

Physics of Sports

Goal: Explain the physics behind a particular aspect of your favorite sport.

Overview:

In this project, you will tie together all of the physics principles you've learned about in order to describe what's going on in one simple action. You will analyze this motion using graphing, kinematics formulas, forces (Newton's Laws), momentum, work, energy and power. Of course, we haven't learned many of these topics yet, but as we do them, you should be thinking about how they apply to your situation. You will also give a written explanation of what's going on and why things happen the way they do. For example, why do football players lower their body before attempting to tackle another player?

Instructions:

Choose a very brief situation from sports (or elsewhere, subject to teacher approval) to which you can apply the principles of physics you have learned. The situation should involve an impact, change in momentum, and/or transformation of energy.

Ideas:

- a bat, club, racket, or hand hitting a ball
- a football tackle
- a racecar turning (or crashing)
- drag racing
- shooting an arrow
- pitching a baseball
- the high jump or pole vault
- a gymnastics maneuver
- a wrestling or martial arts maneuver
- flying a plane
- rowing a boat
- pedaling a bicycle

Necessary components of the project, 1 page each:

Graphs (Position vs. time and Velocity vs. time)

Kinematics analysis (formulas and solutions)

Free Body Diagram, showing forces involved

Momentum analysis (formulas and solutions)

Work and Energy analysis (formulas and solutions)

Power analysis (formulas and solutions)

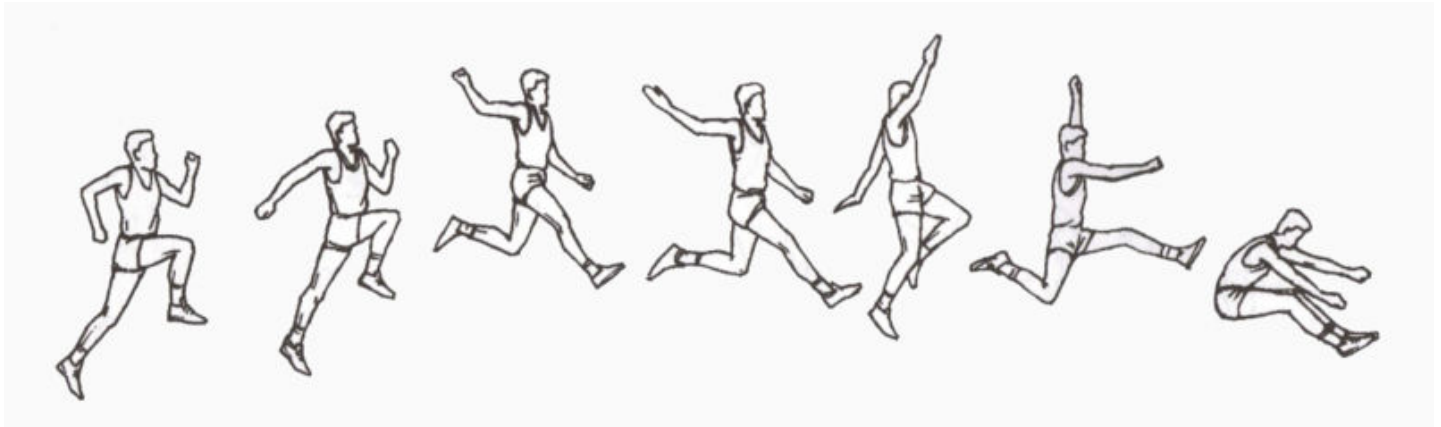
Written descriptions, 1 paragraph for the above elements will go on each page

Multimedia presentation of your findings (poster, powerpoint presentation, video, other ideas?)

Rubric:

Graphs	Possible score	Exceptional (100%)	Very good (90%)	Good (80%)	Fair (70%)	Lacking (60%)
Kinematics	10	Both graphs done on computer or extremely neat, contain all necessary elements of good graphs	Done on computer or neatly done, only 1 or 2 elements of good graphs missing	Done by hand, pretty neat, contains most elements of good graphs	Done by hand, not very neat, a few elements missing	Done by hand, messy, several elements missing
Kinematics paragraph	10	Clearly and thoroughly explains how graphs show the motion of the object. Descriptive and accurate.	Thoroughly explains how graphs relate to motion of object, mostly accurate	Relates graphs to motion, could be more clear and thorough	Relates graphs to motion, not very clear or thorough	Relationship between motion and graphs is unclear, poorly described.
Free Body Diagram	10	Superb, neat FBD of object and the forces acting on it. Length of arrows proportional to magnitude of force. All forces labeled.	Pretty neat FBD, all forces shown, lengths indicate magnitude. 1 missing element.	Could be neater, lengths do not indicate magnitude. 1-2 elements of good FBD missing.	Somewhat messy. 3-4 elements missing	Messy, several elements missing.
FBD Paragraph	10	Every force clearly described in detail. Effects of each force described.	Most forces clearly described in detail. Not all effects explained.			
Momentum analysis Paragraph	10					
Work and Energy analysis Paragraph	10					
Power analysis Paragraph	5					
Presentation	5					
Effort/quality of work	10	All elements are neat, easy to read, typed, correct spelling, well-formatted				

Example: Long Jumping



In the Olympic sport of long jumping, the competitor must run and jump as far as they can, leaving the ground before a certain line and not touching the ground for as much distance as possible. The official score is the distance from the starting line to the nearest spot they touch the ground.

