PHYSICS 231
Lecture 12:work, energy and power

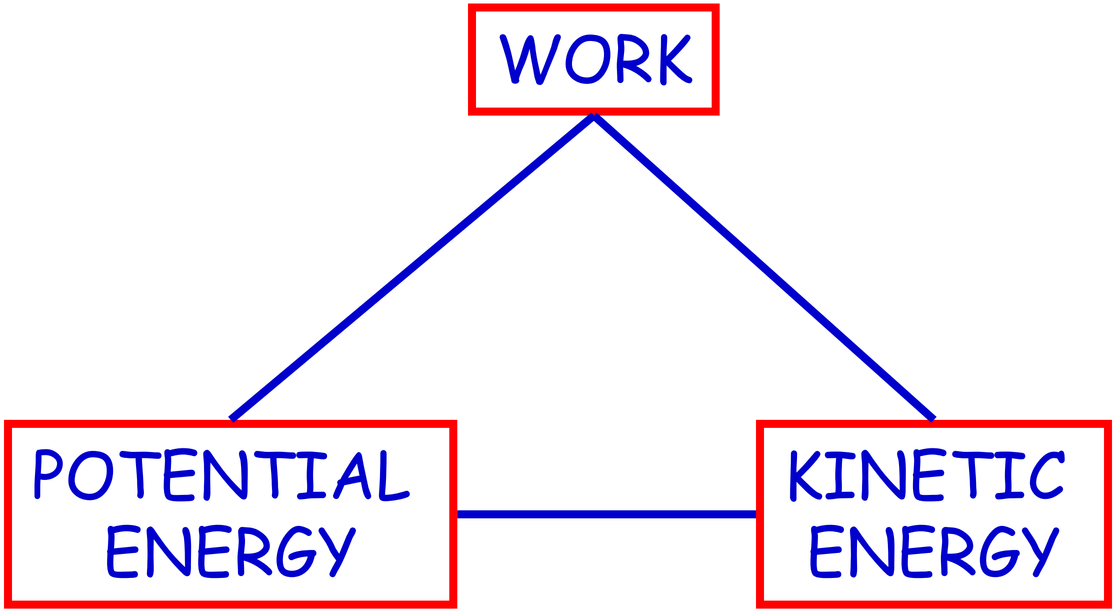
Previously

- Work: $W=F\cos(\theta)\Delta x$ — Energy transfer
- Power: $P=W/\Delta t$ — Rate of energy transfer
- Potential energy (PE) — Energy associated with position.
- Gravitational PE: mgh — Energy associated with position in grav. field.
- Kinetic energy KE: $\frac{1}{2}mv^2$ — Energy associated with motion

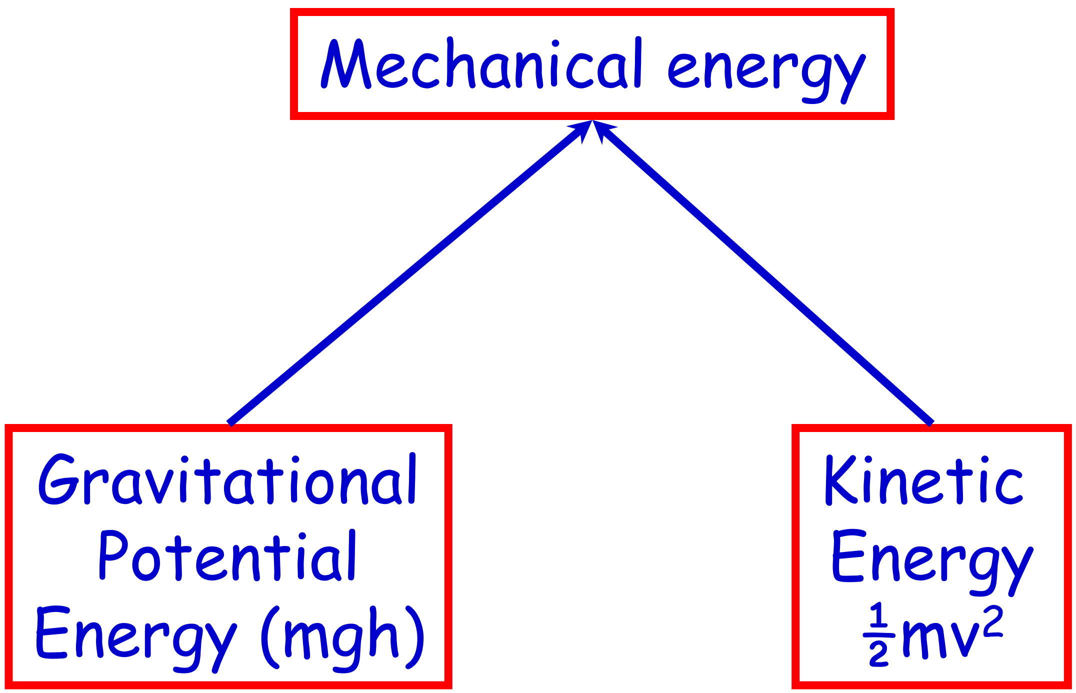
NEXT:

