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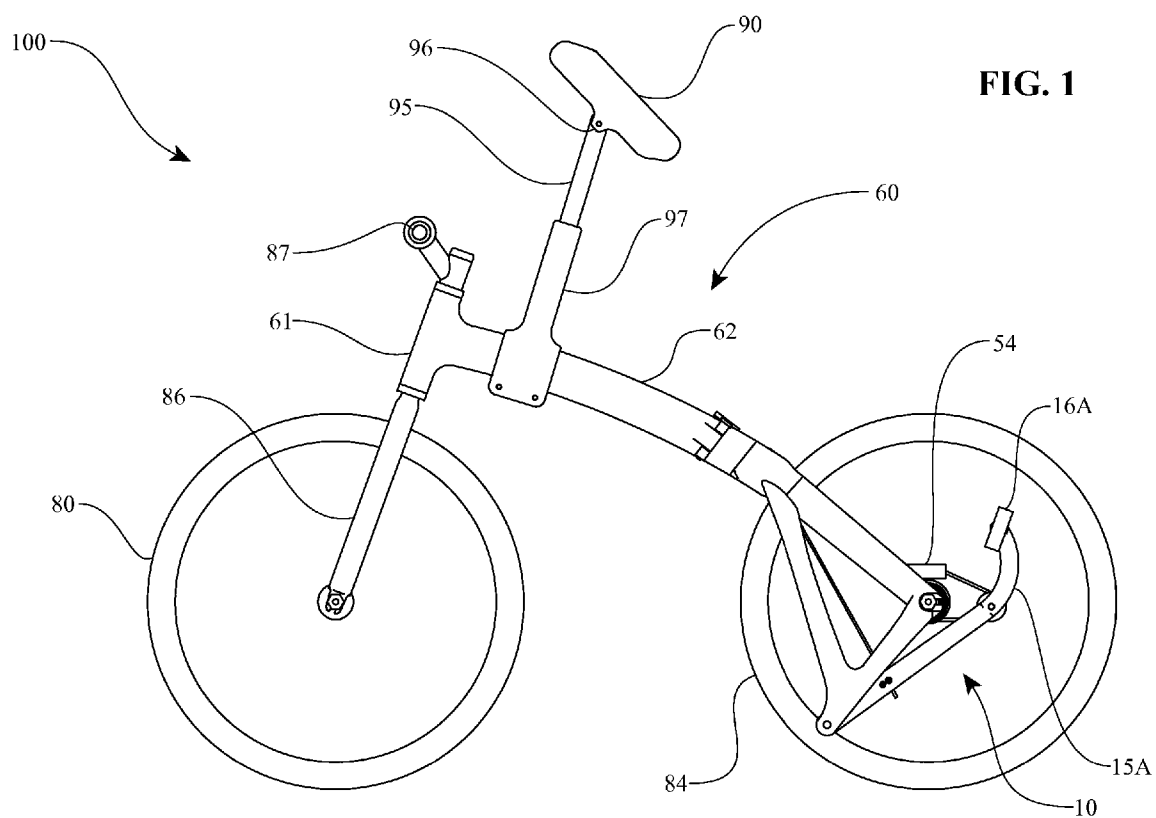
## Publication Classification

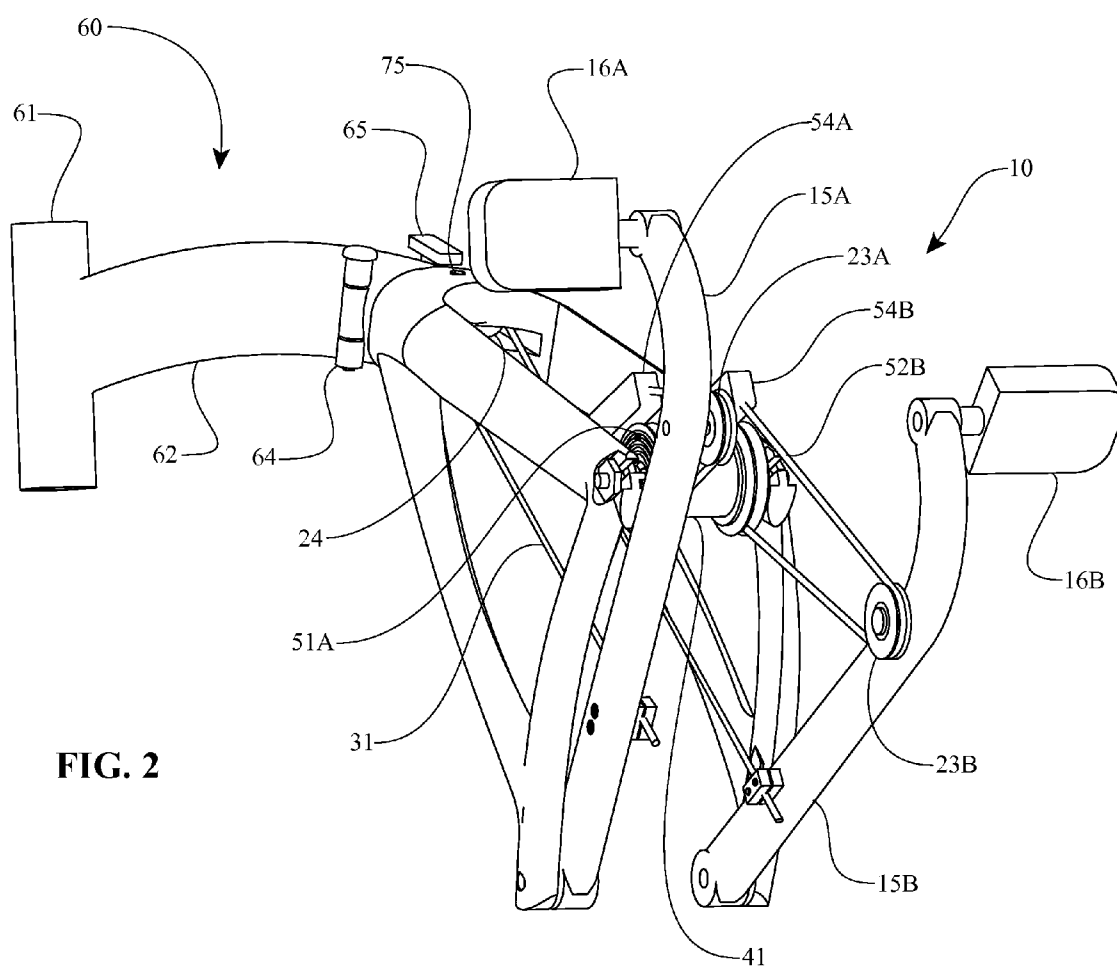
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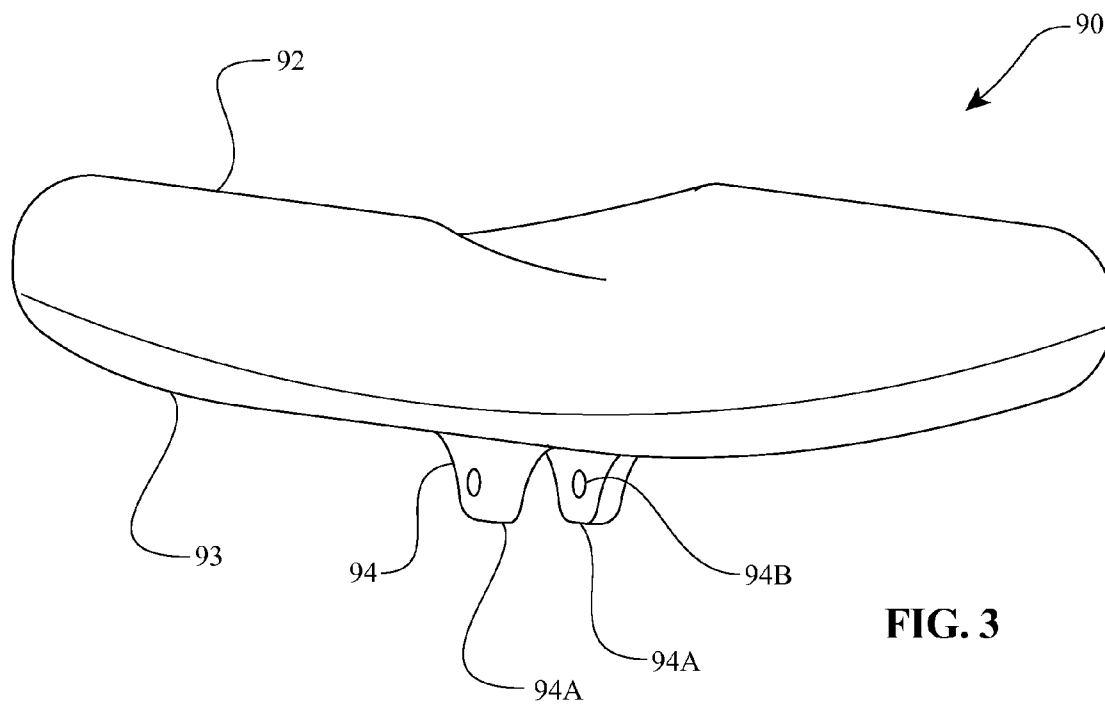
(57) **ABSTRACT**

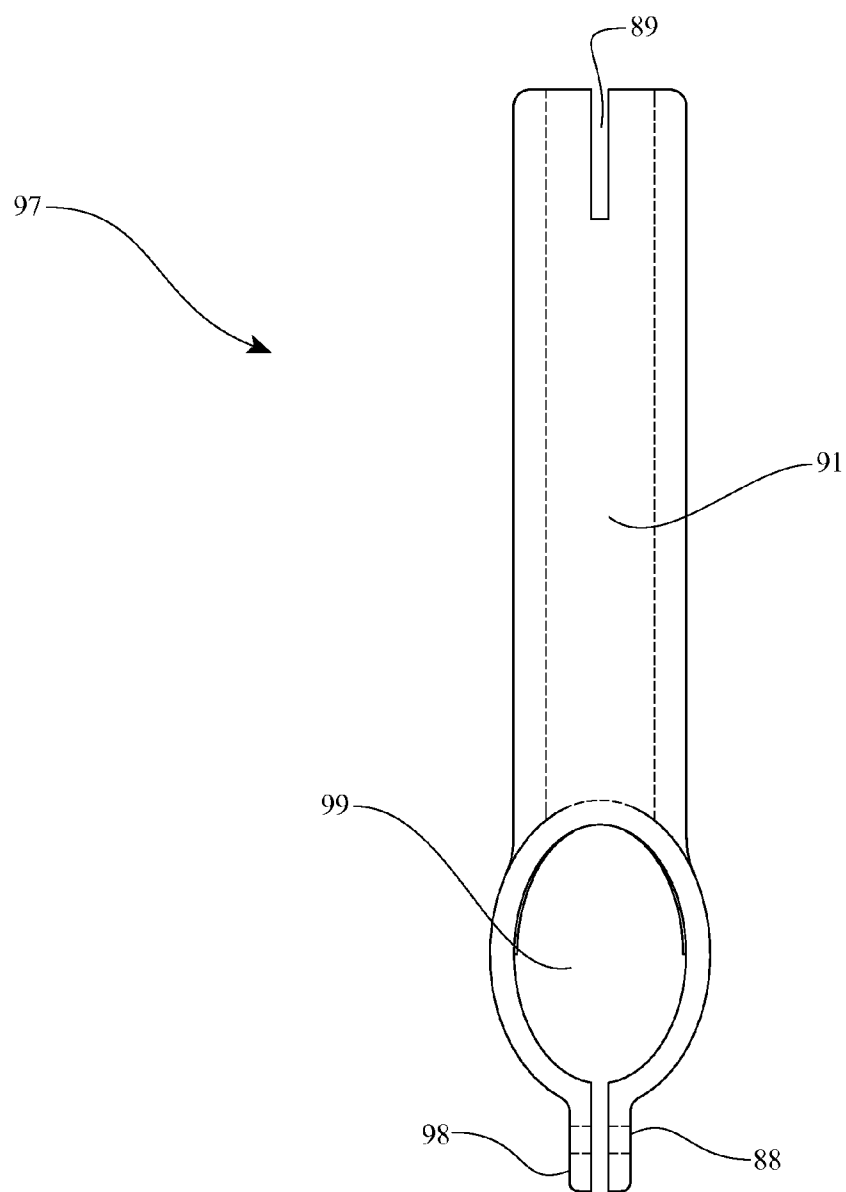
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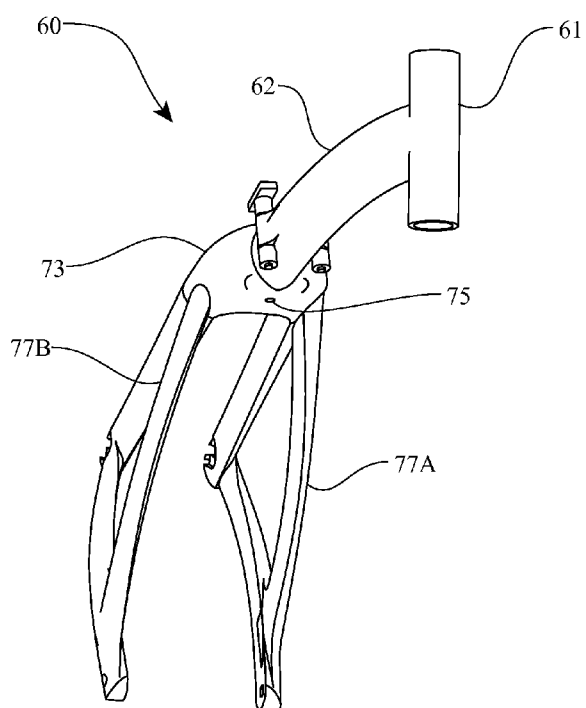
(60) Provisional application No. 60/799,601, filed on May 11, 2006.



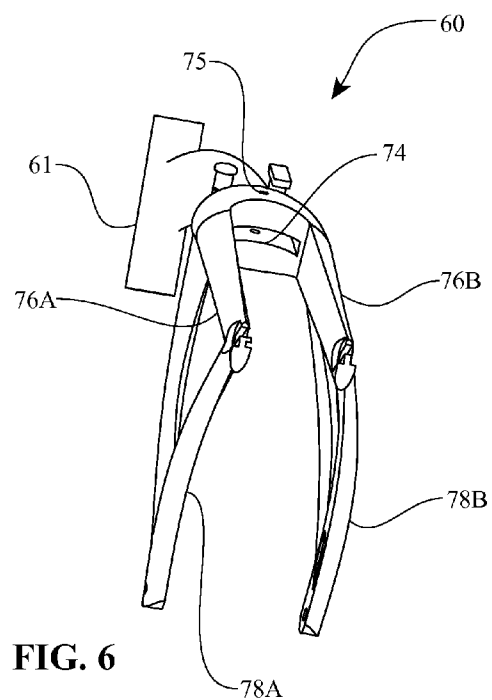




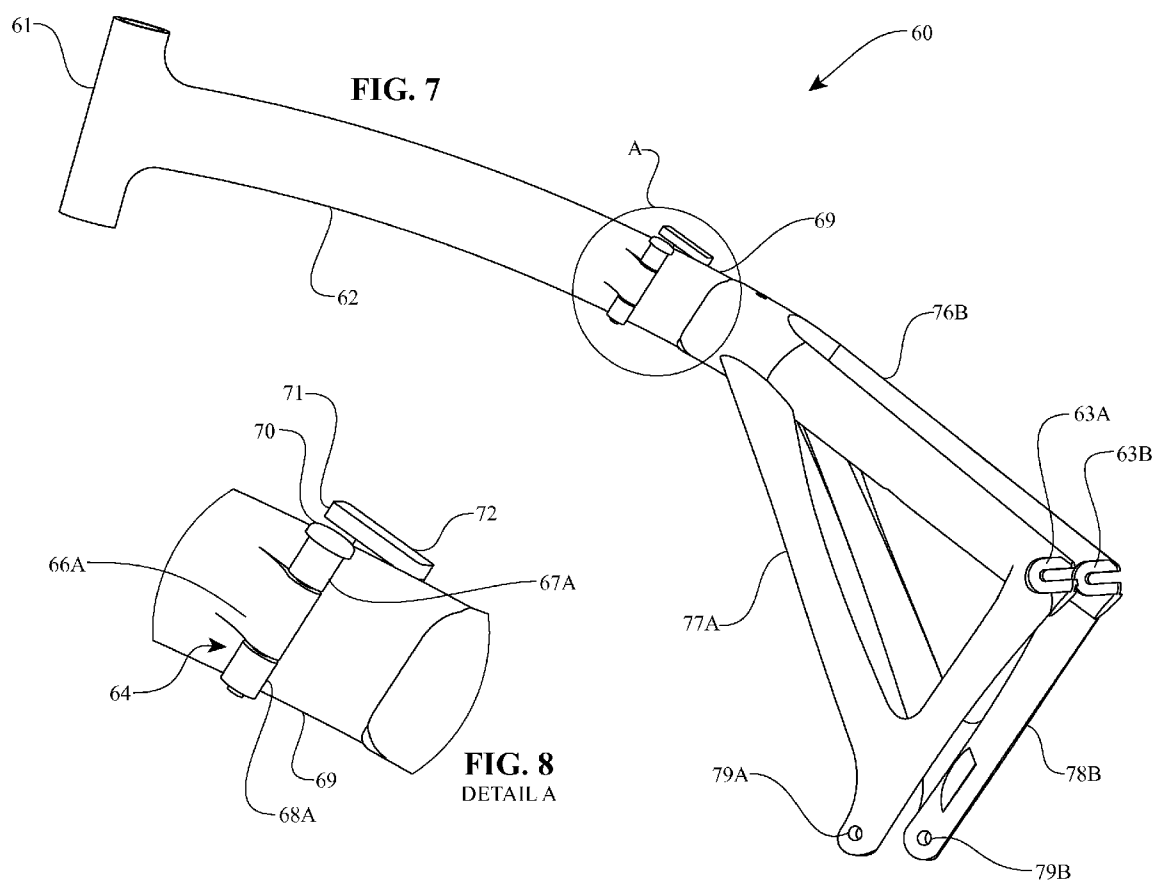


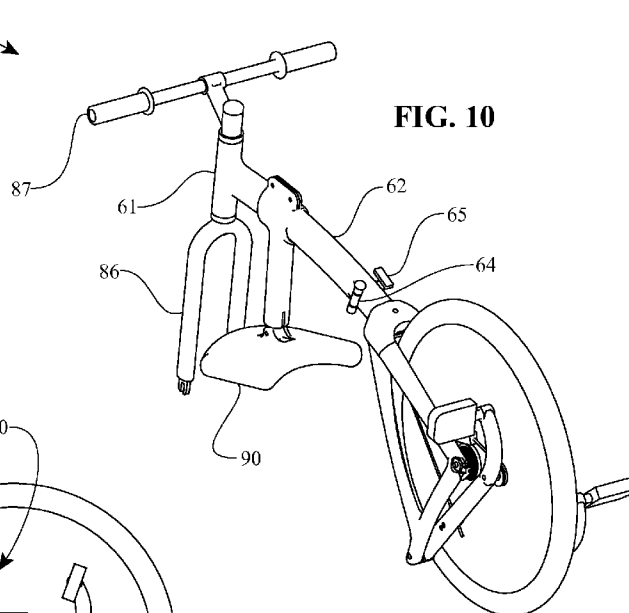
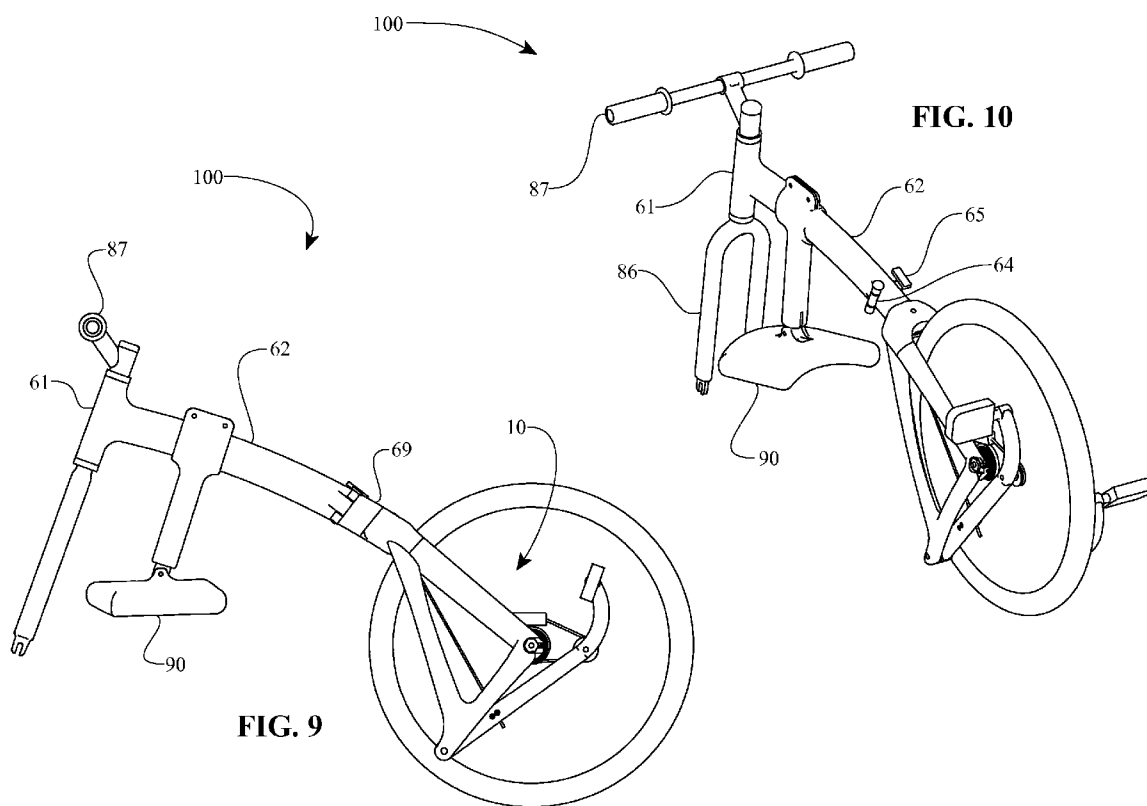


