Reminders

- **New deadline on “Holding a board” problem: 6pm today.**

- **Watch out for the final sprint!**
- **RQ#9 due tomorrow 10am**
- **RQ#10,11 due Monday 07/16 10am**
- **RQ#12,13 due Tuesday 07/17 10am**

- **HW#6 due *Tuesday* 7/10, 11:59pm.**
- **HW#7 due Sunday 7/15, 11:59pm**
- **HW#8 due Mon 7/16, 11:59pm**
- **HW#9 due Tue 7/17, 11:59pm**

- **Lab sessions this week: Torques!!:**

- **EXAM 3: Next Thursday (07/12).**

  Topics:
  - Torques and equilibrium (Chapters 9, secs 1-3 and **related Lab material**),
  - Uniform Circular motion (chapter 5)
  - Work and Energy (chapter 6)

Chapter 6 - Energy, Work

- New way of looking at problems
- *Conservation* laws
- Need to learn to think in terms of energy and work
- *Work, Kinetic Energy, Potential Energy*, Conservative and non-conservative forces

Work

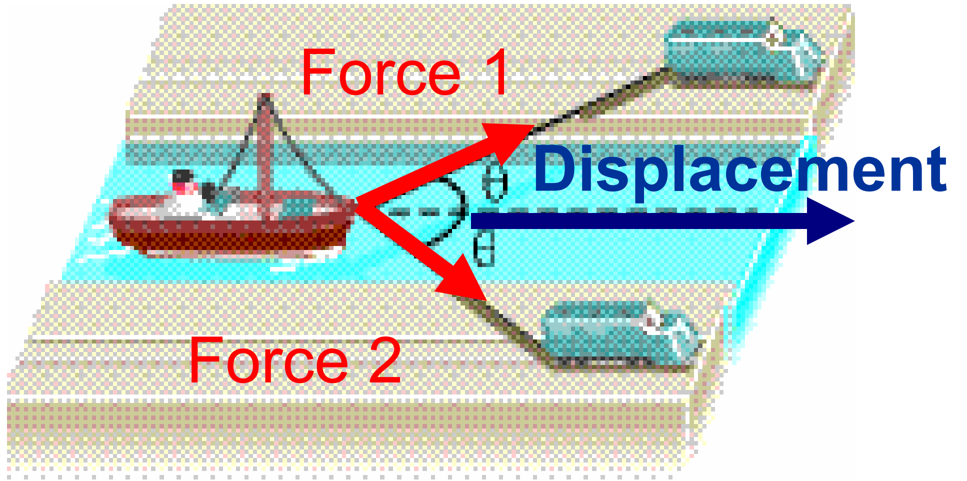
- Work done by a force or group of forces (identify!)

Work = (mag of force) (mag of displacement) (cos θ)

θ → angle between *Force* and *displacement* (vectors!)

$$W = F\, d \cos\theta$$

- Signs: θ angle between force and displacement
  - **same direction (+)**
  - **opposite direction (-)**
  - **perpendicular (0)**

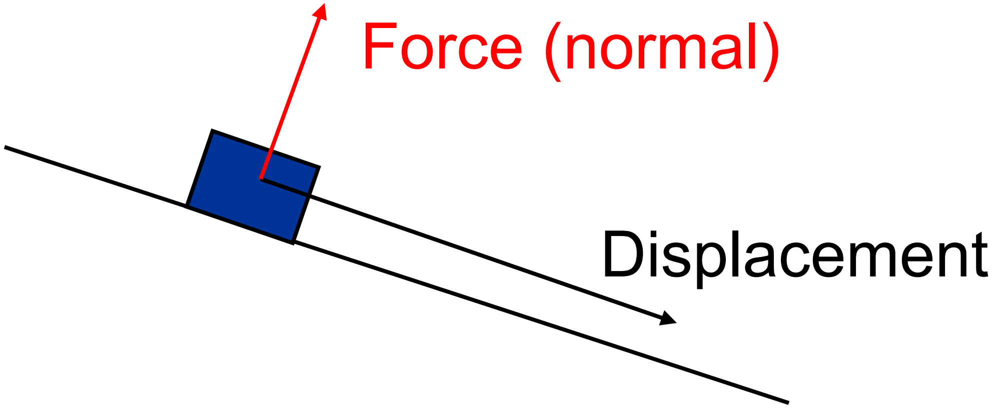


- Unit: *Joule* (J). 1 J = 1 N.

