Physics Final Project – Movie Scenes Notes & Ideas: Hancock (2008)

* 4:50
  + Hancock pursues a runaway vehicle
  + Enters the car of the perpetrators going at \_\_\_\_\_\_ m/s, places his foot down through the car and into the pavement; halting its acceleration. Criminals then go flying forward into the window of the car.
    - If the car has a mass of \_\_\_\_\_\_ kg and it accelerates at \_\_\_\_\_\_ m/s^2, how much force is required by hancock to bring it to a complete stop?
    - Time = 5s to come to a stop.
  + *Forces?*
  + *Inertia*
  + *Friction?*
  + *1D Mtion?*
* 09:54 - ?????
  + Hancock bl\*\*s his l\*\*\*d --- calculate the hang time if initial ?????
* 15:18
  + Hancock stops a moving train
  + Calculate Hancock’s mass if train moving w/ force of \_\_\_\_\_ N, and accelerates at \_\_\_\_\_\_ m/s^2.
    - Draw a vector of the situation?
  + Train moves back a little bit
  + Hancock completely stops its acceleration
  + *Newton’s Third Law*
  + *Newton’s Second Law*
* 17:54
  + Hancock drags Ray’s car into drive at an angle of \_\_\_\_\_ degrees
    - Calculate the coefficient of friction of the ground if the car has a weight of 1700N.
  + *Friction*
  + *Impact angle on friction*
  + *Weight*
  + *Normal Force*
* 22:53
  + Hancock propels himself upward into the sky
    - Calculate normal force generated by the ground if the force ??
  + *Normal Force*
  + *Vectors*
  + *Gravity?*
  + *Forces*
* 26:00
  + Hancock throws a kid in the air after he taunts him one too many times
    - Calculate the max height and hang time of the kid if he’s thrown at an initial velocity of 50m/s & is in the air for 20 seconds.
    - Calculate vertical & horizontal velocity if thrown at an angle of 30 degrees
  + If the kid has a mass of \_\_\_\_\_ kg, how much force is generated when he comes back down to earth?
  + *1D Motion?*
* 29:00
  + Hancock throws a whale back into the water
    - Max height if thrown at angle of \_\_\_\_ degrees at \_\_\_\_ m/s
  + *Projectile Motion*
  + *2D Motion*
* 35:00
  + Hancock shoves a guy’s head up another’s rear.
    - Calculate the force of the thrust if HC shoes the guy’s head at \_\_\_\_\_ m/s^2 and it weighs \_\_\_kgs.
    - Calculate the angle if it’s thrusted at a h velocity of \_\_\_\_\_ m/s
      * Distance of \_\_\_ m
      * Time = \_\_\_\_\_ s
  + *2D Motion*
  + *Forces*
  + *Vectors*
* 38:00
  + HC throws a basketball into a hoop from a distance of \_\_\_\_\_m. Max height if thrown at angle of \_\_\_\_\_ degrees at \_\_\_\_\_ m/s.
    - Calculate the hang time of the ball if hoop is 4m in the air.
  + *Projectile motion*
  + *2D motion*
  + *Vectors*
* ***Bad Physics?***
  + 43:44
    - Ball bounces back very far after hitting rim.
      * How much force is required for that?
  + 26:00
    - Kid falls back down & his acceleration is completely stopped on the way down by Hancock?
* 48:40
  + HC deflects a rocket with his bare hands
  + If the force is 300 N, what’s the normal force generated by HC’s hand?
  + *Forces*
  + *Normal Force*
  + *Inertia*
* 50:00
  + HC picks off crooks one by one
    - How fast?
  + *Acceleration*
  + *2D Motion*
  + *Forces*
* 1:00:00
  + Ray’s wife throws hancock through the house.
  + *Projectile motion*
  + *2D motion*
  + *Forces*
  + *Newton’s Laws*
  + *Inertia*
* 1:18:00
  + HC throws a guy through the store
  + *Projectile motion*
  + *2D Motion*
  + *Newton’s Laws*
* 1:19:00
  + HC throws a candy bar at a guy and launches him out a window
  + *Forces*

QUESTION DRAFTS:

UNIT 1:

SCENE (4:50) – Hancock wakes up from a drunken slumber to pursue a getaway vehicle.

