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(12) **United States Patent**
Kamen et al.

(10) **Patent No.: US 7,004,271 B1**
(45) **Date of Patent: Feb. 28, 2006**

(54) **DYNAMIC BALANCING VEHICLE WITH A SEAT**

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(73) Assignee: **DEKA Products Limited Partnership**, Manchester, NH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 56 days.

(21) Appl. No.: **10/436,889**

(22) Filed: **May 13, 2003**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/386,686, filed on Aug. 31, 1999, now Pat. No. 6,561,294.

(51) **Int. Cl.**
B62D 61/00 (2006.01)

(52) **U.S. Cl.** **180/21**; 180/7.1; 180/8.2; 180/65.8

(58) **Field of Classification Search** 180/21, 180/7.1, 8.2, 65.8, 907, 5.26, 218, 6.5, 13; 280/5.28, 5.38, 208, 78, 209, 215, 205, 229, 280/266, 282
See application file for complete search history.

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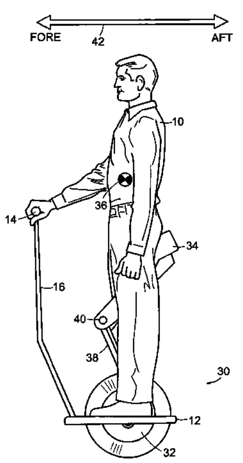
Primary Examiner—Hau Phan
(74) *Attorney, Agent, or Firm*—Bromberg & Sunstein LLP

(57) **ABSTRACT**

A device for transporting a human subject over a surface. The device is a dynamically balancing vehicle having a control loop for providing balance. The device includes a platform defining a fore-aft plane. The platform supports a payload including the human subject. A ground contacting module is included which may include one or more wheels. A ground-contacting member is movably coupled to the platform. The platform and the ground-contacting module form an assembly having a center of gravity that is defined with respect to the ground-contacting member and which includes any loads on the device. The device further includes a support. The support may be a seat for supporting the subject and the support is coupled to the platform in such a manner as to permit variation of the position of the center of gravity in the fore-aft plane by translation and rotation of at least a portion of the support. In one embodiment, translation and rotation of the seat of the device are mechanically coupled together.

6 Claims, 17 Drawing Sheets



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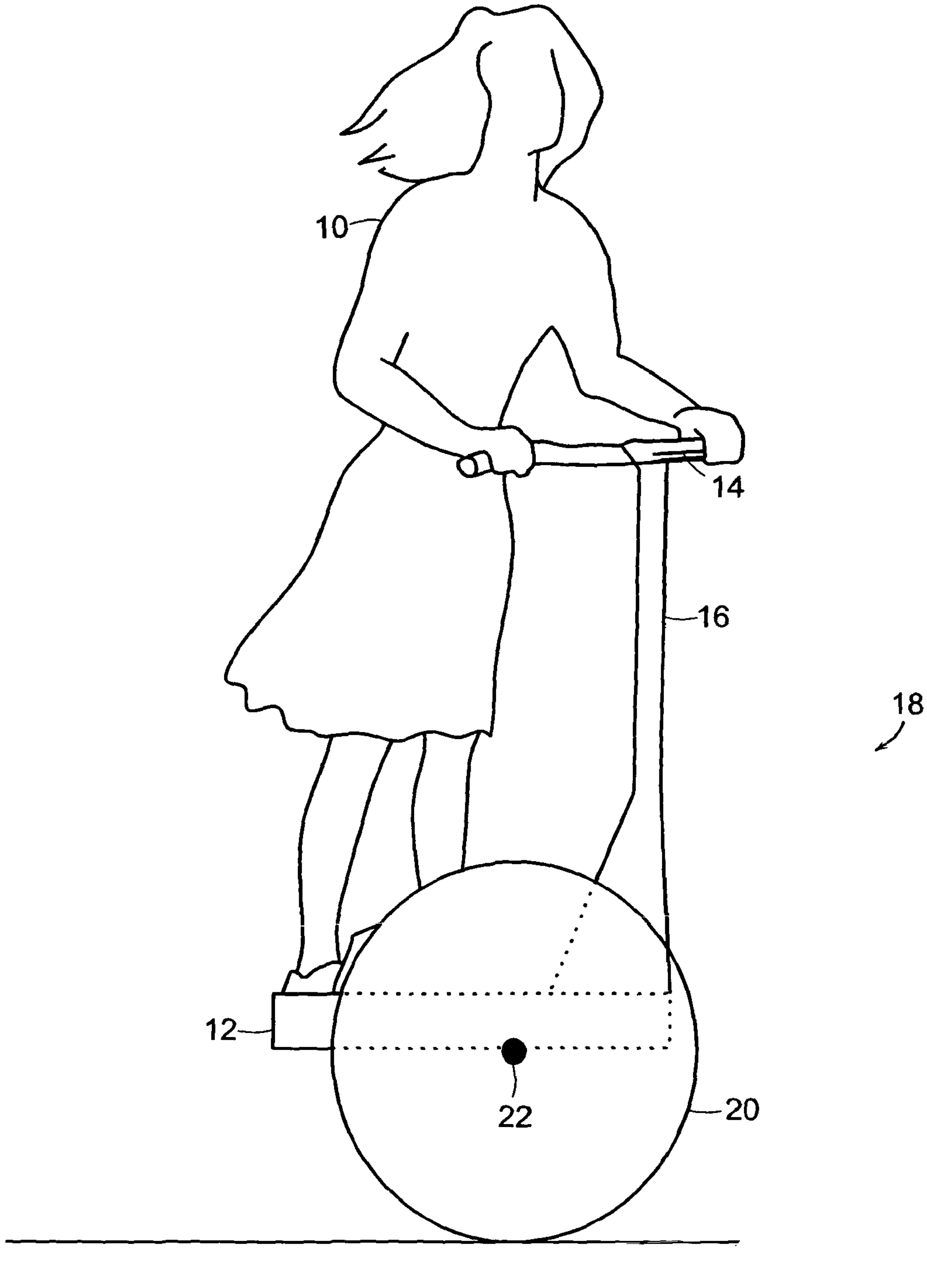


