Zorb Mechanics

Caution – this question contains content from every element of the Mechanics 1 A-level module, and may be unsuitable for younger audiences.

zorbing [‘zɔ:bɪŋ]

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(Individual Sports & Recreations / Extreme Sports)

Informal the activity of travelling downhill inside a large air-cushioned hollow ball

[C20 Z + ORB (sphere) + -ING[1]]

For generations mankind has gazed in wonder upon the majestic hamster in his hamster-ball and dreamed of achieving the same kind of sublime locomotive experience.
Now, for little more than £1000, we can.

The following Mechanics question is an epic in four parts, and covers Kinematics, Forces, Friction, Newton’s Laws, Connected Particles, Momentum and Projectiles. Hold on tight...

Part 1

A Zorb™ is lowered down a grassy slope by means of a uniform, non-elastic rope attached via a smooth pulley to a Mini™ parked on the horizontal plateau above. The Zorb™ and rider weigh 150kg, and, due to the motion of the Zorb™, can be considered to be frictionless. The Mini™ weighs 500kg, and has failing brakes, consequently experiencing a coefficient of friction equal to 0.2. The grassy slope is inclined at an angle of θ to the horizontal. Find the least value of θ for which motion will occur.

Part 2

The slope is actually inclined at 50° to the horizontal. The Zorb™ is released from rest at the top of the 60m slope. After 20m, the rope is cut and the Zorb™ continues on for a further 30m before colliding with an uphill Zorber™. Draw a force diagram to show the forces acting on the Zorb™ and Mini™ at the start of motion, and hence show that the initial acceleration of the Zorb™, correct to 2 decimal places, is $0.22ms^{-2}$.

Calculate, to 1 d.p., the downhill velocity at the instant the rope is cut and the acceleration for the second part of its journey.

Hence, or otherwise, show that the speed of the Zorb™ at the moment of collision is $21.4ms^{-1}$ to 1 decimal place.

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Part 3

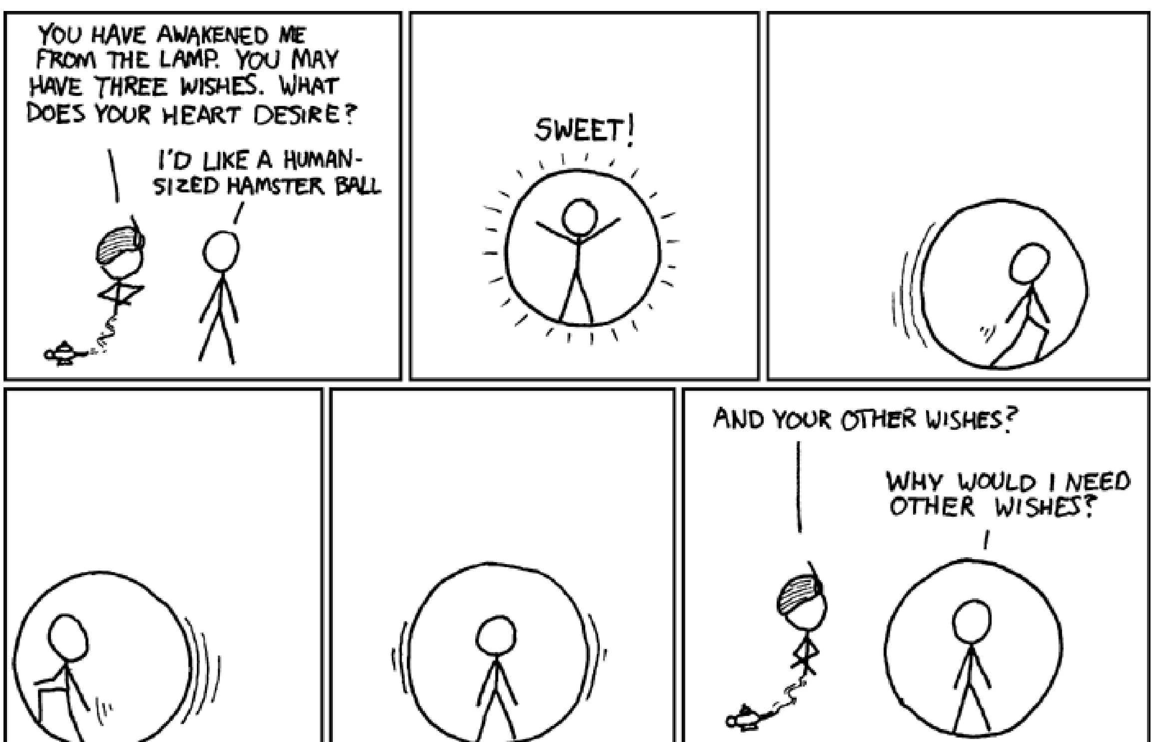
The Zorb™ collides with a younger Zorber™, weighing, in total, 100kg, travelling uphill at $10ms^{-1}$. As a result, the original Zorber™ is (temporarily) brought to rest. Show that the momentum of the larger Zorb™ has a magnitude of $3210kgms^{-1}$ to the nearest 10, and hence calculate the resulting velocity with which the smaller Zorb™ now moves downhill.