- Conservative force: — Work done does not depend on path
- Non-conservative force: — Work done does depend on path
- Mechanical energy ME: — $ME=KE+PE$
  - Conserved if only conservative forces are present
    $KE_i+PE_i=KE_f+PE_f$
  - Not conserved in the presence of non-conservative forces
    $(KE_i+PE_i)-(KE_f+PE_f)=W_{nc}$

Work and energy



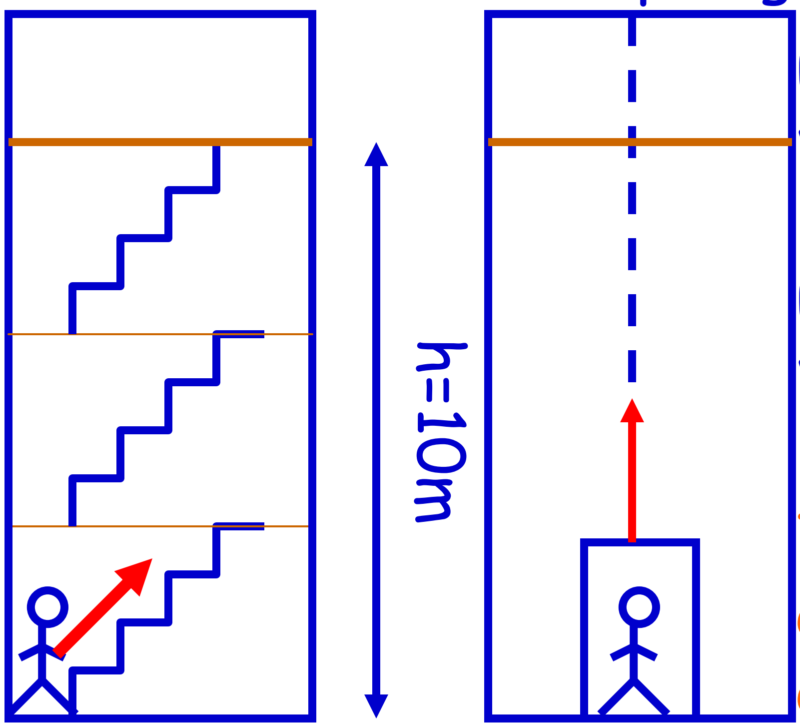
Mechanical Energy



Conservative forces

A force is conservative if the work done by the force when Moving an object from A to B does not depend on the path taken from A to B.

Example: gravitational force



Using the stairs:

$W_g=mgh_f-mgh_i=mg(h_f-h_i)$

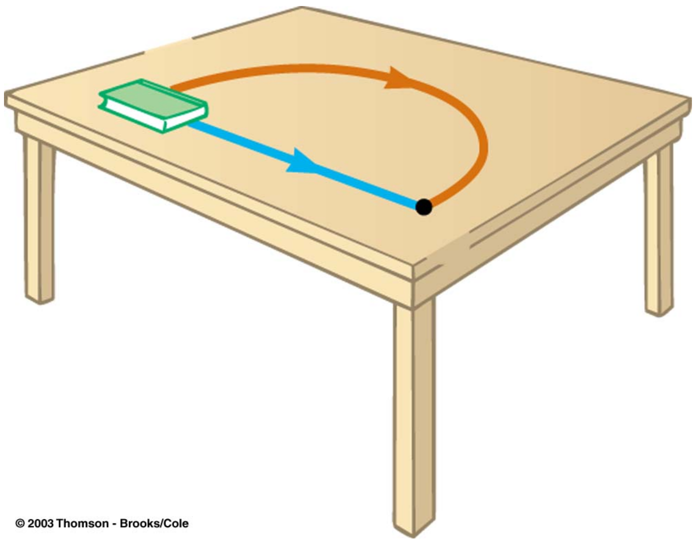
Using the elevator:

$W_g=mgh_f-mgh_i=mg(h_f-h_i)$

The path taken (longer or shorter) does not matter: only the displacement does!