FIG. 1A
PRIOR ART

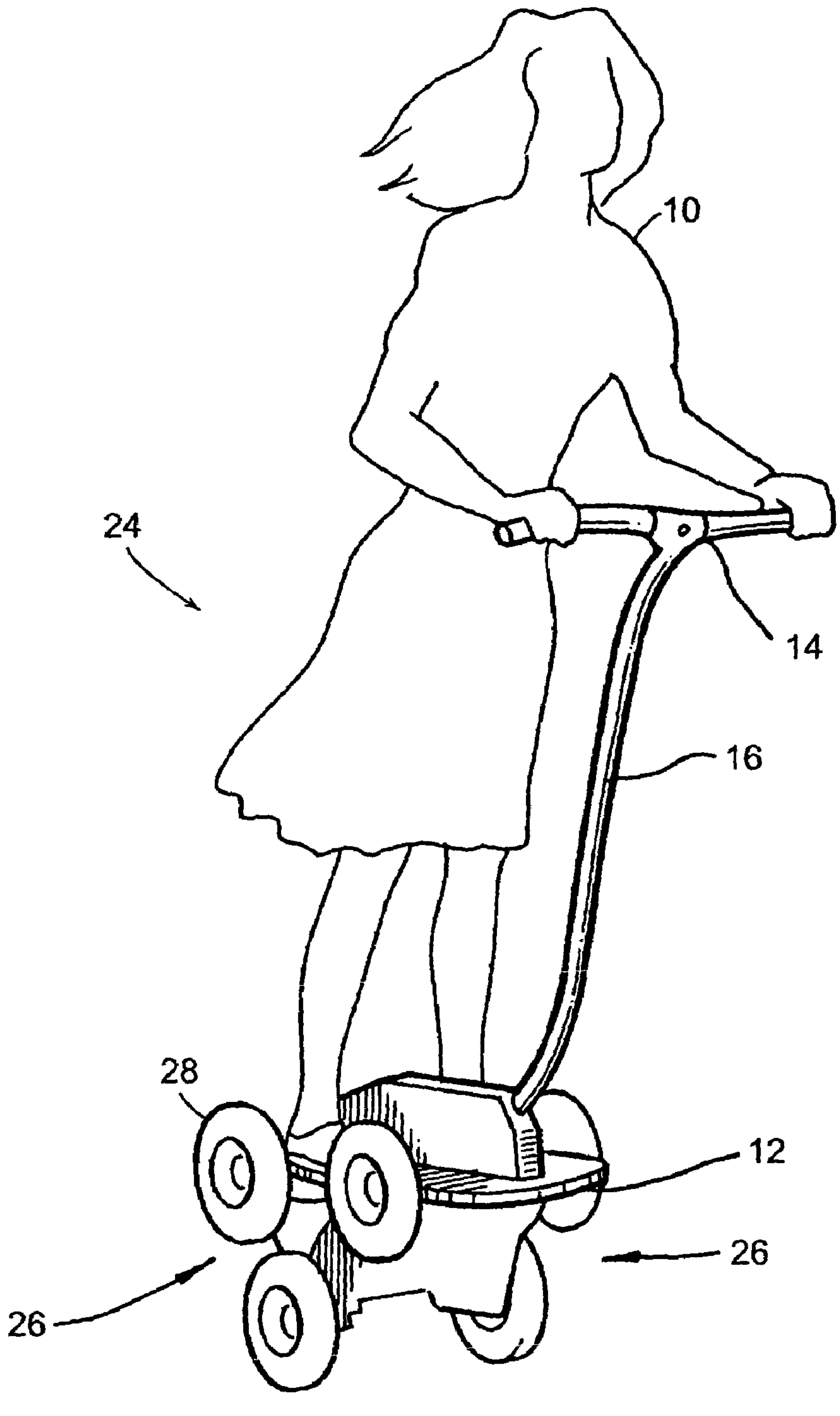


FIG. 1B
PRIOR ART

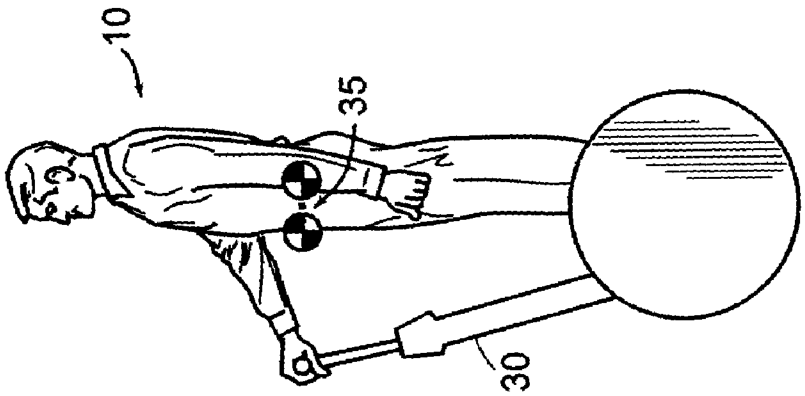


FIG. 2B
PRIOR ART

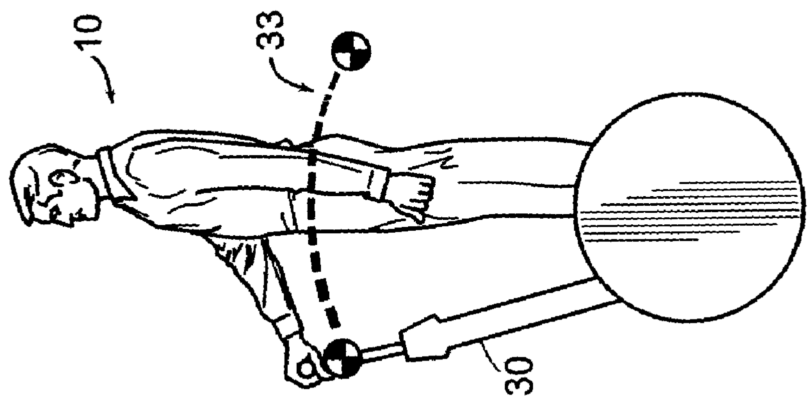


FIG. 2A
PRIOR ART

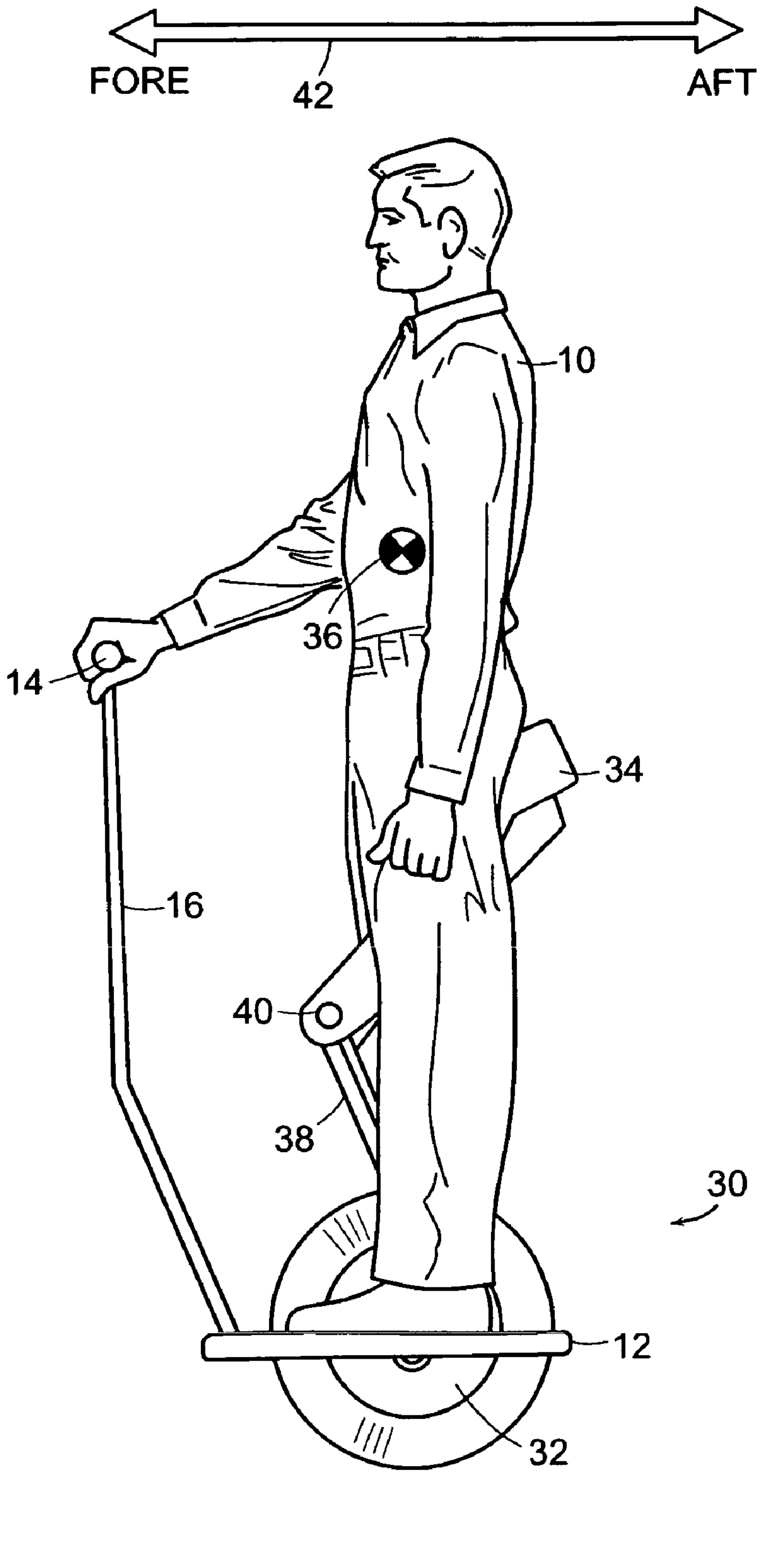
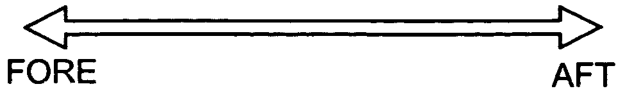