A crate (weight=40N) is sliding down a ramp 10m long. The normal force on the crate is 30N. What is the work done by the *normal* force as it slides the length of the ramp?

(1) -264J (2) -100J (3) 0J (4) 100J

(5) 264J (6) 400J (7) 700J



Force is perpendicular – cos(90) = 0

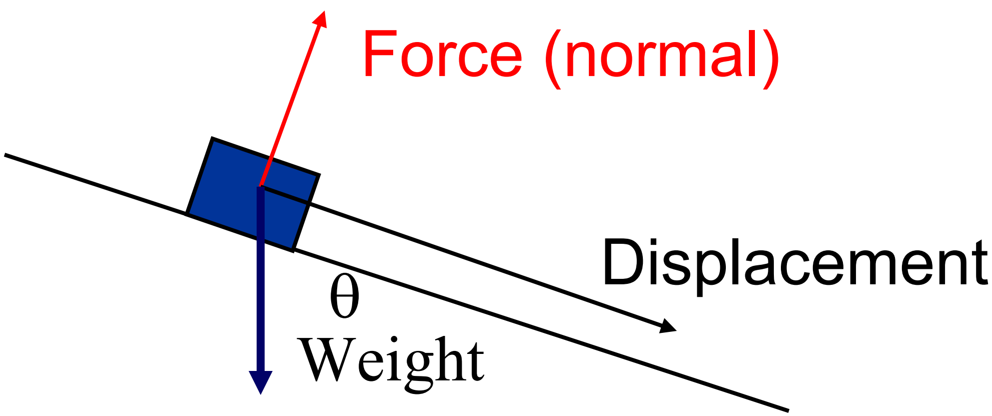
W = (mag of force) (mag of displacement) (cos θ)

$\theta = 90^{o}$ therefore W = 0

A crate (weight=40N) is sliding down a ramp 10m long. The normal force on the crate is 30N. What is the work done by gravity as it slides the length of the ramp?

(1) -264J (2) -100J (3) 0J (4) 100J

(5) 264J (6) 400J (7) 700J



- Are the force and the displacement in the same direction?
  - No!
- What is the angle between them?
- Normal force = component of the weight perpendicular to the surface!

$$F_N = W \sin\theta$$

W = (mag of force) (mag of displacement) (cos θ)

= 40N · 10m · cos (41.4°) = 264N

- Solve for θ and calculate work.