**Revised Concepts Demonstrated:**  
This scene demonstrates **kinematics in one dimension** with Hancock’s constant velocity and acceleration. Hancock's flight path changes in speed and could be broken down using **vectors**, as well as **unit conversions** between miles and meters.

**Is this “Good Physics”?**

The movie never explains how Hancock is able to overcome the force of gravity and maintain flight in the air. In real life, he’d fall straight to the ground shortly after attempting to.

**Question (Enhanced):**  
Hancock takes off and flies directly after the getaway vehicle, covering a distance of 8 miles. His initial speed is 30 m/s, and he decelerates at a constant rate of -15 m/s² when approaching the vehicle. Assume no air resistance and ignore the forces required for flight.

1. **Distance Conversion:**
   * Convert 8 miles to meters.
2. **Travel Time Calculation:**
   * How long does it take Hancock to travel 8 miles if he maintains a speed of 30 m/s?
3. **Deceleration Duration:**
   * Once he reaches the vehicle, how long does it take for Hancock to come to a complete stop with a deceleration of -15 m/s²?
4. **Stopping Distance:**
   * How far does Hancock travel while decelerating to a stop?
5. **Total Flight Distance:**
   * Calculate the total distance Hancock covers from takeoff until he stops. How does this compare to just the 8 miles he intended to fly?
6. **Realism Check (Conceptual):**
   * Considering the physics principles of flight, discuss whether Hancock’s ability to fly as shown in the movie aligns with Newton's laws. What forces would he realistically need to overcome, and how might they affect his motion?

SCENE (29:00)

**Scene Description (29:00):**  
Instead of gently carrying it, Hancock HURLS a beached whale from the shore back into the ocean. The whale travels in an arc before landing on a passing ship.

**Concepts Demonstrated:**  
This scene illustrates kinematics, focusing on the displacement, speed, velocity, and acceleration of the whale. Though the whale was thrown in an arc, we can reimagine the scene to examine the concept of freely falling bodies.

**Question:**

Assume Hancock throws the whale straight up for no reason with an initial velocity of 20 m/s,

1. Calculate the whale's acceleration immediately after Hancock releases it. Is the acceleration constant, or does it change as the whale moves?
2. Calculate the displacement of the whale
3. **Maximum Height Calculation:**
   * Calculate the maximum height the whale reaches above the ground.
4. **Time to Reach Maximum Height:**
   * How long does it take the whale to reach this maximum height?
5. **Total Time in the Air:**
   * Assuming Hancock catches the whale just before it hits the ground, calculate the total time the whale spends in the air.
6. **Velocity Right Before Catching (Conceptual):**
   * What would be the velocity of the whale just before Hancock catches it on the way down? Explain why this velocity is the same magnitude as the initial velocity (in opposite direction), using kinematic concepts.
7. **Realism Check (Conceptual) - BONUS:**
   * In reality, would throwing a whale upward with such a force be safe or even possible? Discuss the challenges of overcoming the whale’s massive weight and the role gravity would play in making this kind of throw incredibly difficult.

UNIT 2 :

Scene (26:00)

**Scene Description (26:00):**  
After being taunted by a 10 year old, Hancock loses his patience and throws the kid straight up into the air. While the child is in the air, Hancock takes about 12 seconds to walk a short distance and finish a conversation, before positioning himself to catch the child just before he hits the ground.

**Concepts Demonstrated:**  
This scene illustrates **Newton's laws of motion** (especially the second and third laws) and **kinematics in two dimensions**. Specifically, we can explore free-fall motion, the forces on the child, and the timing of Hancock's actions to catch him. It also provides an opportunity to discuss **gravitational force** and **the normal force** when Hancock catches the child.