**FIG. 5**

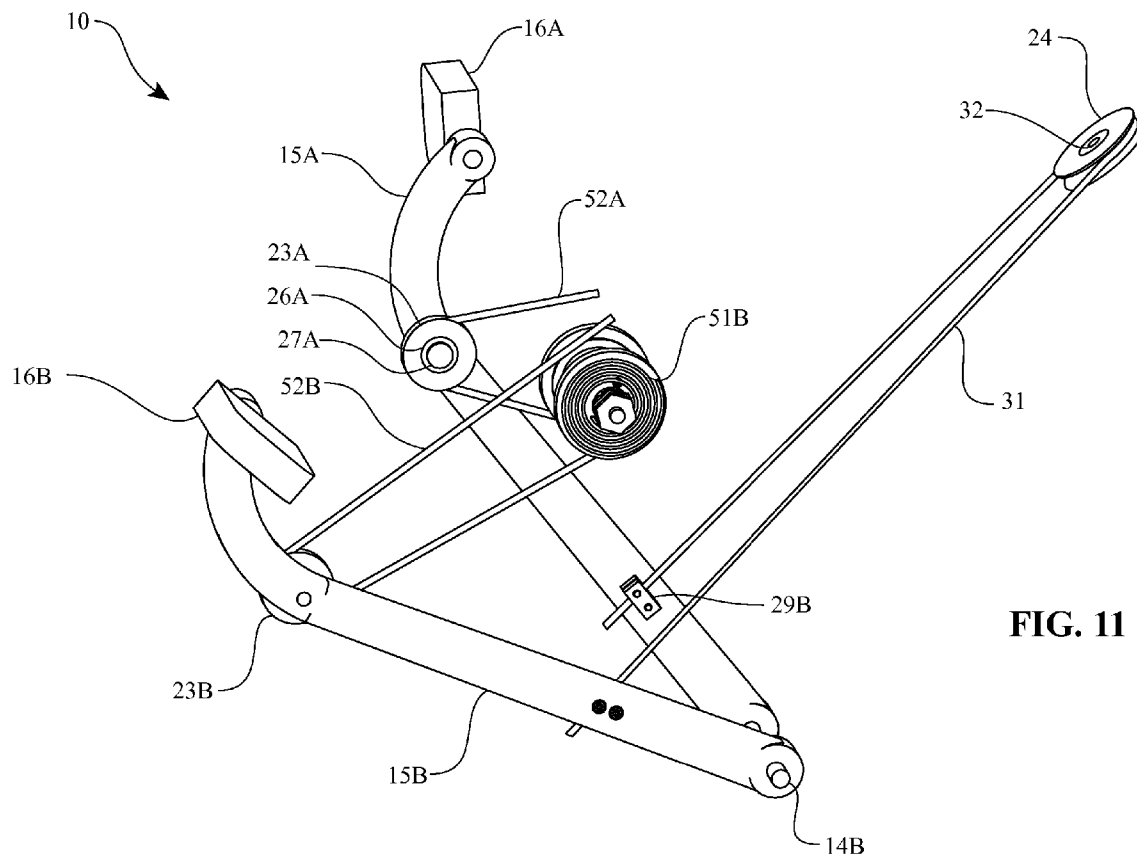


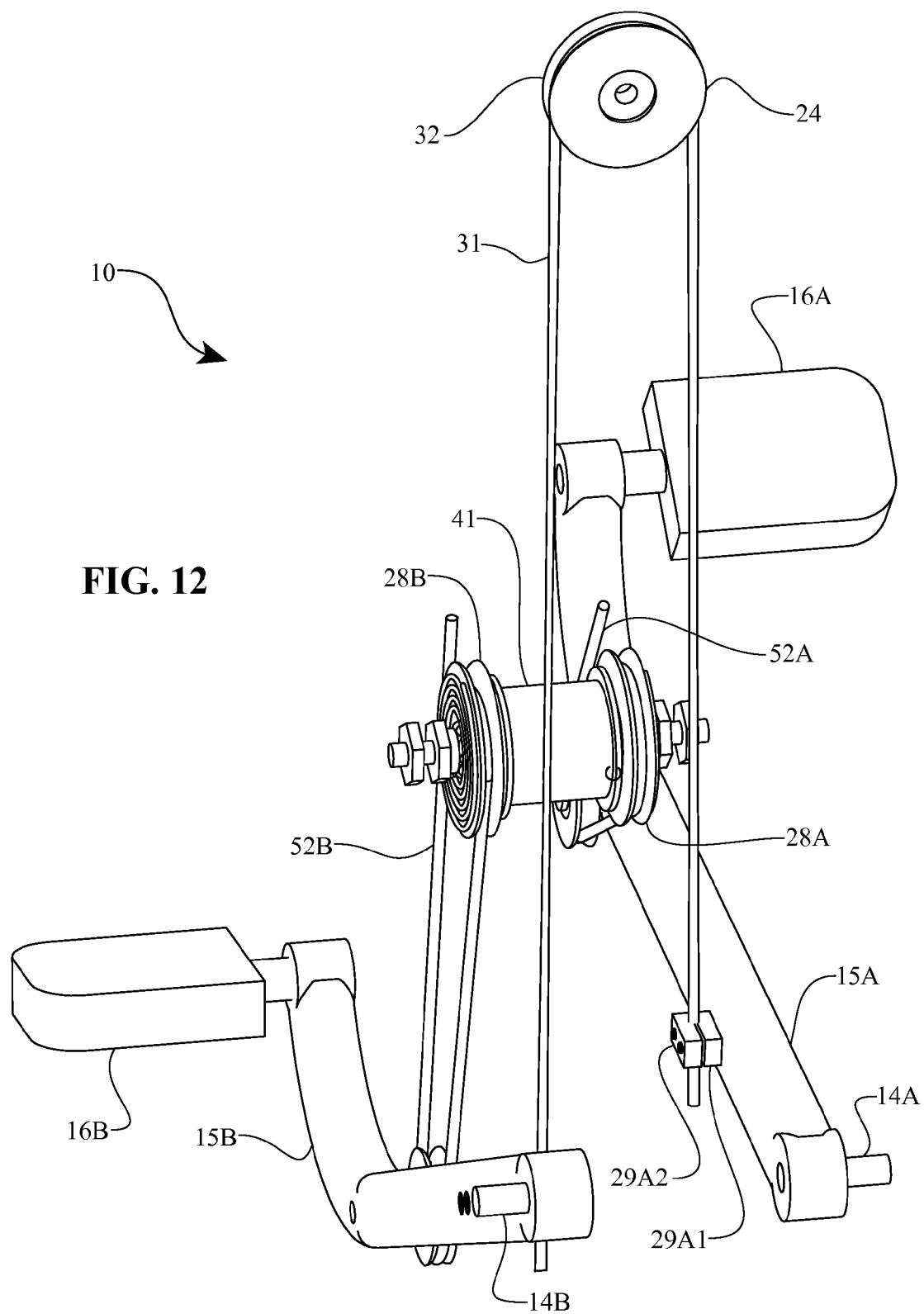
**FIG. 6**











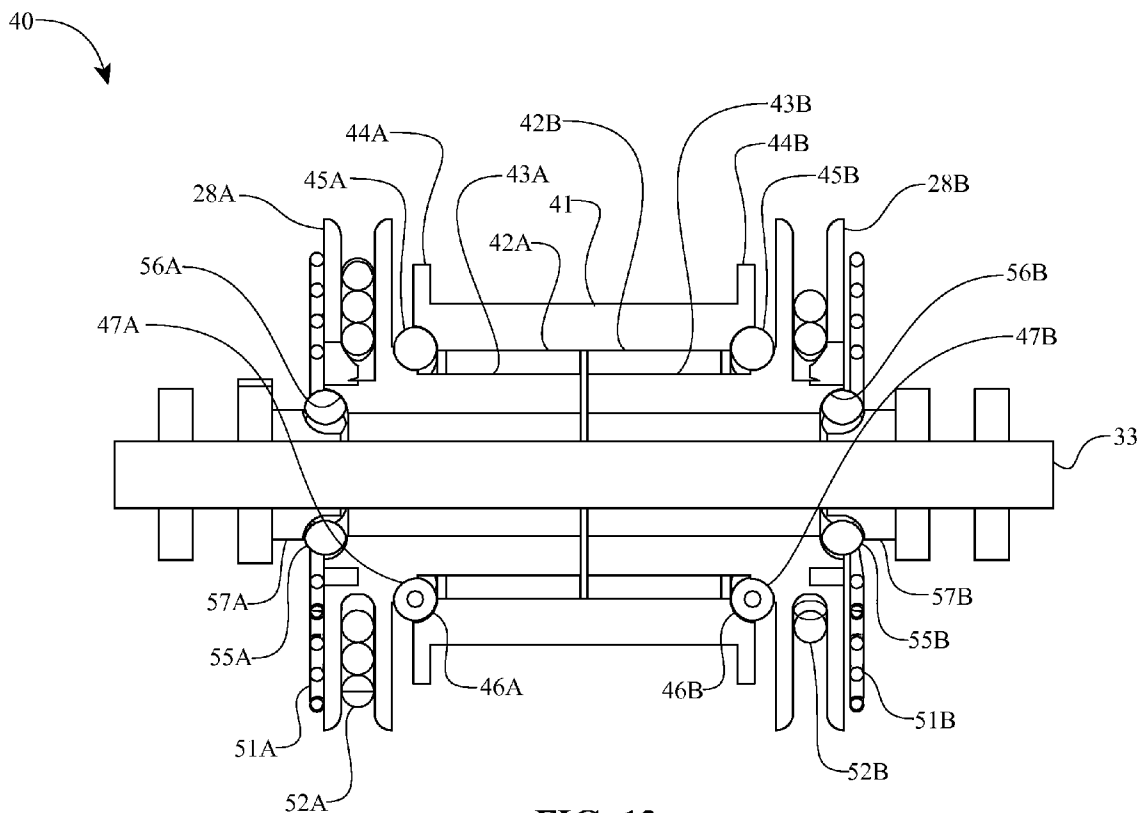


FIG. 13

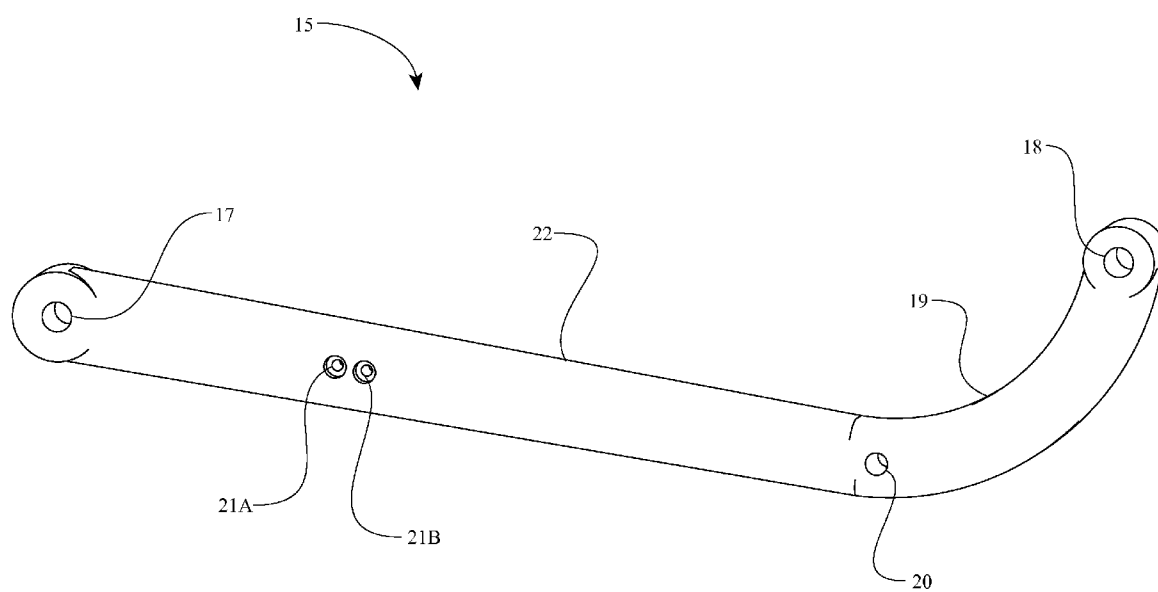


FIG. 14

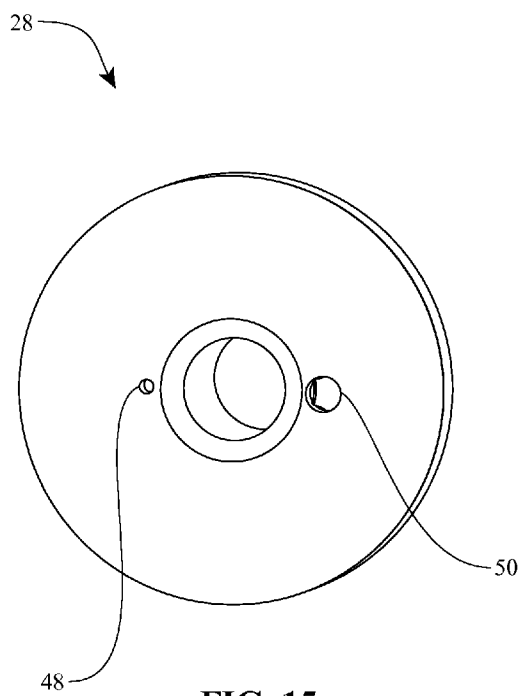


FIG. 15

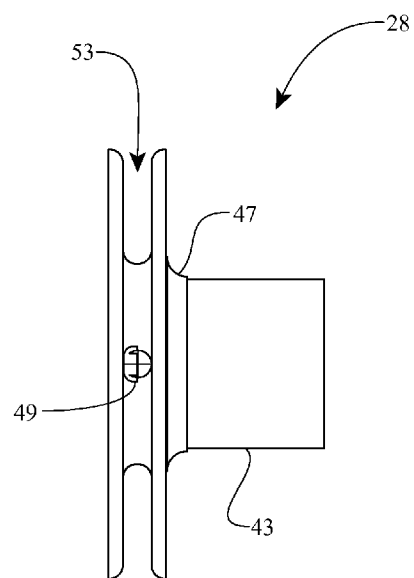


FIG. 16

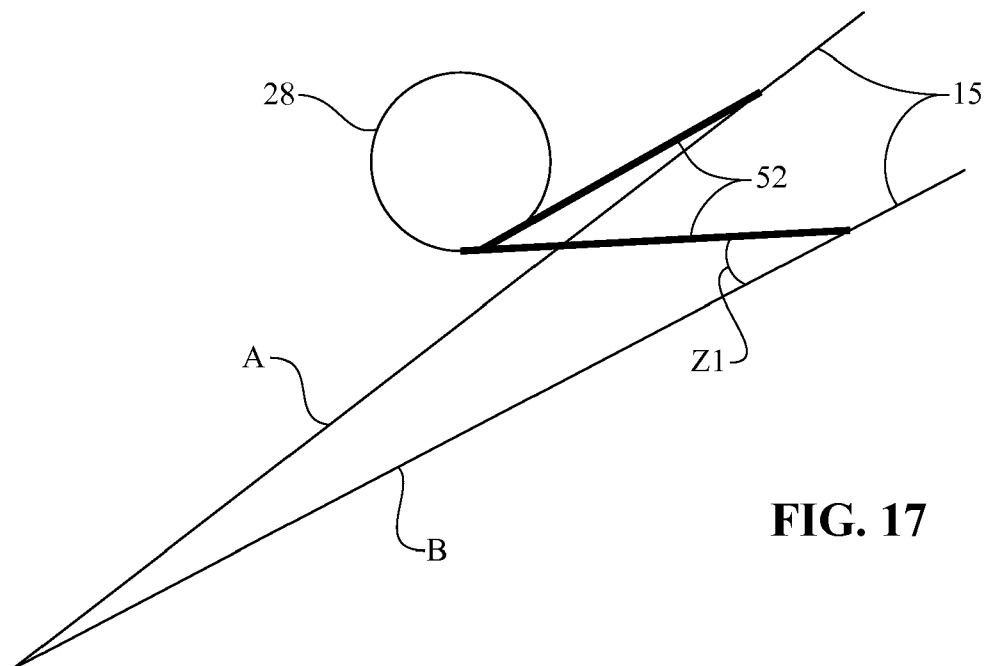


FIG. 17

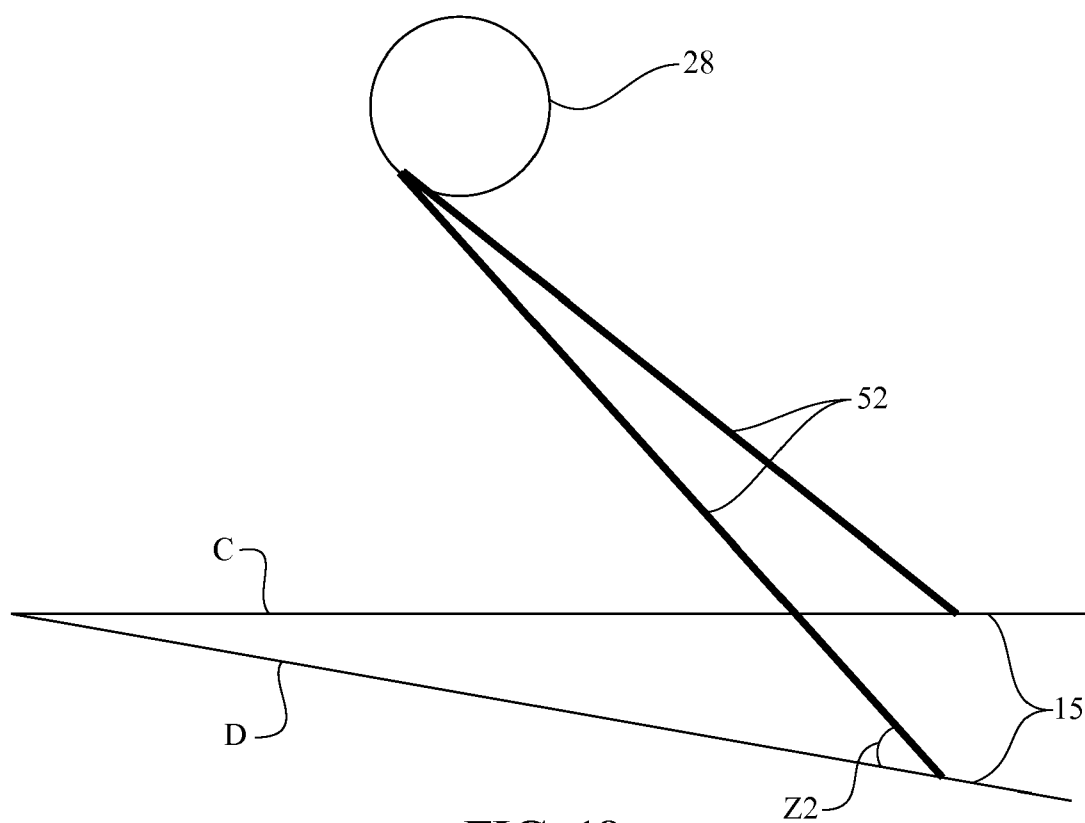
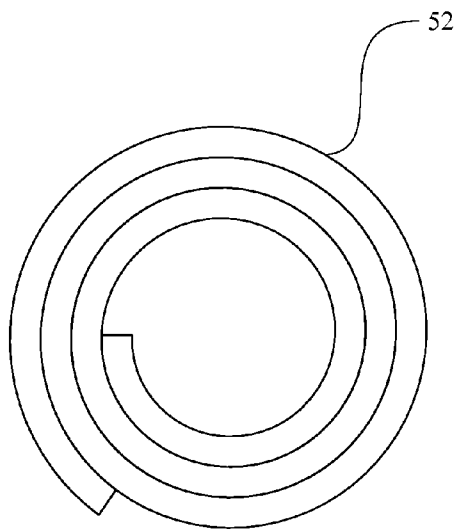
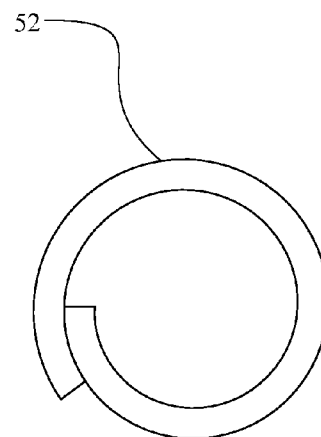


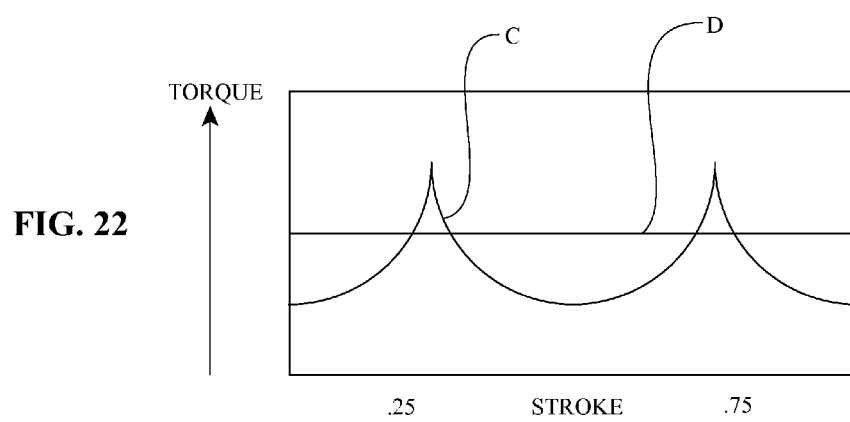
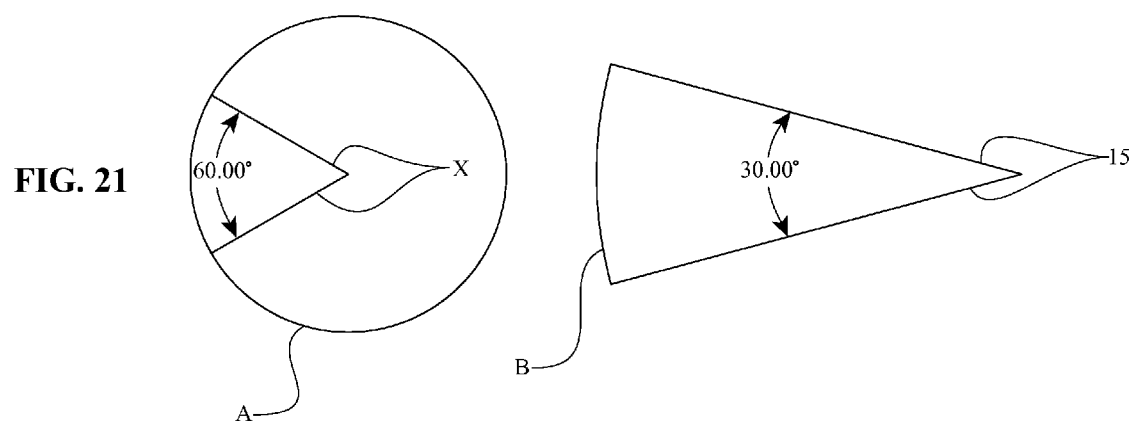
FIG. 18