Non conservative forces

A force is non-conservative if the work done by the force when moving an object from A to B depends on the path taken from A to B.



Example: Friction
You have to perform more work Against friction if you take the long path, compared to the short path. The friction force changes kinetic energy into heat.

Heat, chemical energy (e.g battery or fuel in an engine) Are sources or sinks of internal energy.

Conservation of mechanical energy only holds if the system is closed **AND all forces are conservative**

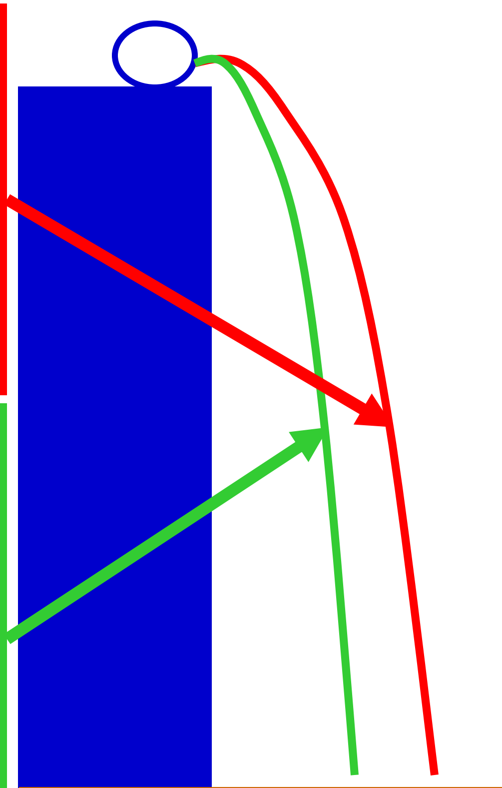
$ME_f - ME_i = (PE+KE)_f - (PE+KE)_i = 0$ if all forces are conservative

