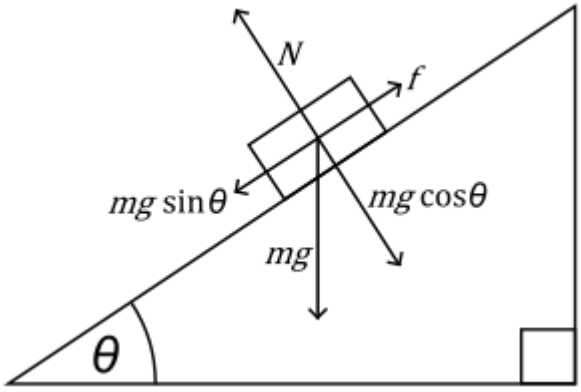
# Batman Begins

1. "Batman begins, appropriately enough, tells the story of how Batman begins. Traumatized by the murder of both his parent when he is a boy, Bruce Wayne disappears from his life of wealth and privilege, and spends the early years of his adulthood traveling the world trying to understand the criminal mind. Eventually, Ra's Al Ghul the mysterious leader of a secret Ninja-like organization called the _____, dedicated to "true justice" tracks him down.
2. Ra's trains Bruce in the "way of the Ninja" but when it turns out the organization is really out to eliminate evil by killing everyone in his hometown, Bruce gets upset, burns down Ra's' house, and escapes back to Gotham City. Bruce contacts Alfred, (his butler), who arrives in a private jet to pick him up. Alfred reveals that Bruce, who has been away for seven years, has been declared dead by William Earle so that Earle can take Wayne Enterprises public. Bruce says it's a good thing he willed everything to somebody. Who was that somebody?
3. After setting fire to Ra's house, Bruce pulls the unconscious Ra's out before he is burned. They then slide down a steep snow-covered slope towards the edge of a precipice.
   Look at the picture with the accompanying force diagram below for their trip down the slope.




We'll assume Bruce and Ra's have the same mass of 80 kg, so m = 2 (80 kg) = 160 kg. Acceleration due to gravity is "g" and g = -9.8 m/s². We can estimate the slope to be around 40 degrees, which is a typical incline in mountainous terrain. The variable symbols of N = Normal Force; and f = kinetic friction. To determine the force of kinetic friction we need to know the coefficient of kinetic friction between snow and clothing. The coefficient describes the relative "stickiness" between the two materials. It depends on the clothing material and on the snow conditions. Assuming dry snow and warm wool fleece (both reasonable assumptions considering the extreme cold and low mountain humidity), a "μ" of around 0.2 is probably in the right range.

Using the coordinate axes defined as x-axis parallel to the plane and y-axis perpendicular to the plane, we'll apply the second law of motion to both the x and y direction and assume the two adversaries comprise a single system/object. First we will look at their acceleration

while sliding, and use this to determine their acceleration. Note that " m g" is the weight of the two men and are replaced by ( -m g cos ɵ) in the y-direction and (-m g sin ɵ) in the x-direction.

F net in the y direction = N – mg cos ɵ = m a = 0 (in the y direction).

Solving for N: N = m g cos ɵ

Additionally;

F net in the x direction = -m g sin ɵ + f = m a (in the x-direction)

Since friction has the formula f = μ N then we need to substitute to get:

-m g sin ɵ + μ N = m a

Substituting N = m g cos ɵ

Then; - m g sin ɵ + μ (m g cos ɵ) = m a

a. With solved equation above, find the acceleration of the two men as they slide towards the precipice. (Hint: Use the data given above and solve for a).

b. Find the time elapsed in the action sequence. The actual scene can be notoriously unreliable. Usually there are multiple cuts, and we can't be sure that these don't overlap in time or are completely consistent with each other. However in this scene it looks pretty straightforward.

c. Use the measured time and calculated acceleration "a" to find the velocity at the bottom of the slope.

