

## Intermediate Dynamics: Group Exercises 1

### Galilean Relativity

#### 1 Trajectories and kinematics

Two inertial observers, Yvonne and Zach observe a fly. According to Yvonne, the trajectory of the fly is given by

$$x = 30 \text{ m/s } t + 5 \text{ m}$$
$$x = 40 \text{ m/s}^2 t^2.$$

Zach travels with velocity 20 m/s along the  $x$  axis as observed by Yvonne. In the following, assume that Zach and Yvonne's coordinates are related by Galilean transformations with their origins coinciding at  $t = 0$ s.

- Determine an expression for the trajectory of the fly as observed by Zach.
- Determine expressions for the velocity and acceleration of the fly as observed by Yvonne.
- Determine expressions for the velocity and acceleration of the fly as observed by Zach.
- Do they agree on the velocity? The acceleration?

#### 2 Momentum conservation

An observer at rest with respect to a sheet of ice observes two identical hockey pucks that travel along a straight line toward each other. Puck A travels right with speed 10 m/s and puck B left with speed 20 m/s. The pucks collide and stick together. Zog, at rest with respect to the ice, observes the situation and concludes that total momentum is conserved. Geraldine, travels with velocity 5 m/s to the right with respect to Zog.

- Determine an expression for the velocity of the pucks after collision as observed by Zog.
- Using Galilean velocity transformations determine the velocities according to Geraldine of the pucks before collision and after the collision.
- Determine the total momentum of the system as observed by Geraldine before collision. Is this the same as what Zog observed?
- Determine the total momentum of the system as observed by Geraldine after collision. Is this the same as what Zog observed?
- According to Geraldine, is total momentum conserved in the collision?
- Do Zog and Geraldine agree on the physical law, "If the net external force on a system is zero, then the total momentum of the system is conserved?"
- (*More challenging.*) Try this entire exercise for two different pucks of arbitrary masses.

### 3 Relative velocities of waves

Two observers, Yvonne and Zach, are situated near a still lake. Yvonne is in a boat anchored in the lake and is at rest with respect to the water and the shore. She produces waves that propagate in all directions and observes that the wave speed is 25 m/s. Zach travels directly east at a constant velocity of 15 m/s with respect to Yvonne (i.e. as observed by Yvonne). Both focus on the waves which propagate directly east and directly west.

- a) What are the velocities of the east traveling wave and the west traveling wave as measured by Yvonne?
- b) What are the velocities of the east traveling wave and the west traveling wave as measured by Zach?
- c) Do all observers agree that the waves travel with the same speed? Does the observed velocity of the wave depend on the direction in which it is traveling?