Example: throwing a snowball from a building neglecting air resistance

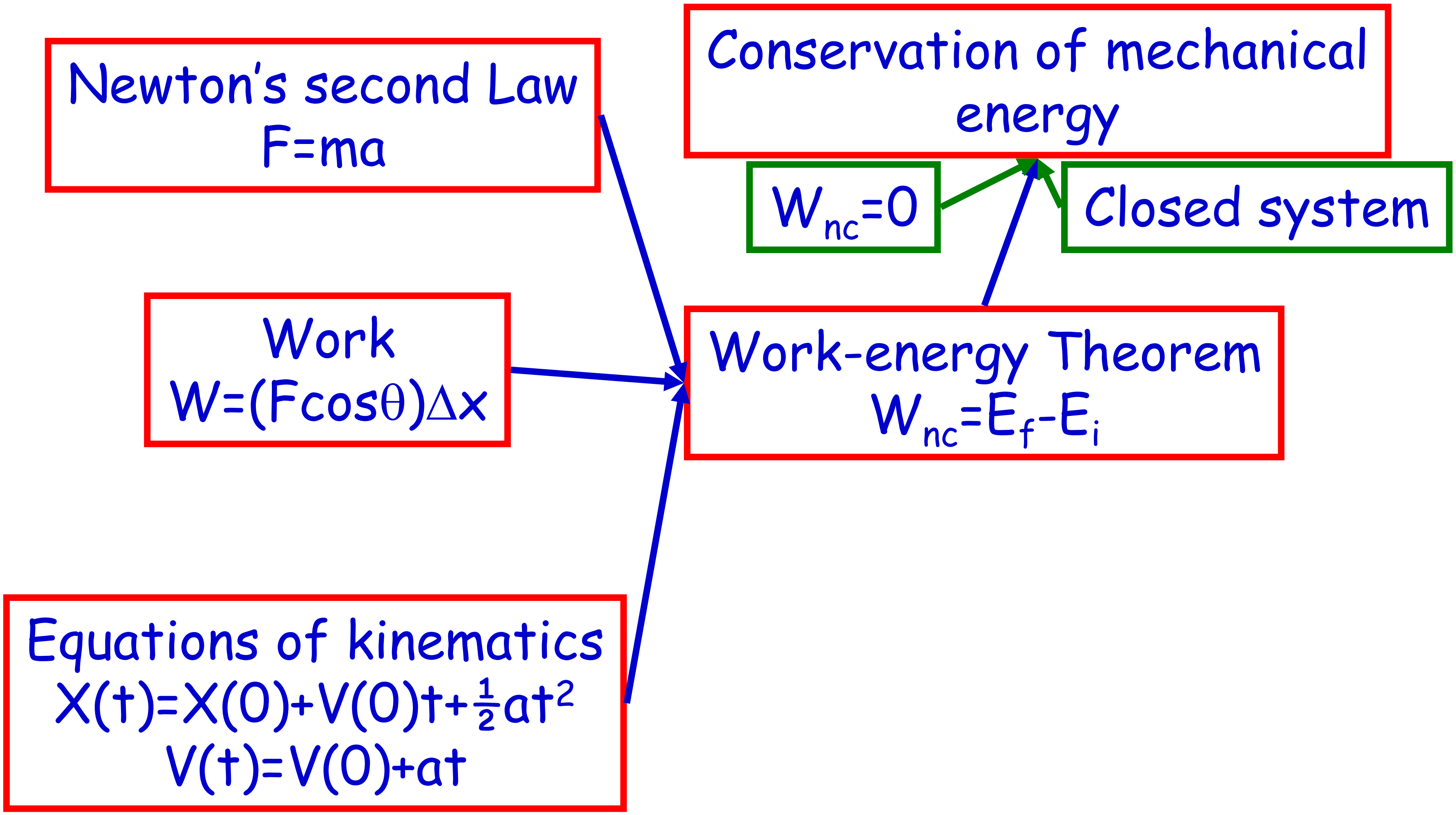
$ME_f - ME_i = (PE+KE)_f - (PE+KE)_i = W_{nc}$ if some forces are nonconservative.

W_{nc}=work done by non-conservative forces.

Example: throwing a snowball from a building taking into account air resistance

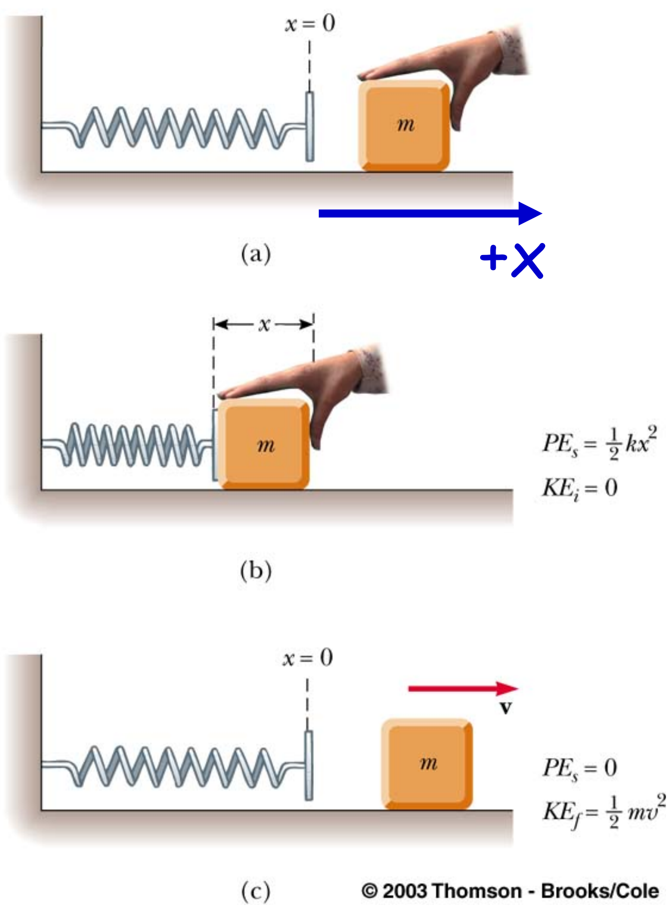


Overview



Newton's second Law
F=ma
Conservation of mechanical energy
$W_{nc}=0$
Closed system
Work
$W=(F\cos\theta)\Delta x$
Work-energy Theorem
$W_{nc}=E_f-E_i$
Equations of kinematics
$X(t)=X(0)+V(0)t+\frac{1}{2}at^2$
$V(t)=V(0)+at$

