SPH4U UNIVERSITY PHYSICS

DYNAMICS

- Frames of Reference (P.108-113)

Frame of Reference

Air shows provide elements of both excitement and danger. When high-speed airplanes fly in constant formation, observers on the ground see them moving at high velocity. Seen from the cockpit, however, all the planes appear to have zero velocity.


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Frame of Reference

*Observers on the ground are in one frame of reference, while the pilots are in the plane's frame of reference. A **frame of reference** is a coordinate system relative to which motion is described or observed.*


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Frame of Reference

FRAME OF REFERENCE (FOR)

- coordinate system relative to which motion is described or observed

PRACTICE

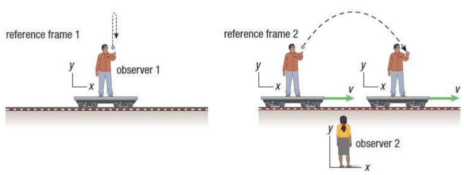
1. How can you tell if two objects are in motion with respect to one another?

   if the straight line segment between the two objects changes in length, direction, or both

Frame of Reference

PRACTICE

2. Is there a right or wrong way to choose a frame of reference?



   No, but some frames of reference make the calculations and predictions much easier than do others.

Inertial Frame of Reference

When you are riding in a car that is moving at a constant velocity, motion inside the car seems similar to motion inside a parked car or even in a room in a building. A frame of reference that is at rest or moving at a constant velocity is called an ***inertial frame of reference****.*

Inertial Frame of Reference

In fact, if you could not see what was happening outside the car and the car ran perfectly smoothly, preventing you from feeling any bumps or vibrations, there are no experiments that you could conduct that would allow you to determine whether the car was at rest or moving at a constant velocity. Newton's laws apply in exactly the same way in ***all*** *inertial frames of reference.*

INERTIAL FRAME OF REFERENCE (a = 0)

- frame of reference that is at rest or is in uniform motion
- Newton's laws are valid

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Non-Inertial Frame of Reference

However, if the car were to accelerate (either by speeding up or slowing down), its speed would be changing. An accelerating frame of reference is called a ***non-inertial frame of reference****. Newton's laws of motion do* ***not*** *apply to a non-inertial frame of reference.*

NON-INERTIAL FRAME OF REFERENCE (a≠0)

- frame of reference that is accelerating
- Newton's laws are not valid

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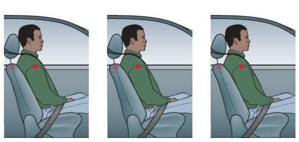
Inertial & Non-Inertial Frames of Reference

For example, consider a passenger riding in a car that suddenly begins to slow down. In the first three frames, the passenger and the car are moving at the same velocity (a=0). As such this is an ***inertial*** *frame of reference. This is evident as the distance between the cross on the seat and the dot on the passenger's shoulder remains constant.*



|<----------------- inertial ----------------->|

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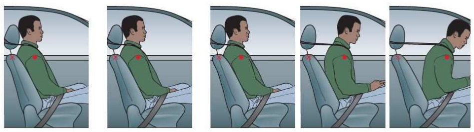
Inertial & Non-Inertial Frames of Reference

However, when the car begins to slow down the passenger, due to inertia, continues to move with the same constant velocity until the seatbelt acts on him (a≠0). As such, this is a ***non-inertial*** *frame of reference. And since a change in direction is also an acceleration, the same situation (i.e. a non-inertial frame of reference) occurs when a car turns a corner.*

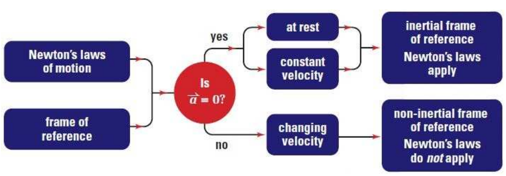


|<---------------- inertial ---------------->|<---- non-inertial ---->|

Inertial & Non-Inertial Frames of Reference

PRACTICE

3. Design a concept organizer to help organize your thoughts as they relate to inertial and non-inertial frames of reference.