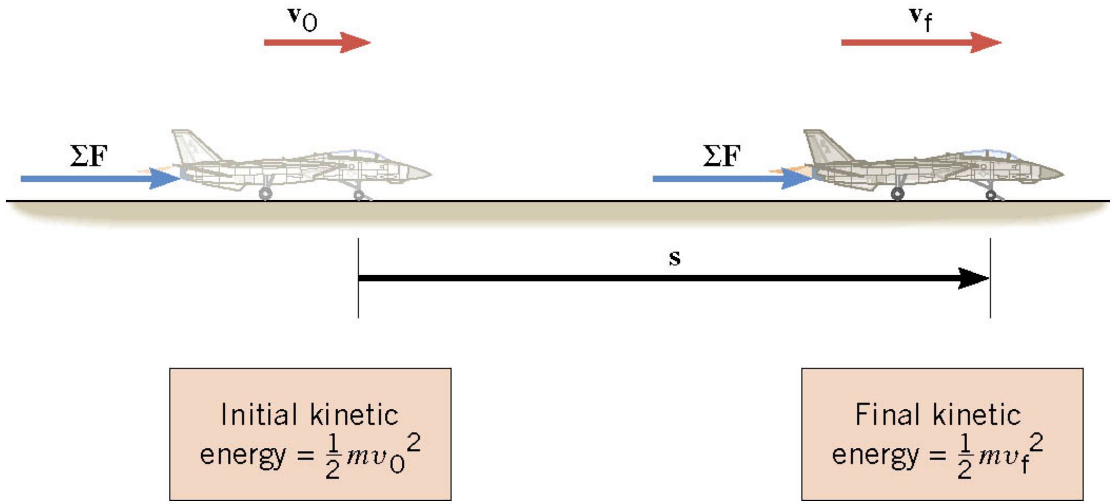
Work-Kinetic Energy Theorem

- *Definition* of Kinetic energy (object mass *m*, velocity *v*):
  - **$KE = \frac{1}{2} m v^2$**
- Work done by $F_{NET,EXTERNAL}$: $(\Sigma F)\, s = (ma)\, s$
- Using const acceleration eqn's (see text)

$$(\Sigma F)s = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_0^2$$

$$W_{NET} = KE_{FINAL} - KE_{INITIAL}$$

(Work-Energy theorem)



A crate is moving horizontally across a floor to the right with a kinetic energy of 100J. You do +300J of work on the crate as it moves 5m. The magnitude of the work done by the frictional force which is opposing you is 150J. The weight of the crate is 50N. What is the kinetic energy of the crate after moving 5m?

(1) 50J	(2) 100J	(3) 200J	(4) 250J	(5) 300J
(6) 350J	(7) 400J	(8) 450J	(9) 500J	(0) 2100J

Apply Work-Kinetic energy theorem: $W_{NET} = \Delta E_k$

$W_{NET} = 300J - 150J = +150J$

$KE_{FINAL} = KE_{INITIAL} + W_{NET} = 100J + 150J = 250\ J$

Work done by gravity – Gravitational potential energy

- signs?
- Lower an object 2m. W_g =?
- Drop 0.2kg object. Ignore air resistance. Speed after drops 2m?

  6.3 m/s

- Lower and raise back to same spot: $W_g = 0$
  - **"Conservative force" – can treat in terms of stored energy**
- Work: $W_g = mg(h_0 - h_f)$
- Potential Energy for gravity: $PE = mgh$ --> $W_g = -\Delta PE$
- *Must* choose reference level !!!!
  - **arbitrary choice**
  - **be consistent once select**

Book A is raised from the floor to a point 2.0m above the floor. An identical book (B) is raised from a point 2.0m below the ceiling to the ceiling. Which book undergoes the greatest increase in gravitational potential energy?

1. Book A
2. Book B
3. Same for both books

Change in gravitational potential energy depends on change in height.

Conservative and Non-Conservative Forces

p157:

- Version 1: A force is conservative when the work it does on a moving object is independent of the path between the object's initial and final positions.
- Version 2: A force is conservative when it does no net work on an object moving around a closed path, starting and finishing at the same point.

- Conservative: gravity, springs, electrical force
  - **Potential energy (formula depends on Force)**
- Non-conservative: Friction, air resistance, tension, normal force, engines, etc…