A spring

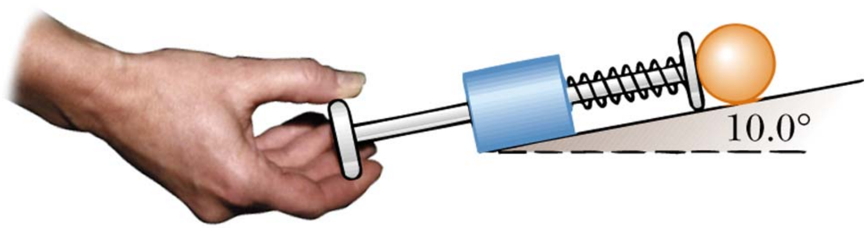


$F_s=-kx$ k: spring constant (N/m)

$F_s(x=0)=0$ N
$F_s(x=-a)=ka$
$\bar{F}_s=(0+ka)/2=ka/2$

$W_s=F_s\Delta x=(ka/2)*(a)=ka^2/2$
The energy stored in a spring depends on the location of the endpoint: elastic potential energy.

PINBALL



The ball-launcher spring has a constant k=120 N/m. A player pulls the handle 0.05 m. The mass of the ball is 0.1 kg. What is the launching speed?

$(PE_{gravity}+PE_{spring}+KE_{ball})_{pull}=(PE_{gravity}+PE_{spring}+KE_{ball})_{launch}$

$mgh_{pull}+\frac{1}{2}kx_{pull}^2+\frac{1}{2}mv_{pull}^2 = mgh_{launch}+\frac{1}{2}kx_{launch}^2+\frac{1}{2}mv_{launch}^2$

$0.1*9.81*0+\frac{1}{2}120(0.05)^2+\frac{1}{2}0.1(0)^2=$

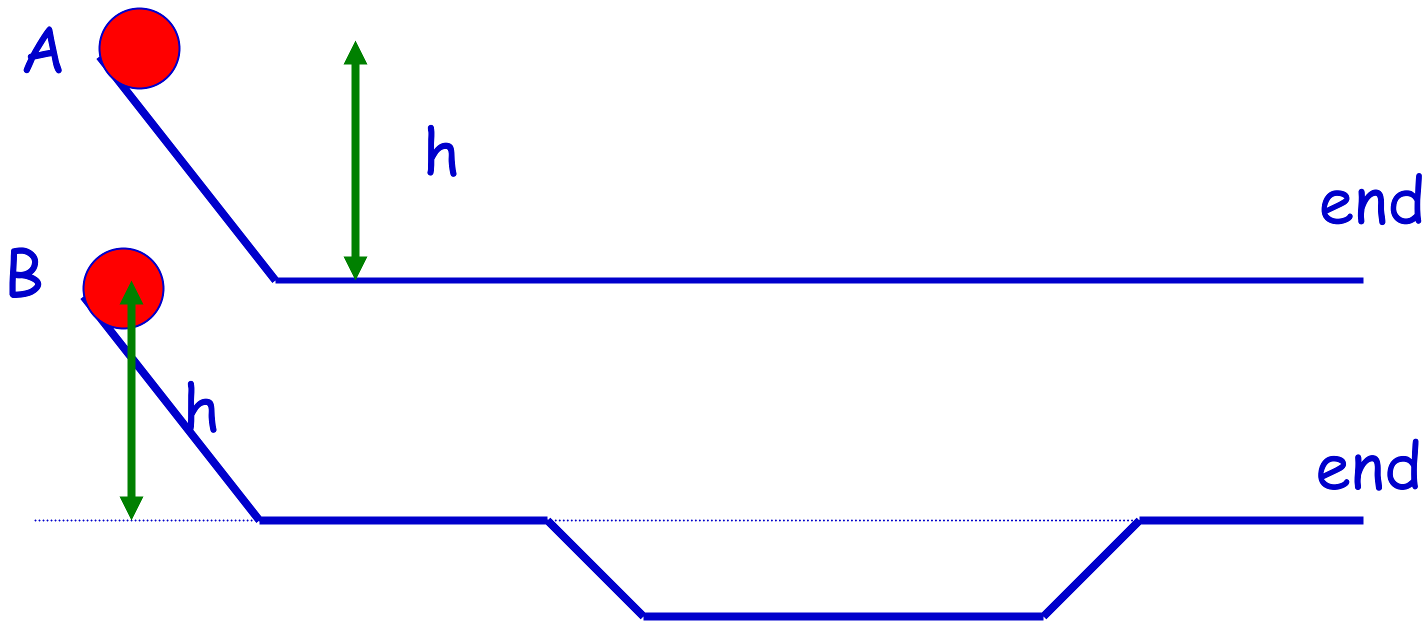
$0.1*9.81*(0.05*\sin(10^o))+\frac{1}{2}120*(0)^2+\frac{1}{2}0.1v_{launch}^2$

