frictional resistance between the band 38 and surface of the cylindrical component 21. Straightening action of the leg causes the cylindrical component 21 to advance toward the back of the shank 11 which allows the spring 42 to retract. In this case the frictional forces between the band 38 and the surface of the cylindrical component 21 diminish the force of the spring 42 because the motion is reversed now which produces relatively smooth knee straightening. While strap and cord means 38 and 29 are shown and preferred, it is to be understood that other frictional connecting elements may be used to produce like results.

It is also to be understood that other forms of knee brakes may be produced in the manner of applicant's teachings. As shown in Fig. 2, an overrunning clutch may be used to provide considerable resistance to knee bending and relatively free movement during knee straightening action. The member 18 is fixed with respect to a cammed member 45 that rotates within a drum 46 retained thereon in any well known manner. Balls 47 are retained within the drum 46 and spring biased to their clutching or wedging position between the cammed portions and the drum as is well known in the art. Around the drum 46 is a brake band 48 which is fixed with respect to the shank 11 by the bracket 49 whose frictional resistance on the drum is adjustable by the nut 50 as is familiar to those skilled in the art. Upon knee bending, the cam member 45 rotates clockwise with respect to the drum 46 whereupon the balls 47 wedge between the cam surfaces and the drum 46 carrying the drum against the resistance of the brake band 48 to resist knee bending. During straightening action of the knee, the cammed member 45 rotates counterclockwise with respect to the drum wherein the balls slide around the inner surface of the drum 46 and cause no slip between the drum 46 and band 48. This latter action provides a substantially free knee straightening motion as is desirable for the amputee using the leg. A cammed member 51 is rotatively mounted with respect to one end of the band with a lever 52 thereon to permit the amputee to disable the clutch at will.

In another modification shown in Fig. 3, thigh part 10 has an irregular cam 55 fixed with respect thereto. Frictionally engaging the surface of cam 55 is a cam follower member 56 supported by a shaft 57 slidable through an elongated nut 58 threadedly mounted in a block 59 fixed to the shank 11. The cam follower member 56 is resiliently held against the surface of cam 55 by a spring 60 compressed between the cam follower 56 and the nut 58 the compression of which is adjustable by the threaded position of the nut 58. The surface of the cam 55 is so contoured that the cam follower 56 will be moved to increasingly compress the spring 60 upon the knee being bent toward a sitting position to resist such knee bending motion. The amount of resistance to knee bending offered may be selected by choice of cam contours. The resistance is greatly reduced during the knee straightening motion since the friction between 55 and 56 works now in the reverse sense and diminishes the stretching action of the spring 60. The cam surface is also contoured at 61 such that in the sitting position the prosthesis the cam follower will be riding cam portion 61 in which the spring compression remains constant and the shank will not be easily disturbed in either direction of movement.

Returning again to the preferred construction shown in Fig. 1, it may become necessary for an amputee wearing the leg of the type shown to condition the leg for free knee action in either direction, as for bicycling or the like. To accomplish this, a latching member 65 is pivotally supported from the shank 11 and has an end cam portion 66 eccentric to the pivot of the member and engageable with the cord 39 at a point where the cord passes over the pulley 41. An overcenter spring 67 is seated at one end of a bracket fixed to the shank 11 and the other end pivotally connected to the lower portion 68 of the latching member 65 such that in the position shown in Fig. 1 the cam portion 66 is removed from the cord 39 to allow operation of the knee brake. An inward pressure on the lower portion of the latching member 65 compresses the spring 67 through its overcenter position to bring the cam portion 66 into engagement with the cord 39. The cord 39 can now pass clockwise over the pulley 41 but is prevented from passing counterclockwise over this pulley. This permits an amputee to condition the leg for walking in which the knee brake is operable, or to switch the latch member 65 to render the strap 38 frictionally ineffective to resist any movement for such periods of bicycling or like uses in which it would be fatiguing for the amputee to overcome the frictional forces of the knee brake with his good leg. If the latching member is switched to disable the knee brake for bicycling when the knee is substantially straight, the first knee bend will have to be made against the spring and frictional forces of the knee brake but thereafter these forces are disengaged until the latching member 65 is switched back to its original position shown in Fig. 1.