**FIG. 19**



**FIG. 20**







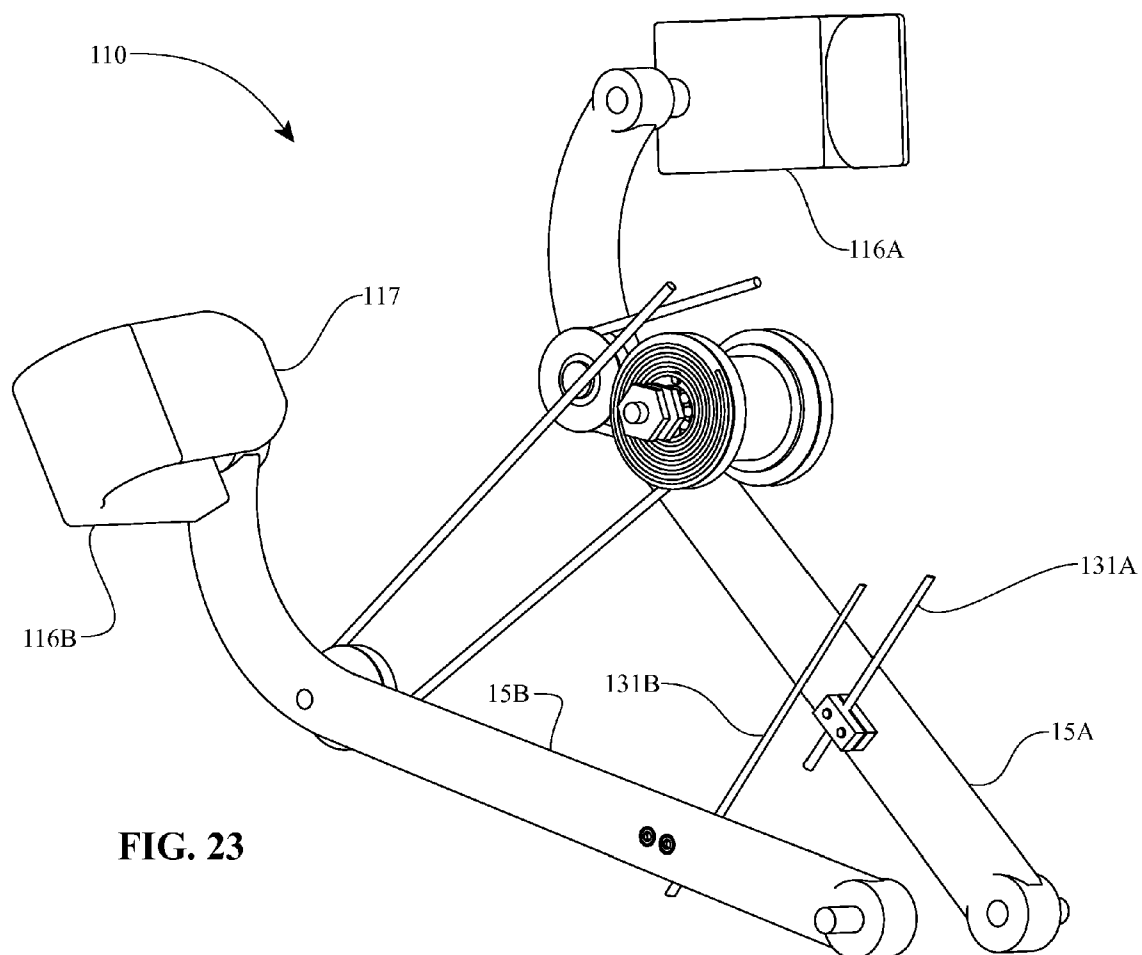
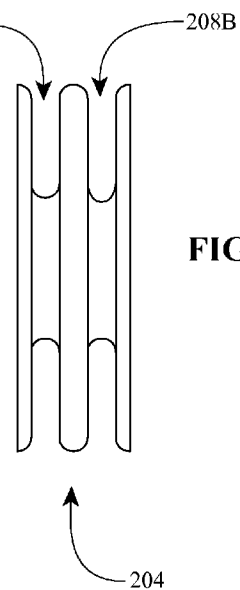
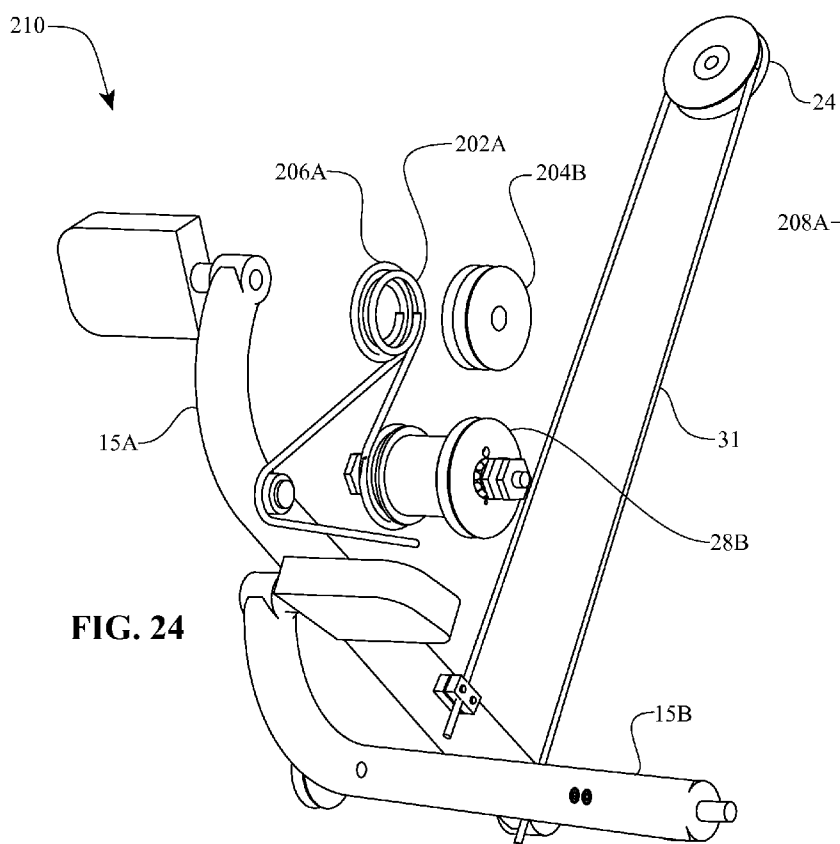
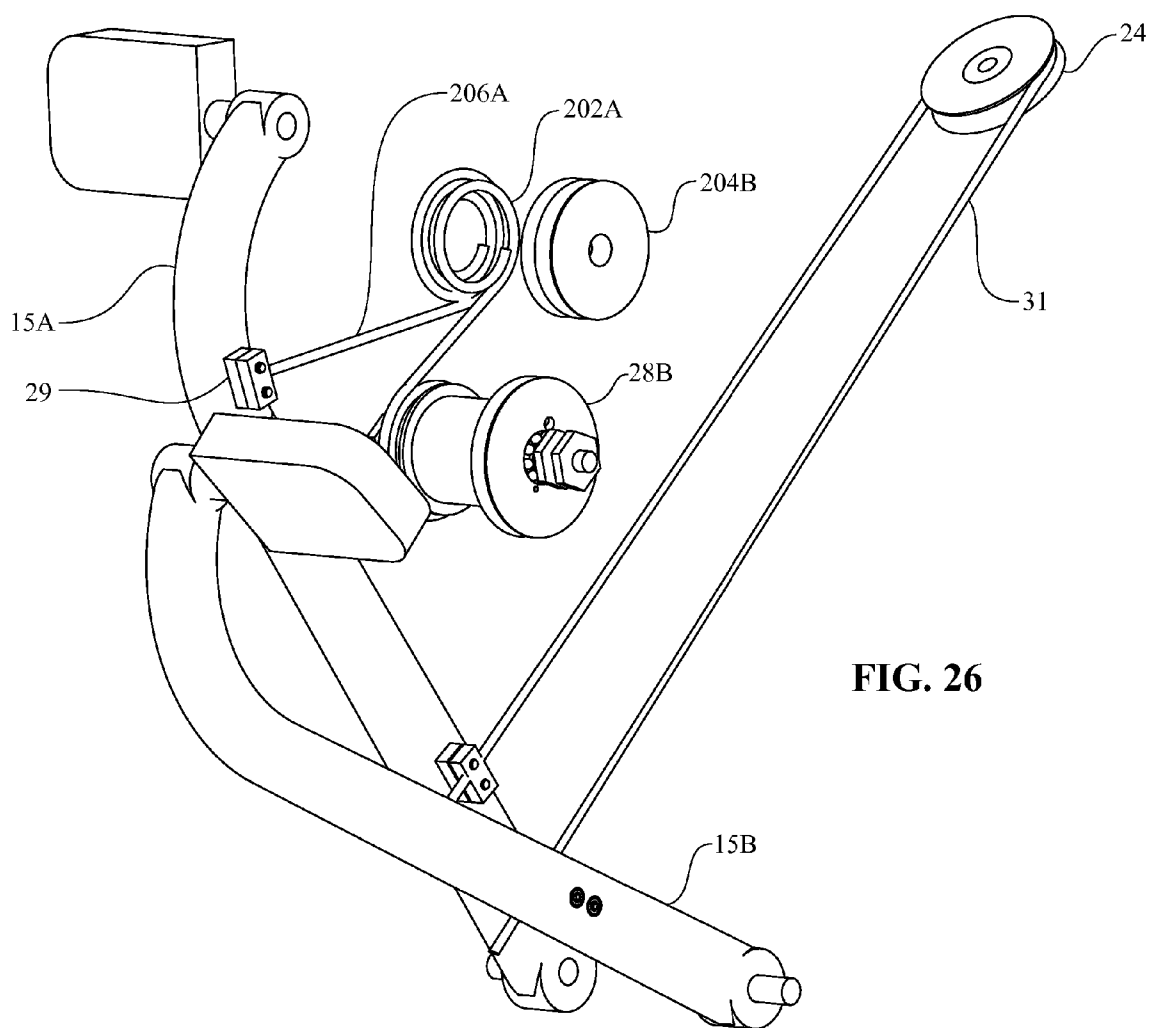
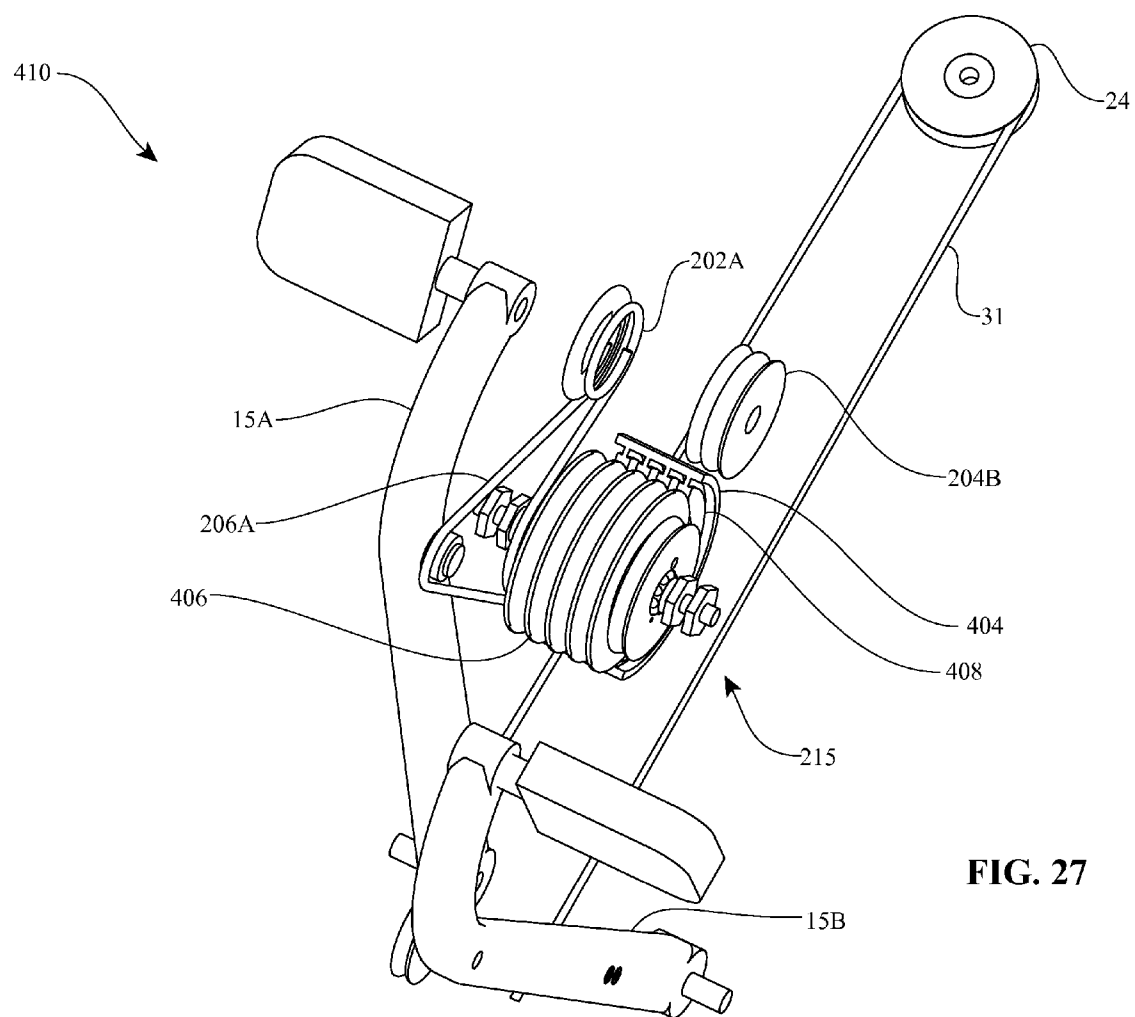


FIG. 23







**FIG. 27**

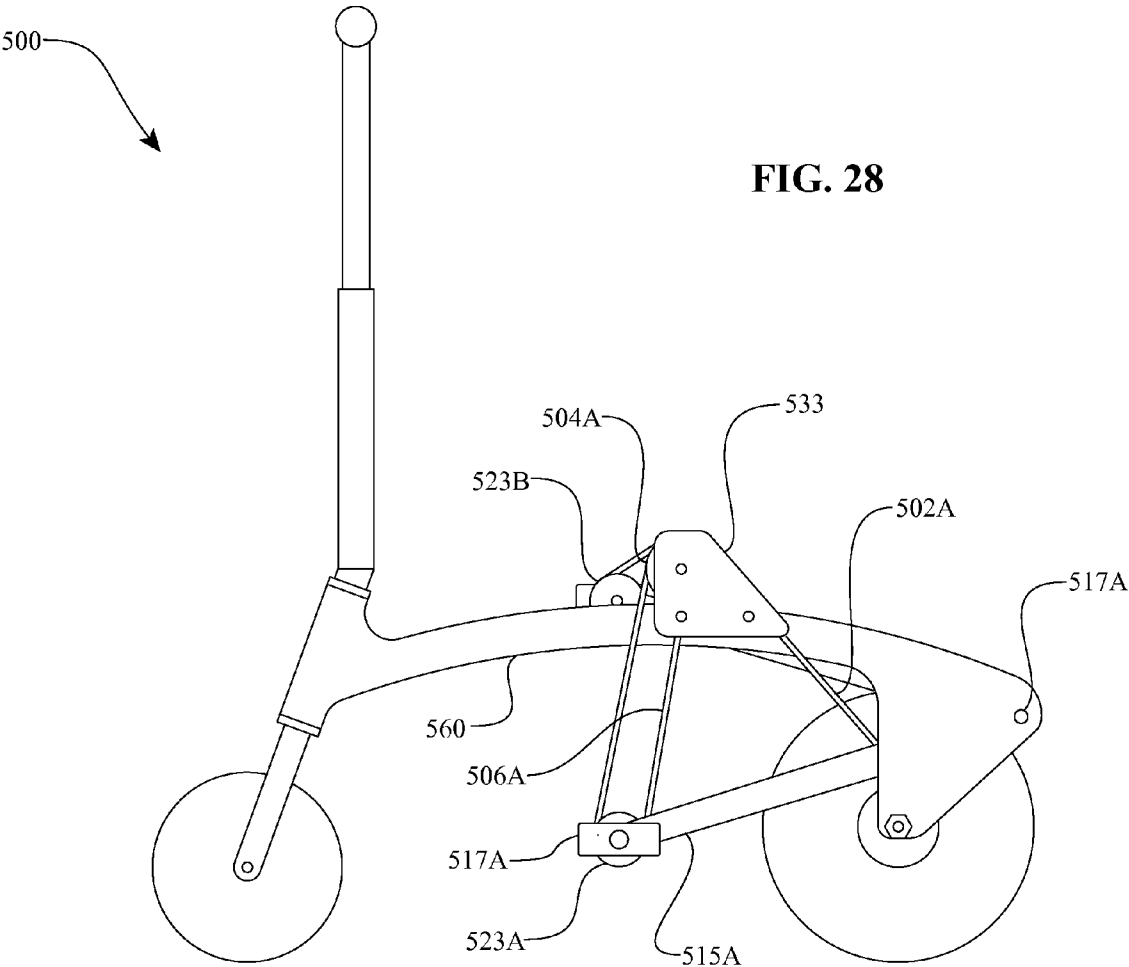
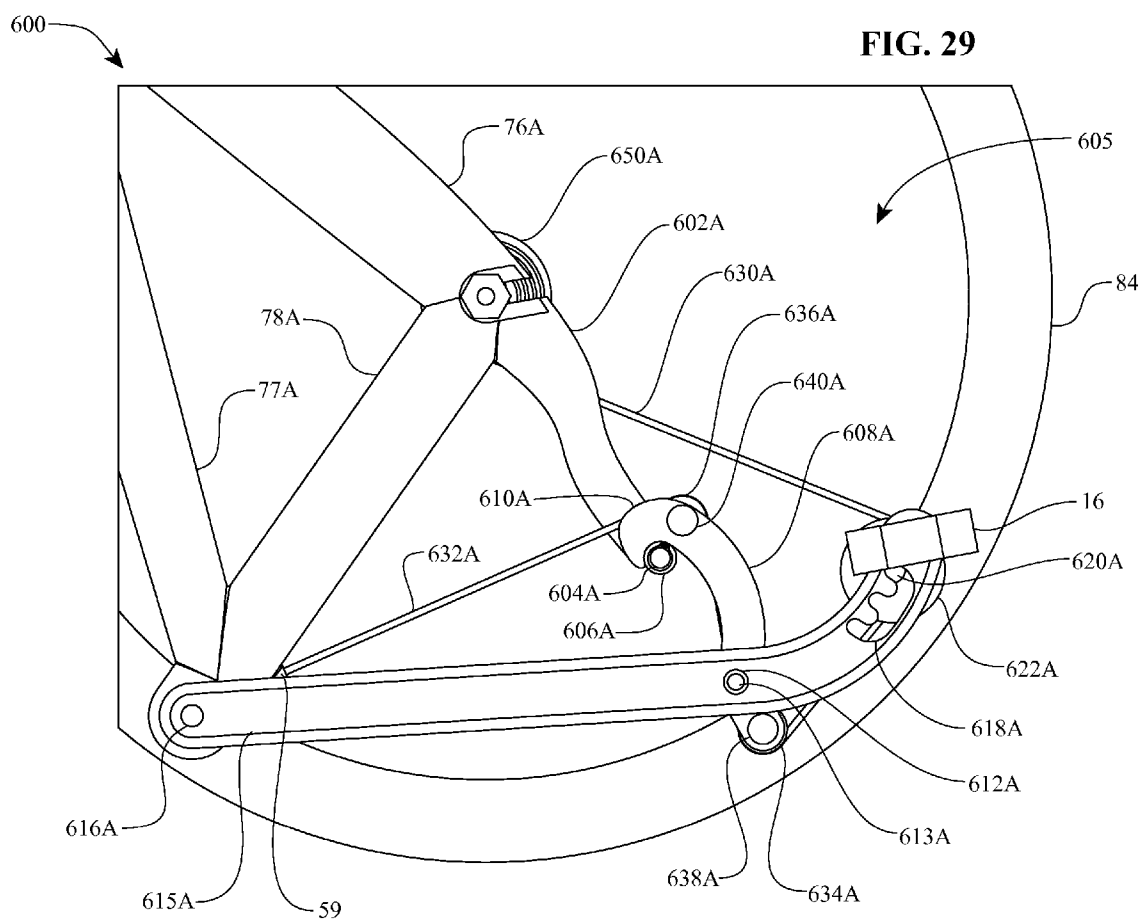
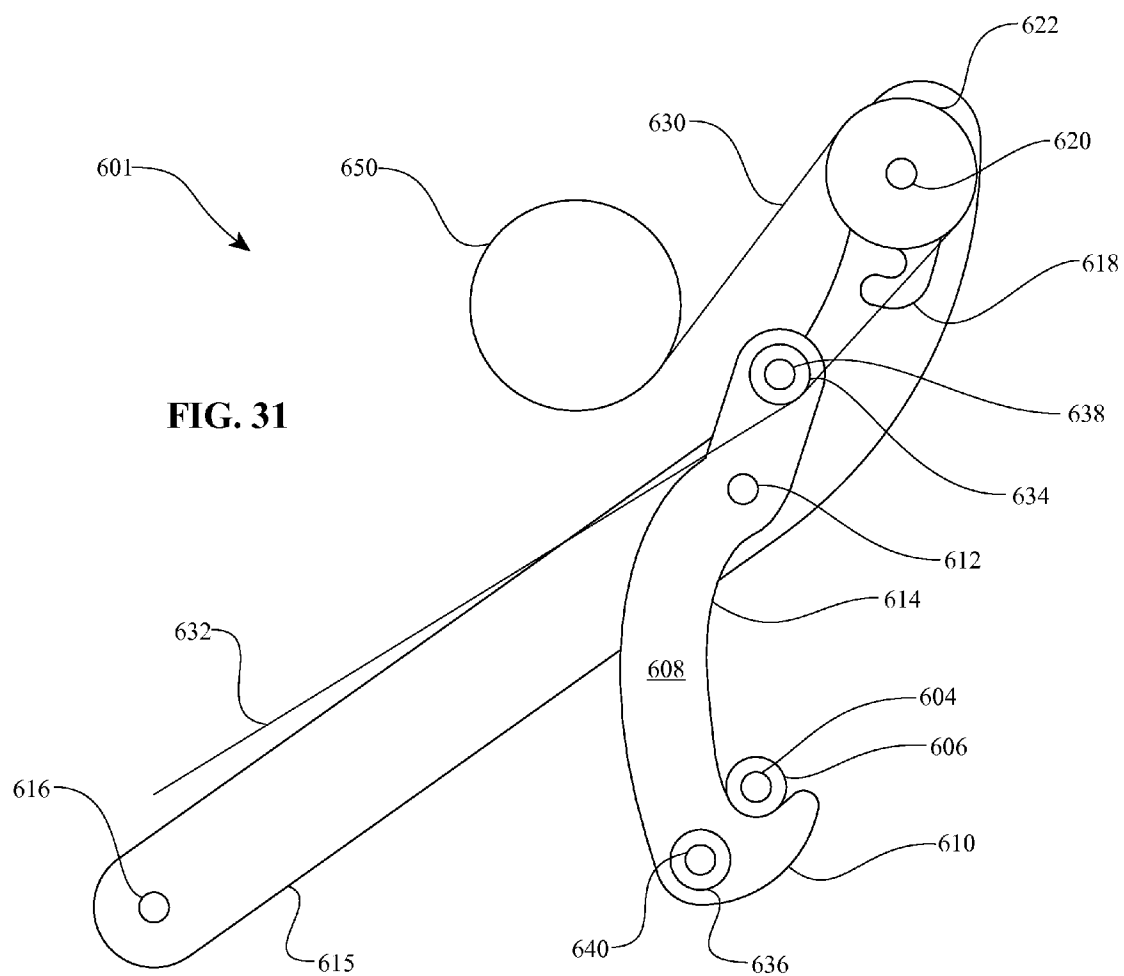