FIG. 3



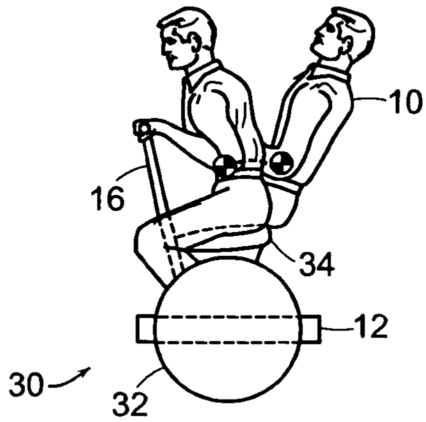


FIG. 3A

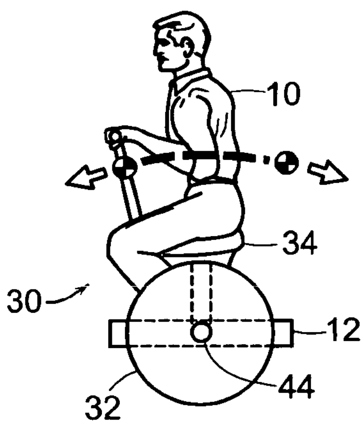


FIG. 3B

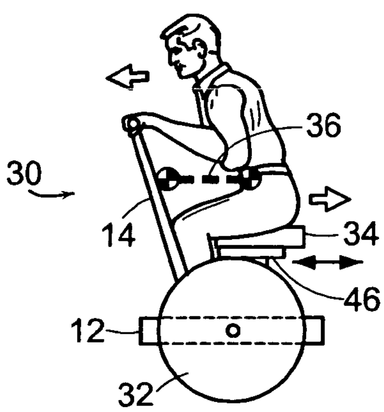


FIG. 3C

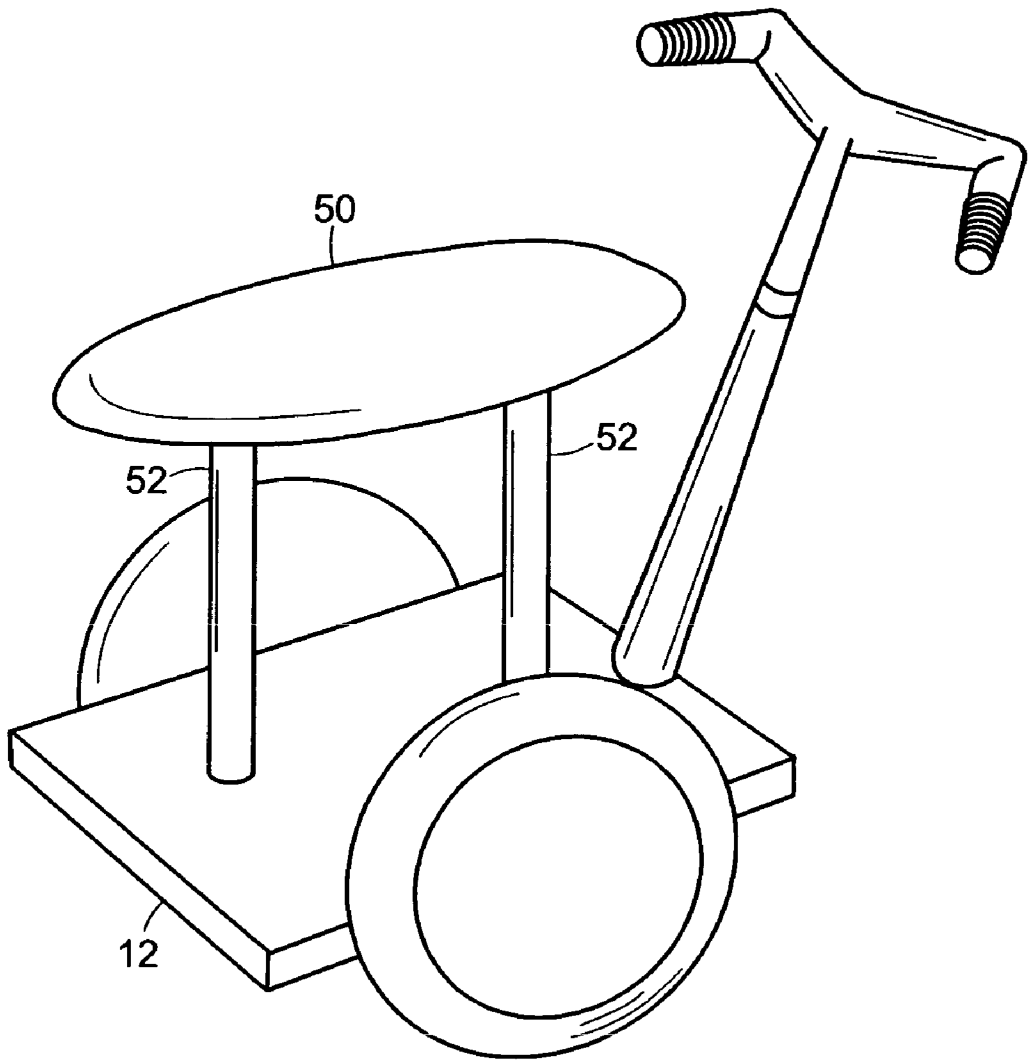


FIG. 3D

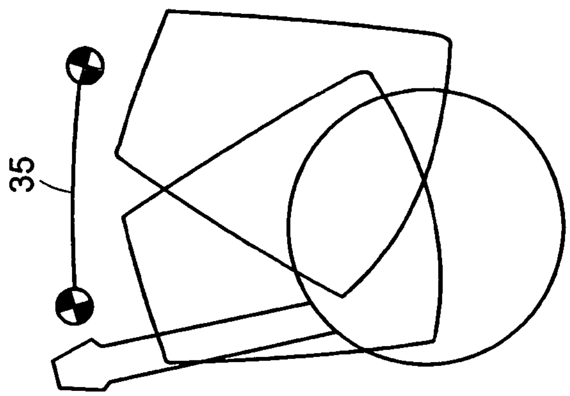


FIG. 4C

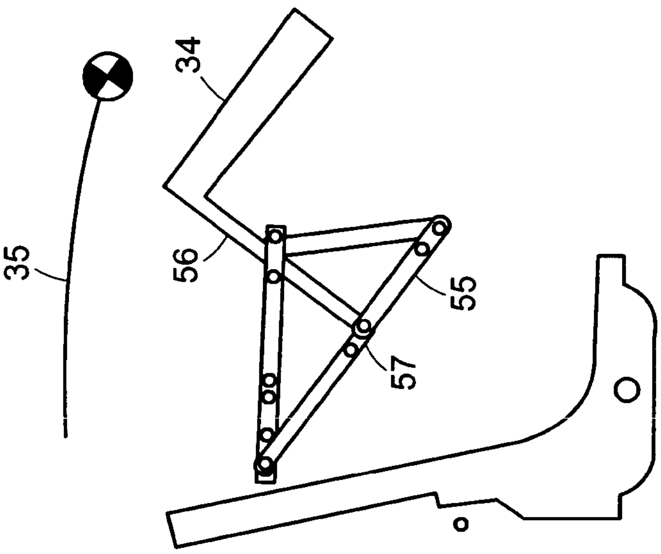


FIG. 4B

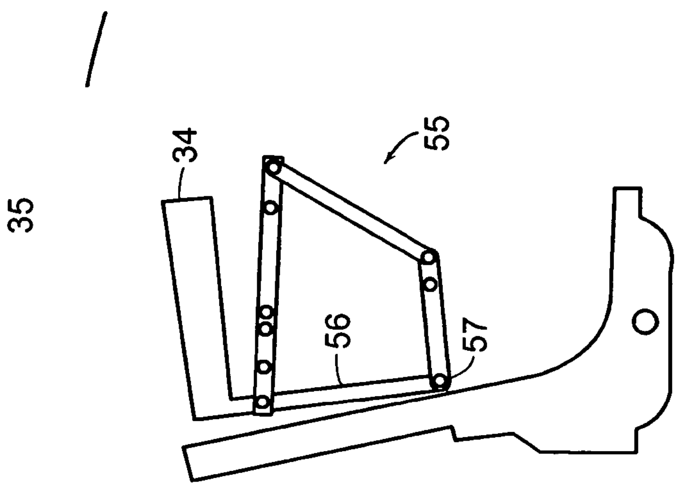


FIG. 4A

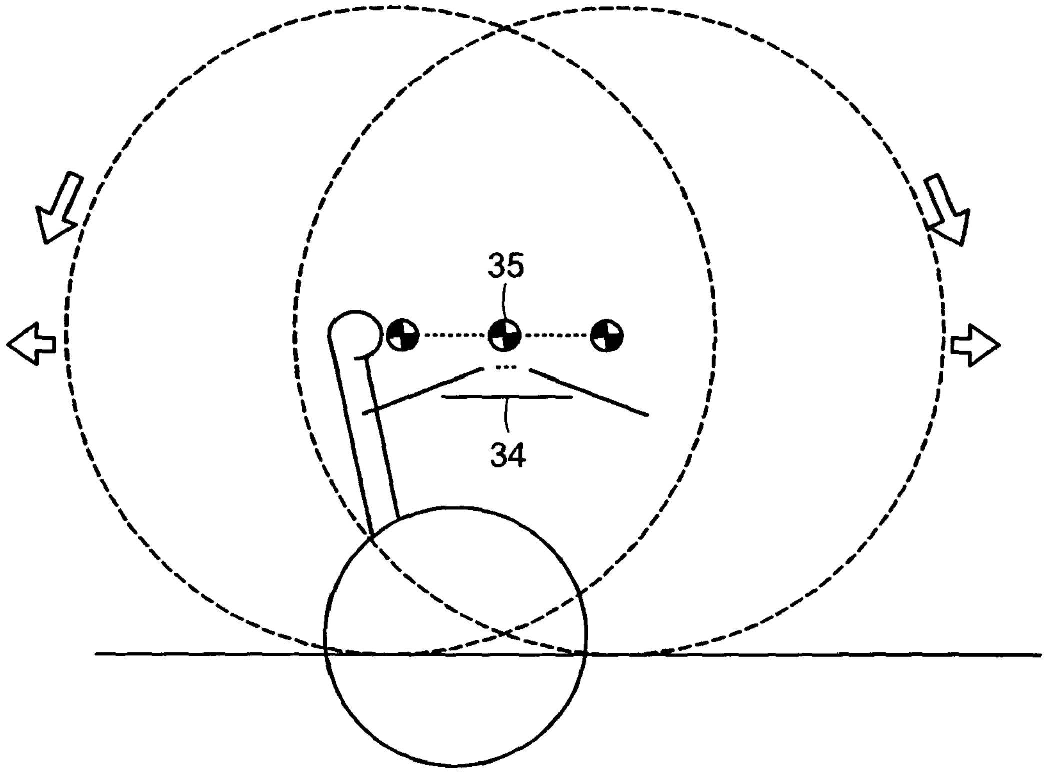


FIG. 4D

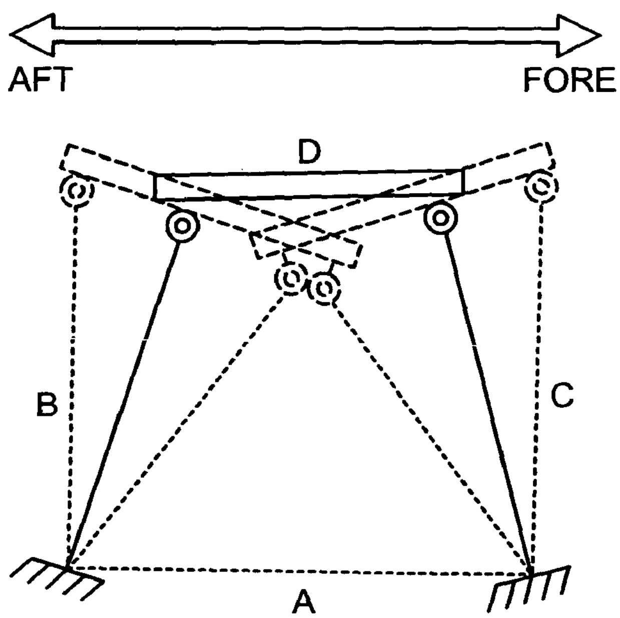


FIG. 4E

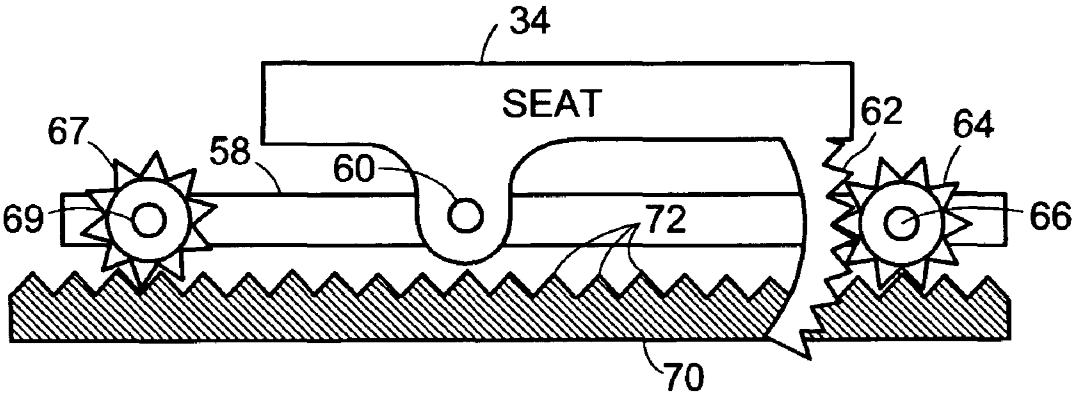

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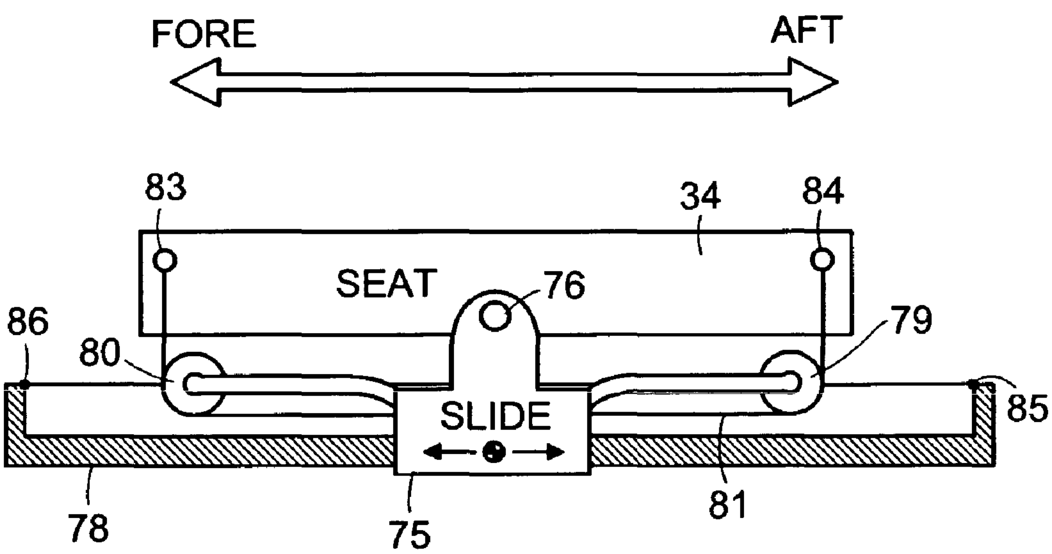
FIG. 5A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SLIDE
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81

