Day 5

Physics of Sports

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http://pages.jh.edu/~maliyou1/Physics_of_Sports/

Image https://www.disneyclips.com/imagesnewb/skating.html

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Plan for Today

- Part 1: Energy in Sports (cont. from Day 4)
  - Physics of Basketball (Chapter 7)
  - Physics of Ping-pong
- Part 2: Physics and Engineering of Sporting Equipment (Selection from Chapter 8)

Efficiency

- Also note that, Physicists and sports equipment manufacturers use the coefficient of restitution (COR) e to classify collisions. It is simply the ratio of the separation speed to the approach speed:

The efficiency of a basketball bounce

Lisa, Michael. *The Physics of Sports*. McGraw-Hill Higher Education, 20150220. VitalBook file.

Work and Energy

- https://www.youtube.com/watch?v=pmOXi-My6ZI (Software??)

A candy bar has enough energy to …

- PowerBar has 240 Cal of food energy
- But 1 Cal = 4184 J
- Hence this is about 10^6 Joules
- Q: How much weight can this energy lift 2m off the ground?
- Sol: PE = $mgh = wh$
- => w = PE/h = $10^6/2 = 5\text{x}10^5$ N = 112,000 lb = 56 tons !
  Q: And what about speed?
- Sol: Use KE = $\frac{1}{2} mv^2$ to get v= 8170 mph

Overall Efficiency

$$\eta_{\text{glucose}\rightarrow\text{mechanical energy}} = \underbrace{\eta_{\text{glucose}\rightarrow\text{ATP}}}_{\lesssim 50\%} \times \underbrace{\eta_{\text{ATP}\rightarrow\text{mechanical energy}}}_{\lesssim 50\%} \lesssim 25\%$$

ATP = adenosine triphosphate = fuel used by muscle cells

Keeping Score: Energy Accounting in Sports

$$\text{total energy} = \underbrace{\mathrm{KE} + \mathrm{PE}_{\text{grav}} + \mathrm{PE}_{\text{elast}}}_{\text{also known as mechanical energy}} + E_{\text{chem}} + E_{\text{therm}}$$

So why then we can’t really get the weight or speed calculated earlier, even with 25% efficiency?

- While we can eat and store sufficient energy to do such tings, we neither have the strength nor the power to use that energy.
- The crucial concepts here, and in much of sports, are **work** and **power**.
- Work quantifies the transfer of energy when an athlete exerts a force. If the force is constant:

Lisa, Michael. The Physics of Sports. McGraw-Hill Higher Education, 20150220. VitalBook file.

Work-Energy Theorem

Lisa, Michael. The Physics of Sports. McGraw-Hill Higher Education, 20150220. VitalBook file.

Let find the force needed to convert that much energy to useful work

- Energy of PowerBar = 10^6 Joules
- F = Work / distance
- = 10^6 * 0.25 Joules / 1 m (Note 25% efficiency)
- = 250,000 N
- = 56,200 lb !!

Finally, lets deal with “Power”

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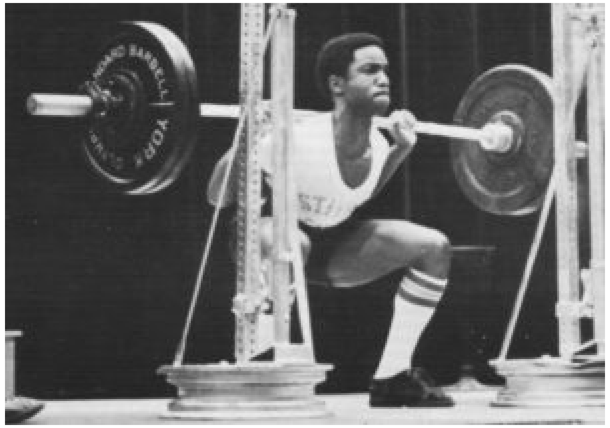
Let’s check the Power required now:

- <u>**This is something you have to do**</u>:
- Knowing the force, you can find acceleration, provided you know the mass of the ball.
- Chose any ball you want and use its mass.
- Find a using Newton’s law
- Find time (delta t, to be exact) using kinematic equations
- Find Power output using the power equation

Conclusion:

- We consume a lot of energy. We store it; we convert it into heat; we convert it into useful work.
- The point is, however, that the human engine can convert that energy only so quickly.
- Just as a truck engine can’t burn through its entire tank of fuel in an instant, neither can we process a PowerBar in a very short time.