Part 4

The 100kg Zorb™, now propelled downhill, immediately hits a rock which alters the direction but not the velocity. Instead of travelling downhill at an angle of 50° to the horizontal, it is now launched into the air away from the slope, aimed upwards at 50° above the horizontal. Find the maximum height this Zorb™ reaches relative to its launch point.

Using some information from Part 2, show that the vertical distance above the ground of the launch point is 7.66m to 2d.p. and calculate the horizontal distance from the launch point to the level ground.

Calculate the time taken for the Zorb™ to reach the ground, and hence the horizontal distance reached beyond the base of the slope.



xkcd.com

Clohesy

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Part 2

The slope is actually inclined at 50° to the horizontal. The Zorb™ is released from rest at the top of the 60m slope. After 20m, the rope is cut and the Zorb™ continues on for a further 30m before colliding with an uphill Zorber™. Draw a force diagram to show the forces acting on the Zorb™ and Mini™ at the start of motion, and hence show that the initial acceleration of the Zorb™, correct to 2 decimal places, is $0.22ms^{-2}$.

Calculate, to 1 d.p., the downhill velocity at the instant the rope is cut and the acceleration for the second part of its journey. **$3.0ms^{-1}$ and $7.5ms^{-2}$**

Hence, or otherwise, show that the speed of the Zorb™ at the moment of collision is $21.4ms^{-1}$ to 1 decimal place.

Zorb Mechanics

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Part 3

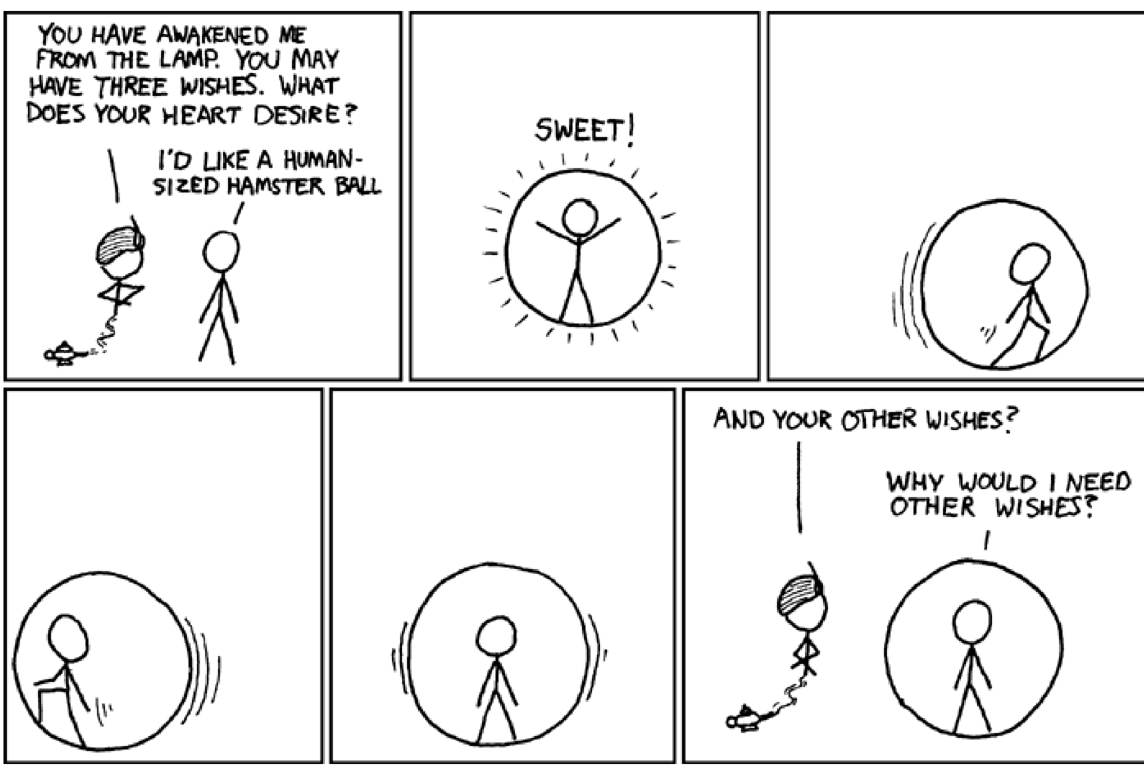
The Zorb™ collides with a younger Zorber™, weighing, in total, 100kg, travelling uphill at $10ms^{-1}$. As a result, the original Zorber™ is (temporarily) brought to rest. Show that the momentum of the larger Zorb™ has a magnitude of $3210kgms^{-1}$ to the nearest 10, and hence calculate the resulting velocity with which the smaller Zorb™ now moves downhill. **$22.1ms^{-1}$**

Part 4

The 100kg Zorb™, now propelled downhill, immediately hits a rock which alters the direction but not the velocity. Instead of travelling downhill at an angle of 50° to the horizontal, it is now launched into the air away from the slope, aimed upwards at 50° above the horizontal. Find the maximum height this Zorb™ reaches relative to its launch point. **14.6m**

Using some information from Part 2, show that the vertical distance above the ground of the launch point is 7.66m to 2d.p. and calculate the horizontal distance from the launch point to the level ground. **6.43m**

Calculate the time taken for the Zorb™ to reach the ground, and hence the horizontal distance reached beyond the base of the slope. **3.8s and 54.8m**



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Clohesy