The latching member 65 may be operated automatically by making it dependent on the angular respective positions of the thigh and shank. As illustrated in Fig. 4, a link element 70 is pivotally connected to the lower ends of the cylinder 21 by hook and eye or other suitable means 71 and to the latching member 65 by one end of the link element passing through a hole in the lower portion 68 thereof. The link element 70 consists of two parts 70*a* and 70*b* which are telescoping parts limited in movement by an outwardly turned end of the part 70*b* slidable in a slot in the part 70*a*. The slot in the part 70*a* is of such length that the part 70*b* will engage the end

of the slot and thereafter impart movement to the latching member 65 at desirable angles of the knee. For example, the most probable arrangement would be that when the knee approaches the extreme bent position in which the bumper 29 limits the knee bend the cylinder 21 will withdraw from the latching member 65 and the part 70b of the link 70 will engage the right hand end of the slot in part 70a and trip the latch member 65 over center in a clockwise direction to bring the cam 66 into engagement with the cord 39. The knee brake is then ineffective to offer any resistance to knee action until the knee approaches the straight position and cylindrical member 21 strikes the stop 28 wherein the cylindrical member 21 moves toward the latching member 65 to bring the part 70b into engagement with the left hand end of the slot in part 70a to transmit motion to the latching member 65 rotating it over center of the spring 67 to remove the cam portion 66 away from the cord 39 thus rendering the knee brake again effective. In a somewhat similar manner, the latching member 65 could be mechanically connected to a thigh part to provide automatic operation thereof.

It is believed that the use of the artificial leg incorporating this invention will be apparent and the advantages pronounced in view of the above description, but a better understanding may be had if certain advantages are explained in the operation of the device. An amputee using an artificial leg of the above described type can walk in a more normal manner. Upon taking a step forward with the artificial leg, the heel will first engage the floor which will be cushioned by the resilient member 31 at the same time causing the connecting member 24 with the piston 25 to slide outwardly of the cylindrical component 21. The frictional resistance between the piston 25 and the cylindrical component 21 is provided on the most part by the action of the spring 42 to pull the center portion of the connecting element 15 laterally. As the weight of the amputee passes over the leg the knee will remain straight and weight will be increasingly placed on the ball of the foot until the leg is substantially straight with the body. As the leg passes behind the amputee's body the connecting member 24 with the piston 25 will slide inwardly of the cylindrical component 21. Just prior to the amputee setting his good foot down for taking a step, the weight of the amputee is substantially on the ball of the foot 12 which cushions the amputee by reason of the resilient block 23. The initial bending of the knee is relatively easy since the initial arc of the fulcrum point 16 is in or near the dead center position and the pressure on the ball of the foot can not exert any torque on the knee joint. After a slight bend of the knee the strap 38 will begin to slip which offers together with the spring 42 resistance to further knee bending. Resistance offered by the knee brake means may be adjusted to meet individual amputees. The knee of the artificial leg will now proceed to bend and the toe will move upwardly until the bumper 26 rests against the stop 27 thus permitting the amputee to carry this leg forward for another step without striking the floor. The shank 11 will swing into a straight leg position smoothly since the connecting element 15 is traveling towards the spring 42 and the friction of the strap 38 over the cylindrical component 21 reduces now the force of the spring 42.

The amputee may be able to ride a bicycle with comparative ease by switching the latch means

65 to bring the cammed portion 66 into engagement with the cord 39, or if this latching means is automatic the leg must be positioned to switch the latch 65. In either case, cord 39 will be pulled upon knee bending which stretches spring 42 and the latching member 65 will hold the spring 42 stretched leaving the strap 38 limp and ineffective to function as a knee brake. The amputee may then pedal to propel the bicycle without having to overcome spring and friction forces of the knee brake. Switching the latch member 65 back to the position shown in Fig. 1 places the knee brake immediately back in operation for walking, or the like.

There are no undesirable strains, awkward or unsightly positions of the amputee in the normal use of the above described leg as often realized in standing or sitting positions. Since the pantograph arrangement provided by the points 13, 14, 16 and 17 has fulcrum points 16 and 17 in substantial alignment with the knee pivotal point 13 when the leg is in its straight position, a turning torque can not be applied to the knee against which the amputee must muscularly resist. When the amputee sits down, the knee would be bent substantially 90 degrees wherein the pantograph tries to raise the toe of the foot 12 with respect to the shank until the bumper 26 engages stop 27. To keep the foot flat on the floor during the sitting down exercise, the amputee merely must apply a slight downward pressure on the shank sufficient to overcome the frictional resistance between the cylindrical component 21 and the piston 25. The foot will then remain flat without any effort being exerted and subsequent standing or walking will return the foot to its normal position. In the sitting position, furthermore, fulcrum point 16 is in front of the knee pivotal point 13 whereby the pulling force of the spring 42 can not act. Thus, the prosthesis is prevented from unintentional straightening which could cause disagreeable incidents.

It is to be understood that various modifications and changes may be made without departing from the spirit and scope of our invention and we desire to be limited only by the scope of the appended claims.