Class work 1



https://www.hudsonvalleyscoliosis.com/lamar-gant-scoliosis/

- In 1985, legendary American power lifter Lamar Grant became the first man to deadlift five times his body weight. All muscle at 132 lb, Grant lifted 661 lb about 2.5 ft off the ground! In the dead lift, a barbell is lifted off the ground to about thigh level, the back is straightened, and then the weight is lowered.
- (a) How much work did Grant do on the bar while lifting it?
- (b) In horsepower (h.p.), what was the power of the lift?

Problem 3, Chapter 7 of Lisa, Michael. The Physics of Sports. McGraw-Hill Higher Education, 20150220. VitalBook file.

Class work 1

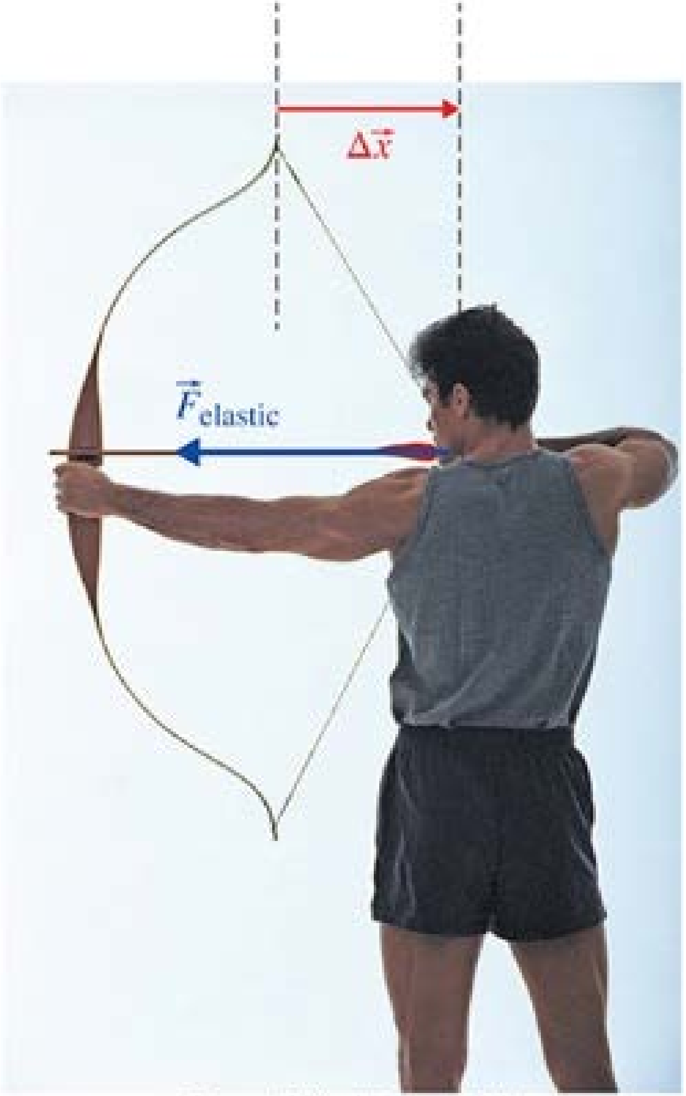
http://www.timeoutdubai.com/knowledge/news/61932-watch-reebok-do-dubai-skydive-to-promote-new-shoes