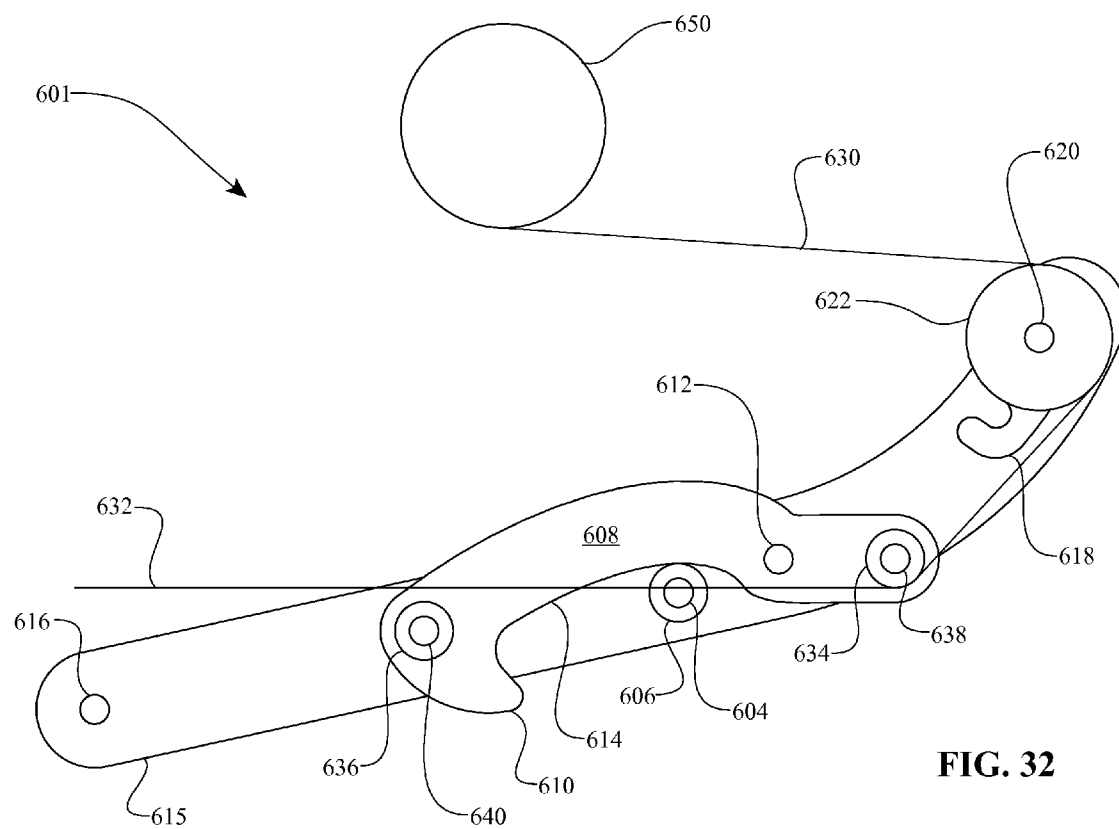
FIG. 29

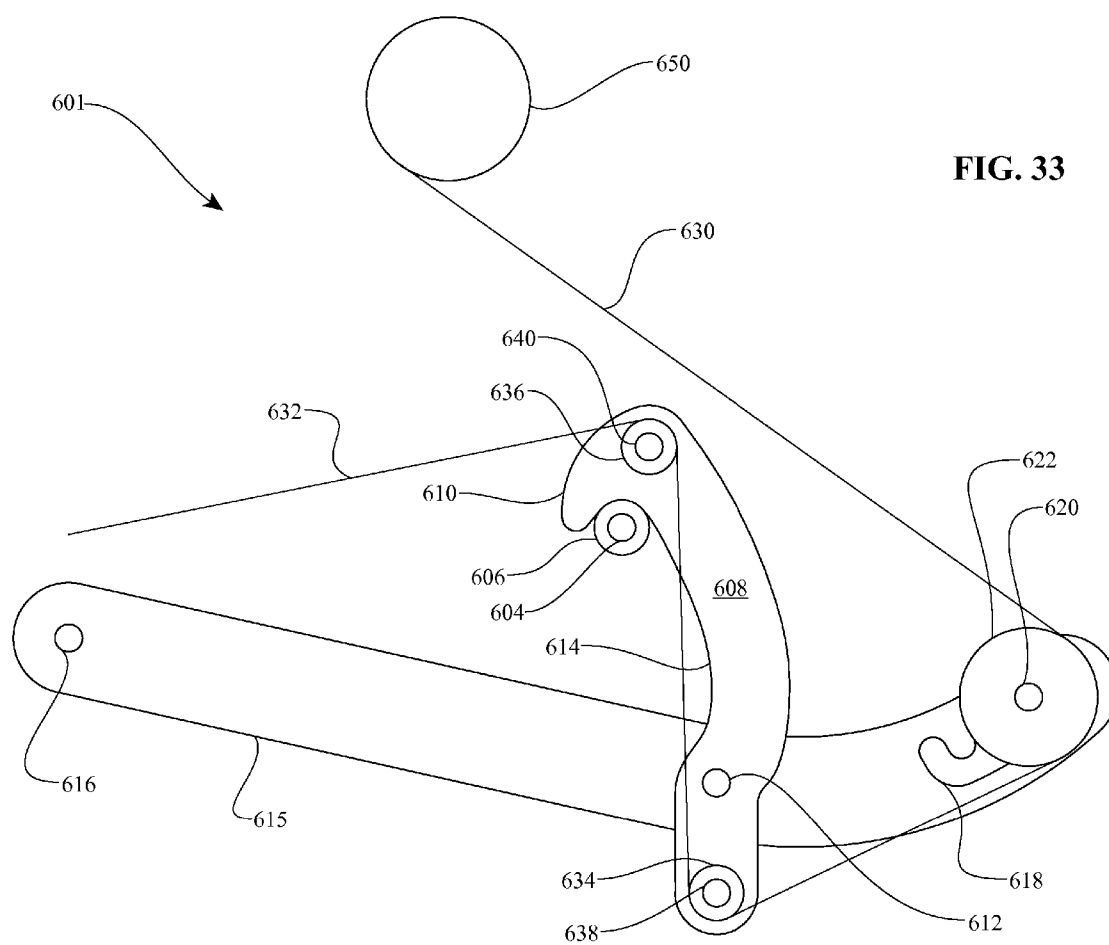


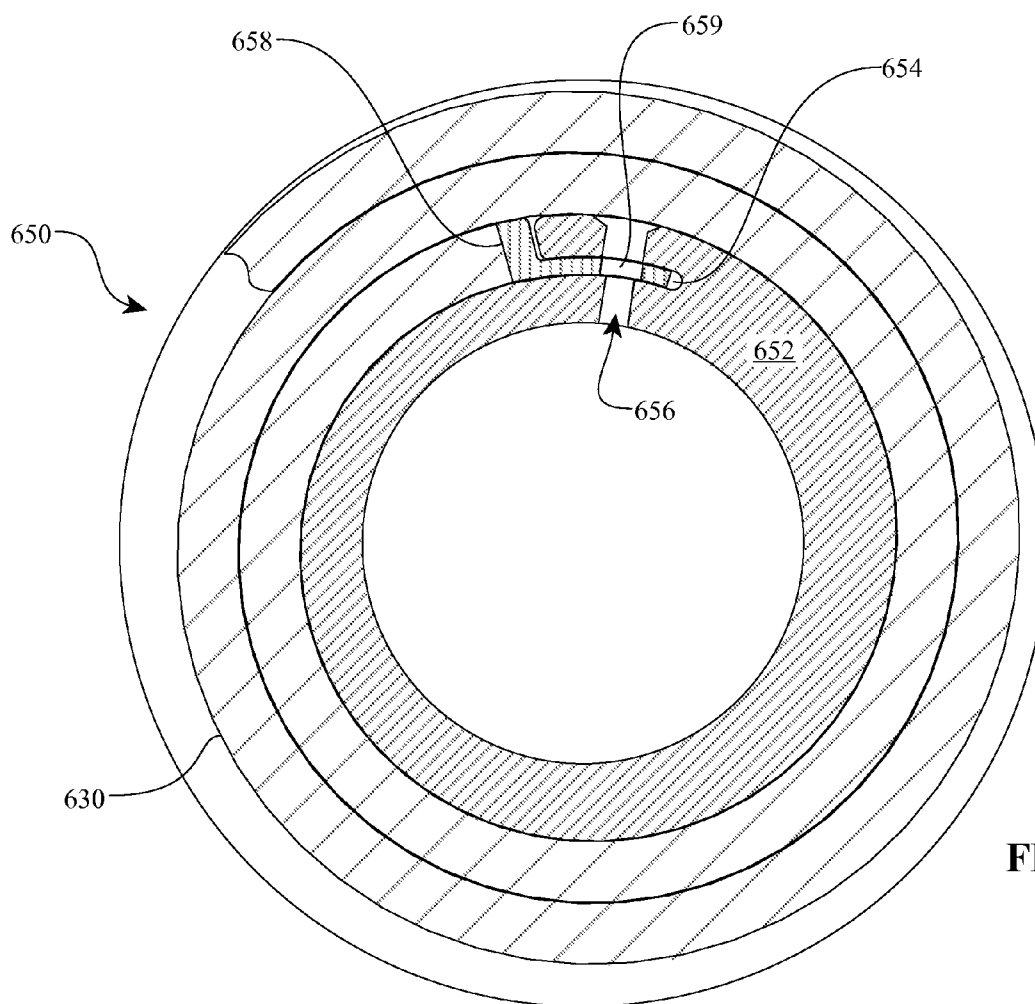




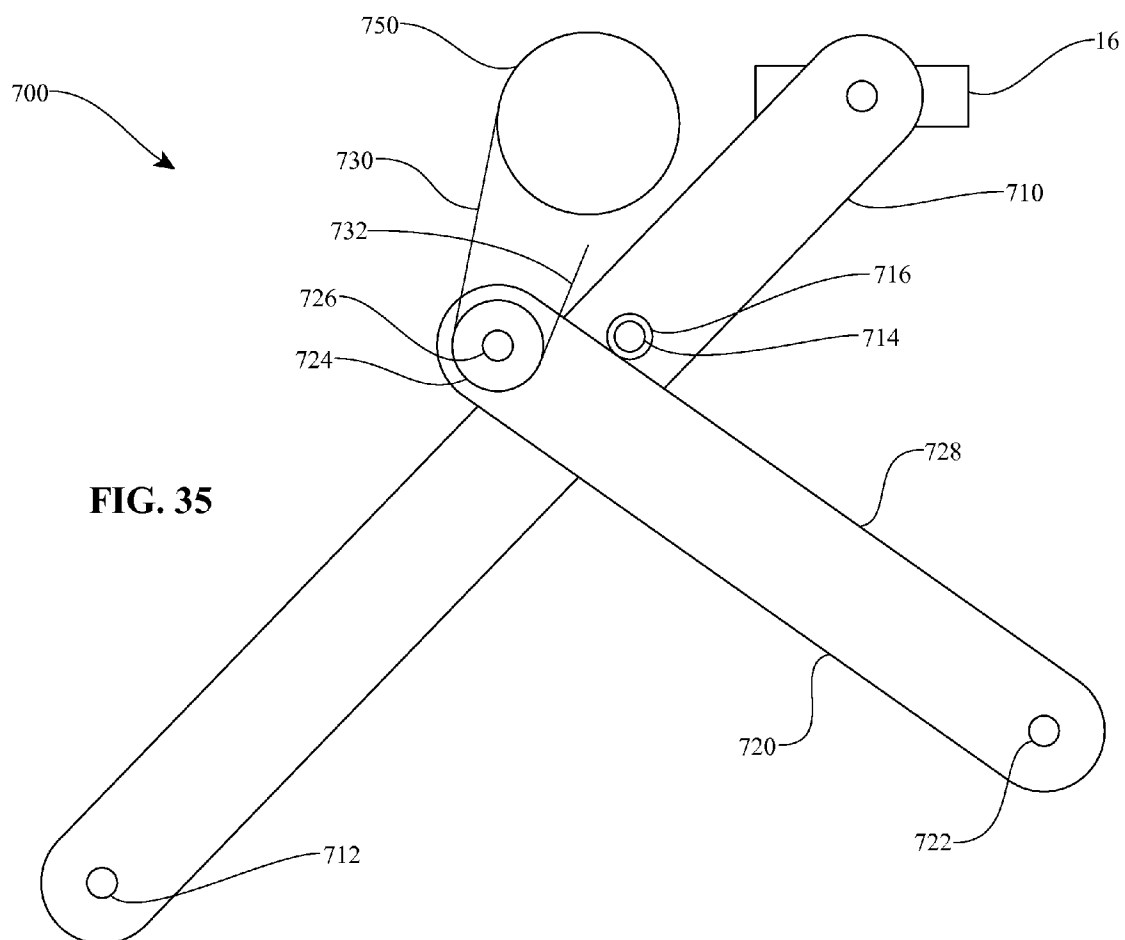


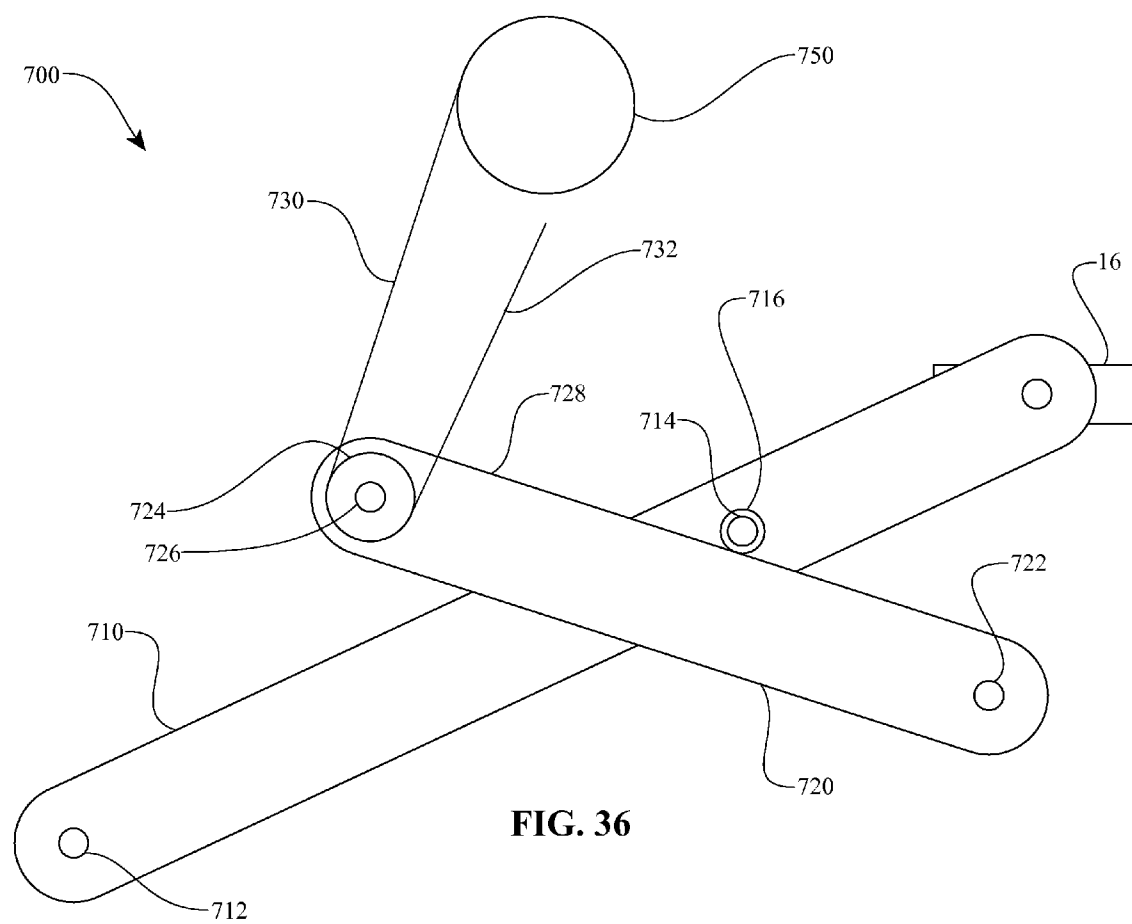


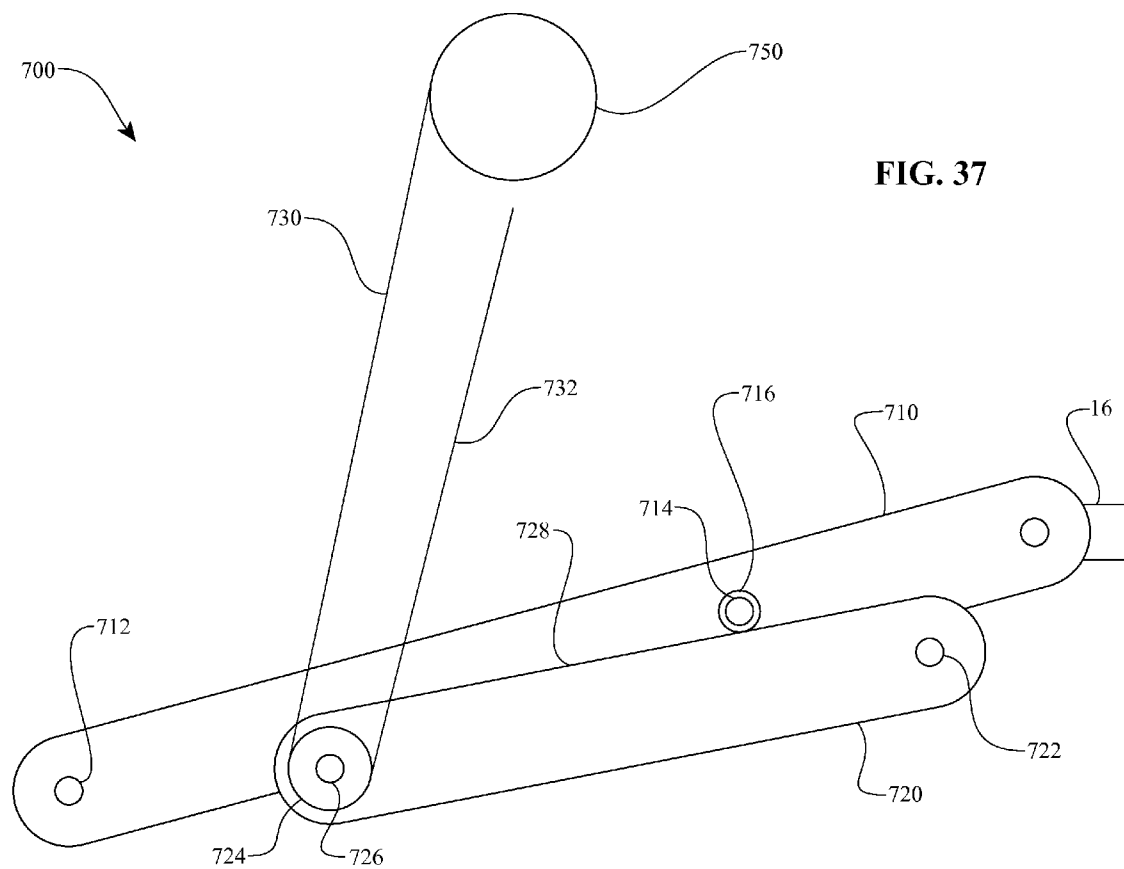


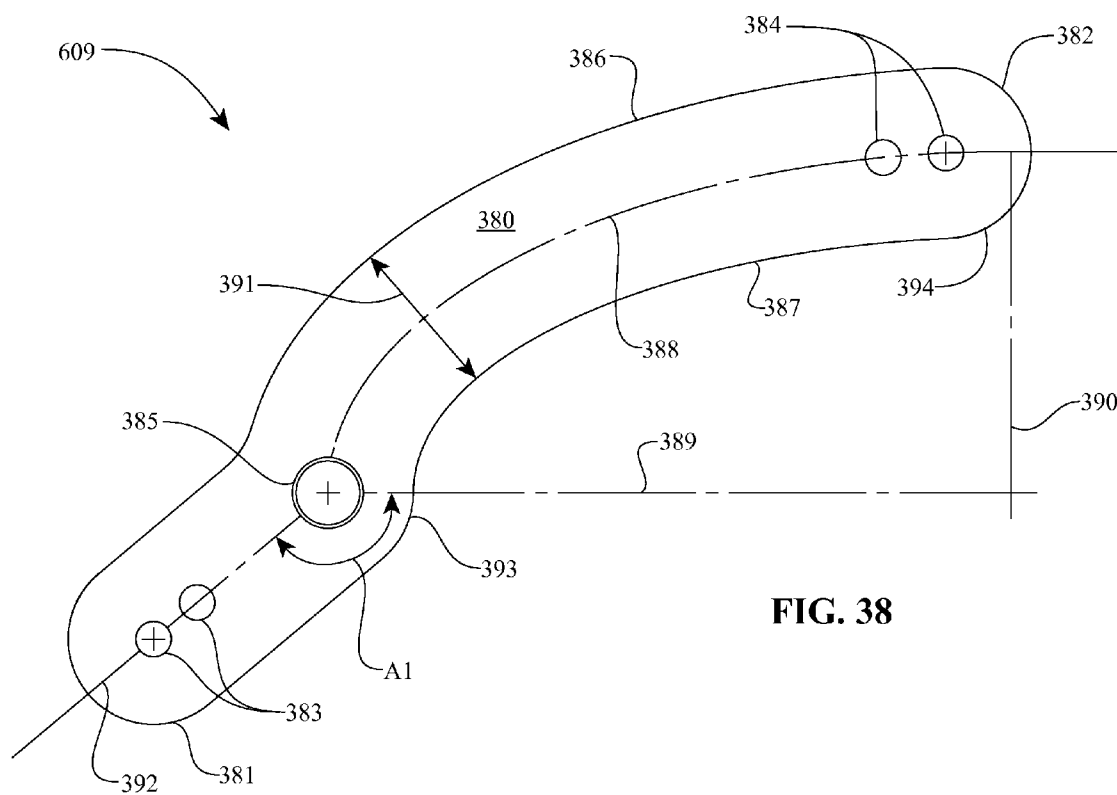


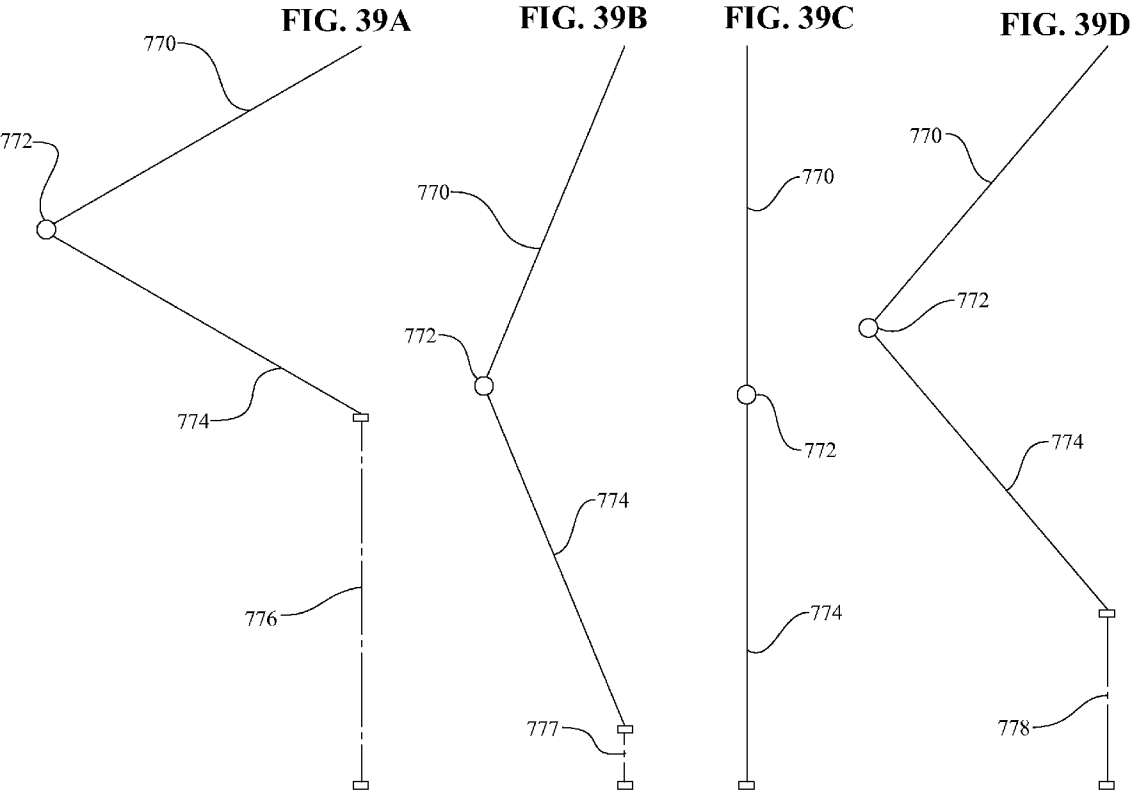
**FIG. 34**













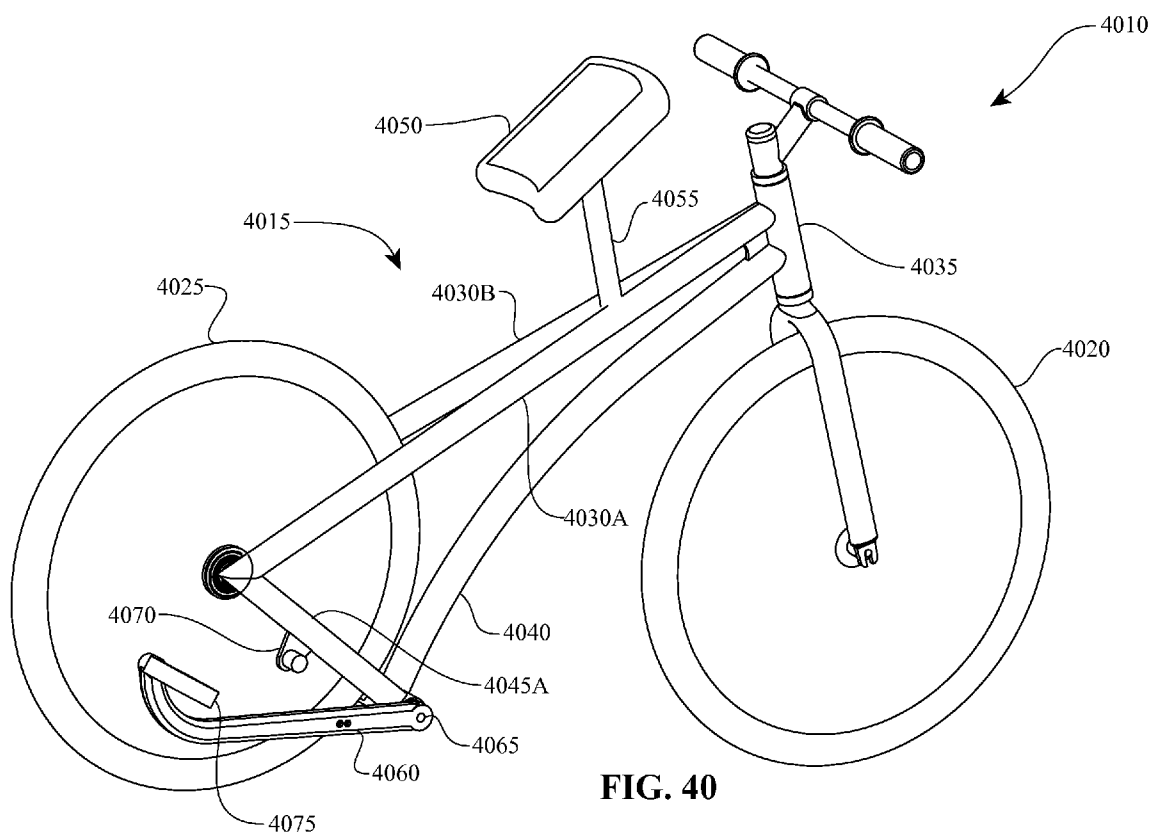


FIG. 40

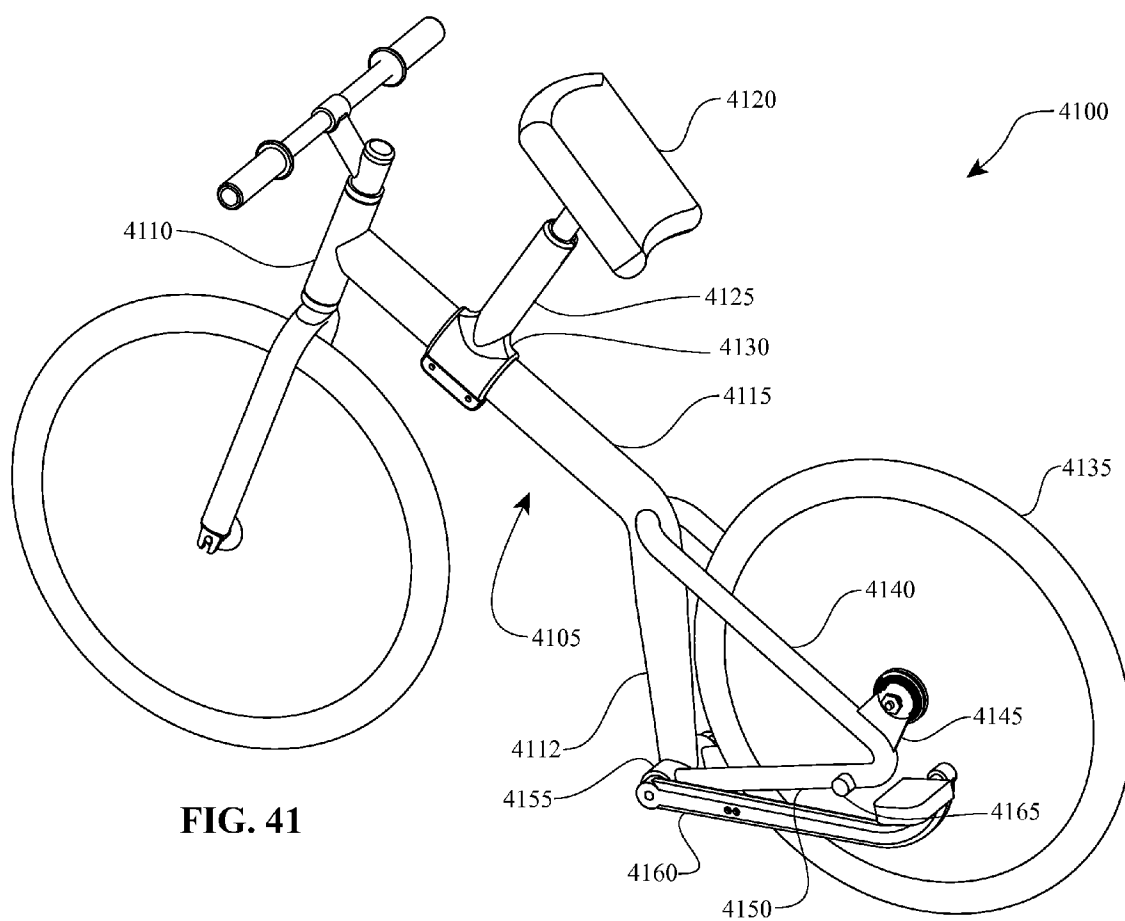


FIG. 41

## CONTINUOUSLY VARIABLE DRIVETRAIN

### RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 11/747,068, filed on May 10, 2007, which claims priority to U.S. Provisional Patent Application 60/799,601, filed on May 11, 2006. The entire disclosure of each of the above applications is hereby incorporated by reference in its entirety.

[0002] This Application is related to U.S. patent application Ser. No. \_\_\_\_\_ Attorney Docket No. LINEARB.031C2, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C3, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C4, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C5, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C6, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C7, U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C8, and U.S. patent application Ser. No. \_\_\_\_\_, Attorney Docket No. LINEARB.031C9, all filed on even date and which are hereby incorporated by reference in their entirety.

### BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates generally to mechanical power transmission systems and more specifically to continuously variable drivetrains.

[0005] 2. Related Art

[0006] Pulley and belt systems used to transmit mechanical energy are very common and have been used extensively in industry for decades. Their benefits of low cost, reliability, modularity, and high efficiency have created thousands of applications. Typically, two pulleys are used, although three, four, five, or more pulleys may be employed. Generally one belt or cable is used, although systems with multiple belts are not uncommon, such as those used in automobiles. With these systems, two or more pulleys have two or more annular grooves that are designed to accommodate two or more belts. Pulleys can be made from steel, aluminum, plastic, and other materials. The material choice is often determined by the amount of power to be transferred. Pulleys come in many different sizes, ranging from miniature pulleys with a diameter of less than 10 millimeters to very large pulleys over a meter in diameter. Belts are made from many different materials, but all of them are flexible. Often, a rubber belt is used with embedded steel strands to increase strength. Other common materials used in belt construction are urethane, neoprene, steel, and composites. The belt profile can be round, V shaped, flat, grooved, or other shapes. Timing belts use a series of tooth shaped ridges which engage corresponding indentations in a pulley to maximize power transfer and eliminate slip. Some belts employ grooves to allow them to wrap around smaller diameter pulleys.

[0007] Most pulley and belt drivetrains are endless, which means that they transfer power rotationally from one pulley to another. The pulleys are rigidly attached to rotating drive and driven shafts and a circular belt rotates endlessly in a

closed loop. Idler pulleys are frequently used to create and maintain tension on the belt to prevent slippage and premature failure. Idler pulleys do not transfer power and typically employ a bearing in the bore of the pulley to minimize friction and increase life. The bearing and idler pulley assembly is often pressed over a non-rotating shaft.

[0008] Reciprocating pulley and belt, or cable, drivetrains are often found in human powered systems. Exercise equipment frequently uses a cable that is attached to weights at one end and to a bar or other device which a person can push or pull. The weight is lifted and then returned to its resting state. An idler pulley is generally suspended at a height above the weights. This lifting and lowering of the weight creates reciprocating motion of the cable and pulley. Similarly, exercise machines such as those simulating the motion of climbing stairs can use similar reciprocating pulley and cable drivetrains. All of these drivetrains suffer from a loss of kinetic energy at the end of each stroke. For example, in a bicep curl, the human grasps a bar with both hands and lifts the bar to a position near the chest, and then returns it to the resting state. Kinetic energy is created during movement of the bar and then lost when the movement is stopped at the end of the stroke. Some exercise machines, including Nautilus type equipment, employ a cam which causes the weights to move more rapidly at the end of the stroke. This effect creates more efficient exercise by minimizing the loss of kinetic energy. The exercise is also more efficient because it becomes more difficult as the muscle contracts. During contraction the mechanical advantage of a muscle increases and it becomes more powerful. As the muscle position changes and creates a larger mechanical advantage, with cam or Nautilus type equipment, the weight simultaneously becomes more difficult to lift.

[0009] Linear drive systems in human powered vehicles have been attempted many times. However, they are not as efficient as commonly used drivetrains, such as sprocket and chain systems used on bicycles, due to the loss of kinetic energy at the end of each stroke. Many of the human powered linear drive systems are also complex, and each gear, bearing, pulley, cable, chain, or sprocket used in the drivetrain reduces efficiency. The complex systems are also heavy, and weight is a significant factor in human powered vehicles because it increases inertia and power requirements. Complex systems are also more expensive and more prone to breaking.

[0010] The most common human powered vehicle is a bicycle. A bicycle uses a sprocket and chain drivetrain which very efficiently transfers human power to the rear wheel. However, power is only efficiently created through about 60 degrees of the stroke, and only becomes very efficient for about 30 degrees of the 360 degree rotary stroke. This stroke also creates two large torque spikes per revolution. In order to reduce stress on the body (especially the knees), and minimize fatigue, a high pedaling speed is required to achieve high efficiency. This high pedaling speed reduces the torque spikes and also creates momentum to carry the pedals through the power phase of the stroke. However, the majority of people are not comfortable pedaling at a high speed and consequently do not maintain a cadence which maximizes the efficiency inherent in a bicycle's rotary stroke.

[0011] Further, the most common complaint from individuals riding bicycles is discomfort created by the bike seat.

This discomfort is significant enough to keep many people from riding bikes, and to reduce the frequency that others use their bicycles. Recent studies showing that bicycle riding contributes to impotence and other health problems aggravate the discomfort problem caused from bike seats. However, maximizing the efficiency inherent in the bicycle drivetrain requires that the user stay seated while pedaling. This position is more conducive to a higher cadence and expends less of the user's energy. Riding a bicycle seated creates a situation where most of the user's weight is on the seat, and thus prevents the majority of the user's weight from being applied to the pedals. This loss in force can only be regained by pedaling at high speed, where there is a corresponding drop in torque and less force needs to be applied to the pedals to maintain an efficient power output.

[0012] The second most common complaint among bicycle users is difficulty when shifting. While this is rarely a problem with avid cyclists, infrequent users routinely shift in the wrong direction, shifting to a higher gear when starting up a hill, or vice versa. This problem can lead to the chain coming off of a sprocket, binding of the chain, a broken chain, and in rare cases the user getting injured in a fall. The problem frustrates enough people that it reduces the percentage of the population that ride a bicycle.

[0013] There exists a need for a human powered drivetrain that eliminates the torque spike inherent in a bicycle drivetrain and that allows lower speed, efficient pedaling at a cadence comfortable for the majority of people. There also exists a need for a linear drivetrain that minimizes or eliminates the loss of kinetic energy at the end of each stroke. There exists a need for a simple, inexpensive, lightweight, and efficient linear drivetrain that can be altered to accommodate different user sizes and preferences. Additionally, there exists a need for human powered vehicles where discomfort from the seat is eliminated and that allows most or all of the user's weight to be applied to the pedals. Finally, there exists a need for a drivetrain which eliminates shifting of the derailleur system used to vary speed and torque on hills.