$0.15=8.5E\text{-}03+0.05v^2$

v=1.7 m/s

end

Ball on a track



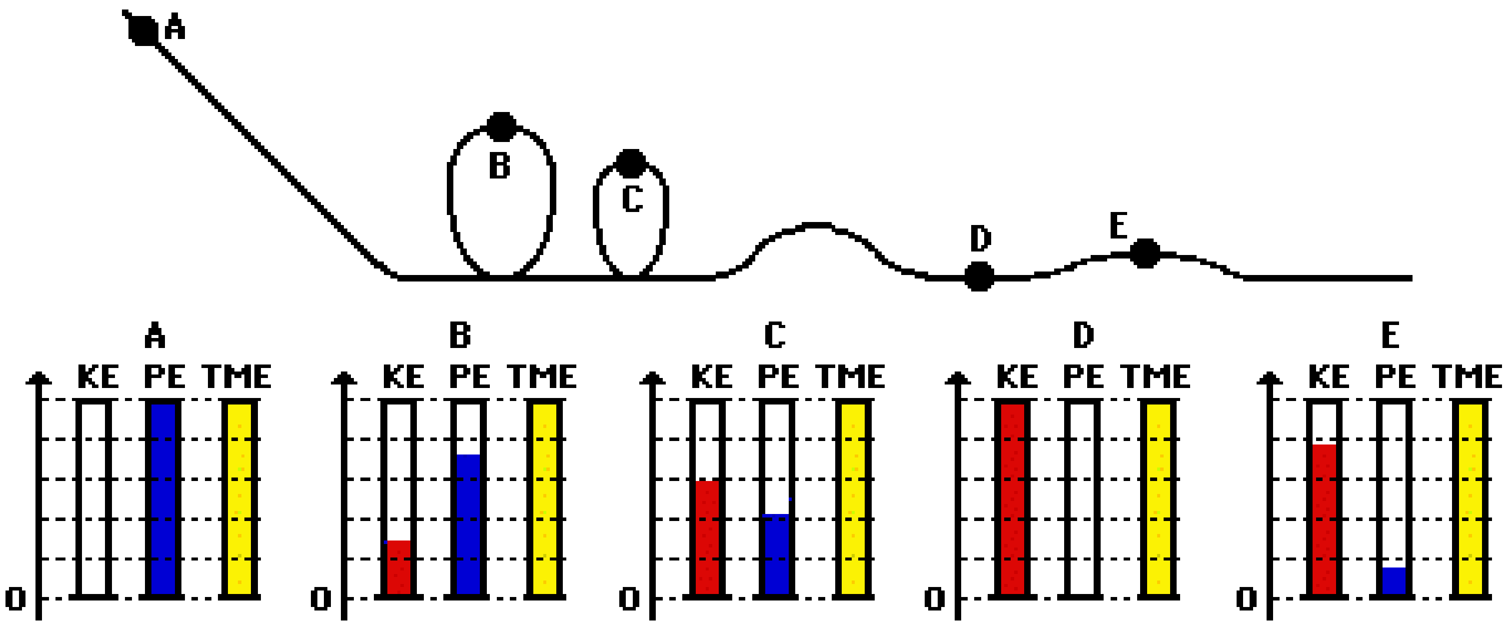
In which case has the ball the highest velocity at the end?

