SPH4U: Frames of Reference

Recorder:	
Manager:	
Speaker:	
0 1 2 3 4 5	

Your friend is standing on a bus that is travelling east and speeding up at a constant rate along a level road. While this is happening she holds up a rope with a ball attached to the end of it. The ball is allowed to hang freely. Assume east is to the right. Answer the following questions while the bus is accelerating and the ball hangs in a steady way (not swinging around!)

1. **Represent.** Draw a motion diagramfor the ball relative to eachframe of reference while the bus accelerates in a steady way.

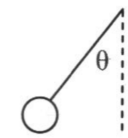
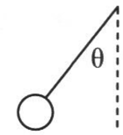
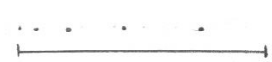
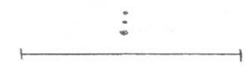
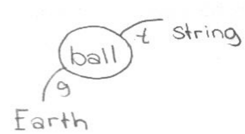
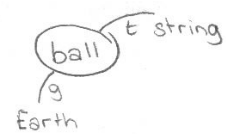
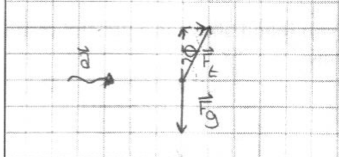
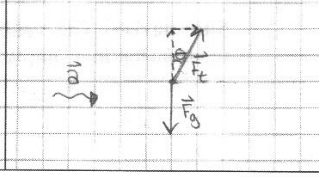
2. **Represent and Explain.** Draw an interaction diagram for the ball according to an observer in each frame of reference. Are there any differences between the two interaction diagrams?

   There are no differences between the two interaction diagrams since the same types of forces are acting on the ball

3. **Represent.** Draw a force diagram for the system of the ball according to an observer in each frame of reference. Do not include fictitious forces yet. Include an acceleration vector!

4. **Reason.** There is a contradiction within one of the force diagrams. Explain carefully.

   There is a contradiction within the 2nd force diagram since there is acceleration according to the force diagram, but the motion diagram does not show that it is accelerating

	Earth frame	Bus frame
Sketch		
Motion Diagram		
ID		
FD		

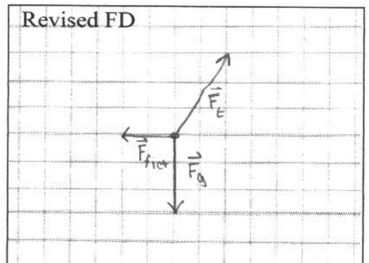
The rules we have learned for forces and motion breakdown in accelerating frames of reference producing contradicting results like the one above. To "patch things up" and help our rules work again, we introduce a convenient fiction - a **fictitious force.** A fictitious force is not a part of any known interaction and thus is not a real force, but we may work with it as if it was. Such a force is only ever noticed or needed in an accelerating frame of reference and should never appear in a FD by an observer who is not accelerating.

5. **Represent.** Draw a revisedFD for the bus frame of reference. Add a fictitious force, F_{fict}, such that FD agrees with the motion of the ball according to an observer on the bus.

6. **Explain.** How does the direction of the fictitious force compare with the acceleration of the bus, a_b, as measured in the earth frame?

   The direction of the fictitious force is opposite as compared to the acceleration of the bus as measured in the earth frame.

Revised FD



7. **Summarize.** Think of other situations where you have been accelerated. Except when in free fall, we feel as if we are somehow being pushed. In all these situations, how does the direction of your acceleration compare with the direction of the sensation you feel? When we are in the cart of a rollar coaster and the rollar coaster accelerates, we feel as if we are pushed back against our seats. The direction of acceleration is opposite of the sensation we feel

8. **Analyze.** From the Earth frame of reference, write an expression for the *x*- and *y*-components of Newton's 2nd law. Solve for the acceleration a_b in terms of θ and g.

$F_{nety} = ma_y$

$F_{tx} - F_g = 0$

$F_t \cos\theta - F_g = 0$

$F_t \cos\theta - mg = 0$

$F_t \cos\theta = mg$

$F_t = \frac{mg}{\cos\theta}$

$F_{netx} = ma_x$

$F_{tx} = ma_x$

$F_t \sin\theta = ma_x$

$\frac{mg \sin\theta}{\cos\theta} = ma_x$

$a_x = \frac{g\sin\theta}{\cos\theta}$

$= g\tan\theta$

9. **Reason.** Will the two observers agree on the size of any of the forces in their FDs? Explain.
The two observers will agree on the size of tension because the angle between the string and the holder isn't changing. They will also agree on the force of gravity since the mass of the ball isn't changing

10. **Analyze.** From the bus frame of reference, use Newton's 2nd law to write an expression for the size of the fictitious force. Since both observers agree on the size of the *x*-component of the force of tension, we can use the results from the earth frame to eliminate F_{Tx} and create a new expression for the size of the fictitious force, in terms of *m* and a_b.

$F_{netx} = ma_x$

$F_{tx} - F_{fict} = 0$

$F_t \sin\theta - F_{fict} = 0$

$\rightarrow F_{fict} = F_t \sin\theta$

$F_{fict} = ma_x$

11. **Summarize.** The result you found above is a general result that applies to the size of all fictitious forces.State this relationship in a simple way.
The acceleration is opposite of the fictitious force.