FIG. 5B

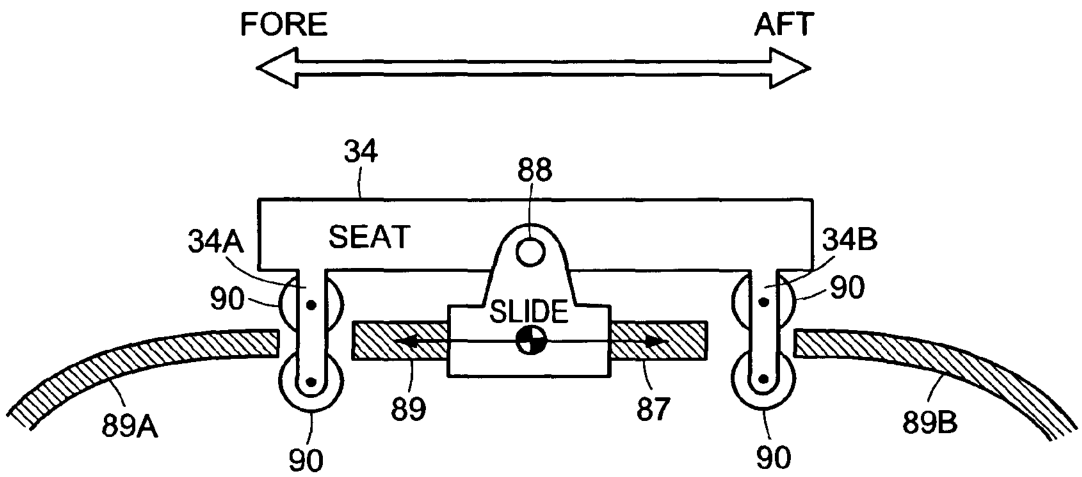
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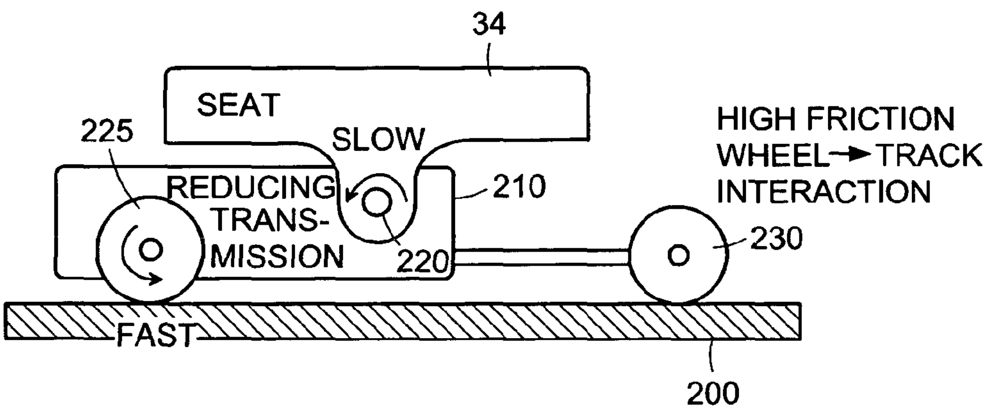
FIG. 5C


34
SEAT
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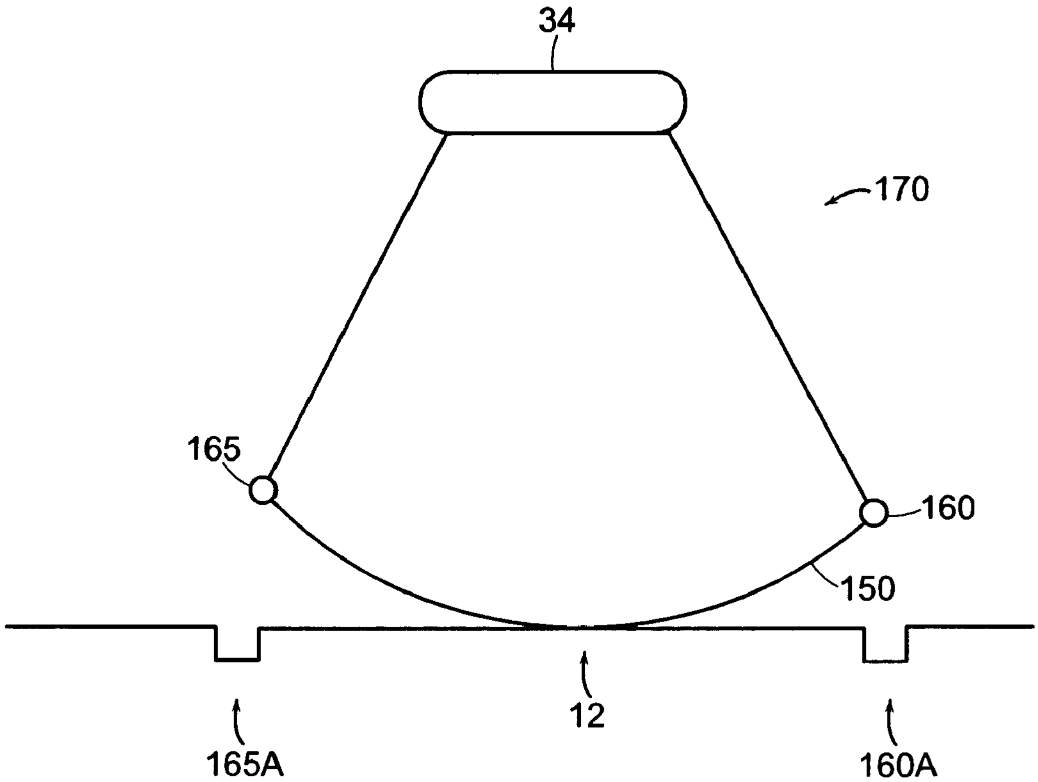
SLOW
HIGH FRICTION
WHEEL→TRACK
INTERACTION
REDUCING
TRANS-
MISSION
210
220
230
FAST
200

FIG. 5D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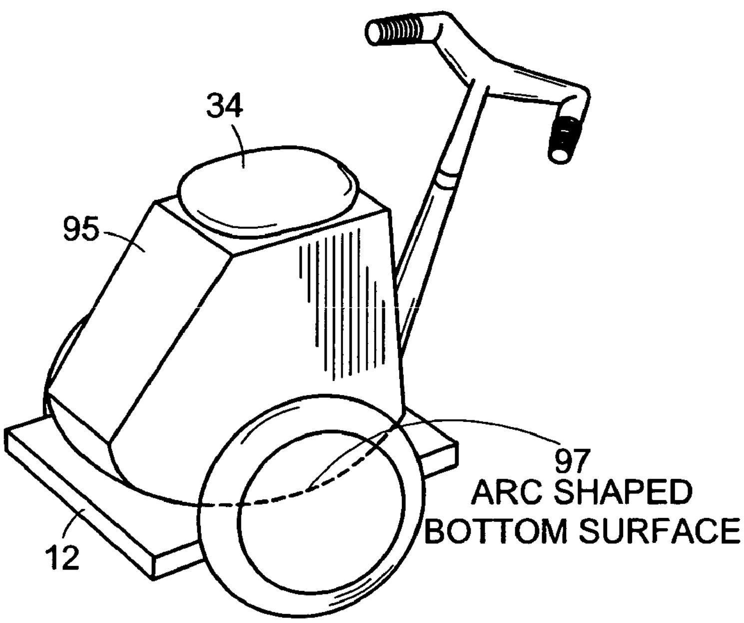
160A

FIG. 5E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ARC SHAPED
BOTTOM SURFACE
12