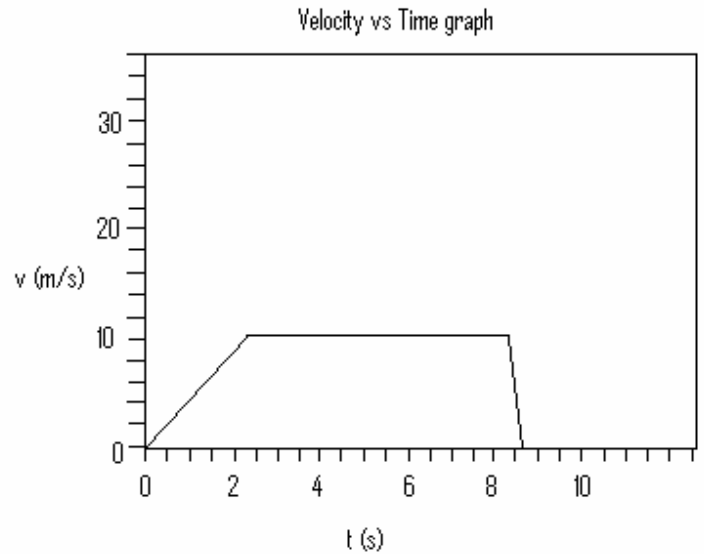
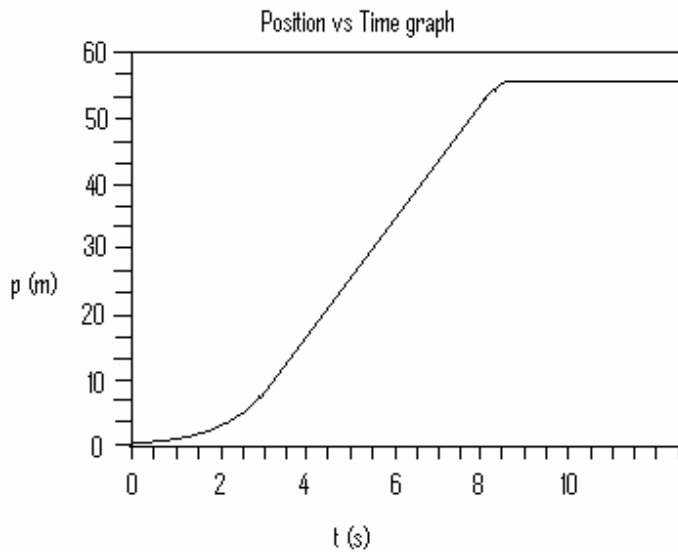
The distance they can traverse depends on many things: how close their takeoff foot gets to the line, the way they land, the wind, etc. While true competitors must consider all of these things, the basic physical equation which determines the jumper's distance is very simple: it is their forward velocity at takeoff multiplied by the time they spend in the air:

$$\text{distance} = (\text{forward velocity at takeoff}) \times (\text{hang time})$$

This is because their forward velocity does not change much during the short time (about one second) they are in the air. Only air resistance can slow them down, and this is not very important unless the wind is very strong. So because the velocity is constant, and because we only are interested in the distance they go in the air, we get our equation from the basic kinematics equation of $d = v t$.

Kinematics

Since the jumpers get a very long track on which to accelerate before jumping, the forward velocity at takeoff equals the jumper's top speed. (So it is not surprising that many of the best long jumpers are also great sprinters. The great Jackie Joyner-Kersey, for example, has won Olympic gold medals in both sports). So the jumper accelerates to top speed, stays at that velocity during the jump, and then quickly comes to a stop in the sandy landing area.

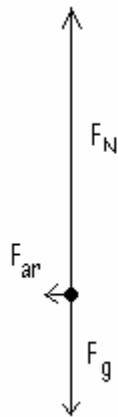


Forces

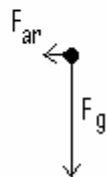
The first important force involved is friction between shoes and track, accelerating the jumper to top speed. So this force points forward.

The time the jumper spends in the air depends on how great of a downward normal force they deliver against the ground in their last steps (actually it is the upward normal force the ground delivers to them, but these two forces are equal, as we know).

Since the jumper's forward velocity is constant from before takeoff to landing, there is no significant force in that direction (except a small amount of air resistance). On takeoff the push the jumper gets from the ground is greater than the force of gravity, so the jumper accelerates upwards. After takeoff, gravity is the only force.



During Takeoff



After Takeoff

You might be wondering if the two factors (hang time and forward velocity) are really independent. The human body is very complicated, so it is not easy to say how a faster or slower takeoff speed will affect the jumper's ability to get a long hang time. But we can think of the two variables as being separate, at least in theory.

To see this, imagine standing on one of those airport "moving sidewalks" and jump straight up. If you look at the wall, you notice that you move forward while in the air, even though you come down on the same spot on the sidewalk (it moved under you while you were in the air). If Michael Jordan jumped as high as he could on the same sidewalk, with his incredible hang time, he would go much farther forward during his time in the air. Also, if we increased the speed of the sidewalk (forward velocity), anyone would go farther during their jump.

Energy and Power

The power is given by the amount of work done in the final upward push divided by the time it takes to make that push...