**Question:**  
Assume Hancock throws the child vertically upward with an initial velocity of 58 m/s at an angle of 63 degrees. Neglect air resistance.

1. **Initial Velocity Components**
   * Calculate the initial vertical and horizontal components of the child’s velocity.
2. **Maximum Height Calculations**
   * Calculate the maximum height the child reaches. Could he see his house from up there?
3. **Time to Reach Maximum Height:**
   * How long does it take the child to reach this height?
4. **Total Time of Flight:**
   * Calculate the total time the child spends in the air. Does this align with Hancock’s conversation duration of 12 seconds? Is that enough time for the kid think about the mistakes he made?
5. **Range Calculation:**
   * Calculate the horizontal distance (range) traveled by the child from Hancock's throw to where Hancock catches him. If Hancock had to wait in a specific spot to catch the kid, how far would he have to stand?
6. **Force Calculation at Catch (Conceptual):**
   * When Hancock catches the child, he must apply an upward force to stop the child’s downward motion. Assuming the child has a mass of 30 kg, calculate the force Hancock would need to apply upward to catch the child safely without injury. Which of Newton’s laws explains this scenario?
7. **Effect of Gravity (Conceptual):**
   * Identify the role of gravity throughout the child’s motion. Which of Newton’s laws explains why the child decelerates while going up and accelerates while coming down?
8. **Realism Check (Conceptual):**
   * In reality, would throwing a child upward with such a force cause harm due to the rapid acceleration and deceleration? Discuss the risks and forces involved in such an action using Newton's laws.
   * In real life, this would be child endangerment (obviously). Discuss the force involved in stopping the kid compared to normal human limits. Would any regular human actually survive being caught this way?

UNIT 3:

**Scene Description (17:54):**  
After preventing a train from hitting the car of public relations manager, Ray, Hancock decides to carry the car back to Ray's house. He drags the car up a slight incline into the garage.

**Concepts Demonstrated:**  
This scene allows us to explore **work done by a force**, **kinetic energy**, **gravitational potential energy**, **nonconservative forces** (friction), and the **conservation of mechanical energy**.

**Question:**  
Assume Hancock drags Ray’s 1500 kg car up a 5° incline over a distance of 50 m to the garage. The frictional force opposing the motion is 3000 N, and Hancock maintains a constant speed of 4 m/s as he moves the car up the incline.

1. **Work Done Against Friction:**
   * Calculate the work done by Hancock to overcome the frictional force as he drags the car up the incline.
2. **Work Done Against Gravity (Potential Energy Change):**
   * Calculate the increase in gravitational potential energy of the car as it is raised to the height of the incline. (Hint: find the vertical component of the displacement.)
3. **Total Work Done by Hancock:**
   * Taking into account both the frictional force and the change in gravitational potential energy, calculate the total work Hancock performs to move the car up the incline.
4. **Kinetic Energy and Constant Velocity (Conceptual):**
   * Calculate the change in kinetic energy of the car.
   * Since Hancock moves the car at a constant speed, explain why there is no change in kinetic energy. Discuss how this fact affects the total work-energy balance in this scenario.
5. **Energy Lost to Nonconservative Forces:**
   * What is the total energy lost to friction as Hancock drags the car up the incline? Discuss how this energy loss affects the conservation of mechanical energy.
6. **Realism Check (Conceptual):**
   * Given the forces Hancock had to overcome, discuss the physical feasibility of a human being exerting this much work. Compare this to the work-energy theorem, which states that the total work done is equal to the change in mechanical energy, and explore whether Hancock’s abilities are plausible.

**Scene Description (4:50):**  
Hancock wakes up from a drunken slumber to catch a getaway vehicle. He flies in a series of sharp, circular arcs, changing direction rapidly, while dodging birds and other debris to catch up with the car.