FIG. 6

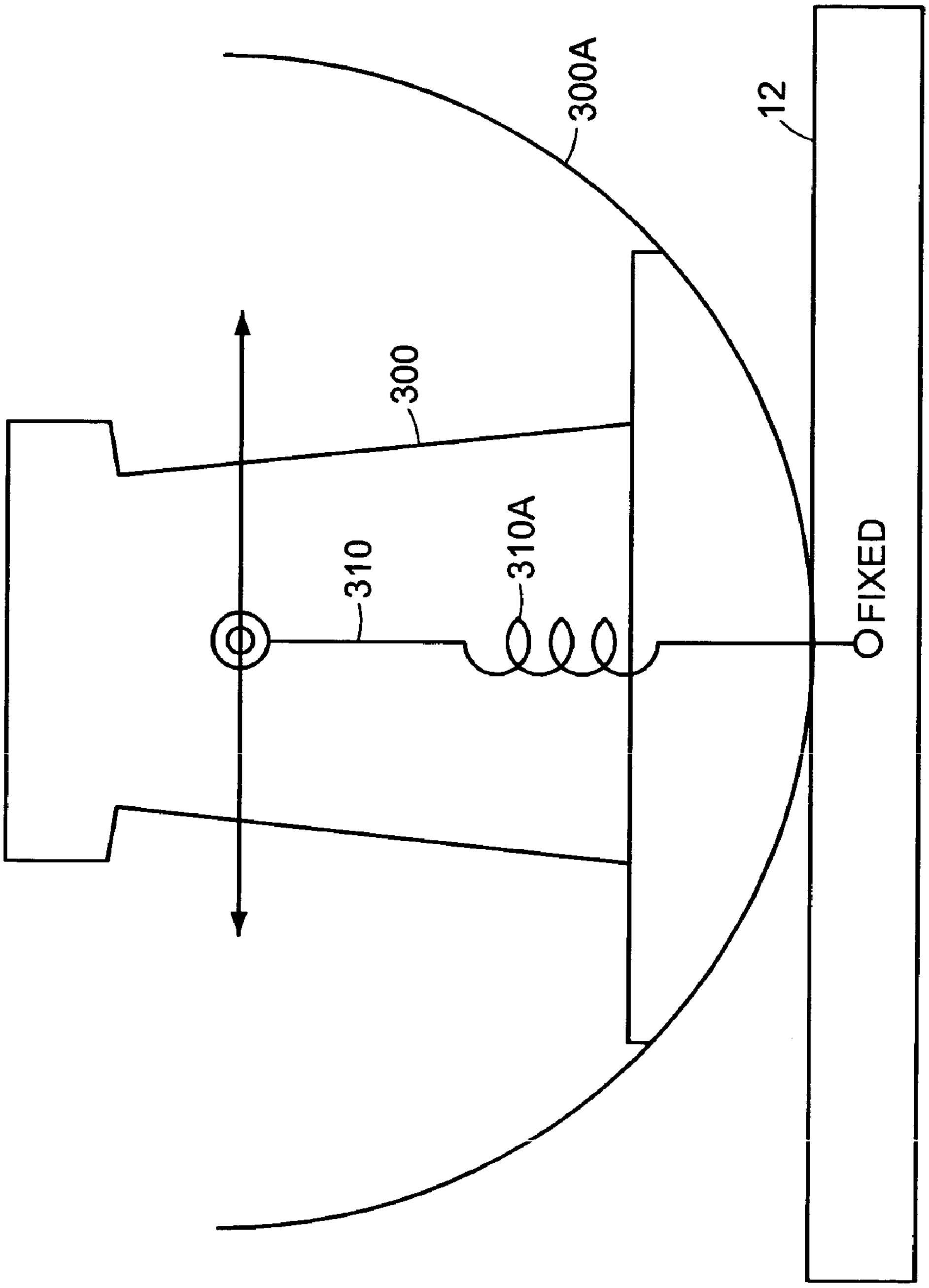


FIG. 6A

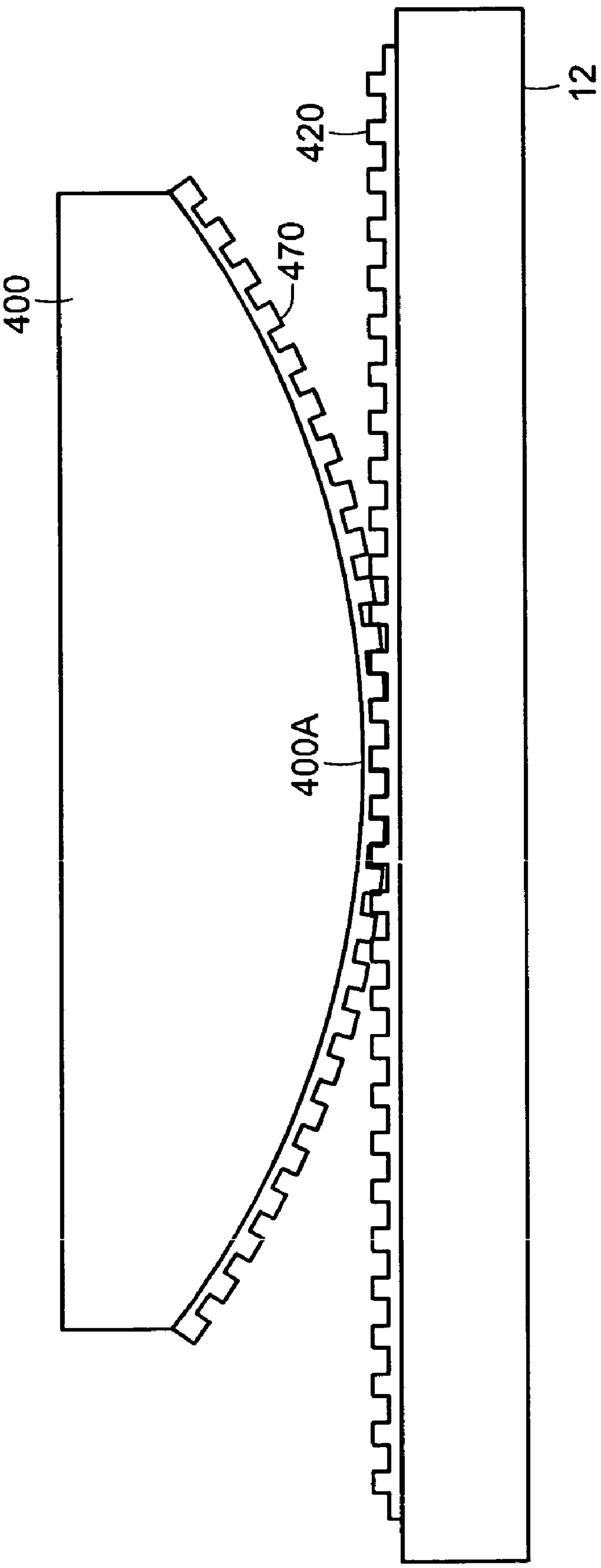


FIG. 6B

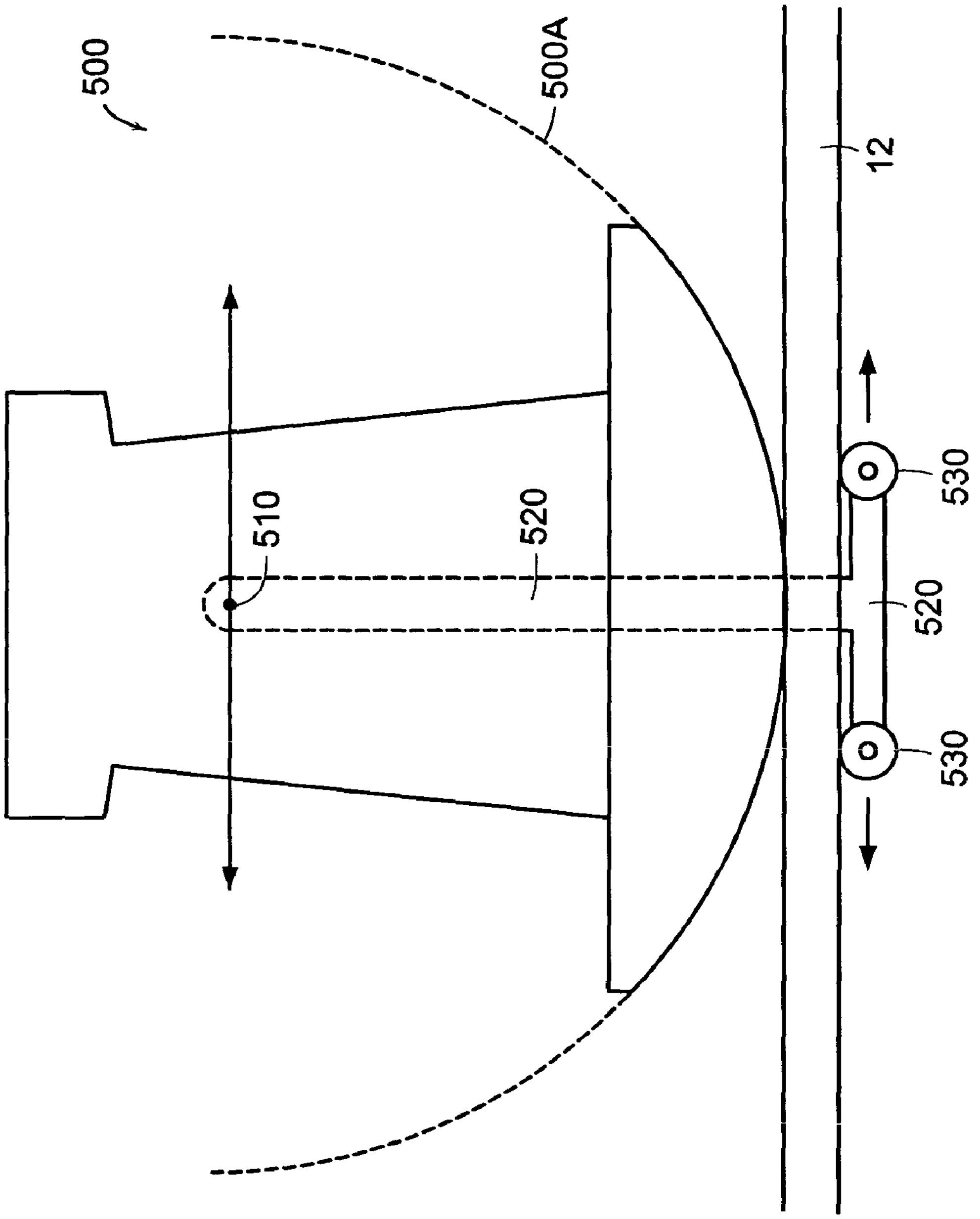


FIG. 6C

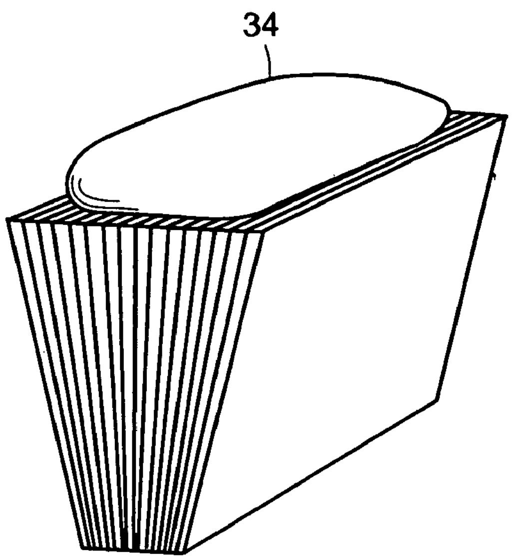


FIG. 7A

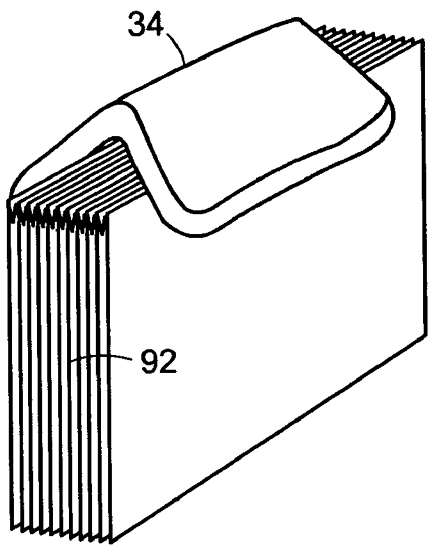


FIG. 7C

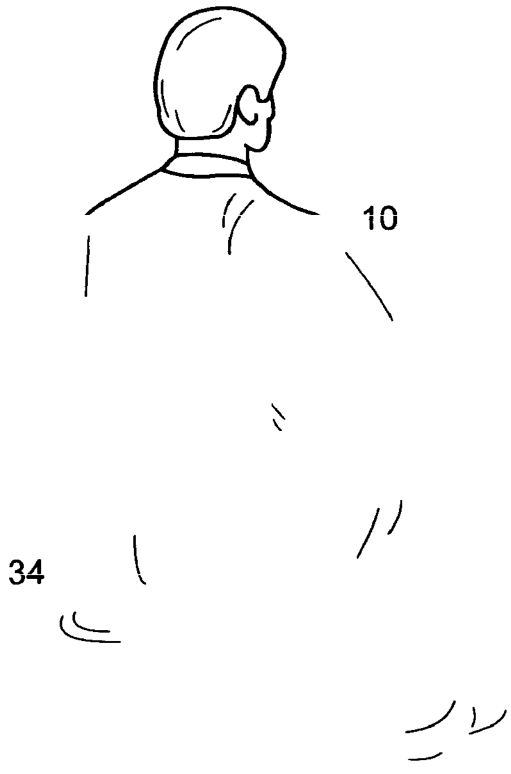


FIG. 7B

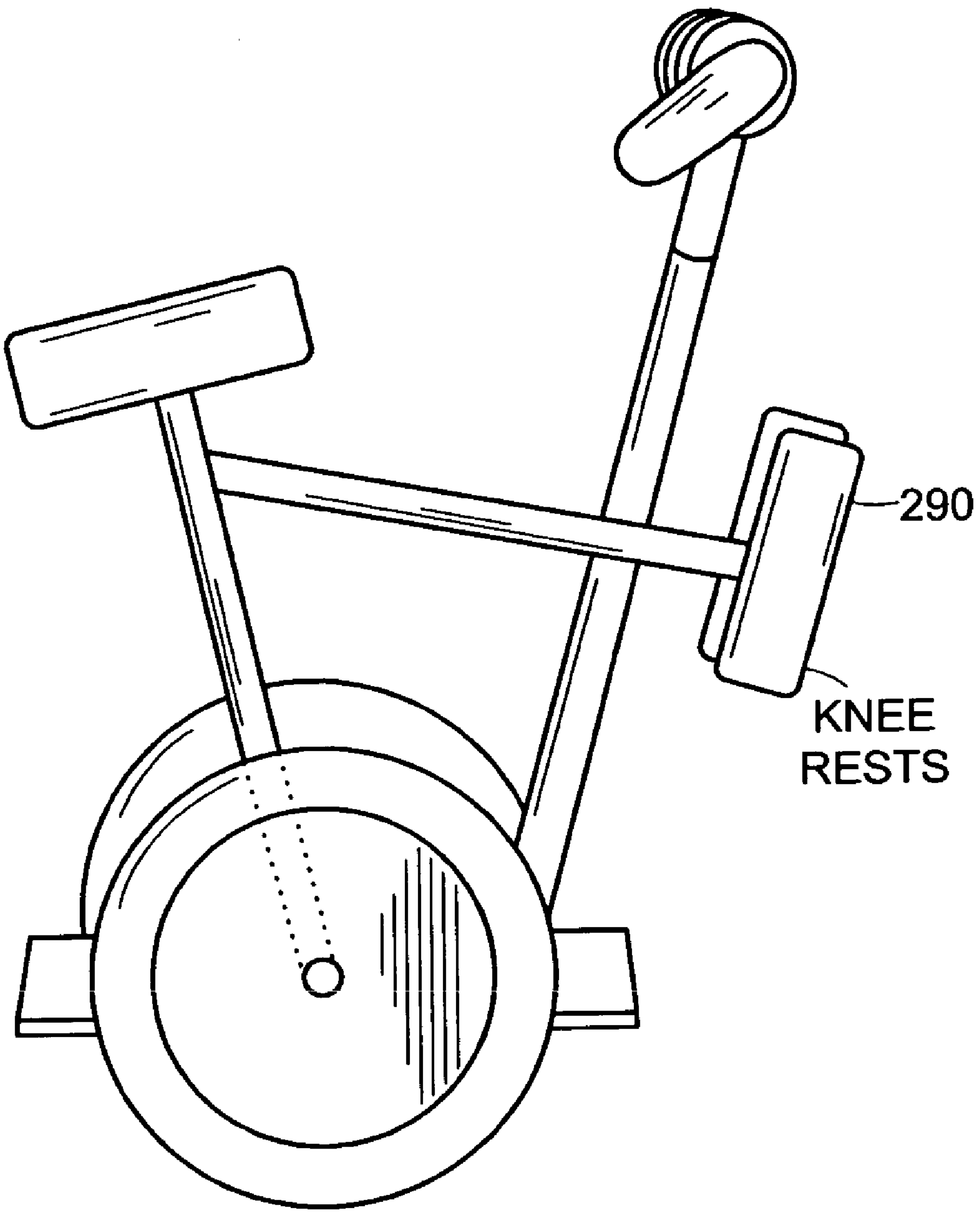
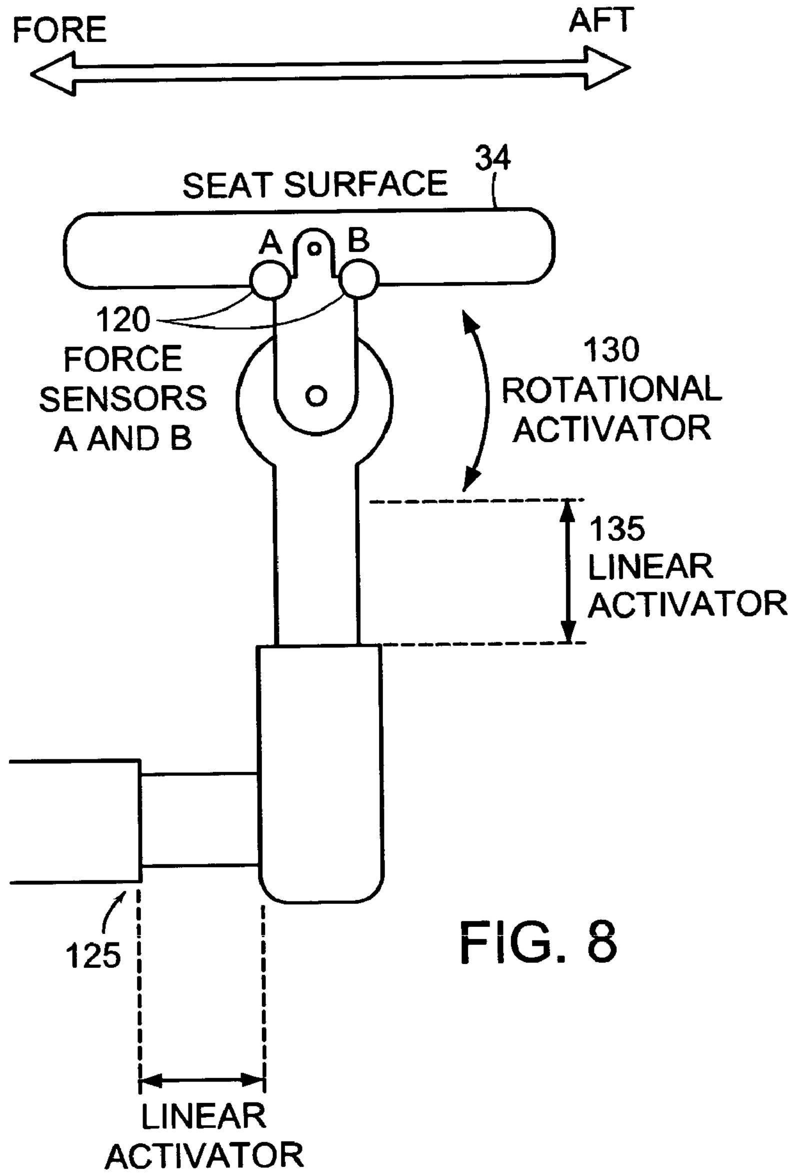


FIG. 7D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FORCE
SENSORS
A AND B
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ROTATIONAL
ACTIVATOR
135
LINEAR
ACTIVATOR
125
LINEAR
ACTIVATOR

FIG. 8

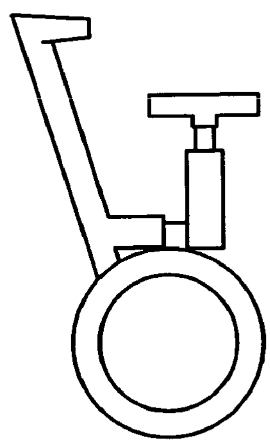

FIG. 8A

DYNAMIC BALANCING VEHICLE WITH A SEAT

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a U.S. continuation-in-part patent application of U.S. patent application Ser. No. 09/386,686 which was filed on Aug. 31, 1999, and which is now U.S. Pat. No. 6,561,294. This application claims priority therefrom and the priority application is incorporated herein by reference in its entirety.

TECHNICAL FIELD AND BACKGROUND ART

The present invention relates to personal vehicles that have assisted balancing. In prior art systems, such as the self balancing vehicles shown in U.S. Pat. No. 5,871,091 personal vehicles may be self-propelled and user-guidable, and, further, may entail stabilization in one or both of the fore-aft or left-right planes, such as when no more than two wheels are in ground contact at a time. Vehicles of this sort may be operated in a mode in which motion of the vehicle, including acceleration (both linear and turning), is controlled partially or entirely by leaning of the vehicle as caused by a subject riding the vehicle. Several such vehicles are described in U.S. application Ser. No. 08/384,705 which is incorporated herein by reference.

Such balancing vehicles may lack static stability. Referring, for example, to FIG. **1A**, wherein a prior art personal transporter is shown and designated generally by numeral **18**, a subject **10** stands on a support platform **12** and holds a grip **14** on a handle **16** attached to the platform **12**, so that the vehicle **18** of this embodiment may be operated in a manner analogous to a scooter. A control loop may be provided so that leaning of the subject results in the application of torque to wheel **20** about axle **22** thereby causing an acceleration of the vehicle. Vehicle **18**, however, is statically unstable, and, absent operation of the control loop to maintain dynamic stability, subject **10** will no longer be supported in a standing position and will fall from platform **12**. Another prior art balancing vehicle is shown in FIG. **1B** and designated generally by numeral **24**. Personal vehicle **24** shares the characteristics of vehicle **18** of FIG. **1A**, namely a support platform **12** for supporting subject **10** and grip **14** on handle **16** attached to platform **12**, so that the vehicle **24** of this embodiment may also be operated in a manner analogous to a scooter. FIG. **1B** shows that while vehicle **24** may have clusters **26** each having a plurality of wheels **28**, vehicle **24** remains statically unstable and, absent operation of a control loop to maintain dynamic stability, subject **10** will no longer be supported in a standing position and may fall from platform **12**.