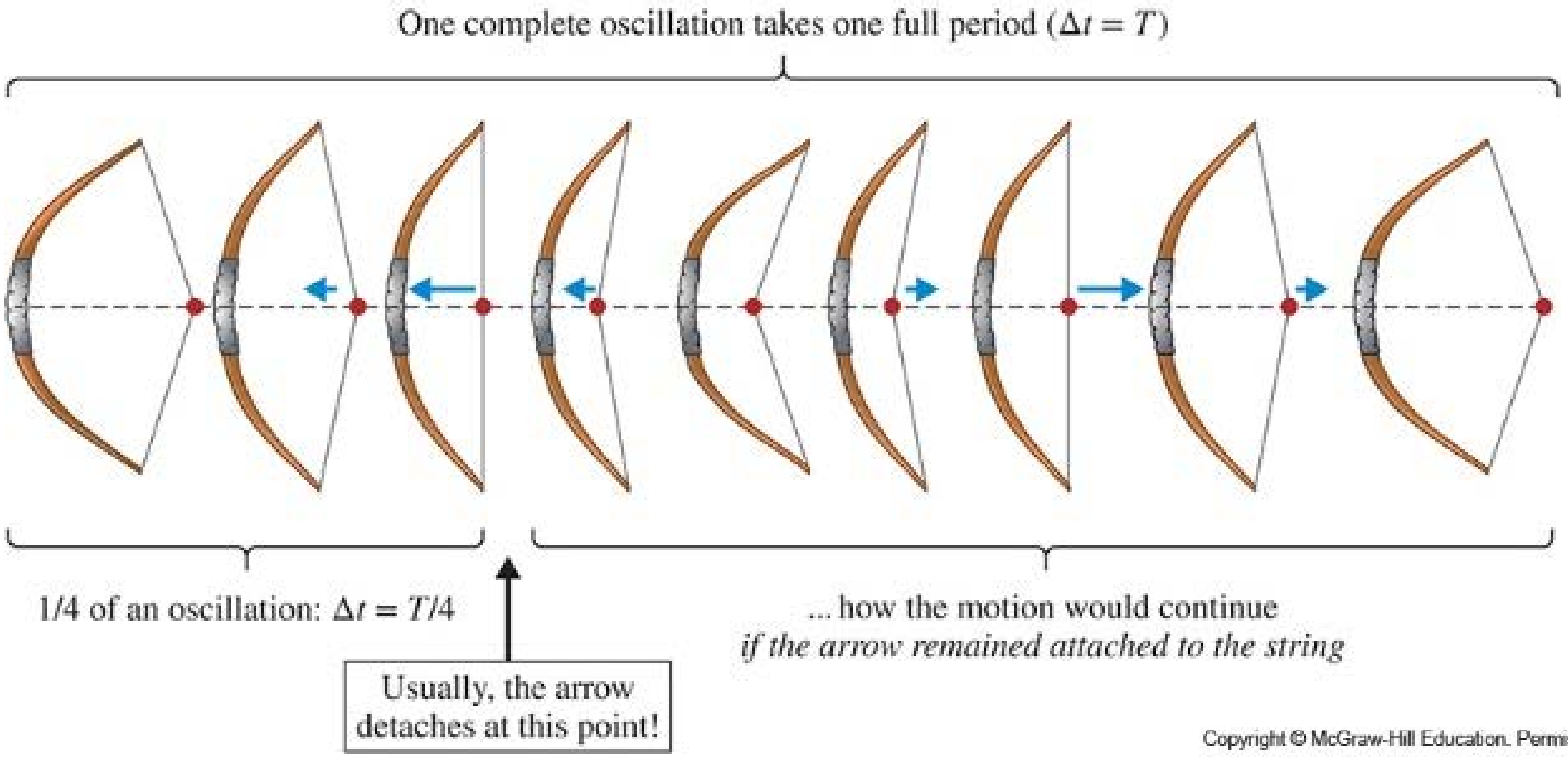
- A 100-kg skydiver falls with terminal velocity of 50 m/s .
- (a) Is air drag doing positive or negative work on the diver?
- (b) How much power is generated by air drag? That is, at what rate is work being done?
- (c) How much work is done by the air drag when the skydiver falls 1 km at terminal velocity?
- (d) For how long would this much energy provide power to a typical household? (The typical household consumes about 1 kW of electrical power.)

Problem 6, Chapter 7 of Lisa, Michael. The Physics of Sports. McGraw-Hill Higher Education, 20150220. VitalBook file.