**Concepts Demonstrated:**  
In addition to kinematics, this scene could be a demonstration of **centripetal motion** as Hancock makes the sharp turns to dodge objects in his path. **Question:**  
Assume that during the pursuit, Hancock performs a sequence of sharp circular maneuvers to maintain a high-speed trajectory around corners, as he tries to match the car’s direction.

1. **Uniform Circular Motion:**
   * If Hancock maintains a constant speed of 45 m/s while turning in a circular path with a radius of 30 m, calculate the magnitude of the centripetal acceleration he experiences during each turn.
2. **Centripetal Force Needed for Turning:**
   * Hancock has a mass of 90 kg. Using the centripetal acceleration found in Part 1, calculate the centripetal force required to keep him moving in his circular path. Discuss the source of this force in terms of Hancock’s superpowers and relate it to a real-world situation (like a car making a sharp turn).
3. **Banked Curves Conceptual Analysis:**
   * Imagine Hancock’s turns resemble banked curves as he tilts his body sharply during each maneuver. Describe how banking would reduce the reliance on friction (or, in Hancock’s case, his own propulsion) to maintain the circular path. What angle of banking would theoretically minimize the need for additional force?
4. **Energy in Vertical Circular Motion (Conceptual):**
   * During the pursuit, Hancock occasionally gains altitude as he loops over buildings. Describe how his gravitational potential energy changes as he rises and falls, assuming he follows a vertical circular arc of 100 m. Discuss the impact of these energy changes on his speed and centripetal force needed at the top and bottom of the arc.
5. **Comparing to Satellite Motion:**
   * Suppose Hancock could maintain circular motion in a stable orbit around Earth, similar to a satellite. What speed would he need to stay in orbit at a low altitude (say, 200 m above the ground)? Compare this with the speeds observed in the scene and discuss whether these speeds align with real orbital motion concepts.
6. **Realism Check (Conceptual):**
   * In reality, humans (and even most vehicles) would be unable to sustain such high centripetal accelerations without significant physical strain or structural support. Reflect on the physical stresses Hancock would experience based on his calculated centripetal acceleration and force, and explore the physical limits a human body would face under similar circumstances.

FINAL AND ADJUSTED:

STRUCTURE REVISIONS:

At the start of each unit, instead of

UNIT 2

Problem 2:

When Hancock catches a 30-kg child falling downward at 20 m/s, he brings the child to rest in 0.5 seconds by exerting an upward force.

* **a.** What is the average force Hancock exerts on the child?
* **b.** How many times greater is this force compared to the child’s weight?
* **c.** Explain the relationship between Hancock’s force, the child’s weight, and the net force during the catch using Newton’s laws."

Unit 3

Scenario: Car chase in the intro

Runaway cars are moving along a banked curve with a radius of 100 m100 \, \text{m}100m. The road is designed for a speed limit of 50 m/s50 \, \text{m/s}50m/s, and Hancock is flying above, observing the scene.

**Question 1A: Force Diagram on a Banked Curve**

* Draw a **free-body diagram** for a car moving along the banked curve. Label all forces acting on the car, including:
  + The gravitational force (FgF\_gFg​),
  + The normal force (FNF\_NFN​),
  + The static friction force (FfF\_fFf​), if present.
* Indicate how these forces contribute to the centripetal force required for the car to navigate the turn.
* Explain why friction might not be necessary at the speed limit but becomes critical if the car is moving faster or slower.

Unit 4:

Scenario: Hancock stops a train from colliding with a car by standing in front of it.

**Impulse and Momentum Questions**

**Question 1A: Impulse and Momentum of the Train**

* The train has a mass of m=5000 kgm = 5000 \, \text{kg}m=5000kg and is traveling at a speed of v=30 m/sv = 30 \, \text{m/s}v=30m/s before the collision.
  + Calculate the **momentum** of the train before the collision.
  + If Hancock applies a constant force to stop the train over a period of t=5 st = 5 \, \text{s}t=5s, calculate the **impulse** exerted on the train by Hancock.