A standing rider **10** of the vehicle **30** places his feet on the platform and shifts weight back and forth in a relatively wide and flat path **33**. The slight amount of strength that is needed to resist gravity and inertia in transversing this arc is well within the strength and coordination of an average user's muscles. The center of gravity of the vehicle and rider **35** moves in an arcuate fashion as the rider leans either forward or backward. When a seat is added to such a vehicle, movement of the center of gravity in the manner described above may no longer be possible and an alternative mechanism for shifting the center of gravity is required. The mechanism needs to provide adequate range of motion while allowing the rider to resist gravity and inertia.

SUMMARY OF THE INVENTION

A device for transporting a human subject over a surface is disclosed. The device is a dynamically balancing vehicle having a control loop for providing balance. The device includes a platform defining a fore-aft plane. The platform supports a payload including the human subject. A ground contacting module is included which may be one or more wheels. The ground-contacting member is movably coupled to the platform. The device and any load on the device has a center of gravity that is defined with respect to the ground-contacting member. The device further includes a support. The support may be a seat for supporting the subject and the support is coupled to the platform in such a manner as to permit variation of the position of the center of gravity in the fore-aft plane by translation and rotation of at least a portion of the support. The translation and rotation of at least a portion of the support are mechanically coupled in one embodiment.

The transportation device further includes a drive which is coupled to the ground-contacting module and which delivers power to the ground-contacting module in a manner responsive to the position of the center of gravity. The drive supplies force so as to balance the vehicle. In one embodiment, the support rotates about a virtual pivot point which lies above the support. The structure of the support allows the support to rock about an arc or other path.

The support may include a mechanical linkage such as a four bar linkage. In one embodiment, each bar of the four bar linkage is coupled together with pivots. A fifth bar may be included for holding a seat. The fifth bar is attached at one of the pivots of the four bar linkage. In another embodiment, the fifth bar is attached to one of the bars of the linkage. In one embodiment, the four bar linkage forms a parallelogram and changes shape as a user of the vehicle moves on the seat shifting the center of gravity.

In one embodiment, the device includes pressure sensors for activating the drive and causing the control loop to become active. The pressure sensors may be placed in the platform for activation or the pressure sensors may be placed in the seat. In yet another variant, a mechanical contact is attached to the support which contacts the pressure sensors that are coupled to the platform.

In another embodiment of the invention, the support includes a seat that is slideably mounted. The support includes one or more rails for allowing the seat to slide. The seat need not be capable of rotation in such an embodiment, but does allow for the user to change the center of gravity for controlling the vehicle. In another variation of the sliding seat, the sliding seat does rotate. As the seat slides along the rails a mechanism causes the seat to rotate. In one embodiment, the rails include one or more sprockets that engage with protrusions that are coupled to the seat and thus cause rotation as the seat is rolled on the rails. In another embodiment, the support may include one or more pulleys that assist the seat in sliding along the one or more rails. In yet another embodiment, the seat is coupled to friction wheels that ride on a friction surface.