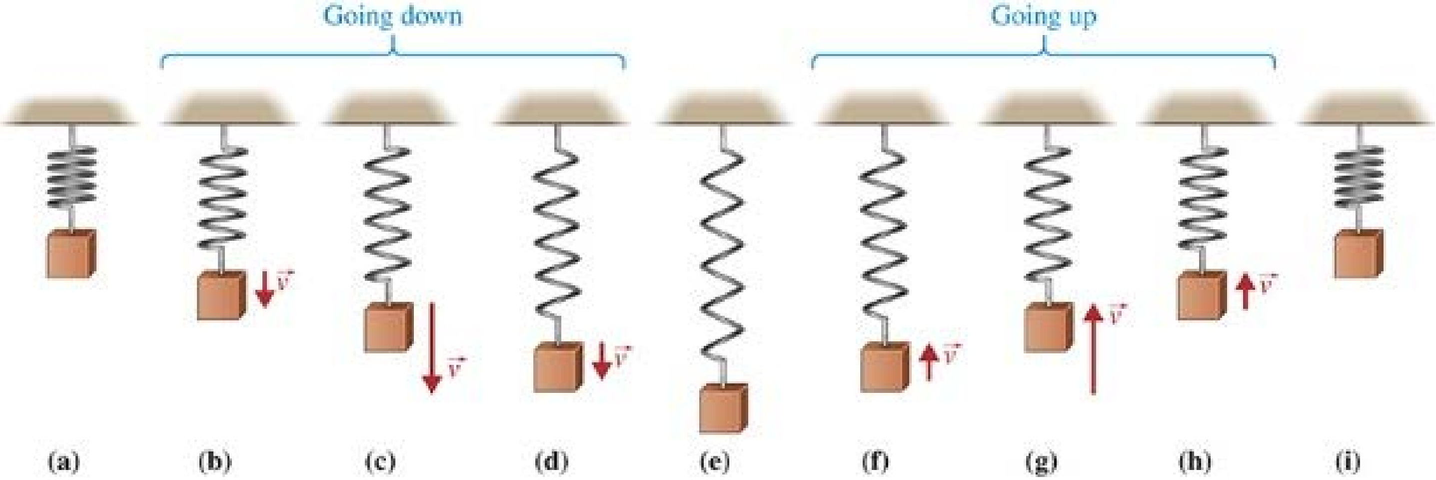
Physics and Engineering of Sporting Equipment

Elasticity

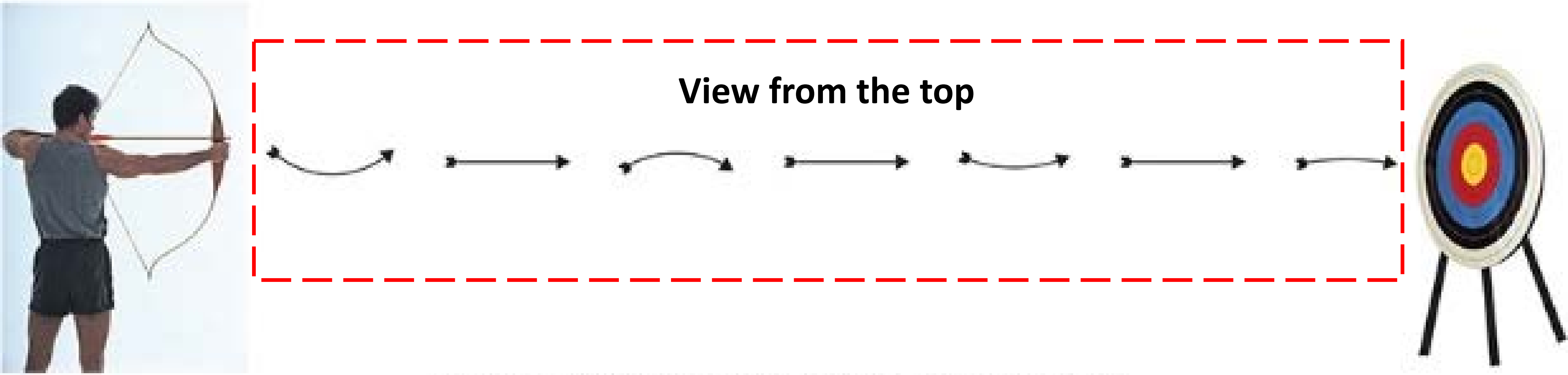




One complete oscillation takes one full period ($\Delta t = T$)
1/4 of an oscillation: $\Delta t = T/4$
... how the motion would continue
if the arrow remained attached to the string
Usually, the arrow detaches at this point!



