Read the following article entitled “Up in the Air, and Down, With a Twist”. Answer the following questions. Your answers should consist of a short paragraph or diagram as indicated. Answer the questions, concisely but completely.

1. Describe the motion of Mr. Onge once he leaves the ski jump.
2. Draw a free-body diagram of the skier when he or she is skiing down the ramp.
3. Draw a free-body diagram of the skier when he is in the air.
4. Why does the jumper’s center of mass trace out a perfect parabola?
5. In your own, words, what is angular momentum?

Once you have answered the questions, you may enjoy the following video.
http://tiryurl.com/2fm28mm
February 2, 2010

Up in the Air, and Down, With a Twist

By HENRY FOUNTAIN

PARK CITY, Utah — The first time you watch skiers hurtle off a curved ramp at 30 miles per hour, soaring six stories in the air while doing three back flips and up to five body twists, you can't help but think: These people are crazy.

Keep watching and you will quickly have second — and third — thoughts. You begin to notice how the skiers adjust their starting point on the inrun to reach the proper takeoff speed, how they practice odd arm movements, like giant Barbie dolls whose limbs are being manipulated by unseen hands.

Freestyle aerialists, as these athletes are known, are not actually throwing caution, along with themselves, to the winds. It is not fate that plops them down at the end of their jumps, more or less upright and safe, in a cloud of powdery snow. It is physics, and plenty of preparation.

Aerials, in which skiers are judged on how stylishly they perform their flips and twists and whether they stick their landings, has been an Olympic medal event since 1994 and will be featured in prime time this month at the 2010 Games in Vancouver, British Columbia.

It has roots in freestyle skiing, the devil-may-care approach to the sport that started catching on in the 1960s and '70s. But aerials has developed into a serious discipline that borrows much from gymnastics. It is two parts hot-doggery to one part Nadia Comaneci, with Isaac Newton keeping everybody honest.

"The forces are pretty simple," said Adam Johnston, a physics professor at Weber State University in Ogden, Utah, who broke away from his teaching duties one recent afternoon to watch aerialists with the United States Freestyle Ski Team train at Utah Olympic Park, which was built for the 2002 Games in Salt Lake City.

"There's the force of the ramp on his skis, and the force of gravity on him," Dr. Johnston said, after Ryan St. Onge, the reigning world champion in men's aerials and a member of the Olympic team, zipped down a steep inrun, leaned back as he entered the curved ramp until he was nearly horizontal and flew off at a 70-degree angle. "That's all there is."

But it is enough to create torque that sends Mr. St. Onge somersaulting backward as he takes to the air, arcing toward a landing on a steep downslope that the skiers and coaches have chopped and fluffed for safety.

"Once he's in the air, the only force on him is gravity," Dr. Johnston said. "You could trace his center of mass as a perfect parabola through the whole thing. From the physics point of view, that's one of the
beautiful things.”

To ensure he will have sufficient rotational, or angular, momentum to see him through three flips, Mr. St. Onge raised his arms entering the ramp, distributing his mass away from his center of rotation, which is near his hips. In physics, he increased his rotational inertia, resulting in more rotational momentum.

The same principle rules sports like figure skating, in which a skater speeds or slows a spin by moving the arms in or out. It is called the conservation of rotational momentum, and Mr. St. Onge, who is 26 and first joined the ski team 12 years ago, may not be able to recite the related formula — for the record, it is rotational momentum equals rotational inertia times rotational velocity — but he knows what is going on. He will bring his knees up, for instance, on his last flip if he needs to rotate a little more for the landing.

“We get longer if we’re too fast with a flip, or shorter if we’re too slow,” Mr. St. Onge said.

During a jump, he does this more or less intuitively because, like other team members, he has spent hours practicing without skis on trampolines and — in the warm months — skiing off ramps lined with a plastic snowlike surface into water.

But while not in the air, Mr. St. Onge devotes a lot of time to analyzing what he does. “I probably spend 80 percent of my time thinking about it, and 20 percent doing it,” he said.

His preparations extend to the ramp itself, called a kicker and made by compacting snow into a huge block and then shaping it to the curve decreed by the sport’s governing body, the International Ski Federation.

Over the season at the Olympic Park, the snow has been compacting further and the inrun has been building up, so that when the team showed up for several days of training the kicker was about six inches short of the required 13.5 feet. A small block of snow was added to bring it to the proper height.

But this had skewed the ramp’s curvature, as Mr. St. Onge, ever the perfectionist, had learned by measuring it with a digital level. “That’s always the first thing I do,” he said. “I do that more than most people, absolutely.”

Not finding the angles to his liking — parts of the curve were off by a degree or two — he spent more time carefully shaving down certain areas with a metal scraper welded to the business end of a pitchfork.

“My try very hard to jump off the same ramp week to week to week,” he said.

A proper ramp provides a good start to a jump. If a skier just holds his body still, the rotational momentum will result in a triple flip in layout, or nontwisting, position. While it looks death-defying, that kind of jump is kid stuff to a judge. So aerialists add body twists, rotating about a second axis, one that runs head to toe. In this training jump, Mr. St. Onge adds a full twist in both the second and third flips— a lay-full-full in the language of the sport.

Aerialists have several ways to produce twisting motions, said Fred Yeadon, a professor at Loughborough University in England who studies biomechanics in sport and who made some of the first studies of aerialists at the 1988 Winter Olympics in Calgary, where freestyle skiing was a demonstration sport.
The simplest is called contact twisting — jumping and turning on takeoff. Another is through counterrotation, called hula twisting because the skier circles the hips as if using a hula hoop. “It’s what cats do to land upright when they fall,” Dr. Yeadon said. “Humans can do this as well. They get half a twist with every wiggle they do.”

But to really twist, skiers have to use the tilt method, which transfers some of the somersaulting rotational momentum to the head-to-toe spin axis. They move their arms up or down and forward or back, which tilts the body to one side. The more tilt, the faster the spin, as more momentum is transferred.

A skier will usually use all three twisting methods, in combination or separately at various times in the jump. Mr. St. Onge, for example, will sometimes do half a hula near the end of his jump to slow his twist down for landing. And when doing a double-full-full-full, which requires four full twists, including two in the first flip, he will use all three methods at takeoff.

“You start your motions and make them as small and efficient and strong as possible,” he said, “so you can do the maximum amount of work with the least amount of movement.”

So much twisting can make it harder to keep an eye on the landing area, which skiers try to do to judge their rotation and land without falling back or, worse, pitching forward.

“It’s all about picking that one spot,” Mr. St. Onge said, “and making sure that’s exactly where you’re going to land.”

Perfect landings are rare, but so are severe crashes.

“We can crash every jump of the day and not feel sore,” he said.

By contrast, Mr. St. Onge said, in “conventional” ski jumping, the Nordic kind, a skier can crash once and feel it for the rest of the year. The reason is speed. He has never been interested in trying that kind of jumping, in which skiers may reach 60 miles per hour.

“It terrifies me,” he said. “Flying through the air at 100 kilometers per hour just seems silly.”