In one embodiment, the support includes a convex radial base that allows the support to rock in response to a user shifting his weight. The convex radial base may be coupled to the platform at a pivot point that translates fore and aft with the motion of the seat. In other embodiments, the convex radial base may have different radii of curvature along its convex surface.

In certain embodiments, the support may include a damper such as a spring to return the support to a predetermined position. In one embodiment, the support preferably returns to a position, such that the vehicle remains substantially stationary when no force is applied to the support. In such an embodiment, the vehicle may still move slightly as the control loop balances the vehicle.

It should be recognized that a controller is either coupled to the drive or part of the drive and the controller is part of a control loop which is responsive to changes in the center of gravity. In certain embodiments, the seat may be coupled to the platform by a universal pivot. In another embodiment, the seat is coupled to a control stalk.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

FIG. **1**A is a side view of a prior art dynamically balancing vehicle of the type of which an embodiment of the invention may be advantageously employed;

FIG. **1**B is a side view of a further prior art dynamically balancing vehicle of the type of which an embodiment of the invention may be advantageously employed;

FIG. **2** is a prior art dynamically balancing vehicle having a platform that rotates in an arc;

FIG. **3** shows a dynamically balancing vehicle having a seat;

FIG. **3**A shows a dynamically balancing vehicle in which the seat is coupled to a control stalk;

FIG. **3**B shows a dynamically balancing vehicle in which the seat is coupled to the platform by a pivot;

FIG. **3**C shows a dynamically balancing vehicle in which the seat is slideably mounted;

FIG. **3**D shows a dynamically balancing vehicle having a seat;

FIG. **4**A shows the seat of the dynamically balancing vehicle mounted on a four bar linkage;

FIG. **4**B shows one position of the four bar linkage as would occur if a rider leaned backwards shifting the center of gravity in the aft direction;

FIG. **4**C shows that the four bar linkage simulates a rocking motion such that there is translation and rotation of the seat;

FIG. **4**D shows the center of gravity translating in a straight line while the seat both translates and rotates;

FIG. **4**E shows a bar linkage mechanism for translation and rotation wherein one or more bars are flexible;

FIG. **5**A is an embodiment of the dynamically balancing vehicle in which the seat is attached to a bar via a pivot;

FIG. **5**B is an embodiment that shows the seat attached to a slider about a pivot point wherein pulleys help to control rotation;

FIG. **5**C shows a seat that is coupled to a slider that rides on at least partially curved rails;

FIG. **5**D shows a seat coupled to a track which includes friction wheels wherein the seat both translates and rotates;

FIG. **5**E shows a support structure having a plurality of pins which will engage with recesses in the platform;

FIG. **6** shows a side view of an embodiment of the dynamically balancing vehicle with a detachable rocker seat;

FIG. **6**A shows the support structure attached to the platform via a simple cable under tension;

FIG. **6**B shows the support structure including a series of teeth on the bottom arced surface and also on the platform;

FIG. **6**C shows the support structure coupled to the platform about a pivot point;

FIG. **7**A shows a folding seat which can be attached to a dynamically balancing vehicle wherein the seat is positioned as if a rider is sitting on the seat;

FIG. **7**B shows a rider sitting on the folding seat;

FIG. **7**C shows the position of the folding seat when a rider engages/disengages with the vehicle;

FIG. **7**D shows an embodiment of a dynamically balancing vehicle having knee supports; and

FIG. **8** shows an embodiment of a support structure which includes both translational and rotational mechanical actuators.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

A balancing vehicle is shown in FIG. **3**. The balancing vehicle includes a ground-contacting module **32** which, in the embodiment that is shown, is a pair of co-axial wheels powered by motors. A controller is coupled to the motor for providing a control signal in response to changes in the center of gravity of an assembly that includes the vehicle along with a rider. As the rider **10** mounts the vehicle, the controller module senses the change in the center of gravity **36** and controls power to the wheels **32** based upon changes to the center of gravity **36** about a fore-aft plane **42** using a control loop. As the center of gravity **36** moves forward in the fore direction, power is provided to the wheels and the vehicle will move forward. As the center of gravity moves in the aft direction in response to the movement of the rider, the vehicle will slow and reverse direction such that the vehicle moves in the aft direction. As a change in the center of gravity is sensed, torque is applied to one or more the wheels (or other ground contacting members) of the vehicle by operation of the control loop and a wheel actuator (not shown). The pitch of the vehicle may also be sensed and compensated for in the control loop. The control module includes gyroscopes for sensing changes in the position of the center of gravity. The vehicle that is shown includes a platform **12** for supporting the rider and a control stalk **14** and **16**. Appropriate force transducers may be provided to sense leftward and rightward leaning and related controls provided to cause left and right turning as a result of the sensed leaning. The leaning may also be detected using proximity sensors. Similarly, the vehicle of this embodiment may be equipped with a foot- (or force-) actuated switch located on the platform **12** to activate the vehicle, in such a manner that the switch is closed so as to power the vehicle automatically when the subject contacts the platform **12**. This embodiment further includes a support **34**, **38**, **40** for the rider; the support may include a seat **34** on which the rider can rest.

In a first embodiment, the seat **34** is attached to the control stalk **16** as shown in FIG. **3**A. The rider **10** then uses his body and momentum to move the center of gravity of the combination of the vehicle and the rider in either a forward or in an aft direction. In another embodiment, the seat **34** is attached to the platform **12** via a pivot point **44** as shown in FIG. **3**B. The pivot may be a simple pivot such that the pivot moves only in the fore and aft directions or the pivot may be a universal pivot so that the seat may pivot in any direction. One example of a universal pivot is a spring. Further, the pivot may be mounted to the platform along the axis of the wheels, or the pivot may be mounted at other locations such as along the rear edge of the platform.

In yet another embodiment, a seat is attached to the platform using one or more rails **46** on which the seat **34** slides as shown in FIG. **3**C. In such an embodiment, the movement of the seat **34** by the rider causes a change in the position of the center of gravity of the vehicle and its load. If the seat is moved in the fore direction sensors sense the resulting tilt of the vehicle and cause the vehicle to increase in speed in the fore direction. If the seat is slid in the aft direction, the vehicle **30** will slow down correspondingly. In certain embodiments of the invention, a centering mechanism, such as, a spring may be incorporated with either the pivot or sliding seat, so the seat will return to a position such that the vehicle is substantially stationary when a rider disengages from the vehicle. In another embodiment, as shown in FIG. **3**D, a seat **50** is mounted to the platform **12**. The seat and the linkage **52** to the platform does not include a pivot. The seat in this embodiment preferably extends the length of the platform. When a rider engages the vehicle and sits on the seat, the rider may adjust the center of gravity by sliding her body along the length of the seat.

In a further embodiment, the vehicle includes a bar linkage mechanism, such as a four bar linkage, that is attached to the control stalk as shown in FIG. **4**A. The four bar linkage mechanism is also attached to a seat by another bar (seat post) which is coupled to the four bar linkage about a common pivot point of the four bar linkage or coupled to a bar in the linkage. The four bar linkage mechanism allows the seat to move in an arc which simulates a rocking motion similar to that of a rocking chair about the base platform as shown in FIG. **4**C. FIG. **4**B shows one position of the four bar linkage **55** as would occur if a rider leaned backwards shifting the center of gravity in the aft direction. The rider both moves in the aft direction and also rotates in the aft direction and as such both, translation and rotation are coupled together. Viewed in another way, the four bar linkage allows the seat to move in an arc about a virtual pivot point. The virtual pivot point can be located at a point above the seat. In other embodiments, the virtual pivot point may be located below the seat. As the seat **34** both translates and rotates the center of gravity **35** moves in a straight line in the fore-aft plane as shown in FIG. **4**D. In other embodiments, the center of gravity need not move in a straight line and the position of the center of gravity may vary. The motion of the seat creates a rider experience that is different from the seats discussed above in FIGS. **3**A–**3**D. In this embodiment, there is no position that the seat automatically returns to. As such, there are no peaks or wells in terms of the amount of energy that is required to move the center of gravity. In this embodiment, no arm force is required to maintain a position of the center of gravity relative to the wheel axis as is the case with simple and universal pivots as shown in FIGS. **3**A–**3**C. This allows both ease of pitch control and the ability of the rider to find the center of gravity position above the axle of the vehicle so that the vehicle is substantially stationary. The virtual pivot mechanism allows the seated rider, to have a similar experience on the dynamically balancing vehicle that a standing rider would have.

In the version of the vehicle described with respect to FIGS. **4**A–**4**E, the control stalk is held by the rider by a pair of hand grips that extend from the control stalk. As a rider sits on the seat, the seat can move about the fore-aft plane and the seat will both shift and rotate when the rider moves, thus changing the center of gravity.

Although the embodiment, shown above has a linkage mechanism for providing the coupling of rotation and translation, other structures and systems could also be designed to provide this functionality such as those shown in, but not limited to FIGS. **5**A–E and FIGS. **6**, **6**A, **6**B, and **6**C and the present invention is not intended to be limited to mechanical linkages.

In a further embodiment, the four bar linkage includes non-rigid members that can flex. For example, FIG. **4**E shows a support structure where members B and C each flex and member D is rigid as are the couplings of members B and C to platform A. In this embodiment members B and C are shown such that the two members lean inwards to meet member D. As force is placed on the seat through member D by the rider in the fore-aft direction, the members B and C will flex such that the seat will move in a rocking motion about a virtual pivot point that lies above the seat. The motion of members B and C is shown in FIG. **4**E by the dotted lines. As such, member D which supports the seat will both translate and rotate. Further, pivots may be included in such an embodiment, so that the linkage both pivots and flexes. For instance, pivots may be placed at the point where member D comes into contact with members B and C as shown in the figure. In still another variation, members B and C may be positioned so rather than leaning inward, the two members are outward leaning. In this type of embodiment, the seat will move much like a rocking chair. If a rider leans in the fore direction the seat will translate in the fore direction and the seat will rotate such that the fore-most part of the seat will be lower than the aft-most part of the seat. This is different from the embodiment that is shown in FIG. **4**E wherein if a rider causes the seat to translate in the fore direction, the seat will rotate such that the fore-most part of the seat is elevated as compared to the aft-most part of the seat.

FIGS. **5**A–**5**E each show different embodiments in which both translation and rotation are coupled. In FIG. **5**A the seat **34** is attached to a bar **58** via a pivot **60**. The seat further includes a series of protrusions **62** formed in an arc which mesh with a sprocket **64**. The sprocket **64** is attached to the bar **58** and can spin about an axis **66**. The bar includes a second sprocket **67** which can rotate about a central axis **69**. The sprockets **64**, **67** each reside on a strip/track **70** that includes protrusions **72** that mesh with the sprockets **64**, **67**. As a user of the vehicle moves the seat in a fore or aft direction the seat will translate and rotate due to the protrusions **62** that are formed in an arc and which are coupled to the seat. In other embodiments, the track on which the seat slides may have a different profile. For example, the track may be convex, concave, or have a varying profile along its length. If the track has a varying profile, the rider needs to apply more force to move the seat along certain portions of the track. Thus, different track profiles may be employed in order to shape the path of the center of gravity and the center of gravity need not move in a straight line.