**Question 1B: Impulse Exerted by Hancock**

* During the collision, Hancock applies a force to the train that brings it to rest.
  + Draw a **force vs. time graph** to represent the impulse exerted on the train over the 5 s5 \, \text{s}5s collision duration.
  + From the graph, explain how the area under the curve corresponds to the impulse and what this implies about the change in momentum.

Question 2:

Imagine Hancock’s force causes a rotational motion of the train’s wheels as he stops the train.

**Question 2A: Describe the relationship** between the tangential velocity of a point on the edge of the wheel and the angular velocity of the wheel. What happens to the tangential velocity as the angular velocity changes?

**Question 2B:**

* Given that Hancock applies a force that causes the wheels to stop, calculate the **angular displacement** θ\thetaθ of a wheel from the moment Hancock applies the stopping force until it comes to rest, assuming the initial angular velocity of the wheels is ωi=15 rad/s\omega\_i = 15 \, \text{rad/s}ωi​=15rad/s and the angular deceleration is constant.
* **What factors would affect the time it takes for the train’s wheels to stop?**

**Question 2C:**

* **Sketch a diagram** showing the initial and final positions of a point on the train's wheel as it undergoes rotational motion. Label the initial and final angular velocities and the corresponding tangential velocities. Include arrows for the direction of motion at both positions.

Unit 5:

Scenario: Hancock tosses a car onto a building with a spike on it.

**1. Torque and Rotational Dynamics:**

**Part 1: Conceptual Question**

* When Hancock tosses the car onto the spike, the car may experience some rotation as it comes to rest.
  + **Explain how torque** is generated when the car is placed on the spike. What factors determine the amount of torque exerted on the car as it begins to rotate around the spike?

**Part 2: Calculation Question**

* Assume that the car has a mass of m=1200 kgm = 1200 \, \text{kg}m=1200kg and the spike is located at the car's center of gravity. The car’s center of mass is 2 m2 \, \text{m}2m from the point where the spike touches. If Hancock tosses the car at an initial angle θ=10∘\theta = 10^\circθ=10∘, calculate the torque experienced by the car at the moment of contact with the spike. Assume the car is in equilibrium when it starts rocking.
  + **How would the torque change if the angle θ\thetaθ were increased to 20∘20^\circ20∘?**

**Part 3: Diagram Question**

* **Draw a diagram of the car in the moment before it balances on the spike.** Show the forces acting on the car, including its weight, the normal force from the spike, and the torque that causes the car to rock. Label the center of gravity and the line of action of the forces.

**2. Center of Gravity and Equilibrium:**

**Part 1: Conceptual Question**

* When the car is placed on the spike, it begins to rock back and forth.
  + **Explain how the position of the car’s center of gravity** influences its stability. What happens to the car’s equilibrium when its center of gravity moves farther from the spike?

**Part 2: Calculation Question**

* If the spike is located 0.5 m from the car's center of gravity, calculate the **potential energy** of the car when it is displaced at a small angle θ=5∘\theta = 5^\circθ=5∘ from its equilibrium position. Assume the mass of the car is 1200 kg1200 \, \text{kg}1200kg and the height of the center of gravity above the spike is h=2 mh = 2 \, \text{m}h=2m.
  + **How does the displacement angle affect the potential energy as the car rocks back and forth?**

**Part 3: Diagram Question**

* **Draw a diagram of the car at its equilibrium position and when displaced by a small angle.** Show the center of gravity, the force of gravity, and the line of action of the normal force from the spike. Label the distance between the center of gravity and the point of contact with the spike.

**3. Angular Momentum and Rotational Motion:**

**Part 1: Conceptual Question**

* The car is rocked back and forth by small forces after it lands on the spike.
  + **Discuss how angular momentum is involved** in the motion of the car. When the car tilts, what happens to its angular momentum, and what role does the spike play in transferring momentum?