We claim:

1. In a thigh prosthesis having a knee joint joining a socketed thigh part with a shank part and an ankle joint joining the shank part with a foot part comprising; a pantograph and knee brake, a fulcrum journal in said foot part forward of said ankle joint, a fulcrum journal in said thigh part in substantial alignment with and between said knee joint and the fulcrum in said foot part when the leg is extended, the two fulcrum journals being joined by an extensible element impositively held in a predetermined contracted position to enable said extensible element to provide dorsal flection of the foot relative to knee bending for normal leg movements and desirable foot extension during knee bending by slight pressure on the heel of the foot to lengthen said extensible element, and said knee brake being selectively operable to control said knee joint in accordance with selected walking conditions whereby various leg uses are simulated and the thigh prosthesis is not subjected to jack-knifing during standing of the wearer and the foot may be placed flat on the floor during the sitting position of the wearer.

2. A thigh prosthesis as set forth in claim 1 wherein said selectively operable knee brake is

a clutch in which a frictional band is wound around said extensible element and adjustably biased to said shank behind said extensible element whereby the knee bending operation increases said biasing means thus increasing the frictional slip between said frictional band and said extensible element, and leg straightening reduces said brake friction.

3. A thigh prosthesis as set forth in claim 1 wherein said selectively operable knee brake is an overrunning clutch operatively connected between said thigh and shank parts to frictionally retard knee bending and permit substantially friction free leg extending to provide simulated foot and leg motions.

4. In a thigh prosthesis having a knee joint journaling a socketed thigh part with a shank part and an ankle joint journaling said shank part to a foot part, the improvement which comprises; a pantograph including a fulcrum journal in said foot part forward of said ankle joint, a fulcrum journal in said thigh part removed from said knee joint and adapted to be in substantial alignment with and between the fulcrum journal of said foot and said knee joint when said shank is extended and rotatable forward about said knee joint upon knee bending, and an extensible element connecting the two said fulcrum journals to provide relative dorsal foot flection with knee bending and lengthening of said extensible element to extend the foot for some conditions of knee bending, said extensible element having a smooth outer cylindrical surface; a frictional strap element wrapped around the smooth outer surface of said extensible element the strap ends of which are attached to the back wall of said shank, one end being connected to the back wall of said shank through a spring adjustable to tension said strap on said extensible element whereby knee bending motion is restricted by the friction and the spring forces of the strap element and the spring as a result of the extensible element being withdrawn from the back wall of said shank causing said strap element to unwind and said spring to stretch, bending said knee to the sitting position such that the fulcrum journal in said thigh moves in an arc of which said extensible element is substantially tangent reduces said spring and said friction forces to zero, and knee straightening motion is substantially free from resistance as a result of the extensible element approaching the back wall of said shank to rewind said strap element and reduce spring tension; and a switching means operable to render said spring ineffective to allow free movement of the knee joint in either direction.

5. A thigh prosthesis as set forth in claim 4 wherein a flexible tension member connects said one end of the strap element with said spring by passing said tension member over a pulley, and said switching means includes a lever with an eccentric cam surface selectively engageable with said flexible tension member adjacent said pulley adaptable to hold said flexible tension member against the tension of said spring to loosen said strap about said extensible element.

6. A thigh prosthesis having a knee joint journaling a socketed thigh part with a shank part and an ankle joint journaling said shank part to a foot part, the invention which comprises; a pantograph means connecting said thigh and foot parts to provide related knee and foot movements; a knee brake including strap means operative to frictionally resist knee bending in accordance with strap tension, said strap tension being provided by one end of the strap being securely fastened to said shank and the other end connected by a flexible tension member passed over a pulley to a spring adjustably attached to said shank; and a lever spring biased to either of two limited positions, said lever having an eccentric cam portion adaptable in one of said limited positions to engage said flexible tension member opposite said pulley to restrain said spring from tensioning said strap whereby said knee brake is ineffective allowing free knee and ankle movement.

7. A thigh prosthesis comprising socketed thigh, shank and foot parts journaled at knee and ankle joints in a manner corresponding to a natural leg; a selectively engageable knee brake means including a cylindrical member connecting said thigh and shank parts, the connection of said cylindrical member in said thigh part being on a journal removed from said knee joint to produce angular movement of said cylindrical member upon knee bending; and a friction member wound about said cylindrical member and adjustably and resiliently biased to said shank in a manner to cause unwinding of said friction member during knee bending producing increased spring and friction forces on said cylindrical member opposing the bending movement and to cause winding of said friction member during knee straightening producing relatively reduced spring and friction forces opposing knee straightening movement.

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