$$v = v_o + a\,t$$

d. Alternatively, if we estimate the distance down the slope to be 30 meters, the use the following formula to find the velocity:

$$v^2 - v_o^2 = 2\,a\,\Delta x$$

e. Do the velocities agree? If not ,,,,,,average them……

f. As Ra's falls over the edge, Bruce is able to hold on to him with one hand while he digs the sword in with the other. They come to a stop very rapidly, half a second at most. In this time they slow from your calculated velocity to a dead stop. Calculate the deceleration. [Hint: $a' = (v-v_o)/t$] where a' is the deceleration while stopping.

g. What forces are being exerted on each of Bruce's arms during the deceleration? [$F = 160\text{ kg } (v-v_o)/ t$] Also 4.45 N = 1 lbs

h. For Bruce, because his deceleration is along the line of slope, we will figure his forces parallel to this plane. If we define the following variables:

   $F_2 = m_2 g$ = Ra's weight hanging over the edge. (Remember $m_1 = m_2 = 80$ kg)
   Therefore, Ra's weight component parallel to the plane is $[m_2 g \cos(90°\text{-}40°)]$.

   $F_1 = m_1 g$ = Bruce's weight.
   Therefore, Bruce's weight component parallel to the plane is $[m_1 g \sin 40°]$.

   So if these two forces are counteracted by the force of the sword on Bruce, then calculate the amount of force that causes the abrupt deceleration. Does this agree to the above calculation?

i. Are your calculated forces reasonable for Bruce to hold on for 0.5 seconds? Why?

j. Even though Bruce is a trained Ninja, he is still human. Not superhuman…. How could the Movie director have improved this scene to make it possible to save himself and Ra's?

4. After Bruce returns to Gotham City and decides to announce his return to Wayne Enterprises, Earle warns him that he cannot prevent the Company form going public at this later stage. Bruce explains that he is not bothered by this and that all he wants is a job, preferably in Applied Sciences. Earle sets this up and Bruce goes to meet his new 'boss' Lucius fox. Fox explains to Bruce that the AS department is dead end where earl can put people to stop them from causing trouble. Fox introduces Bruce to some of the equipment, a Kevlar battle suit, grapple gun and harness. Later, Bruce realizes he could use a lightweight fabric to make a glider wing or parachute. Fox shows him a memory cloth which can be assigned any type of rigid shape when an electric current passes through it.
   a. Does a cap like this exist in real life? How can electricity cause fiber to go rigid?

   b. How strong must Batman's arms be to support the wings? (It's interesting to note that birds have extremely strong chest muscles and very light bones. What relevance does this have?)

   c. Is the cape big enough to accomplish the gliding stunts batman uses? Explain.

5. Fox also introduces him to a tank-like transport called the Tumbler, designed as a bridging vehicle for the army, which can accelerate to high speeds, is armed, and can perform a "rampless" jump.

   The tumbler is actually a real car, or more accurately several different cars that were built specifically as prototypes for the movie. No CGI here, not even the flames ejected from the rocket engine. All of the scenes with the Bat-mobile that we see in "Batman Begins" were filmed using these prototypes. When the Bat-mobile is racing along city streets, that's one of the "race versions" which were constructed around a stripped out NASCAR race car at a cost of about $250,000 each. They each equipped with special suspension systems similar to those found in Baja racing trucks, and in order to help the car negotiate high speed turns, each wheel is equipped with extra brakes that can be activated separately with hand levers. Engaging the supplemental brakes on only one side provides a greater net torque on the car and a tighter turning radius compared to normal braking.

   The prototype is also outfitted with a rugged steel frame, which, with the aid of the suspension, allows the car to execute 30 foot jumps without crumpling on impact. And it attains a top speed over 100 mph. there is also a much less outfitted "opening version" that they use to film Batman getting in and out of the vehicle. The "jet version" is one of the race versions outfitted with propane tanks that ignite for scenes involving rocket thrust, and there is even a miniature version which they film jumping ravines and other obstacles. However, the scene where he jumps through the waterfall was actually filmed using the race version.