**Part 2: Calculation Question**

* The car is rotating around the spike after being displaced by an angle θ\thetaθ. If the car has a rotational inertia I=1500 kg⋅m2I = 1500 \, \text{kg} \cdot \text{m}^2I=1500kg⋅m2 and is rotating with an angular velocity of ω=3 rad/s\omega = 3 \, \text{rad/s}ω=3rad/s, calculate the **angular momentum** of the car about the spike.
  + **If the angular velocity increases, how would this affect the angular momentum?**

**Part 3: Diagram Question**

* **Draw a diagram of the car as it rocks back and forth** on the spike. Label the center of gravity, the angular velocity vector, and the moment arm that contributes to the angular momentum. Indicate the direction of the car’s angular momentum.

**4. Simple Harmonic Motion (SHM) and Oscillations:**

**Part 1: Conceptual Question**

* The car on the spike rocks back and forth like a pendulum.
  + **Explain why the motion of the car can be approximated as simple harmonic motion** when it is displaced by small angles from its equilibrium position. What are the key conditions for SHM to occur in this system?

**Part 2: Calculation Question**

* If the car’s moment of inertia is I=1500 kg⋅m2I = 1500 \, \text{kg} \cdot \text{m}^2I=1500kg⋅m2 and the distance from the spike to the center of gravity is r=2 mr = 2 \, \text{m}r=2m, calculate the **period of oscillation** for the car’s rocking motion. Assume that the car behaves as a simple pendulum in SHM.
  + **How would the period change if the mass of the car were doubled?**

**Part 3: Diagram Question**

* **Sketch a diagram of the car during its oscillation.** Label the equilibrium position, the displacement angle, and the forces involved (gravitational force, restoring force from the spike). Show the direction of motion at both extreme positions of the oscillation.

**5. Pendulum Motion and Frequency:**

**Part 1: Conceptual Question**

* The car rocks back and forth like a pendulum after being tossed onto the spike.
  + **Explain how the motion of the car compares to that of a simple pendulum.** How does the length of the pendulum (distance from the spike to the center of gravity) affect the frequency of the oscillations?

**Part 2: Calculation Question**

* If the car has a moment of inertia of I=1500 kg⋅m2I = 1500 \, \text{kg} \cdot \text{m}^2I=1500kg⋅m2 and is rocking with a period of T=2 secondsT = 2 \, \text{seconds}T=2seconds, calculate the **frequency** of the oscillations.
  + **What would happen to the frequency if the moment of inertia were halved while keeping the mass and length constant?**

**Part 3: Diagram Question**

* **Draw a diagram of the pendulum-like motion of the car** on the spike. Label the forces involved, including gravity, the normal force from the spike, and the restoring force. Show the angle of displacement and the direction of motion at each extreme of the oscillation.

**6. Energy Considerations and Potential Energy:**

**Part 1: Conceptual Question**

* As the car rocks back and forth, it undergoes periodic changes in potential and kinetic energy.
  + **Explain the transformation of energy** in the rocking car system. What happens to the potential and kinetic energy of the car as it moves from the highest point of its oscillation to the lowest point?

**Part 2: Calculation Question**

* The car has a mass of m=1200 kgm = 1200 \, \text{kg}m=1200kg and is displaced by an angle θ=5∘\theta = 5^\circθ=5∘. Calculate the **potential energy** at the maximum displacement, assuming the height of the center of gravity is h=2 mh = 2 \, \text{m}h=2m.
  + **If the car rocks back and forth, what is the kinetic energy at the lowest point of the motion?**

**Part 3: Diagram Question**

* **Sketch a diagram showing the car’s position at maximum displacement and the lowest point.** Indicate the potential and kinetic energy at each position and explain how they change as the car moves through its oscillation.