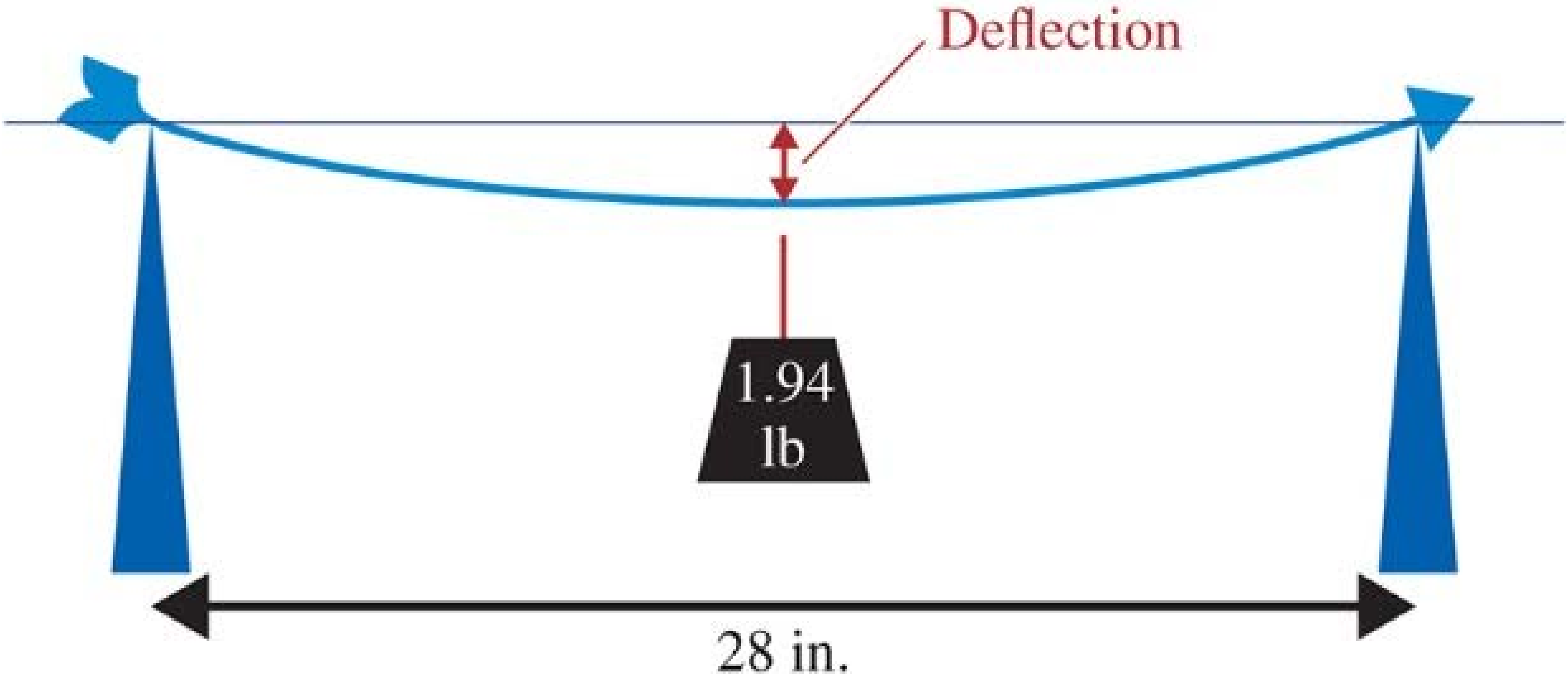
Going down
Going up
$\vec{v}$
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)