   These high performance vehicles are capable of accelerating to 60 mph in 5 seconds. Calculate this acceleration in "$m/s^2$". Use $a = (v-v_o)/t$
   Note: 1.61 km = 1 mile; 3600 sec. = 1 hour; 1000 m = 1 km;

6. A worker at Wayne Enterprises, which now manufactures weapons, reports that one of their prototype weapons has been stolen from a cargo ship. The weapon was a powerful microwave emitter, designed to vaporize water. Is it possible for to vaporize water with microwaves? Explain.

7. Falcone is the top criminal leader in Gotham City. On Batman's first night out as a vigilante, he intercepts a drug shipment, captures Falcone and provides the police with the evidence to indict him. Falcone and his men are eventually transferred to the Arkham Asylum with the help of the hospital's corrupt administrator, Dr. Jonathan Crane, who has been paying off Falcone to ship a toxic hallucinogen into Gotham City. Crane has a criminal alternative-name. What is it?

8. Crane works with the toxin in his experiments, using his patients as guinea pigs. When Falcone demands a bigger share, Crane gasses Falcone with the same toxin, literally driving him insane? How does this toxin affect Falcone's personality?

9. While investigating the drugs, Batman encounter Crane, who also sprays him with the toxin. Alfred rescues him , using an antidote developed by Fox. It's interesting that one of Bruce's allies is the jack of all trades super scientist/engineer Mr. Lucius Fox. Mr. Fax can not only design super hi-tech mechanical gadgets for Bruce, but when Batman is exposed to the psychotropic drug, Fox is able to come up with the antidote in a few hours. This guy's wasting his time at Wayne Enterprises, he should be working full-time in medical research! The brilliant "scientist jack of all trades," the guy who can make a nuclear fusion reactor and at the same time understands molecular biology at an advanced level, is pretty common in the movies. Is this sort of thing existent or nonexistent in real life?

10. Who is Rachel and how does she relate to Bruce?

11. When Rachel travels to Arkham to investigate Falcone's insanity, Crane shows her that the toxin has been placed somewhere. Where or what has he done with the toxin?

12. Crane sprays Rachel with the toxin. However, Batman also douses Crane with the toxin and interrogates him; Crane claims to be working for Ra's al Ghul, despite his apparent death. Batman escapes with Rachel in a lengthy car chase, taking her to the cave where he inoculates her with the antidote. During the car chase, the tumbler jumps from on building to the next to get away from the police. Assuming the velocity of the tumbler is 120 km/hr; the height difference of the second building is 20 meters and the distance between buildings is 50 meters, is Batman make it in real life without Hollywood tricks?
    a. Change 120 km/hr to m/s. (Use 1000m = 1 km; and 3600 sec = 1 hr)

    b. How long will it take the Bat-mobile to fall 20 m? (Use: $\Delta y = v_{oy}t + \frac{1}{2}gt^2$) Note: $g = -9.8\ m/s^2$; $v_{oy}$ = initial velocity in the vertical direction = 0 m/s…….solve for t and substitute.

    c. What is the horizontal distance that he traveled in the Bat-mobile? Use $d_x = v_x t$.

    d. Will Batman make the jump? Refer to your calculations.

    e. What was his vertical velocity? Use $v_y = v_{oy} + gt$.

    f. Change your velocity in part (e) to km/hr.

    g. Do you think his shocks will withstand the abrupt collision?