Non-conservative Forces and Energy

$W_{NET} = \Delta KE$

$KE_F = KE_0 + W_{NET}$

$(W_{NC} + W_C) = \Delta KE$

Conservative forces – can treat as Potential Energy

$W_{NC} = \Delta KE + \Delta PE$

Total Mech Energy: $E = KE + PE$

$W_{NC} = \Delta E$

$E_F = E_0 + W_{NC}$

$(KE_F + PE_F) = (KE_0 + PE_0) + W_{NC}$

Conservation: If $W_{NC} = 0$, $E_F = E_0$ AND

$KE_F + PE_F = KE_0 + PE_0$

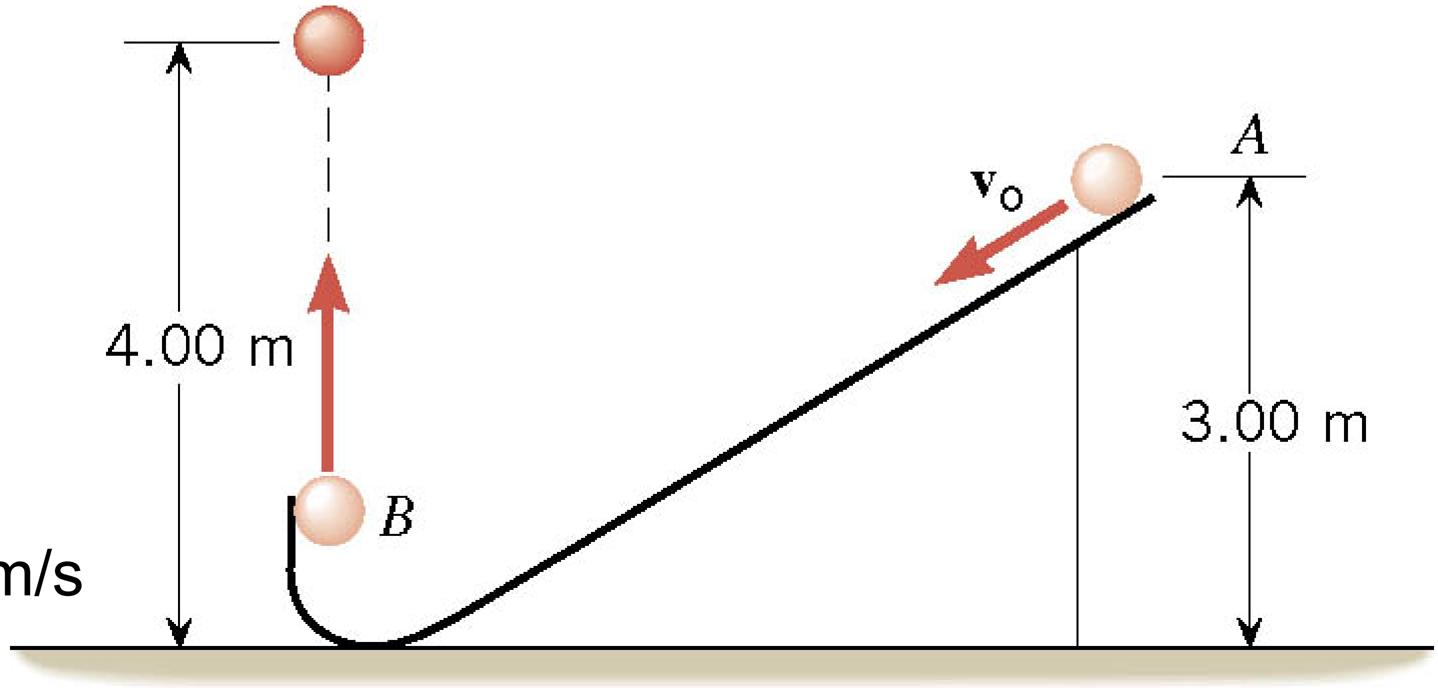
Solving Problems

- Energies? v? h? No time? (clues)
- Set up table of KE, PE, E at different times
  - ***Choose* reference level for PE**
- Any W_{NC}?
- $W_{NC} = \Delta E$ *or*

$$(KE_F + PE_F) = (KE_0 + PE_0) + W_{NC}$$

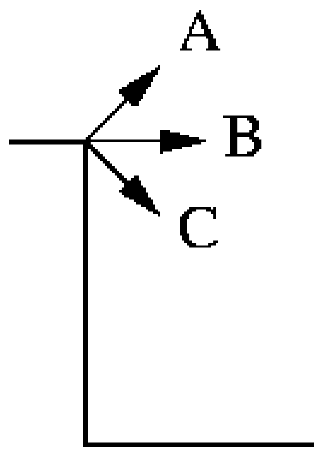
Problem 6.38 - Cutnell

A particle, starting from point A in the drawing, is projected down the curved runway. Upon leaving the runway at point B, the particle is traveling straight upward and reaches a height of 4.00m above the floor before falling back down. Ignore friction and air resistance. Find the speed of the particle at point A.



Vo=4.4 m/s

3 balls of the same mass are thrown from a cliff, all with a speed of 25m/s. A is thrown upward at an angle of 45°. B is thrown horizontally. C is thrown downward at an angle of 45°. Which one is traveling fastest when it hits the ground?