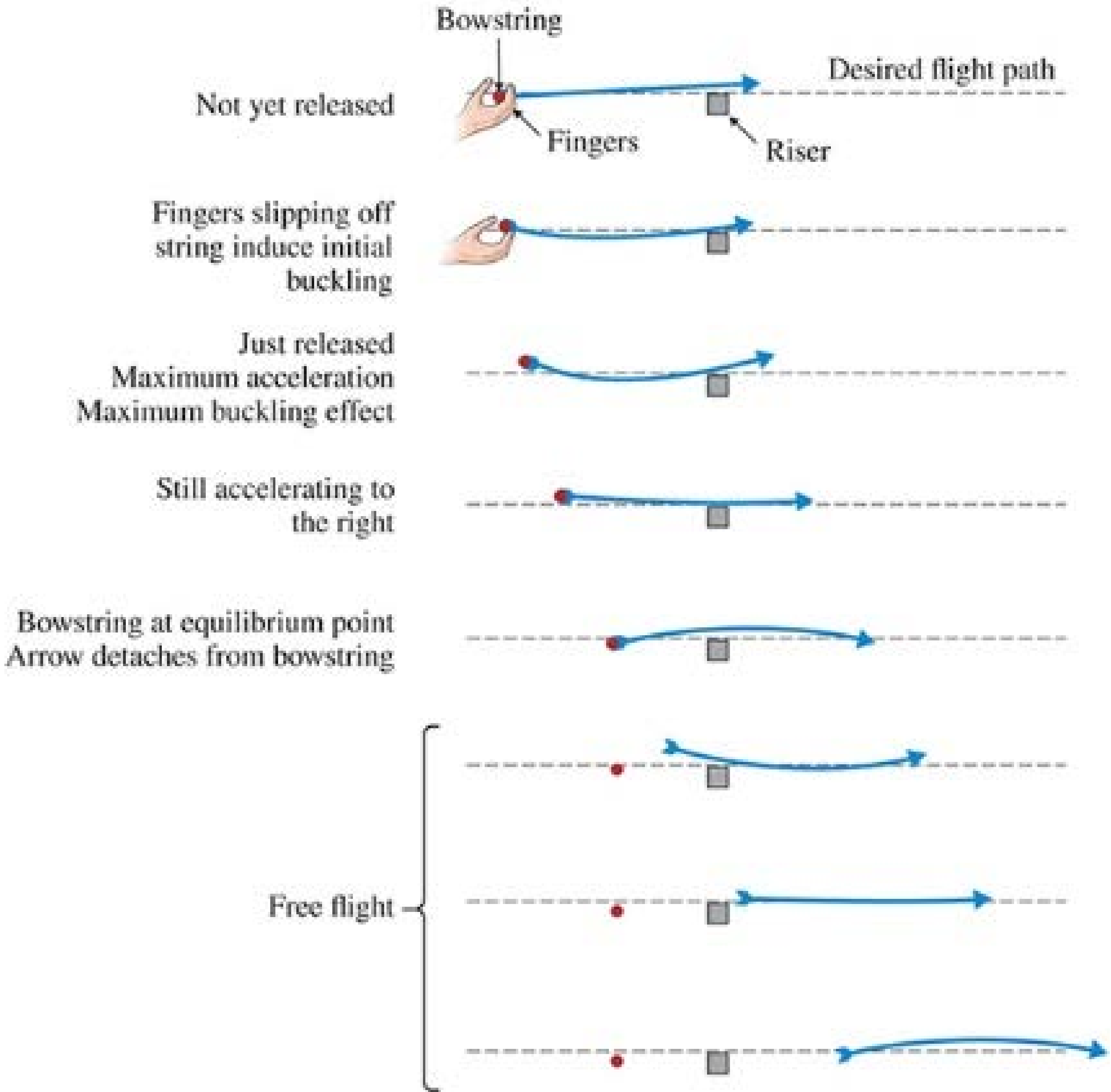


Left: © Comstock/JupiterImages RF; Right: © Comstock/Alamy RF.

If an arrow is deformed and free of other forces, it will oscillate between being bent in one direction and being bent in the other. As time passes, internal friction forces and stabilization by the fletching at the tail damp the amplitude of the oscillations. (© Comstock/JupiterImages RF); Right: (© Comstock/Alamy RF).

- Watch: Physics of Archery, https://www.youtube.com/watch?v=6_Gj1xPm0Hk




Bowstring
Desired flight path
Not yet released
Fingers
Riser
Fingers slipping off string induce initial buckling
Just released
Maximum acceleration
Maximum buckling effect
Still accelerating to the right
Bowstring at equilibrium point
Arrow detaches from bowstring
Free flight