Inertial & Non-Inertial Frames of Reference

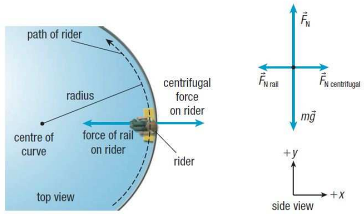
Clearly, in most cases, it is easier to work in an inertial frame of reference so that you can use Newton's laws of motion. However, if a physicist chooses to work in a non-inertial frame of reference and still apply Newton's laws of motion, it is necessary to invoke hypothetical quantities that are often called fictitious forces. ***Fictitious forces*** *are inertial effects that are perceived as "forces" in non-inertial frames of reference, but do not exist in inertial frames of reference.*

FICTITIOUS FORCE

- inertial force perceived as a force in a non-inertial FOR
- does not exist (i.e. a "centrifugal" force)

Inertial & Non-Inertial Frames of Reference

For example, consider a merry-go-round. As it spins, it feels as if you are being pushed to the outside of the merry-go-round's circle. This force in a rotating frame of reference (i.e. a non-inertial frame of reference), acting away from the centre, is a fictitious force called the ***centrifugal force****.*



Inertial & Non-Inertial Frames of Reference

NOTE!

Centrifuges are frequently used in medical laboratories to separate blood samples. The centrifuge rotates the test tubes containing blood samples at high speeds. Since red blood cells are the densest components of blood, centrifugal force will move the cells toward the bottom of the tube. The red blood cells settle on the bottom due to the spinning motion of the centrifuge.

Inertial & Non-Inertial Frames of Reference

PRACTICE

4. Passengers in a high-speed elevator feel as though they are being pressed heavily against the floor when the elevator starts moving up. After the elevator reaches its maximum speed, the feeling disappears.
   (a) When do the elevator and passengers form an inertial frame of reference? A non-inertial frame of reference?

   (a) Inertial FOR – when feeling disappears (a = 0)
   Non-Inertial FOR – when feeling pressed (a > 0)

Inertial & Non-Inertial Frames of Reference

PRACTICE

4. Passengers in a high-speed elevator feel as though they are being pressed heavily against the floor when the elevator starts moving up. After the elevator reaches its maximum speed, the feeling disappears.
   (b) Before the elevator starts moving, what forces are acting on the passengers? How large is the external (unbalanced) force? How do you know?

   (b) F_g & F_N
   $F_{net} = 0$ since $F_{net} = ma$ & $a = 0$

Inertial & Non-Inertial Frames of Reference

PRACTICE

4. Passengers in a high-speed elevator feel as though they are being pressed heavily against the floor when the elevator starts moving up. After the elevator reaches its maximum speed, the feeling disappears.
   (c) Is a person standing outside the elevator in an inertial or non-inertial frame of reference?

   (c) Earth and everything on it are in continual circular motion. Earth is rotating on its axis, travelling around the Sun and circling the centre of the galaxy. The direction of motion is constantly changing, which means the motion is accelerated. <u>Earth is a non-inertial frame of reference</u>. However, in everyday life, the effects of Earth's rotation are usually not detectable.

Inertial & Non-Inertial Frames of Reference

PRACTICE

4. Passengers in a high-speed elevator feel as though they are being pressed heavily against the floor when the elevator starts moving up. After the elevator reaches its maximum speed, the feeling disappears.
   (d) Is the pressure that the passenger's feel a fictitious force? Justify your answer.

   (d) Yes – it is an inertial effect (body at rest wants to stay at rest).

Inertial & Non-Inertial Frames of Reference

PRACTICE

5. Suppose you are on a train moving with a constant velocity. Another train on parallel tracks is moving with the same velocity. A passenger in the other train is tossing a ball vertically in the air.
   (a) Describe how the path of the ball would look to you.

   (a) the ball's path would be up and down

Inertial & Non-Inertial Frames of Reference

PRACTICE

5. Suppose you are on a train moving with a constant velocity. Another train on parallel tracks is moving with the same velocity. A passenger in the other train is tossing a ball vertically in the air.
   (b) Describe how the path of the ball would look if the trains moved in opposite directions.

   (b) the ball's path would be parabolic