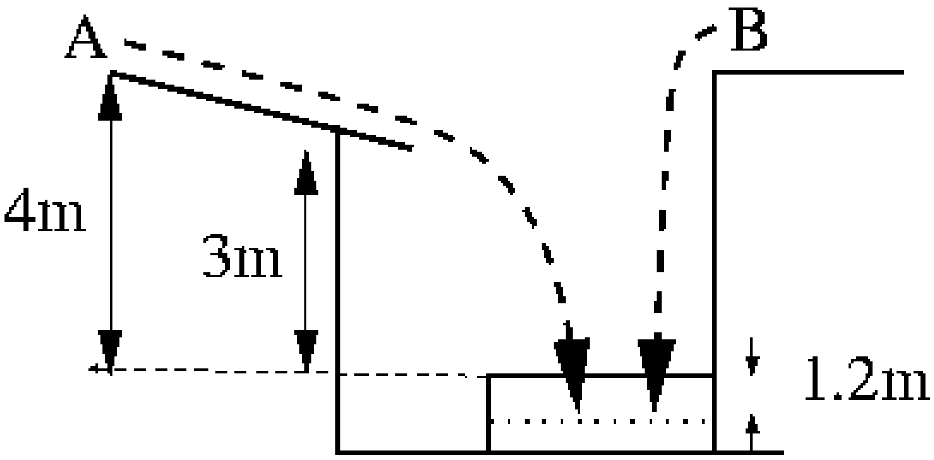
1. A
2. B
3. C
4. All three are traveling the same speed

Same initial KE, same change in PE, same increase in KE.

Work and Energy – Basic Concepts

- Work : $W_{NET} = F_{NET}\, d \cos\theta$
- θ: angle between Force and displacement
- Kinetic Energy: $KE = 1/2\, m\, v^2$
- Work-KE theorem: $W_{NET} = \Delta KE = KE_f - KE_i$
- Work done by Gravitational force: $W_g = mg(h_0 - h_f)$
- Gravitational Potential energy: $PE = mgh$, $W_g = -\Delta PE$
- Total Mechanic Energy: $E = KE + PE$
- Conservative (C) and Nonconservative (NC) forces:
- $W_{NET} = W_{NC} + W_C$ and $W_{NC} = \Delta E$
- If $W_{NC} = 0$, $E_F = E_0$ AND $KE_F + PE_F = KE_0 + PE_0$

At the same time that Stuntman A slides down the roof, Stuntman B steps off a roof (starting at the same height) on the other side of the street. Assume a 'no-friction' roof and negligible air resistance. Which Stuntman is traveling faster when they make contact with the pad?



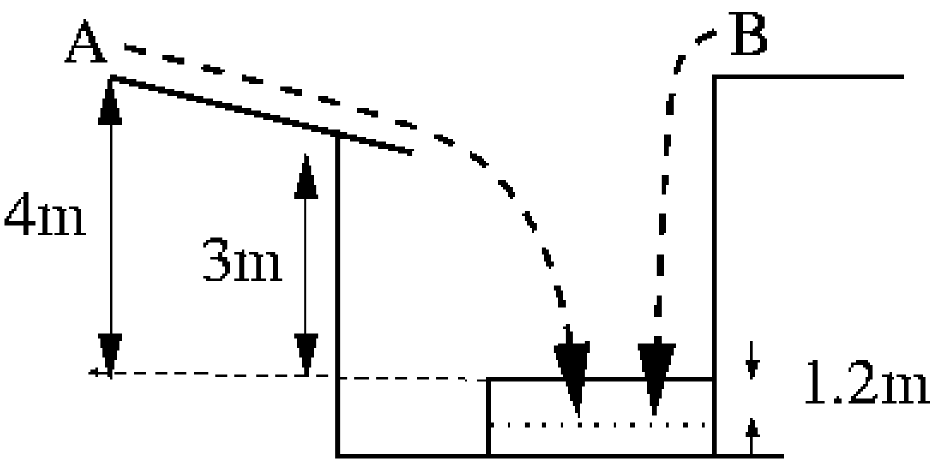
(1) A

(2) B

(3) both have the same speed

Start at same height and initial speed, end at same height, same energy lost due to pad, no friction

At the same time that Stuntman A slides down the roof, Stuntman B steps off a roof (starting at the same height) on the other side of the street. Which Stuntman makes contact with the pad first?