13. At Bruce's birthday celebration at Wayne Manor, Bruce is confronted by Ducard, who reveals to be the real Ra's al Ghul, and has now arrived in Gotham personally to destroy the City. He had conspired with Crane to poison Gotham City and now plans to vaporize it with the stolen microwave device and cover all of Gotham in the poison, causing mass hysteria form the hallucinogen. After Bruce pretends to be drunk to get everyone to leave, Ra's' men burn down the mansion, release all the inmates at Arkham, and vaporize the water in the mains around the area. Although Wayne Manor is destroyed, Bruce escapes. Who helps Bruce escape?
14. Who does Rachel deliver the antidote to?
15. Batman reveals his identity to Rachel and then has Gordon drive the Bat-mobile to Wayne Tower, the central hub of the Gotham elevated rail system. Ra's boards a train, planning to take the vaporizer to the main water-line hub at the tower and set off a chain reaction that will vaporize the entire water supply. The manner in which the Microwave emitter is used to vaporize the city's water would not go as intended. If the microwave emitter is located inside a train that has a very metallic exterior, will this be a problem? Explain……
    (Hint: A fork placed within a relatively low powered kitchen microwave would encounter a photoelectric effect resulting in a disruption to the focusing of the microwaves beams)

16. Batman confronts Ra's on the train and the two fight. During their battle, Batman goes to stop the train, but Ra's destroys its controls. Although, Gordon destroys the elevated tracks and Batman escapes the train as it crashes, leaving Ra's to die. Let's determine the speed of the subway car as it crashes into the ground below.
    a. Measure the time of the duration of fall for the train.
    (Note: t = # of frames/23.72 frames/s = 85 frames / 23.72 frames/s = 3.583 sec)
    Since it is clear by watching the movie, the producers slowed it down by a factor of two, the actual fall time of the train is half of the above calculations.
    b. Calculate the vertical distance in meters and feet of the fall (Δy). (Use $\Delta y = v_{oy}t + \frac{1}{2}gt^2$)
    Refer to #12 (b) to get the data for g and $v_{oy}$.

    c. Gotham cars are probably the same size as a standard NYC subway care such as the R160F class. In this scene, the trains fell in such a way that they formed a right triangle with the ground being one leg, the height of the bridge being the other leg, and the displacement of the train cars being the hypotenuse. The displacement was equivalent to about the length of two Gotham cars, and the hypotenuse is therefore 36.68 m. We can use this quantity to find the horizontal displacement of the train cars by using the Pythagorean Theorem:

$$\Delta x^2 + \Delta y^2 = c^2$$

where, Δx = horizontal displacement;
Δy = height of the bridge = answer from #16 (b)
c = the displacement of the first car from the beginning to the end of the fall.

$$\Delta x^2 + \Delta y^2 = (36.68\ m)^2$$

Solve and calculate Δx in meters?

d. What is the train's horizontal velocity? (Use $v_x = \Delta x/t$)

e. How does the $v_x$ change throughout the time the train leaves it's tracks? (Hint: There is no gravity in the horizontal direction)

f. What is the vertical component of the velocity just before the first cart hit the ground? (Use: $v_y = v_{oy} + gt$) Remember $g = -9.8\ m/s^2$ and $v_{oy} = 0$ m/s.

g. Change your calculated $v_x$ and $v_y$ from (m/s) to mph. (Use 1.61km = 1 mile; and 3600 sec = 1 hr.

h. Us e the Pythagorean Theorem to calculate the magnitude of the resultant velocity.

Use $v_x^2 + v_y^2 = v^2$

i. At what angle did the train hit the ground? ($\tan \theta = v_y / v_x$)

j. Name two sources of error that you can think of:

17. Following the battle, Batman becomes a public hero and Bruce gains control of his company, having secretly bought a majority of its stock shares. Who does he fire?
18. Does Bruce end up with Rachel or does he lose her at the end?
19. Gordon, newly promoted to lieutenant, shows Batman the Bat-Signal and mentions a costumed criminal who leaves Joker playing cards at crime scenes. Batman promises to investigate, and disappears into the night. The bat signal is a few feet across and is projecting the signal onto clouds far above. To do this, the light beam should get wider as it climbs up (like a flashlight's beam aimed at the ceiling). Yet the shot of the clouds shows rays of light getting wider as they go downward, like sun rays through the clouds. How is this possible? Explain.