#### SUMMARY OF THE INVENTION

[0014] The systems and methods herein described have several features, no single one of which is solely responsible for its desirable attributes. Without limiting the scope as expressed by the claims that follow, its more prominent features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description of the Preferred Embodiments" one will understand how the features of the system and methods provide several advantages over traditional systems and methods.

[0015] In one aspect, a pulley and cable drivetrain is disclosed which continuously varies speed and torque throughout its stroke. In some systems the continuously variable drivetrain incorporates two pedals, which are contacted by a person's feet, and move in reciprocating motion to transmit power. Each pedal attaches to a crank which rotates along an arc defined by a pivot point at an end opposite the pedal. The cranks attach to a frame, which in some systems comprises the support structure for a human powered vehicle or exercise equipment. Also attached to each crank is a pulley, the pulley positioned at a distance

from the crank pivot point to produce the correct rotational speed of a drive pulley. The drive pulley, of which there is one for each crank, has a drive cable wrapped around a deep annular groove. The drive cable terminates at the interior of the drive pulley.

[0016] In one aspect the drive cable then travels around a first idler pulley and at a second end is attached to the frame. A second, dependent cable is used to raise one pedal while the other is depressed. The dependent cable is attached at each end to each of the cranks. The dependent cable then travels around a second idler pulley which is attached to the frame. The idler pulley is positioned above the cranks so that the dependent cable is tensioned by each crank.

[0017] In some applications the continuously variable drivetrain is used in conjunction with human powered vehicles, specifically a bicycle. The drivetrain allows the seat to be removed from the bicycle. The user stands on the pedals near the rear of the bicycle and in some aspects leans forward on a chest support.

[0018] In some embodiments the dependent cable and the dependent pulley are eliminated to allow each crank to be operated independently of the other. This allows the user to pedal with one leg, both legs simultaneously, or to vary the starting and ending positions of the stroke. In some such systems, the pedals may utilize a cover which extends over the top of the foot or fasteners to attach the user's shoes to the pedals.

[0019] In some systems the idler pulley is eliminated and the drive cable terminates at and is attached to the crank. This has the effect of reducing the speed at which the drive pulley rotates. In other systems two or more idler pulleys are attached to each crank, which increases the speed at which the drive pulley rotates.

[0020] In some systems a compound pulley is used to accelerate the ratio change of the continuously variable drivetrain. The compound pulley, one for each drive pulley, incorporates two deep annular grooves to accommodate two cables. One cable is the drive cable and the second cable is the compound cable. Depending on whether the stroke is in its power or return phase, one cable is unwinding from the compound pulley while the other cable is winding onto the compound pulley.

[0021] In another aspect, a compound pulley is attached to each crank, and a lever is attached to each crank. The lever is connected to the crank with a lever pivot, and in one embodiment has lever pulleys attached at both ends of the lever. A lever cable runs from the compound pulley, around the lever pulleys, and terminates at a strong stationary structure, such as the frame. The lever contacts a roller, which causes the lever to swing and pull more cable at the end of the stroke than at the beginning of the stroke.

[0022] One aspect of the invention is directed to a drivetrain having a crank coupled to a lever pivot, and a lever operably coupled to the crank; the lever is configured to rotate less than 360 degrees about the lever pivot during a power phase of a stroke. Yet another aspect of the invention concerns a drivetrain having a crank, a pulley attached to the crank, a lever operably coupled to the crank, and a lever stop operably coupled to the lever.

[0023] A different aspect of the invention relates to a drivetrain that includes a lever configured to rotate about an

axis during a stroke of the drivetrain, the stroke comprising a power phase and a return phase. The drivetrain additionally includes a hook attached to the lever, a lever stop configured to cooperate with the lever, and a drive pulley operationally coupled to the lever. In some embodiments, the invention concerns a drivetrain provided with first and second rotatable cranks and a crank pivot, wherein the cranks are configured to rotate less than 180 degrees about the crank pivot during a power phase of a stroke. The drivetrain can additionally exhibit first and second lever pivots attached respectively to the first and second rotatable cranks, and first and second levers attached respectively to the first and second lever pivots, wherein the levers are configured to rotate less than 300 degrees during the power phase. The drivetrain, in some cases, additionally includes at least one crank pulley attached to each crank, at least one lever stop operably coupled to each lever, and at least one drive pulley operably coupled to each crank.

[0024] In yet another aspect, the invention is directed to a drivetrain configured to convert human power to mechanical propulsive power. The drivetrain has a lever configured to rotate less than 360 degrees during a power phase of a stroke, a hook attached to the lever, and a first pulley attached to the lever. In other embodiments, the invention covers a drivetrain with two levers and two lever pivots, wherein each lever pivot attaches to a respective lever, and wherein each lever is configured to rotate less than 360 degrees about a respective lever pivot during a power phase of a stroke. The drivetrain can also have first and second lever pulleys attached to each lever, two compound pulleys, and two flexible tension members, each flexible member contacting a respective compound pulley, first lever pulley, and second lever pulley.

[0025] A different aspect of the invention relates to a drivetrain having a crank configured to rotate less than 360 degrees during the power phase of a stroke, a lever pivot coupled to the crank, and a drive pulley having a spiraling root. In some embodiments, the drivetrain includes a flexible tension member operably coupled to the crank and the drive pulley such that a first end of the flexible tension member terminates at the root of the drive pulley, the flexible tension member is spirally wound on the drive pulley at the beginning of the power phase, and the flexible tension member unwinds from the drive pulley during the power phase. Yet one more aspect of the invention concerns a drivetrain having a crank configured to rotate less than 360 degrees during the power phase of a stroke, a lever pivot coupled to the crank, and a lever operably coupled to the crank via the lever pivot; the lever can be configured to rotate less than 360 degrees about the lever pivot during the power phase.

[0026] Still another embodiment of the invention addresses a bicycle having first and second cranks, each crank configured to rotate less than 360 degrees during the power phase of a stroke. The bicycle can have first and second lever pivots coupled, respectively, to the first and second cranks. In one case, the bicycle additionally includes first and second levers operably coupled, respectively, to the first and second cranks, the first and second levers configured to rotate less than 360 degrees about the first and second lever pivots during the power phase. The bicycle can also have a frame, wherein the first and second cranks and/or

the first and second levers are coupled to the frame. In some embodiments, a front wheel and a rear wheel operably couple to the frame.

[0027] One aspect of the invention is directed to a human powered vehicle having a frame, at least one wheel attached to the frame, and at least one crank which is configured to rotate less than 360 degrees during the power phase of a stroke; the crank is operably coupled to the wheel. The human powered vehicle components are configured such that during the power phase a rotation of the crank causes a rotation of the wheel, and wherein the power phase is continuously variable and causes the wheel to rotate more rapidly at the beginning than at the end of the power phase.