In FIG. **5**B the seat **34** attaches to a slider **75** about a pivot point **76**. The slider fits on a rail **78** and the slider **75** can slide on the rail **78**. Attached to the slider at the seat are at least two pulleys **79**, **80**. The pulleys **79**, **80** are positioned toward opposite ends of the seat about the slider. One or more wires or cables **81** are attached to the seat and a fixed portion of the vehicle such as the rail. The cables **81** engage the pulleys **80**, **79**. As the seat is slid by the rider in the forward or aft direction, the pulleys cause the seat to tilt due to changing tension in the cables. The cables are coupled to either end of the rail **85**, **86** or some other component of the vehicle and also to the seat at opposite ends **83**, **84**. In the embodiment as shown, there are two separate cables, one of which runs from rail end **86** across pulley **79** and attaches to the seat at **84**. The second cable attaches to the seat at **83** and across pulley **80** and attaches at the rail end **85**. If the seat is moved in the aft direction, the edge of the seat in the aft direction will be rotated and lowered. Similarly, if the seat is moved by the rider in the fore direction, the fore-most part of the seat will rotate and will be lowered.

In FIG. **5**C, the seat is coupled to a slider **87** about a pivot point **88**. The slider **87** is seated on a rail **89** and provides for the seat to be slid in a fore and an aft direction. The seat also includes two extensions **34**A, **34**B that each have two wheels **90** mounted thereto. Between each pair of wheels is a straight track which includes an arc **89**A, **89**B at each end of the track. As the seat is slid in either the fore or the aft direction the wheels roll along the arc and cause the seat to tilt about the pivot point. It can be imagined that the track has a varying curvature, such that the center portion of the track is itself curved and that the ends have a greater radius of curvature as compared to the center.

In FIG. **5**D, the seat **34** rides on a track **200**. The seat **34** is coupled to a transmission **210** by a pivot **220**. The transmission is coupled to a pair of friction wheels **225**, **230**. In this embodiment, translation of the seat **34** is directly coupled to rotation of the seat. As the seat is moved by the rider and the friction wheels rotate along the track the seat will also rotate. In the embodiment that is shown, the wheels rotate a greater amount than the pivot rotates the seat. The transmission therefore, causes the seat to pivot/rotate at a fraction of the rotation of the friction wheels. It should be understood that all of the tracks that are shown in FIGS. **5**A–**5**D may be the same length as the platform or may extend beyond the length of the platform in the fore-aft direction or may be shorter than the length of the platform. The support structure also will include a mechanism for holding the track at a proper seat height. For example, the track may be mounted to the control stalk, or may sit on its own mounting structure that is coupled to the platform. For example, the mounting structure may be a shaft.

FIG. **6** shows a side view of an embodiment of the dynamically balancing vehicle with a detachable rocker seat. The rocker seat includes a support structure **95**. The bottom portion of the support structure contacts the platform and is shaped like an arc **97** allowing the seat **34** to rock. The arc shaped lower member **97** of the support structure **95** is coupled to the platform **12** via a moving contact point. The arc shaped member **97** member rotates equally in the fore and aft plane in this embodiment. Although in other embodiments, rotation may be limited in either the fore or aft direction. The support structure may also be coupled to the platform via a pair of rails. In this embodiment, the support structure rests on the rails that the rails include a mechanism that constrains the support structure from moving in any other plane other than the fore-aft plane. In such an embodiment, the arch shaped lower portion of the support structure is not coupled to the platform at a contact point. In such an embodiment, the arc shaped member may roll on a series of rails or wheels. In another embodiment, the support structure may include a guide pin that extends through the support structure and is enclosed by the rails on either side of the support structure. In such an embodiment, the seat can rock in the fore-aft direction about a virtual pivot that is above the seat. It should be understood that a virtual pivot point need not be above the seat, in certain embodiments, the virtual pivot point may exist below the seat, for example.

It should be recognized, that the lower surface of the support structure that is formed in an arc may have any number of radii. For example, the lower surface may have a greater curvature at the edges and less of a curvature at its center, so that as the support structure rocks about its central portion, each unit of translation there is proportional to a degree of rotation, but as the support structure is rocked further toward the edges, there is a greater degree of rotation for each unit of translation.

In another version, the lower surface of the support structure **150** includes two pins **160**, **165** at the edges of the arc as shown in FIG. **5**E. As the support structure rocks **170** to the edge, one of the pins **160** or **165** will engage with a recess **160**A or **165**A in the platform **12**. If the rider continues to lean in the same direction, the support structure will rotate about the pin **160** or **165**. Thus, there are two different ratios of translation to rotation for this embodiment. As the support structure **170** rocks about the arc there is less rotation for each unit of translation as compared to motion about the pin **160** or **165** in which there is rotation without translation when the pin engages with the recess of the platform.

The embodiment of FIG. **6**, in which the support structure has an arc as the lower surface, may be coupled to the platform in any one of a number of ways. For example, gravity may hold the support structure on the platform **12**. Further, the platform surface and the bottom surface of the support structure may be formed from materials having a high coefficient of friction. In another embodiment, as shown in FIG. **6**A, the support structure **300** may be attached to the platform **12** via a simple cable **310** under tension (including a spring **310**A). In this embodiment, as the support structure rocks about the arc of the bottom surface **300**A, the spring **310**A stretches, and thus there is a restoring force returning the support structure **300** to a centered position as shown. As shown in FIG. **6**B, the support structure **400** may include a series of teeth **410** on the bottom arced surface **400**A and the platform **12** may include a series of mating teeth **420** for the bottom surface. As the support structure rocks the teeth of the bottom surface and of the platform interlock. In FIG. **6**C, the support structure **500** is coupled to the platform **12** about a pivot point **510**. The pivot **510** is coupled to a member **520** which extends down through the platform and which in this embodiment, rides on a pair of wheels **530**. In this embodiment, the member **520** is rigid. As force is applied to the support structure **500** by the rider in the fore-aft directions, the support structure **500** will translate and the wheels **530** will rotate on the bottom side of the platform as shown. The support structure **500** will also rotate about the pivot point **510** due to the arched bottom side of the support structure **500**A. In this embodiment, the support structure **500** will maintain contact with the platform at all times, including over rough terrain. Again, it should be recognized, that other mechanisms for coupling the support structure to the platform can be envisioned and the present invention should not be limited by the embodiments that are shown.

In one embodiment, the platform of the vehicle includes one or more pressure sensors to sense the rider either engaging or disengaging from the vehicle. When the rider powers-up the vehicle and engages the vehicle, the vehicles enters a balancing mode. A control loop is made operational that senses changes to the position of the center of gravity and that causes the vehicle to move with respect to the changes. If the vehicle includes a seat, the rider may not engage the pressure sensors because her feet may not make contact with the platform or the rider may remove her feet from the platform. In order to overcome this problem, sensors, such as pressure sensors, may be included in the seat. In another embodiment, a mechanical device such as a link or tube may be employed to make contact with the platform when the rider engages the vehicle.

The support structure may be designed to either fold or compress in order to allow for the rider to better engage/disengage with the vehicle and also for shock absorption. For example FIGS. **7**A–C shows a folding seat which may be employed with the previously described vehicles. In FIG. **7**A the seat is in full view and is positioned as if a rider is sitting on the seat. The sides of the seat expand in an outward direction like an accordion when weight is put on the seat. FIG. **7**B shows a rider sitting on the seat. FIG. **7**C shows the position of the seat when a rider **10** engages/disengages with the vehicle. If the rider is already on the vehicle, the seat **34** rises up and folds as the rider stands and the support structure **92** contracts inwardly reducing the size of the support.

The support structure for the seat may also include a mechanism for allowing lateral movement in a plane substantially perpendicular to the fore-aft plane of the vehicle. The vehicle may include sensors to sense the lateral movement. The sensors can be tied into a control loop so that if a rider leans to the right more power is applied to the left wheel allowing the vehicle to turn to the right. In other embodiments of the support structure, lateral movement may not be tied to sensors and a control loop, but may simply perform the function of allowing the rider to readily shift his or her weight of over rough terrain.

The support structure may also include knee rests **290** as shown in FIG. **7**D to allow more consistent rider coupling to the vehicle and to provide postural advantage and/or partial body support.

FIG. **8** shows another embodiment, in which the seat **34** both translates and rotates. It is preferable that translation and rotation are coupled. In this embodiment, there are force sensors **120** in the seat. As a rider shifts his weight on the seat **34**, the force sensors **120** sense the change. Based upon the changes in force, both a linear actuator **125** and a rotational actuator **130** are engaged. If the rider shifts his weight such that more weight is provided to force sensor A than to B, the linear actuator **125** will cause translation of the seat in the fore direction. Additionally, the seat will be rotated in the fore direction by the rotational actuator **130**, such that the fore-most part of the seat will be lowered and the aft-most part of the seat will be raised. The embodiment as shown also includes a linear actuator **135** that provides linear motion in the vertical direction. This actuator **135** makes engagement and disengagement with the vehicle easier. In this embodiment, both translation and rotation are controlled by mechanical actuators. Using mechanical actuators for providing translation and rotation of the seat, assists individuals having a reduced strength capacity when compared to the simpler mechanical designs that require the rider to manually shift the position of the seat, to significantly shift their weight using their own strength, and to maintain a position of either leaning in the fore or in the aft direction using their muscle strength.

The described embodiments of the invention are intended to be merely exemplary and numerous variations and modifications will be apparent to those skilled in the art. All such variations and modifications are intended to be within the scope of the present invention as defined in the appended claims.

What is claimed is:

1. A device for carrying a user, the device comprising:

a platform;

a motorized drive that propels the platform over an underlying surface through motion of at least one ground-contacting member, the ground contacting member characterized by a point of ground contact and an axis of rotation;

a user support having a position defined with respect to the platform and coupled to the platform in such a manner that the user may vary the position of the support with respect to the platform in the course of normal operation of the device by translation of the support in a direction substantially perpendicular to a line running through the point of ground contact and the axis of rotation of the at least one ground contacting member; and

a controller, coupled to the motorized drive, for governing the operation of the motorized drive at least in response to the position of the user support to dynamically control balancing of the device;

wherein the support includes a seat.

2. The device according to claim **1**, wherein the support is coupled to the platform via a universal pivot.

3. The device according to claim **1**, wherein the support includes rails to allow the seat to slide.

4. The device according to claim **1**, wherein the support is coupled to a control stalk.

5. The device according to claim **1**, wherein the seat can translate and rotate in response to a user's movement.

6. The device according to claim **5**, wherein the controller responds to changes in the center of gravity of the device and any load on the device.

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