(1) A

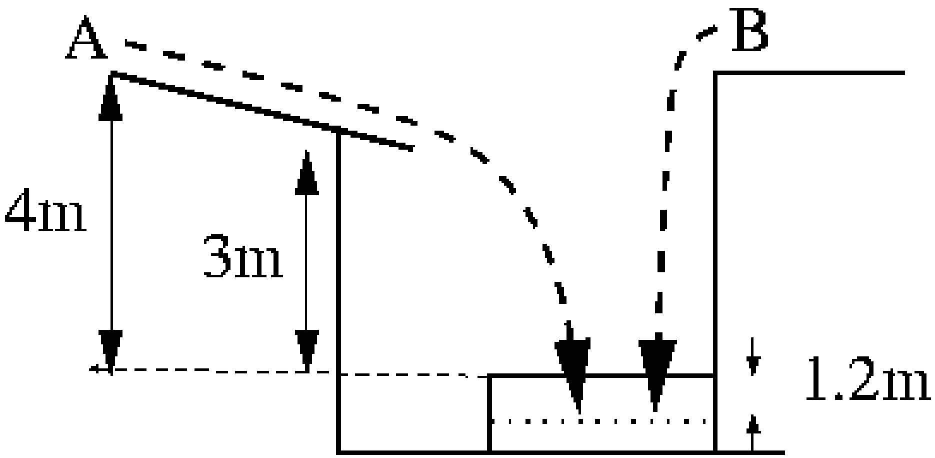
(2) B

(3) both make contact at the same time

Vertical component of the velocity is larger for stuntman B.

Larger horizontal displacement for stuntman A.

Suppose the roof on which A is sliding is NOT frictionless. Which Stuntman is traveling faster when they make contact with the pad?



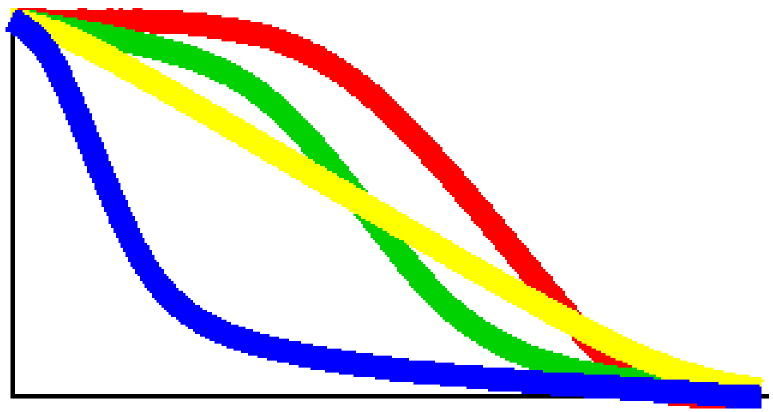
(1) A

(2) B

(3) both have the same speed

Work due to friction reduces total mechanical energy of A.

Four identical balls roll off four tracks. The tracks are of the same height but different shapes, as shown. For which track is the ball moving the fastest when it leaves the track?



(1) Yellow

(2) Red

(3) Green

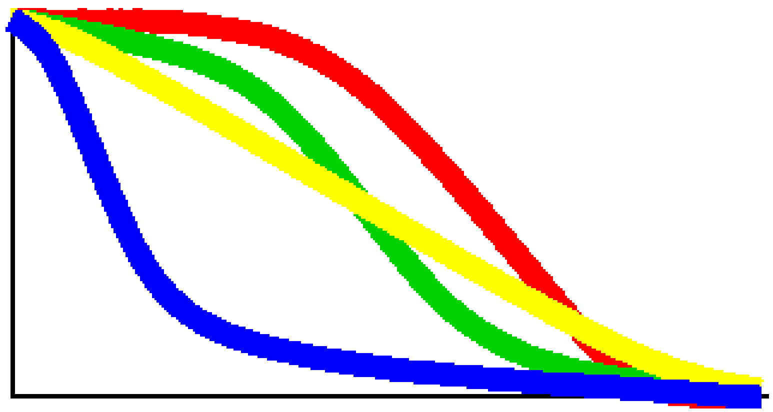
(4) Blue

(5) All the same

Start at same height (same PEi), end at same height (same PEf)