[0028] In some embodiments, the invention addresses a continuously variable drivetrain having first and second foot pedals and first and second cranks; wherein the first and second foot pedals couple, respectively, to the first and second cranks. The drivetrain can be configured such that the cranks are capable of reciprocating motion, and the cranks rotate along an arc defined by a crank pivot point located at an end distal from the pedals. The drivetrain can further include a frame adapted to support the cranks, and first and second drive pulleys coupled, respectively, to the first and second cranks. The drivetrain additionally has first and second crank pulleys coupled, respectively, to the first and second cranks; the crank pulleys can be positioned at a distance from the crank pivot point. In some cases, the drivetrain has a first drive cable wrapped around the first drive pulley and the first crank pulley, and a second drive cable wrapped around the second drive pulley and the second crank pulley.

[0029] These and other improvements will become apparent to those skilled in the art as they read the following detailed description and view the enclosed figures.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. 1 is a side view of a bicycle utilizing a continuously variable drivetrain (CVD) and a chest support.

[0031] FIG. 2 is a perspective view of the frame and CVD of the bicycle of FIG. 1.

[0032] FIG. 3 is a perspective view of the chest support of the bicycle of FIG. 1.

[0033] FIG. 4 is an end view of the support base of the bicycle of FIG. 1.

[0034] FIG. 5 is a front perspective view of the frame of the bicycle of FIG. 1.

[0035] FIG. 6 is a back perspective view of the frame of the bicycle of FIG. 1.

[0036] FIG. 7 is a side perspective view of the frame of the bicycle of FIG. 1.

[0037] FIG. 8 is a Detail A view of FIG. 7.

[0038] FIG. 9 is a side view of the bicycle of FIG. 1 with its front wheel removed and the chest support folded down.

[0039] FIG. 10 is a perspective view of the bicycle of FIG. 1 with its front wheel removed and the chest support folded down.

[0040] FIG. 11 is a perspective view of the CVD of the bicycle of FIG. 1.

[0041] FIG. 12 is a second perspective view of the CVD of FIG. 11.

[0042] FIG. 13 is a cutaway section view of the hub of the CVD of FIG. 12.

[0043] FIG. 14 is a perspective view of a crank of the CVD of FIG. 12.

[0044] FIG. 15 is a perspective side view of the drive pulley of the CVD of FIG. 12.

[0045] FIG. 16 is an end view of a drive pulley of the CVD of FIG. 12.

[0046] FIG. 17 is a schematic view of a portion of a CVD of FIG. 12 showing cable movement at different locations in a stroke.

[0047] FIG. 18 is a second schematic view of a portion of a CVD of FIG. 12 showing cable movement at different locations in a stroke.

[0048] FIG. 19 is a schematic view of a drive cable at the beginning of a stroke.

[0049] FIG. 20 is a schematic view of a drive cable at the end of the stroke.

[0050] FIG. 21 is a graphical comparison of a stroke of the bicycle of FIG. 1 with the stroke of a conventional bicycle.

[0051] FIG. 22 is a chart showing stroke torques of the bicycle of FIG. 1 and a conventional bicycle.

[0052] FIG. 23 is perspective view of an alternative CVD.

[0053] FIG. 24 is a perspective view of yet another alternative CVD.

[0054] FIG. 25 is a front view of a pulley used in the CVD of FIG. 24.

[0055] FIG. 26 is a perspective view of yet one more alternative CVD.

[0056] FIG. 27 is a perspective view of a CVD that can be used in exercise equipment.

[0057] FIG. 28 is a side view of a scooter using a CVD.

[0058] FIG. 29 is a side view of yet another alternative CVD.

[0059] FIG. 30 is a perspective view of the CVD of FIG. 29.

[0060] FIG. 31 is a partially schematic view of the CVD of FIG. 29 at the start of a stroke.

[0061] FIG. 32 is a partially schematic view of the CVD of FIG. 29 at the middle of a stroke.

[0062] FIG. 33 is a partially schematic view of the CVD of FIG. 29 at the end of a stroke.

[0063] FIG. 34 is a section view of a drive pulley used in the CVD of FIG. 29.

[0064] FIG. 35 is a partially schematic view of an alternative CVD at the start of a stroke.

[0065] FIG. 36 is a partially schematic view of an alternative CVD at the middle of a stroke.

[0066] FIG. 37 is a partial schematic view of an alternative CVD at the end of a stroke.

[0067] FIG. 38 is a side view of a lever that can be used with the CVD of FIG. 29.

[0068] FIGS. 39A-39D are schematic views showing contrasting different leg positions of a user operating a conventional bicycle and a CVD.

[0069] FIG. 40 is a perspective view of a bicycle and frame that can be used with the CVDs disclosed here.

[0070] FIG. 41 is a perspective view of yet another bicycle frame that can be used with the CVDs disclosed here.

#### DETAILED DESCRIPTION OF CERTAIN INVENTIVE EMBODIMENTS

[0071] Preferred embodiments of the present invention will now be described with reference to the accompanying Figures, wherein like numerals refer to like elements throughout. The terminology used in the description presented herein is intended to be interpreted in its broadest reasonable manner including its specific use herein as well as other uses in the technical field, even though it is being utilized in conjunction with a detailed description of certain specific preferred embodiments. This is further emphasized below with respect to some particular terms used herein. Any terminology intended to be interpreted by the reader in any restricted manner that is different than an accepted plain and ordinary meaning will be expressly and specifically defined as such in this specification and the descriptions of objects or advantages associated with certain embodiments is not intended to require structure fulfilling those objects in all embodiments.

[0072] The inventive embodiments disclosed here are related to technology described in U.S. Provisional Patent Application 60/799,601, filed on May 11, 2006, which is hereby incorporated herein by reference in its entirety. As used here, the terms “operationally connected,” “operationally coupled,” “operationally linked,” “operably connected,” “operably coupled,” “operably linked,” and like terms, refer to a relationship (mechanical, linkage, coupling, etc.) between elements whereby operation of one element results in a corresponding, following, or simultaneous operation or actuation of a second element. It is noted that in using said terms to describe inventive embodiments, specific structures or mechanisms that link or couple the elements are typically described. However, unless otherwise specifically stated, when one of said terms is used, the term indicates that the actual linkage or coupling may take a variety of forms, which in certain instances will be obvious to a person of ordinary skill in the relevant technology.

[0073] Components which are used on both the left and right side of a vehicle or equipment are designated with the letters a and b. For example, where there are two lever cranks 615, the left lever crank might be labeled lever crank 615a, while the right lever crank might be labeled lever crank 615b. Generally, all of the components on a side are designated with the letter a, and all substantially similar components on another side are designated with the letter b; when a component is referred to generically without a side designation, the a or b suffix is removed.

[0074] FIGS. 1 and 2 depict a bicycle 100, where the bicycle seat has been removed and a chest support 90 added

to accommodate a continuously variable drivetrain 10, hereinafter referred to as a CVD 10. The bicycle 100 also has a front wheel 80, a fork 86, handlebars 87, a frame 60, and a rear wheel 84, typical of conventional bicycles. The front and rear wheels 80, 84 may use bicycle wheels that are spoked, solid, molded, and any other wheels that can be used for a bicycle. In some embodiments, the fork 86 has two blades which attach to the front axle on each side of the front wheel 80; however, the fork 86 may also be of single blade structure. In other embodiments, the fork 86 may be replaced by a component that can provide steering of the front wheel 80. The handlebars 87 may be constructed of aluminum, steel, carbon fiber, wood, or any other suitable material, and the shape can be modified to suit an individual user's preference. Referring now to FIGS. 1-3, the chest support 90 is comprised of a support 92, which can be foam, an inflatable cushion, netting, or any other material which provides support for the user's chest. The size, thickness, and shape of the support can be modified to suit the user's preferences. To accommodate the female anatomy, depressions or cups may be formed into the support 92. In one embodiment, the support 92 is constructed of foam or other lightweight flexible material and a firm support structure 93 is attached to the foam on the underside of the support 92. In a preferred embodiment, a support clamp 94 is positioned underneath and attached to the firm support structure of the support 92. The support clamp 94 provides for attachment of the support 92 to the support tube 95. The support clamp 94 also allows the user to tilt the support 92 to optimize the user's position. The support clamp 94 may be constructed of several different designs, including traditional methods used to attach and tilt a bicycle seat. In one embodiment, the support clamp 94 is plastic and integrally formed with the support structure 93. The support clamp 94 consists of two protrusions 94A extending underneath the support 92, each protrusion 94A having a hole 94B to allow a bolt or quick release clamp to be inserted through the holes 94B in the support clamp 94. The support clamp 94 is positioned over the top of a support tube 95, which has a support hole 96 integral thereto. In other embodiments, the support clamp 94 may use the same design to attach bicycle seats to seat posts. The support tube 95 is positioned between the two protrusions 94A of the support clamp 94 and the support hole 96 is aligned so that it is concentric with the holes of the protrusions. The bolt or quick release clamp is inserted through one protrusion, through the support hole 96, and through the second protrusion. A nut or clamp can be used to secure and tighten the support 92, to hold it in a preferred position.

[0075] Now referring to FIGS. 1-4, the support tube 95 is a cylindrical tube made from aluminum, titanium, steel, plastic, a composite such as carbon fiber, or any other suitable rigid, strong material. The support tube 95 is capable of being raised or lowered so that the height of the support 92 can be adjusted to accommodate different users. The support tube 95 fits into a hole 91 in a support base 97, the hole 91 having a slightly larger diameter than the support tube 95. In a preferred embodiment the support base 97 at a first end is generally cylindrical to allow insertion of the support tube 95, and at a second end has an aperture 99 with an axis approximately 90 degrees to the axis of the support tube 95. At a first generally cylindrical end, the support base 97 has a slot 89 to allow a quick release clamp, commonly used in the art, to be positioned around the first end of the

support base 97 and clamp the support base 97, and squeeze the support tube 95 firmly, thus holding it in position to prevent movement when the weight of the user's chest is on the support 92.

[0076] The aperture 99 is slightly larger than and fits over the frame 60. The aperture 99 is split on a side below the frame to allow frame fastener 98 to fasten securely and rigidly the support base 97 to the frame 60. In one embodiment, the frame fastener 98 has two fastener holes 88 which extend through both sides of the split in the support base 97, to allow common fasteners such as bolts or quick release clamps to be used to tighten the frame fastener 98 to the frame 60. The support base 97 can be moved along the axis of the frame 60 either closer to the front wheel 80, or closer to rear wheel 84, to accommodate preferences and sizes of different users.

[0077] Referring now to FIGS. 1, 2, 5-8, and 13, a frame 60 of the bicycle of FIG. 1 is disclosed. The frame 60 is a structural component, and can be constructed of steel, aluminum, titanium, beryllium, carbon fiber or other composite, a plastic, such as glass filled nylon, or any other suitable material. The frame 60 may be composed of two or more materials. For example, the body of the frame 60 can be made from carbon fiber while the dropouts may be steel. The frame 60 is not subjected to the loads and stresses of a conventional bicycle frame. Because the bicycle seat is eliminated, there is only a small amount of weight from the user distributed to the frame 60. Since the user is standing and leaning forward, most of the user's weight is on pedals 16. The pedals 16 ultimately transfer most of the user's weight to the rear axle 33. There is a small amount of weight on the chest support 90, which is transferred to a top tube 62, and ultimately to a head tube 61. Thus the frame 60 can be made significantly lighter than conventional bicycle frames. The head tube 61, a generally cylindrical part of the frame 60, and common in the art, provides for fastening of the fork 86 and steering of the bicycle 100. Attached to the head tube 61 is the top tube 62, a generally cylindrical tube, typically attached at a first end to the head tube 61 by welding if the frame 60 is metal or plastic. In one embodiment, the frame 60 is molded from plastic and the top tube 62 is integrally formed with the head tube 61. The head tube 61 and top tube 62 may also be joined by gluing, using an epoxy, or other high strength adhesive. The top tube 62 extends rearward toward the rear wheel 84, and terminates at first and second hinges 64, 65. The hinges 64, 65 are composed of strong, rigid tubing such as steel, titanium, or aluminum and provide for folding and storage of the bicycle 100.

[0078] Referring to FIGS. 7 and 8, each hinge is comprised of three separate tubes. The middle sections 66 are welded, or permanently attached to the top tube 62 with adhesive, or the middle sections 66 can be integrally molded into the top tube 62. The top and bottom sections 67, 68, respectively, are permanently affixed to a back tube 69 using the same attachment method as the middle section 66. A permanent pin 70 is permanently inserted into the hinge 64 through the top, middle, and bottom sections 66, 67, 68. The second hinge 65 (not fully shown) utilizes a removable pin 71. The removable pin 71 is inserted into the second hinge 65 in the same manner as the permanent pin 70 is inserted into the first hinge 64. By grasping a handle 72 on the removable pin 71, the user may pull and remove the removable pin 71, so that when the front half of the frame 60 is

folded it will pivot on the axis of the permanent pin 70. In this manner, the frame 60 can be folded approximately in half.

[0079] Still referring to FIGS. 1, 2, 5-8, and 11, the back tube 69 is described. The back tube 69 is a short, generally cylindrical component with approximately the same shape, and made from the same material, as the top tube 62. The back tube 69 extends rearward in substantially the same direction as the top tube 62 and terminates at a pulley mount 73. The pulley mount 73, made from the same material as the top tube 62, attaches, protects, and conceals a dependent pulley 24 in a cavity 74 within the pulley mount 73, and forms an attachment point for the back tube 69, top stays 76, and down stays 77. A pulley shaft hole 75 is also formed in the pulley mount 73, and is a location where a pulley shaft (not shown) is inserted through the top of the pulley shaft hole 75, then through the dependent pulley 24, and finally through the bottom of the pulley shaft hole 75. The pulley shaft may be secured with common fasteners, such as a lock nut or retaining ring, or any other suitable method.

[0080] Top stays 76 can be integrally formed with the pulley mount 73, or made separately and welded, glued, or otherwise bonded to the pulley mount 73. In one embodiment the top stays 76, one on the left side and one on the right side of the frame 60, are made from the same material as the rest of the frame 60, although in other embodiments a different material can be used. Similarly, the down stays 77 are also attached to the pulley mount 73 at a first end, and can be integrally molded or welded, or glued to the pulley mount 73. The down stays 77, in a preferred embodiment, are made of the same material as the top stays 76. The down stays 77, one on the left side and one on the right side of the frame 60, extend down and slightly rearward from the pulley mount 73, and are positioned on each side of the rear wheel 84. The down stays 77 are generally elongated tubes and become wider, or farther apart from each other and the rear wheel 84, near their second end to allow for attachment of cranks 15. Crank connectors 79 are positioned near the second end, near the bottom of the down stays 77, and a crank shaft 14 is attached to each crank connector 79, providing for arcuate motion of the cranks 15. The cranks 15 are positioned between the rear wheel 84 and the crank connectors 79. Joining the down stays 77, slightly above and closer to the rear axle 33, are crank stays 78. The crank stays 78, are made from the same material as the down stays 77, and serve to support and anchor the cranks 15. The crank stays 78 are generally elongated tubes that move closer together and closer to the rear wheel 84 at a second end near the rear axle 33. The crank stays 78 join the top stays 76 at a second end near the rear axle 33. Dropouts 63 can be either attached to the crank stays 78 or molded integrally into the crank stays 78. In a preferred embodiment, the dropouts 63 are constructed of steel or aluminum and serve as an attachment point for the rear axle 33. The rear wheel 84 is positioned between the crank stays 78, the down stays 77, and the top stays 76. The rear axle 33 is attached to the dropouts 63 with standard fasteners such as nuts and washers.

[0081] Referring now to FIGS. 9 and 10, the bicycle 100 can easily be made portable because the top tube 62 is the only component of the frame 60 attaching the front end to the rear end. The down tube, seat tube, and bottom bracket, components of the frame of a conventional bicycle are

eliminated. If the front wheel 80 is removed, and the chest support 90 is collapsed and rotated down 180 degrees so that it is positioned between the frame 60 and the ground or riding surface, the bicycle 100 can be quickly folded to a small size. In addition to folding at the axis of the permanent pin 70, the frame 60 can also be made in two separate pieces (not shown) separated at the axis of the pulley shaft hole 75. In this configuration, a first section comprised of the head tube 61, the top tube 62, and the pulley mount 73 (the back tube 69 and the hinges 64, 65 are eliminated) extends to and terminates at the pulley shaft hole 75. A second section begins at the axis of the pulley shaft hole 75 and extends rearward. The second section is designed to contact the first section at two areas, one on the left side and one on the right side of both the first and second sections. The second section has a second pulley shaft hole 75b formed at the top and bottom concentric with and outside of the pulley shaft hole 75 on the first section. The pulley shaft is inserted first through the top portion of the second pulley shaft hole 75b, then through the top portion of the pulley shaft hole 75, then through the dependent pulley 24, then through the bottom portion of the pulley shaft hole 75, and finally through the bottom portion of the second pulley shaft hole 75b. When the pulley shaft is removed, the first and second sections of the frame 60 separate, splitting the bicycle 100 approximately in half.

[0082] Referring to FIGS. 2, 11, 12, and 14, a CVD 10 is disclosed. The CVD 10 includes two cranks 15a, 15b, which move in reciprocating motion when a user powers the CVD 10. From an original, resting position at the beginning of a stroke, the movement of the cranks 15 can be defined as a power stroke, which occurs when a crank 15 is depressed by a user, and a return stroke, which occurs when the crank 15 returns to its original position at the beginning of the stroke. In some embodiments, the cranks 15 are elongated members which begin with a crank pivot 17 at a first end, and have a first section 22 which is generally straight. In some embodiments, the crank pivot 17 is a through hole providing for attachment of the crank shaft 14. At a second end the cranks 15 include a pedal mount 18 for attachment of the pedals 16. A second section 19 of the crank 15 is designed to position the pedals 16 above the first section 22. In some embodiments, the second section 19 is curved upward so that the cranks 15 can be made from one piece and strength is maximized. In other embodiments, the second section 19 may extend from 10 to 90 degrees, or another angle (for example, 30, 40, 50, 60, 70, 80), to the first section 22. The second section 19 may also be welded to the first section 22, or attached by any other suitable method. The second section 19 serves three functions:

[0083] It provides clearance between the user and the frame 60, allowing the user to pedal higher and at a more favorable angle, thus maximizing power,

[0084] It moves the user forward on the bicycle 100 so that the user's weight is distributed appropriately, and

[0085] It lowers a crank pulley 23 so that a more favorable speed ratio is obtained through positioning of the crank pulley 23 relative to a drive pulley 28.

[0086] The cranks 15 can be made from aluminum, steel, titanium, plastic, a composite such as carbon fiber, or another suitable material. The pedals 16 can be conventional bike pedals or can be platforms that are welded or otherwise



rigidly attached to the cranks **15**. In one embodiment, the pedals **16** are platforms that have limited rotational capability to accommodate the bending of the legs while a user powers the CVD **10**. The pedals **16** can be made from aluminum, steel, titanium, plastic, a composite such as carbon fiber, or another suitable material. The user places a foot on each pedal **16**, and by alternately depressing each pedal **16a**, **16b**, delivers power to the CVD **10**, which power is then transferred to a bicycle, scooter, exercise equipment, boat, submarine, plane, or any other human powered device.

[0087] Also attached to each crank **15** is the crank pulley **23**. In some embodiments the crank pulley **23** is an idler pulley that serves to increase the speed ratio of the CVD **10**. The crank pulley **23** can have an idler bearing **26** inserted into its bore to minimize friction. An idler shaft **27** is inserted through the idler bearing **26** and is then threaded into a pulley connector **20** to fasten the crank pulley **23** to the crank **15**. Alternatively, the idler shaft **27** can be pressed into the pulley connector **20** or welded, or fastened with other conventional fasteners. In some embodiments the pulley connector **20** is a round through hole, but it can be made with a square, hexagonal, or any other suitable shaped hole. The hole can also be blind, and in some embodiments the idler shaft **27** can be made integral with the crank **15**, eliminating the need for the pulley connector **20**.

[0088] Also comprising part of the crank **15** are clamp mounts **21**, which in a preferred embodiment are through holes located on the first section **22** of the crank **15**. The clamp mounts **21** can be countersunk so that if a screw or bolt is used for attachment the heads will be flush with the crank **15**. The clamp mounts **21** allow insertion of fasteners such as screws, bolts, or pins to provide attachment of cable clamps **29**. In some embodiments, the cable clamps **29** are a strong, rigid component made from steel although titanium, aluminum, and other materials may be used. Each cable clamp **29** has two through holes to allow insertion of two machine screws. In some embodiments, the machine screws are inserted first through the clamp mounts **21**, then through a first cable clamp **29A1**, and then threaded into a second cable clamp **29A2**. In other embodiments, the machine screws can be first inserted through the second cable clamp **29A2**. In still other embodiments, only one cable clamp **29A** is used and a dependent cable **31** is clamped between the crank **15** and the cable clamp **29A**.

[0089] The dependent cable **31** is a flexible tension member that in some embodiments has minimal creep and a break strength greater than the maximum force exerted by the user. The dependent cable **31** can be constructed of a composite material such as Vectran or Kevlar, but can also be made from other materials, including steel. A first end of the dependent cable **31** is operably attached to the crank **15a**, and at a second end it is operably attached to the crank **15b**, with the above described cable clamps **29**. At an area near its midpoint the dependent cable **31** wraps around the dependent pulley **24** so that when the crank **15a** is depressed the crank **15b** rises, and vice versa. In one embodiment, the dependent pulley **24** is constructed of aluminum, although steel, plastic (such as glass filled nylon), a composite material, or any other suitable material can be used. The dependent pulley **24** is an idler pulley and has a dependent bearing **32** attached at its center to minimize friction. The dependent pulley **24** is positioned in the cavity **74** of the frame **60** and the pulley shaft (not shown) is inserted through the top of the

pulley shaft hole **75**, through the bore of the dependent bearing **32**, and then through the lower portion of the pulley shaft hole **75**.

[0090] Referring now to FIG. **13**, the hub **40** of the CVD **10** is disclosed. The hub **40** is comprised of a hub shell **41**, a generally cylindrical component that contains and protects the one way clutches **42**, the torque drivers **43**, and the rear axle **33**. The hub shell **41** can be constructed of steel, aluminum, titanium, carbon fiber or another composite, or any other suitable material. In some embodiments, the hub shell **41** includes spoke flanges **44**, so that the hub shell **41** can be attached to the rear wheel **84**.

[0091] Attached to the hub shell **41** on its inside diameter are one way clutches **42**. The one way clutches **42** each alternately provide torque to the hub shell **41**, rotating the rear wheel **84**. In some embodiments the one way clutches **42** are roller clutches of the type utilizing hardened steel pins circumferentially spaced around the inside diameter of the roller clutch housing. Hardened steel ramps are positioned around the pins, and springs are attached to the pins to provide for instant lockup of the roller clutch. In another embodiment, the one way clutch can be of the sprag clutch type, where one or more pawls contact ratchet teeth during lock up. The one way clutches **42** are rigidly attached to the hub shell **41** using an interference fit. They can also be attached with welding, adhesive, or standard fasteners. Contacting the roller clutch pins from the inside of the one way clutches **42** are torque drivers **43**.

[0092] The torque drivers **43** in a preferred embodiment are hardened steel cylinders with a smooth outside diameter. The outside surface of the torque drivers **43** contact the one way clutches **42** using a tolerance so that when torque is transferred to the one way clutches **42** they lock up, thus rotating the hub shell **41**. In some embodiments, when the clutch **42a** is locked up and transferring torque, the clutch **42b** is in clutch mode and freewheeling, and vice versa. The lock up mode of the clutch **42a** occurs when the crank **15a** is depressed, and the clutch **42b** freewheels as the crank **15b** is raised.

[0093] Still referring to FIG. **13**, hub bearings **45** are positioned adjacent to and contact hub races **46** on each side of the hub shell **41**. In a preferred embodiment, the hub bearings **45** are angular contact bearings although radial bearings or thrust bearings may be used. The hub bearings **45** are constructed from individual balls, although cylindrical rollers may be used. In one embodiment, the hub bearings **45** incorporate ball retainers, but individual balls or sealed cartridge bearings may also be used. The hub bearings **45** provide for relative movement between the hub shell **41** and the drive pulleys **28**, and provide radial and axial support to the hub shell **41**. The hub bearings **45** on a second side contact the pulley races **47**, which contact and are attached to the drive pulleys **28**. A second set of bearings, the axle bearings **55**, are positioned adjacent to the drive pulleys **28**, and provide radial and axial support to the drive pulleys **28**. In some embodiments the axle bearings **55** are angular contact bearings but in other embodiments, they can be radial or thrust bearings. The axle bearings **55** on a first side contact the axle races **56** of the drive pulleys **28**. On a second, side the axle bearings **55** contact races on cone nuts **57**. In some embodiments, the cone nuts **57** are threaded nuts which can be screwed onto corresponding threads on the

rear axle 33 and tightened up against the axle bearings 55. The rear axle 33 in one embodiment is a threaded rod that defines the longitudinal axis of the hub 40. The rear axle 33 is attached to the dropouts 63 (shown in FIG. 7) of the frame 60 using conventional fasteners such as threaded nuts and washers.

[0094] Referring to FIGS. 13, 15, and 16, the torque drivers 43 are rigidly attached to and rotate with the drive pulleys 28. The drive pulleys 28 are positioned on each side of the hub shell 41 and are concentric with the rear axle 33, which is also the longitudinal axis of the CVD 10. In some embodiments, the drive pulley 28, the torque driver 43, and the pulley race 47, are constructed from the same piece, preferably hardened steel. However, any one of these three components can be constructed separately, and of different materials. For example, the pulley race 47 and the torque driver 43 may be constructed of a separate piece of hardened steel and attached to the drive pulley 28, which can be constructed of aluminum, mild steel, titanium, plastic, a composite, or any other suitable material. The drive pulley 28 is a disc shaped component with an annular groove in its center to house a drive cable 52.

[0095] In some embodiments each drive pulley 28 contains a spring hole 48, a cable hole 49, and a clamp hole 50. The spring hole 48 provides a space for insertion of a first end of a return spring 51, which can be positioned concentrically with the rear axle 33. In some embodiments, the return spring 51 is made from spring steel wire and spirals radially away from the rear axle 33. The return spring 51 at a first end is attached to the drive pulley 28 via the spring hole 48. At a second end the return spring 51 is attached to the frame 60. Attachment to the frame 60 can be made with standard fasteners or a hole can be created in the frame 60 into which the second end of the return spring 51 can be inserted. In some embodiments the second end is the outside diameter (the larger diameter) of the return spring 51 and the first end is the inside diameter (the smaller diameter). The return spring 51 can be positioned so that the coils decrease in diameter as the return spring 51 is tensioned when a crank 15 is depressed during the power stroke. In some embodiments the return spring 51 only needs to provide enough tension to prevent the drive cable 52 from becoming slack on the return stroke. In other embodiments, the return spring 51 is strong enough to return the crank 15 to the beginning, or top of, the stroke. The tensioned return spring 51 rotates the drive pulley 28 in the opposite direction that it rotates during the power stroke, returning the drive pulley to its original position, and assists in lifting the crank 15 to a position at the beginning of the stroke. The spring hole 48 is slightly larger than the material comprising the return springs 51 and is a perforation in the side of the drive pulley 28 facing away from the center of the hub 40.

[0096] A radially located cable hole 49 positioned at the root of a drive groove 53 in the drive pulley 28 allows for insertion of a first end of the drive cable 52. In some embodiments the drive cable 52 is attached to the drive pulley 28 with a set screw (not shown) or another suitable fastener that is threaded into a clamp hole 50. The clamp hole 50 can be a tapped hole that is located on a side of the drive pulley 28 facing away from the center of the hub 40. The drive cable 52 is then wrapped around the drive pulley 28 within the drive groove 53 so that the drive cable 52 wraps around itself multiple times.

[0097] The number of winds of the drive cable 52 in the drive groove 53 varies considerably with the application, and in the case of a human powered vehicle, is dependent on the speed and diameter of the wheel, propeller, flywheel, or other rotating driven component. The number of winds of the drive cable 52 is also dependent on the size and physical condition of the user and also the diameter of the drive pulley 28. Generally, the drive cable 52 will have from two to six windings but in a few applications the drive cable 52 may be wound more than 12 revolutions around the drive pulley 28 and as few as  $\frac{1}{2}$  revolutions. In some applications, the drive cables 52 are wound a sufficient number of revolutions so that there is approximately one revolution left in the drive groove 53 when the cranks 15 are depressed and at the end of their power stroke. By controlling the amount of the drive cable 52 wrapped around the drive groove 53 and leaving approximately one revolution, less tension is applied to the first end of the drive cable 52. If possible, more than one revolution of the drive cable 52 should remain in the drive groove 53 so that the drive cable 52 is wrapped around itself and friction on the sides of the drive cable 52 and at the root of the drive groove 53 will absorb a significant amount of the tension created when the drive cable 52 is pulled. In one embodiment the root diameter surface of the drive groove 53 is knurled or otherwise roughened so that it grabs the drive cable 52 and distributes the tension on the drive cable 52 to a larger area, lessening the stress on the first end of the drive cable 52.

[0098] Still referring to FIGS. 13, 15, and 16, the drive cable 52, after being wound around the drive pulley 28, travels around the crank pulley 23 (seen in FIG. 11). In one embodiment the drive cable 52 wraps around the crank pulley 23 so that the drive cable 52 first contacts the crank pulley 23 on a forward side facing the hub 40, and it becomes disconnected, or leaves the crank pulley 23 on a rearward side facing away from the hub 40. In some embodiments, the drive cable 52 is routed in the opposite direction around the crank pulley 23 and the manner in which the drive cable 52 is wrapped around the crank pulley 23 is dependent on the desired rate of change of the stroke. The drive cable 52 terminates and is attached to a cable end 54, which is constructed of a rigid, strong material such as aluminum, steel, titanium. The cable ends 54 provide for clamping of a second end of the drive cable 52 using standard fasteners, and are rigidly attached to the frame 60. The cable ends 54 can be welded to the frame 60, fastened with machine screws, nuts, and washers, or any other suitable method. In one embodiment, the drive cable 52 is attached to the frame 60 directly with common fasteners and the cable ends 54 are eliminated.

[0099] Referring to FIGS. 17 and 18, as the cranks 15a, 15b, alternately, are pushed and returned to the beginning of their stroke, the angle at which a crank 15 is positioned relative to a drive pulley 28 changes. This creates the opportunity to vary the speed and the torque at which the drive pulley 28 operates throughout the stroke. FIG. 17 is a schematic view of the crank 15, drive pulley 28, and drive cable 52. In FIG. 17, two positions of the crank 15 are depicted. In position A, which is the location of crank 15 at the beginning of a stroke, the drive cable 52 is shown attached directly to the crank 15. To make the explanation of the following principle easier to understand, the crank pulley 23 is not shown. In position B, the crank 15 has rotated 10 degrees relative to position A, which in some embodiments

is approximately 33% of the length of the stroke. In other embodiments, the stroke length can be made longer or shorter depending upon the size of the user, the size and rotational speed of the wheel, propeller, flywheel, or other rotating driven component, and the diameter of the drive pulley 28. As can be seen in FIG. 17, the difference between the length of the drive cable 52 in positions A and B is very small. In position B, the length of the drive cable 52 is approximately 20% longer than in position A. In some embodiments, this results in the drive pulley 28 rotating a small amount, and when the CVD 10 is used with a bicycle 100, produces a lower speed of the rear wheel 84.

[0100] Referring now to FIG. 18, positions C and D of the crank 15 are depicted. The difference between positions C and D is again 10 degrees, or approximately 33% of the stroke length. Position D represents the crank 15 position at the end of a stroke. It is easily seen in FIG. 18 that the drive cable 52 is longer in position D than in position C. It can be seen by comparing FIGS. 17 and 18 that the drive cable 52 travels over 50% farther with the same 10 degrees of movement of the crank 15 in FIG. 18 than in FIG. 17. This increase in travel of the drive cable 52 increases the speed of rotation of the drive pulley 28 and the speed of rotation of rear wheel 84. The acceleration of the rear wheel 84 changes continuously with respect to time from the beginning of the stroke to the end of the stroke. The continuously (over time) variable speed and torque change can be adjusted by varying the position of the crank pivot 17, the length of the crank 15, the position of drive pulley 28 relative to crank 15, the diameter of drive pulley 28, the position and diameter of the crank pulley 23, the diameter of drive cable 52, and the length of the cable, among other things. Generally, when the crank 15 is at a larger angle relative to the drive cable 52, the crank 15 creates more rotation of the drive pulley 28 for an equivalent distance traveled through the stroke. If the crank 15 is at a small angle relative to the cable 52, the crank 15 will typically produce a small amount of rotation of the drive pulley 28 when the crank 15 is depressed during a stroke. An angle Z between the drive cable 52 and the crank 15 changes continuously throughout the stroke and will cause changes in the rotational speed of the drive pulley 28 if all other variables remain the same. Generally, an angle Z2 of the drive cable 52 relative to the crank 15 is greater at the end of a stroke relative to an angle Z1 at the beginning of a stroke; this results in increased rotation of the drive pulley 28 at the end of a stroke compared to the beginning of a stroke if all other variables remain the same. The change in rotation of the drive pulley 28 is continuously variable.

[0101] Referring to FIG. 19, a schematic view of the position of the drive cable 52 wrapped around the drive pulley 28 at the beginning of a stroke is depicted. To make the explanation of the following principle easier, the drive pulley 28 has been hidden. It can be seen that the drive cable 52 has been wound around the drive pulley 28 approximately 3.15 times. Referring to FIG. 20, a schematic view of the position of the drive cable 52 at the end of a stroke is depicted. To make the explanation of the following principle easier, the drive pulley 28 has been hidden. It can be seen that the drive cable 52 has unwound from the drive pulley 28 so that the number of revolutions remaining is approximately 1.1.

[0102] At the beginning of a stroke, the drive cable 52 has a larger diameter, which decreases speed and increases torque at the drive pulley 28 relative to the smaller diameter of drive cable 52 at the end of a stroke. This variation in speed and torque is continuously variable, meaning that the speed and torque at the drive pulley 28 changes continuously with respect to time throughout the stroke. The rate at which the speed and the torque changes can be varied and is controlled by the root diameter of the drive pulley 28, the diameter of the drive cable 52, the number of revolutions the drive cable 52 is wrapped around the drive pulley 28, the length of the crank 15, the length of the stroke, and other variables.

[0103] By combining an increase in speed inherent in the change in angular position of the crank 15 relative to the drive pulley 28, and the decrease in diameter of the drive cable 52 during the power stroke, a significant increase in speed can be realized at the end of the stroke. Significantly, the increase in speed is non-linear and increases rapidly toward the end of the stroke as the rate of change, or percentage of, the decrease in the diameter of the drive cable 52 accelerates. Simultaneously, the angle of the crank 15 relative to the drive pulley 28 increases the amount of drive cable 52 pulled. The combined effect of these two phenomena creates a seamless increase in speed throughout the stroke. This speed increase is difficult to realize on a CVD bicycle because the bicycle begins to accelerate rapidly, the cranks 15 become difficult to depress, and significantly more force is required to be applied by the user. The amount of acceleration can be controlled through proper design of the CVD 10. In some embodiments, the increase in force required to reach the end of the stroke is insufficient under normal operating conditions. This means that the cranks 15 will slow down and stop on the power stroke before reaching the end of the stroke unless the user applies significant power. This eliminates the loss in kinetic energy at the end of each stroke.

[0104] Referring to FIG. 1, the end of the power stroke occurs when the opposite crank 15 on its return stroke contacts the frame 60. In another embodiment, an intermediary component (not shown) positioned between the crank 15 and the frame 60 stops the return stroke of the crank 15. This intermediary component can be constructed of a resilient material such as urethane or rubber and can be adjusted to suit the preference of the user. The intermediary component can be attached to the frame 60 with common fasteners.

[0105] Referring now to FIGS. 1 and 11-13, the length and position of the stroke can be controlled by varying the length and the position of the drive cables 52 and the dependent cable 31. The length of the dependent cable 31 can be adjusted by loosening the two machine screws that are inserted into the clamp mounts 21 of a crank 15. This loosens the force that the cable clamps 29 apply to the dependent cable 31. The length of the dependent cable 31 can then be lengthened or shortened. If the dependent cable 31 is lengthened the cranks 15 move farther away from the dependent pulley 24, or closer to the ground when the CVD 10 is used in conjunction with the bicycle 100. This changes the position of the user on the bicycle 100 and changes the speed of the bicycle 100. When the cranks 15 move farther from the dependent pulley 24, the distance between each of the cranks 15 also increases and unwinds some of the drive

cable 52 from the drive pulleys 28. This increases the speed ratio of the CVD 10 and the bicycle 100.

[0106] The length of the drive cables 52 can be adjusted in the same manner. If the fasteners attaching the drive cables 52 to the cable ends 54 are loosened, the drive cables 52 can be lengthened or shortened. If the drive cables 52 are lengthened, the return springs 51 wind the additional drive cable 52 onto the drive pulleys 28, decreasing speed and increasing torque to drive pulleys 28. If the drive cables 52 are shortened, speed increases and torque decreases. Thus, the user can configure the speed ratio of the CVD 10 to suit his or her personal preference.

[0107] Referring now to FIGS. 21 and 22, a stroke comparison is made between a traditional rotary stroke on a bicycle and the stroke of the CVD 10. Referring to FIG. 21, a circle A depicts the stroke of a traditional bicycle. Significantly, less than 90 degrees of a 360-degree stroke produces power, and only about 60 degrees of the stroke efficiently produces power, shown by the 60-degree sign between the upper and lower positions X of a conventional bicycle crank. The conventional rotary stroke only becomes very efficient through about half, or 30 degrees of the 60-degree stroke. The arc B depicts the length of the stroke of the CVD 10, which very efficiently produces power through an approximately 30 degree range. Importantly, the user's legs do not move nearly as much as in a conventional rotary stroke, lowering stress on the knees and other joints, and reducing muscle fatigue.

[0108] Referring to FIG. 22, torque is compared between a conventional rotary stroke and the CVD 10 stroke. Increasing torque is plotted on the vertical Y axis on the left side of the graph, while the horizontal X axis depicts time, or the percentage of the stroke completed. The curve C denotes the torque of a conventional rotary bicycle drivetrain through one complete stroke. As the user passes through the 60-degree portion of the stroke where power is produced, a significant torque spike occurs. This torque spike occurs twice per revolution, as a first leg and then a second leg pass through the power portion of the stroke. The torque of the stroke drops sharply when the cranks are substantially vertical, at the beginning and halfway through the stroke. To reduce the size of the torque spike and to maintain momentum through the power portion of the stroke, the user must maintain a high cadence to transfer power efficiently.

[0109] The curve D denotes the torque through the stroke of the CVD 10. Torque is steady and level throughout the stroke because not only are the degrees of rotation through the stroke small (between 20-40 degrees in some embodiments) and ideally configured to produce power, but also because the radius of the drive cable 52 to the center of the drive pulley 28 decreases as the crank 15 moves through the power phase of the stroke. This action decreases torque. Concurrently, as the legs straighten the leg muscles become more efficient and produce more force towards the end of the stroke, offsetting the decrease in distance of the drive cable 52 to the center of the drive pulley 28. Still referring to FIG. 22, the maximum torque produced by the CVD 10 is lower than a conventional rotary drivetrain, reducing stress on the user and the CVD 10 components, but the average torque is higher. This occurs because much more of the user's weight is applied to the pedals 16, due to the fact that there is no seat. Thus, the force applied to the pedals 16 is much greater.

[0110] Referring now to FIG. 23, an alternative CVD 110 with an independent stroke is described. For simplicity, only the differences between the CVD 110 and the CVD 10 will be discussed. The dependent cable 31 is removed and replaced by two independent cables 131a, 131b, which are attached to the cranks 15a, 15b, respectively. At a second end, the independent cables 131 attach to the frame 60. The independent cables 131 can use common fasteners or cable clamps 29 for attachment to the frame 60. Because the dependent cable 31 is eliminated, in some embodiments the crank 15a does not return to its original position when the crank 15b is in its power stroke, and vice versa. This requires that a stop be implemented to end the power stroke of the CVD 110. The independent cables 131, which like the dependent cable 31 are flexible tension members, accomplish this purpose by becoming taut at the end of the power stroke. The length of the independent cables 131 can be adjusted in the same manner as the dependent cable 31. Independent pedals 116 replace the pedals 16 of CVD 10. The independent pedals 116, allow the user to pull the cranks 15 on the return stroke. In some embodiments, a cover 117, attached to the pedals 116, covers the tops of the user's feet. In other embodiments, the pedals 116 incorporate toe clips (not shown) so the user can pull the cranks 15. In still other embodiments, the independent pedals 116 can be clipless pedals and the user wears matching clipless shoes which engage and attach to hooks or other fasteners on the independent pedals 116. In still other embodiments, the return spring 51 (shown in FIG. 11) is configured to lift the cranks 15 during the return phase of the stroke, and the independent pedals 116 are not needed to raise the cranks.

[0111] Still referring to FIG. 23, the user can adjust the length of the stroke as with CVD 10, but can also adjust the height of the stroke by lifting the cranks 15 higher when pedaling, which produces a slower speed and a higher torque. The user can also depress the cranks 15 farther on the power stroke, increasing the speed and reducing the torque. Significant ratio changes in the speed and torque of the CVD 110 can be achieved in this manner. The user can also pedal with one foot only or with both feet at the same time.

[0112] Referring now to FIGS. 11, 24, and 25, an alternative CVD 210 with a compound pulley 204 is disclosed. For simplicity, only the differences between the CVD 210 and the CVD 10 will be described. On one side of FIG. 24, side a, the drive pulley 28a, crank pulley 23a, and compound pulley 204a have been hidden so that the drive cable 202a and the compound cable 206a are visible. On side b of FIG. 24, the drive cable 202b and the compound cable 206b have been hidden so that compound pulley 204b is easily visible. The CVD 210 is similar to the CVD 10, but the CVD 210 includes compound pulleys 204a, 204b. In one embodiment, the compound pulleys 204 attach to the frame 60 in the same manner that the crank pulley 23 connects to the crank 15. The compound pulleys 204 can be made of the same material and in the same fashion as the drive pulleys 28. The drive cable 202 travels from the drive pulley 28 to a first compound groove 208a in compound pulley 204. The drive cable 202 wraps around a first compound groove 208a in the compound pulley 204a, and the drive cable 202 fastens to the compound pulley 204. Compound cable 206 wraps around a second compound groove 208b in the compound pulley 204 and fastens to the compound pulley 204. In some embodiments, the Compound cable 206 then wraps around the crank pulley 23 before terminating at the frame 60.

[0113] Still referring to FIGS. 11, 24, and 25, the compound pulley 204 increases the speed change of the CVD 210 during a stroke, as compared to the stroke of the CVD 10. The drive cable 202 winds onto the compound pulley 204 during a power stroke, while the compound cable 206 unwinds. This creates easy pedaling at the beginning of the power stroke, rapidly increasing the speed of the drive pulley 28, and thus the difficulty of pedaling toward the end of the power stroke. The speed change can be varied by making the first and second compound grooves 208a, 208b different diameters, and by changing the diameter of the compound pulley 204 relative to the drive pulley 28.

[0114] Referring now to FIGS. 11, 24, and 26, an alternative CVD 310 with a compound pulley 204 is disclosed. For simplicity, only the differences between the CVD 310 and the CVD 10 will be described. The CVD 310 substantially similar to the CVD 210, and FIG. 26 is depicted in the same way as FIG. 24. In the CVD 310 the crank pulley 23, the idler bearing 26, and the idler shaft 27 are not used and, rather, the compound cable 206 attaches to the crank 15 instead of to the frame 60. Additional cable clamps 29 are used to attach the compound cable 206 to the crank 15.

[0115] Referring now to FIG. 27, an alternative CVD 410 is disclosed. For simplicity, only the differences between the CVD 410 and the CVD 210 will be described. The CVD 410 is substantially similar to the CVD 210, except that the CVD 410 is configured with an integral brake or generator 215. In some embodiments, an annular flux disc 406 is pressed onto the hub shell 41 with an interference fit. The flux disc 406 can be made from high conducting material, such as aluminum or copper. The flux disc 406 has multiple annular grooves, similar to those in the compound pulley 204. A brake 404, which can be constructed of steel, plastic, a composite, or another suitable material, has annular protrusions which are designed to be inserted into the space between the annular grooves of the flux disc 406. The brake 404 is designed to fasten to a frame or other rigid structure. In one embodiment, a nut (not shown) attaches to the brake and a bolt (not shown) threads into the nut. The bolt and the nut control the position of the brake 404 relative to the flux disc 406. Brake magnets 408, which are glued or fastened with common fasteners to the sides of the protrusions of the brake 404, fit into the spaces between the annular grooves of the flux disc 406 with a small amount of clearance. When the CVD 410 is powered by a user, resistance is controlled by positioning the brake 404 closer or farther from the flux disc 406 by rotating the bolt. When the brake magnets 408 move farther into the flux disc 406, more resistance is created, and vice versa. The resistance for the CVD 410 is created without any contacting parts. The brake magnets 408 can also be the magnets used in a permanent magnet generator and the flux disc 406 can be modified to become the armature of a permanent magnet generator. In this embodiment, the resistance, or braking, produced by the permanent magnet generator is converted to electricity.

[0116] Referring now to FIG. 28, a scooter 500 utilizing a CVD 510 similar to the CVD 210 is disclosed. For simplicity, only the certain features of the scooter 500 will be explained. In a preferred embodiment, the crank pulleys 523 are near the end of the cranks 515 (the end where the pedals 517 attach to the cranks 515) to maximize the amount of travel of both the drive cable 502 and the compound cable 506. The crank pivots 517 are located near the back of the

rear wheel to maximize the length of the cranks 515. A cover 533, which attaches to the frame with common fasteners or by welding, provides attachment for the compound pulleys 504. In other embodiments, the compound pulleys 504 can be attached to the frame with common fasteners. In one embodiment, the compound cable 506 attaches to the cover 533, while in other embodiments the compound cable 506 attaches to the frame 560.