Start with same KE=0. $KEi+PEi=KE_f+PE_f$ therefore same KE_f

Four identical balls roll off four tracks. The tracks are of the same height but different shapes, as shown. For which track does the ball reaches the largest horizontal distance after leaving the track?



(1) Yellow

(2) Red

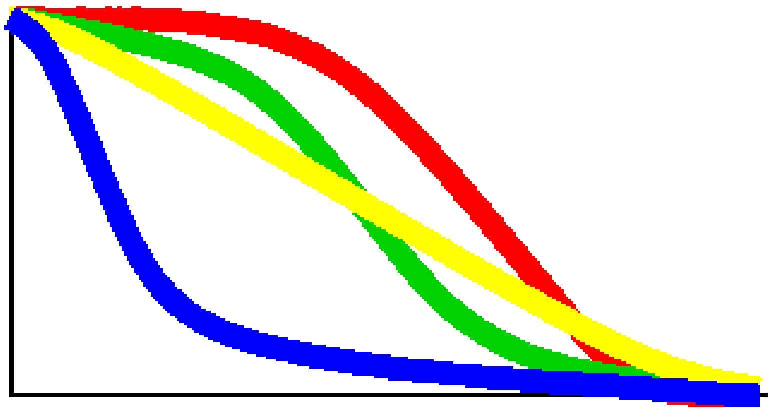
(3) Green

(4) Blue

(5) All the same

Same velocity when leave ramp, same horizontal displacement.

Four identical balls roll off four tracks. The tracks are of the same height but different shapes, as shown. For which track does the trip from start to finish take the least time?



(1) Yellow

(2) Red

(3) Green

(4) Blue

(5) All the same

Greatest acceleration early on

Bowling Ball Pendulum

- Maximum height it reaches on its way back?
  - **About the same**
- Which forces are acting on the ball?
  - **Gravity, tension of the cable**
- $W_{TENSION} = ?$
  - **Zero**
- Any *total* energy lost? Gained?
  - **For short times, energy is almost constant.**
  - **There's some friction. It will come to a rest sometime.**

Power

- Average Power = Work/time
  - **Units: Joule per second (J/s) – watt (W)**
- $\text{Work}_{NET} = \Delta\text{Energy}$

- IF ***F*** constant and same direction as ***d,***

  Average Power = (Force) * (average velocity)

A winch is lifting a 350-kg crate. Starting from rest, it takes 4.0s to lift the crate 1.5m and reach a speed of 0.75m/s. The crate then continues upward at this constant speed.

(a) What is the average power of the winch during the first period?

$$W_{NET}=\Delta KE$$

$$W_{NET}=W_{Gravity}+W_{winch}$$

$$\text{Avg Power}=W_{winch}/t$$

Avg Power = 1311 W

(b) What is the average power of the winch during the period of constant velocity?

Avg Power = Force · velocity

Const, velocity ($F_{NET}=0$) $F_{winch}=mg$

Avg Power = 2573 W

Chapter 6

$W = F\,s\cos\theta$

$W_{NET} = \Delta KE$

$W_{NC} = \Delta E$

$E_F = E_0 + W_{NC}$

$(KE_F + PE_F) = (KE_0 + PE_0) + W_{NC}$

$PE = mgh$

$KE = (1/2)\,mv^2$

$$F_{\text{FRICTION}} = \mu F_N$$

$$\overline{P} = \frac{\text{Work}}{\text{Time}}$$

$$\overline{P} = \frac{\text{Change in Energy}}{\text{Time}}$$

$$\overline{P} = F\overline{v}$$