[0117] Referring now to FIGS. 29 and 30, an alternative CVD 605 used on a bicycle 600 is described. For simplicity, only the differences between the bicycle 100 and the bicycle 600 will be described. The frame 62 of the bicycle 600 can be substantially similar to frame 60 of the bicycle 100 but can have a frame tail 602. The frame tail 602, in one embodiment, extends rearward and downward from the crank stay 78. At a first end, the frame tail 602 can be attached to the frame 62 by welding, with fasteners or adhesive, or any other suitable method to produce a strong, rigid connection. The frame tail 602 is preferably a strong, rigid, part of the frame 62 having a hole to accept a lever stop 604. The lever stop 604 in some embodiments is a hardened pin, but the lever stop 604 can also be configured as a shaft for a bearing. In some embodiments, a lever bushing 606 fits over the lever stop 604 and is held in place by a retaining ring that is inserted into a groove in the lever stop 604 (not shown). The lever bushing 606 can be a low friction cylindrical component that provides for relative motion between the lever stop 604 and the lever bushing 606. In other embodiments, the lever bushing 606 can be a roller bearing, such as a needle roller or radial bearing.

[0118] Still referring to FIGS. 29 and 30, a lever crank 615 can be substantially similar to the crank 15 of bicycle 100 but can have a lever pivot 612 and a lever slot 618. In some embodiments, the lever pivot 612 is a hole for receiving a lever pin 613. The lever pin 613 can be rigidly attached to the lever crank 615 with an interference fit, welding, adhesive, or any other suitable method. The lever slot 618 is preferably a slot formed into the lever crank 615 near the pedal 16. In some embodiments, the lever slot 618 includes multiple notches which allow a compound pulley shaft 620, to be secured at various locations so that the distance between a compound pulley 622 and a lever crank pivot 616 can be adjusted. The compound pulley shaft 620 can be attached to the lever crank 615 with standard fasteners, and in one embodiment a well known quick release (not shown) is used. When the compound pulley 622 is farther from the lever crank pivot 616, more of a drive cable 630 and a compound cable 632 is pulled, and the bicycle 600 shifts into a higher gear. When the compound pulley 622 is closer to the lever crank pivot 616, less drive cable 630 and compound cable 632 is pulled, and the bicycle 600 shifts into a lower gear.

[0119] Still referring to FIGS. 29 and 30, a lever 608 is described. The lever 608 attaches to the lever crank 615 with the lever pin 613, which in some embodiments is a hardened steel pin with a head. In some embodiments, a bushing or bearing (not shown) placed over the lever pin 613 can be used to minimize friction between the lever 608 and the lever pin 613. In one embodiment, a hole is formed into a first end of the lever 608 to which a first lever pulley shaft 638 is rigidly attached with an interference fit, welding, adhesive, or any other suitable method. Positioned over the first lever pulley shaft 638 is a first lever pulley 634, which

is an idler pulley and is free to rotate. In some embodiments, the first lever pulley shaft 638 has a head on one end to prevent the first lever pulley 634 from coming off the first lever pulley shaft 638. At a second end of the lever 608 is a second hole where a second lever pulley shaft 640 is inserted using the same attachment method as the first lever pulley shaft 638. A second lever pulley 636, which in some embodiments is substantially the same as the first lever pulley 634 and is also an idler pulley, is positioned over the second lever pulley shaft 640. A guide surface 614, which is of a shape to produce the desired movement and rotation of the lever 608, is formed on one side of the lever 608 between the second lever pulley 636 and the lever pivot 612. The lever bushing 606 rolls along the guide surface 614 during a stroke. The lever bushing 606 is preferably adapted to minimize friction and is positioned over the lever stop 604. The movement of the lever bushing 606 forces the lever 608 to rotate in a direction that causes the compound cable 632 to wrap around the first and second lever pulleys 634, 636. In some embodiments, the first lever pulley 634 comes in contact with the compound cable 632 before the second lever pulley 636. Both the first and second lever pulleys 634, 636 increase the amount of compound cable 632 that is pulled during the stroke. In some embodiments, the lever 608 is configured to increase the rate of change of the amount of compound cable 632 pulled throughout the stroke. For example, near the beginning of a stroke, the amount of compound cable 632 pulled during the first 5 degrees of rotation of the lever crank 615 can be one centimeter, while in the last 5 degrees of rotation of the lever crank 615 five centimeters of the compound cable 632 can be pulled. The rate of change and length of the compound cable 632 pulled during a stroke are controlled by many variables including the distance from the lever pivot 612 to the crank pivot 616, the length of the lever 608, the shape of the guide surface 614, the location of the lever stop 604, the distance between the lever pivot 612 and the first lever pulley 634, the distance between the lever pivot 612 and the second lever pulley 636, the distance between the compound pulley 622 and the crank pivot 616, the degrees of rotation of the lever crank 615 during a stroke, whether a line drawn between the first lever pulley shaft 638 and the second lever pulley shaft 640 is coincident with the center of the lever pivot 612 or is offset, and the termination point of the compound cable 632.

[0120] Referring now to FIGS. 31-33, in some embodiments a CVD 601 using a lever 608, can include a lever hook 610, which can be a generally curved portion that forms a hook at the end of the lever 608 on the side of the second lever pulley 636. The lever hook 610 preferably limits the rotation of the lever crank 615 during a stroke, catching the lever stop 604 or lever bushing 606 and stopping the rotation of the lever crank 615 at the end of a stroke. In one embodiment, the lever hook 610 can be adapted to stop the rotation of the lever crank 615 as the lever crank 615 returns to the beginning of the stroke.

[0121] Referring to FIG. 31, the lever 608 is shown at the beginning of a stroke. The lever hook 610 has caught on the lever bushing 606 during the return stroke and has prevented the lever crank 615 from swinging closer to a drive pulley 650. It should be noted that the same return spring 51 can be used on the CVD 601 as on the CVD 10, and the return spring 51 is strong enough to rotate the lever crank 615 on the return stroke back to its starting position. As the stroke begins and the lever crank 615 begins to rotate, the lever

pivot 612 begins to move closer to the lever stop 604. In some embodiments, the first lever pulley 634 is in contact with the compound cable 632.

[0122] FIG. 32 depicts the stroke midway through its power phase. The lever crank 615 is close to the lever stop 604. The lever hook 610 has moved away from the lever stop 604, and the lever pivot 612 is closer to the lever stop 604, causing the lever 608 to rotate more rapidly, pulling more of the compound cable 632, and thus increasing the rate of change and accelerating the rotation of the rear wheel 84 (seen in FIG. 29). This occurs because the first lever pulley 634 pulls more of the compound cable 632. Note that the second lever pulley 636 is about to contact the compound cable 632.

[0123] FIG. 33 depicts the stroke at the end of its power phase. The lever crank 615 has passed the lever stop 604, and the lever bushing 606 has rolled along the guide surface 614 until the lever bushing 606 has again contacted the lever hook 610, stopping the lever crank 615 and ending the power phase of the stroke. The lever 608 has rotated in the same direction throughout the power phase of the stroke. During the return phase of the stroke the lever 608 rotates in the reverse direction, returning to its starting position. In some embodiments, the rate of change and rotational speed of the drive pulley 650 continues to increase throughout the stroke because the second lever pulley 636 has engaged and pulled a significant amount of compound cable 632, and the drive cable 630 has continued to lengthen.

[0124] Referring now to FIGS. 31-33, in some embodiments the acceleration of the drive pulley 650 increases linearly throughout the stroke. When the CVD 601 is implemented on a bicycle 600, and the user is ascending a hill, the rear wheel 84 typically rotates more slowly and pedaling becomes more difficult. In this situation, the user is unable to exert enough force to actuate the lever cranks 615 throughout the entire stroke. Pedaling becomes too difficult toward the end of the stroke, which stops the stroke. In such a situation, the user will be pushed toward the beginning of the stroke, where pedaling is easier. This action also moves the user forward on the bicycle 600, which is advantageous when ascending a hill. The user can choose to shorten the length of the stroke to make pedaling easier. When the user rides down a hill, the rear wheel 84 rotates faster and the drive pulley 650 also rotates faster to apply power to the bicycle 600. In this situation, pedaling becomes easier and the user moves farther through the stroke before it becomes too difficult to pedal. This action also moves the user farther back on the bicycle 600, which is advantageous when descending a hill. To summarize, in some embodiments, the CVD 601 automatically shifts the ratio to suit the needs of the user.

[0125] Referring now to FIG. 34, one embodiment of the drive pulley 650 of the bicycle 600 will be described. The drive pulley has a spiraling root 652 at its root. The spiraling root 652 radius increases at a substantially linear rate throughout one turn, or 360 degrees of rotation. In some embodiments, the spiraling root 652 radius increases an amount substantially equal to the diameter of the drive cable 630 over one turn. The drive cable 630 can have a lug 658 attached at an end that terminates at the smallest radius of the spiraling root 652. The lug 658 is a common fastener that has a flat area with a lug hole 659 to allow insertion of a

screw (not shown). The flat portion of the lug **658**, which includes the lug hole **659**, is inserted into a pulley slot **654**, which is formed into the spiraling root **652**. The screw in some embodiments is a flat head screw and can be inserted into a countersunk fastening hole **656** which is aligned radially with the lug hole **659**, so that the flat head screw is first inserted into a countersunk portion of the fastening hole, then through the lug hole **659**, then threaded into a threaded portion of the fastening hole **656**.

[0126] Referring now to FIGS. **35-37**, an alternative CVD **700** is disclosed. The CVD **700** is similar to the CVD **601**, using a crank **710** and a transfer lever **720**. At a first end, the transfer lever **720** pivots about a lever pivot **722**, which can be rigidly attached to a non-moving component, such as a frame (not shown). The components of the lever pivot **722** can be substantially similar to the components of the lever pivot **612**. A pulley shaft **726** and a pulley **724** can be attached near a second end of the lever **720**. At a first end, the crank **710** pivots about a crank pivot **712**. A pedal **16** attaches to a second end of the crank **710**. Also attached to the crank **710** are a stop **714** and a bushing **716**. A drive cable **730** wraps around a drive pulley **750**. A compound cable **732** is rigidly attached to a rigid, non-moving component, such as a frame (not shown).

[0127] FIG. **35** shows the CVD **700** at the beginning of the power phase of a stroke or the end of the return phase of a stroke. The bushing **716** contacts a guide surface **728** on the lever **720** and, as the user actuates the pedal **16**, the crank **710** begins to move through the power phase of the stroke. The bushing **716** rolls on the guide surface **728**. FIG. **36** shows the CVD **700** midway through the power phase of a stroke. The crank **710** and the bushing **716** have moved closer to the lever pivot **722**, which causes the lever **720** to rotate more rapidly, pulling more of the drive cable **730** and the compound cable **732**, which results in an increasing rate of change. FIG. **37** shows the CVD **700** at the end of the power phase of a stroke. The crank **710** and the lever **720** are nearly parallel, and the bushing **716** has moved closest to the lever pivot **722**, which further increases the rotational speed of the lever **720** and the rate of change in the amount of the compound cable **732** and the drive cable **730** pulled. The guide surface **728** can be any shape which produces the desired rate of change. For example, in some embodiments the guide surface **728** is straight, while in other embodiments it is a curve. In still other embodiments, the guide surface **728** is a spline or a curve produced by multiple radii.

[0128] Passing to FIG. **38** now, it is shown a lever **609** that can be used with various embodiments of the CVDs previously described. The lever **609** has generally flat sides **380** that terminate at a lever pivot end **381** and at a distal slider guide end **382**. In one embodiment, the lever **609** includes one or more pulley attachment couplings **383**, which can be holes for receiving the shafts of the pulleys. The pulley attachment couplings **383** can be located at, near, or in the vicinity of the lever pivot end **381**. As illustrated in FIG. **38**, in some embodiments, the lever **609** includes additionally one or more pulley attachment couplings **384** near, at, or in the vicinity of the slider guide end **382**. It is preferable to provide multiple pulley attachment couplings **383**, **384** to, among other things, allow for flexibility in choosing the location of the pulleys (not shown).

[0129] In one embodiment, the lever **609** is provided with a lever pivot attachment coupling **385**, which is positioned

between the lever pivot end **381** and the slider guide end **382**. As shown in FIG. **38**, the lever pivot attachment coupling can be positioned near to the pulley attachment couplings **383**. A mid-lever portion **386** of the lever **609**, between the lever pivot attachment coupling **385** and the slider guide end **382** is preferably provided with a curved guide surface **387**. In one embodiment, the guide surface **387** defines an elliptical arc. For example, for some applications, the guide surface **387** is characterized relative to an elliptical arc **388** having a major axis **389** of about 6-inches and a minor axis **390** of about 3-inches. In the embodiment illustrated in FIG. **38**, a width **391** of the lever **609** can be about 1.5-inches. In some embodiments, an axis **392** collinear with the centers of the pulley attachment couplings **383** and the pivot lever attachment coupling **385** is located at an angle **A1** of about 140-degrees relative to the major axis **389**. In one embodiment, the distance between the centers of the pulley attachment couplings **383** and the lever pivot attachment coupling **385** is about 1-2.5-inches, and more preferably 1.5-2.0-inches. In some embodiments, the guide surface **387** transitions into a radius **393** or a radius **394**, which can be, for example, a 0.75-inch radius. It should be noted that although the guide surface **387** has been described in one embodiment as being defined by an elliptical arc, in other embodiments the guide surface **387** can be defined by various shapes of curves, or even straight lines. For some applications, the guide surface **387** can be composed of multiple, sequential curves, which at least some of them can have different radii.

[0130] Referring now to FIGS. **39A-39D**, some physiological benefits of using a CVD are discussed. FIGS. **39A** and **39B** depict a user's leg position at the top and bottom of a rotary stroke, commonly used on bicycles. FIGS. **39C** and **39D** depict a user's leg position at the top and bottom of a stroke when a CVD is used on a bicycle. FIGS. **39A-39D** show a user's upper leg **770**, knee **772**, and lower leg **774**. FIG. **39A** shows the distance **776** between two pedals of a typical bicycle using 170 mm cranks. The total distance **776** between the pedals is 340 mm. FIG. **39B** shows that at the bottom of a conventional rotary bicycle stroke, the user's leg is slightly bent. FIG. **39B** shows the distance **777** between the bottom of a user's foot at the bottom of a conventional rotary stroke and the bottom/end of the stroke of a CVD. FIG. **39C** shows that at the end of the power phase of a CVD stroke, the user's leg is substantially straight. FIG. **39D** shows the distance **778** between the pedals at the top/start and bottom/end of a CVD stroke, which is 235 mm, or 69% of the length of the rotary stroke. More importantly, the user's leg is bent at an angle of about 91 degrees in FIG. **39D**, while in FIG. **39A** the user's leg is bent at an angle of about 68 degrees.

[0131] Still referring to FIG. **39**, there are many physiological benefits to minimizing the amount a user must bend their legs when pedaling. One obvious benefit is that it is easier, because the user need not move his legs as much or lift his legs as high. Another benefit is that there is less stress on the knees, and this is important for people with knee problems. Another benefit is that more muscles are used in the CVD stroke than in the conventional rotary stroke of a bicycle, and more of an activated muscle is used. Studies have shown that stair climbing, which is analogous to the movement produced by the CVD stroke, activates almost all of the muscles of the lower body, including the hip flexors and the gluteus muscles. Still another benefit of the CVD

stroke is that muscle contractions are more efficient when muscles are lengthened or approach lengthening rather than when they are shortened. Termed concentric (shortening) and eccentric (lengthening) muscle contractions, eccentric muscle contractions can be far more efficient. For example, studies have shown that cycling produces muscle movement that is about 15% efficient, while the muscles used in running up an incline, which more closely approximates the movement produced by the CVD stroke, achieve about 34% efficiency. Still another benefit of the CVD stroke is that the users are able to switch their body weight from side to side, easily applying all of their weight to the power phase of a CVD stroke, which produces much more force than is achieved when a user is applying force to the pedals when seated on a bicycle.

[0132] Referencing FIG. 40 now, a bicycle 4010 that can use various embodiments of the CVDs described here is shown. In one embodiment, the bicycle 4010 includes a frame 4015 supported by a front wheel 4020 and a rear wheel 4025. Top tubes 4030 extend from a head tube 4035 to a wheel axle (not shown) of the rear wheel 4025. The top tubes 4030 can be adapted to receive and secure the wheel axle. The rear wheel 4025 is placed between the top tube 4030A and the top tube 4030B. In some embodiments, a first portion of the top tubes 4030 is actually a single tube, which then bifurcates into two tubes as it approaches the rear wheel 4025. A down tube 4040 extends from the head tube 4035 toward a lower portion of the rear wheel 4025, and is positioned generally in the same plane as that of the rear wheel 4025 (that is, the down tube 4035 preferably terminates in front of, and is aligned with, the rear wheel 4025). Tying tubes 4045 are coupled to the top tubes 4030 and to the down tube 4040. For example, the tying tube 4045A is fastened at one end to the top tube 4030A and at a second end to the bottom tube 4040. In some embodiments, the bottom tube 4040 is provided with an extension, or a support rod, or a shaft (not shown) for coupling the tying tubes 4045 to the down tube 4040. In some embodiments, the bicycle 4010 includes a chest support 4050 that is coupled to the frame 4015 by a chest support tube 4055, which is fastened to one or both of the down tubes 4030. The fastening between the chest support tube 4055 and the down tubes 4030 can be adapted to allow selection of location of the chest support tube 4055 along the length of the down tubes 4030. In one embodiment, reciprocating cranks 4060 can be coupled to crank pivots 4065, which can be supported by and located near, at, or in the vicinity of, the down tube 4040 and/or the tying tubes 4045. Lever stops 4070 can be coupled the tying tubes 4045 to provide a guiding structure for a movement of a lever (not shown in FIG. 40) such as the levers 608 and 720 described above.

[0133] Passing to FIG. 41 now, a bicycle 4100 can include a frame 4105 that includes a head tube 4110 coupled to a down tube 4115. A chest support 4120 can be received and/or supported on a chest support tube 4125, which couples to the down tube 4115 via a chest support tube clamp 4130. In some embodiments, the chest support tube clamp 4130 is adapted to be removable and allow selection of location of the chest support clamp 4130 a desired length of the down tube 4115. As illustrated in FIG. 41, a portion 4112 of the down tube 4115 can bend in front of, and extend toward a lower part of, a rear wheel 4135.

[0134] In some embodiments, downstays 4140 couple the down tube 4115 to a rear wheel axle (not shown) of the bicycle 4100. In one embodiment, for example, the downstays 4140 couple to the rear wheel axle by a bracket 4145. In some embodiments, crank stays 4150 couple the downstays 4140 to the down tube 4115. Hence, in some cases, the down tube 4115 is provided with an extension, connecting hub, or shaft 4155 adapted to couple to the crank stays 4150. As shown in FIG. 41, in some embodiments, the downstays 4140 and the crank stays 4150 can be formed integrally into one piece. The rear wheel 4135 is placed between pairs of crank stays 4150 and downstays 4140.

[0135] A crank 4160, which in some embodiments is reciprocating and adapted to turn only through an angle that is less than 360 degrees, can be coupled to the down tube 4115 and/or to the crank stay 4160. In one embodiment, the crank 4160 is rotationally coupled to the connecting hub 4155. A lever stop 4165 can be attached to the crank stay 4150 to provide a guide structure to a movement of a lever (not shown in FIG. 41) such as the levers 608 and 720 of the CVDs described above.

[0136] The foregoing description details certain inventive embodiments. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the inventions disclosed here can be practiced in many ways. It should be noted that the use of particular terminology when describing certain features or aspects of the inventive embodiments should not be taken to imply that the terminology is being redefined herein to be restricted to including any specific characteristics of the features or aspects of the invention with which that terminology is associated.

What is claimed is:

1. A drivetrain, comprising:

a crank;

a pulley attached to the crank;

a lever operably coupled to the crank; and

a lever stop operably coupled to the lever.

2. The drivetrain of claim 1, wherein the crank is configured to alternately move closer to and farther from the lever stop during a power phase of a stroke.

3. The drivetrain of claim 1, wherein the crank passes by the lever stop during the power phase.

4. The drivetrain of claim 1, wherein the lever stop is stationary relative to the crank and/or the lever.

5. The drivetrain of claim 1, wherein the lever stop is not stationary relative to the crank and/or the lever.

6. The drivetrain of claim 1, wherein the crank and the lever are configured such that the mechanical advantage of the power phase of a stroke decreases continually from the beginning to the end of the power phase.

7. A drivetrain comprising:

a drive pulley;

a crank configured to pivot about a crank pivot;

a crank pulley coupled to the crank at a location on the crank that is distal from the crank pivot, the crank pulley operably coupled to the drive pulley;

a lever coupled to the crank via a lever pivot that is coupled to the crank; and



a lever stop configured to guide a motion of the lever, the lever stop coupled to a structure that is stationary relative to the lever.

8. The drivetrain of claim 7, wherein the drive pulley is coupled to a hub shell, said hub shell adapted to drive a load.

9. The drivetrain of claim 8, wherein the drive load comprises a wheel.

10. The drivetrain of claim 7, wherein the crank comprises lever slots adapted to facilitate selection of a location of attachment for the crank pulley.

11. The drivetrain of claim 7, further comprising first and second lever pulleys, the first lever pulley coupled to the lever at a first end of the lever and the second lever pulley coupled to a second end of the lever.

12. The drivetrain of claim 11, further comprising a flexible tension member coupling the drive pulley, crank pulley, first lever pulley, and second lever pulley.

13. The drivetrain of claim 12, wherein the flexible tension member starts at the drive pulley and ends at a structure that is stationary relative to the crank.

14. The drivetrain of claim 7, wherein the stationary structure comprises a tail that extends from dropouts of a bicycle frame.

15. The drivetrain of claim 13, wherein the stationary structure comprises a crank stay.

16. The drivetrain of claim 7, further comprising a second drive pulley, second crank, second crank pulley, second lever, and second lever stop.

17. A drivetrain comprising:

a crank configured to pivot about a crank pivot;

a lever configured to pivot about a pivot lever;

a lever stop coupled to the crank and configured to guide a motion of the lever;

a drive pulley; and

a lever pulley coupled to the lever and operably coupled to the drive pulley.

18. The drivetrain of claim 17, further comprising a flexible tension member that couples the drive pulley to the lever pulley.

19. The drivetrain of claim 17, wherein the lever comprises a guide surface upon which the lever stop operates.

20. The drivetrain of claim 19, wherein the guide surface comprises a substantially flat surface.

21. The drivetrain of claim 19, wherein the guide surface comprises a curved surface.

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