A) Case A B) Case B C) Same speed

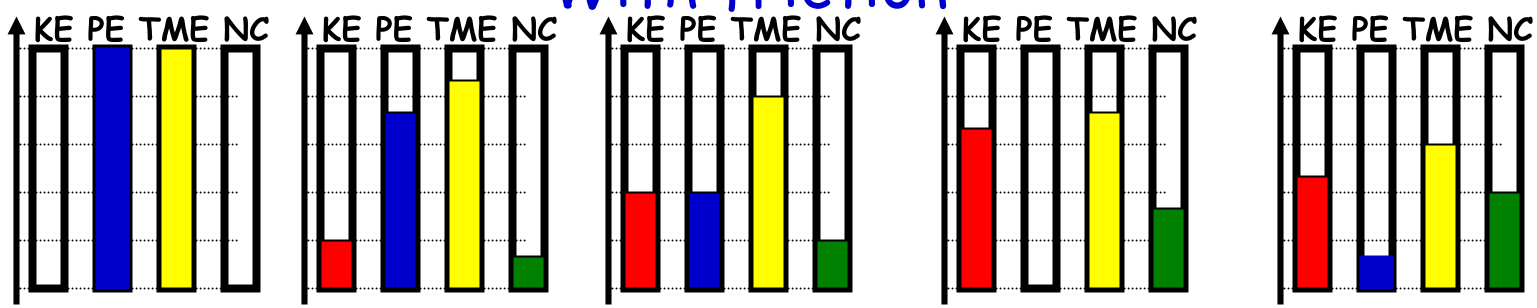
In which case does it take the longest time to get to the end?

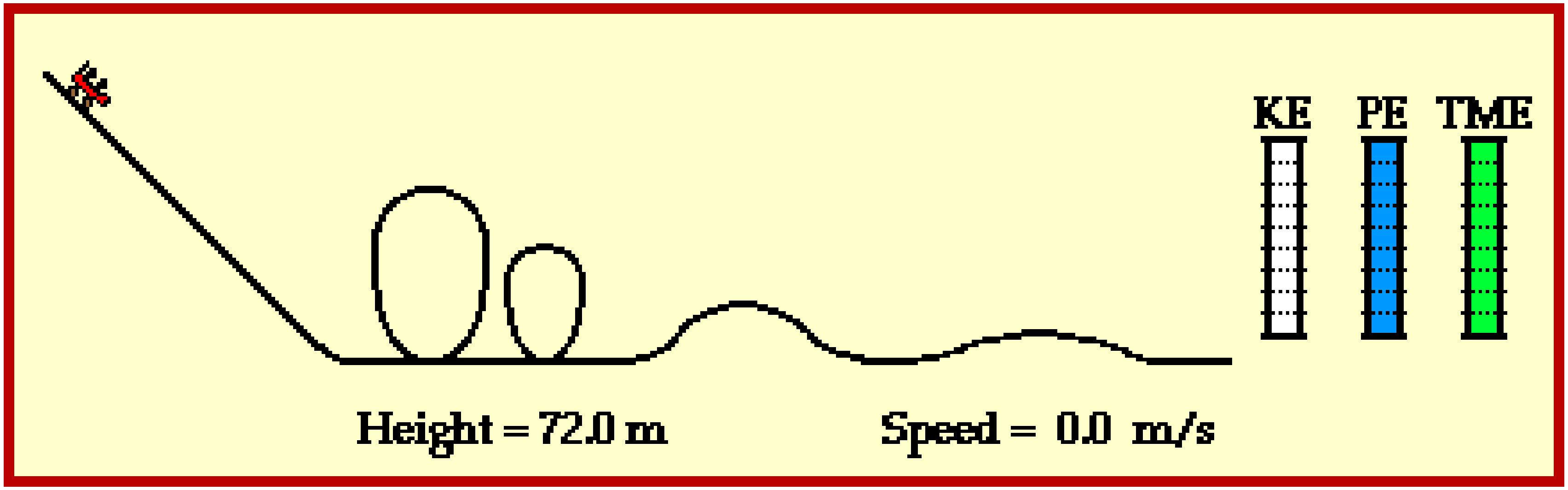
A) Case A B) Case B C) Same time

Race track

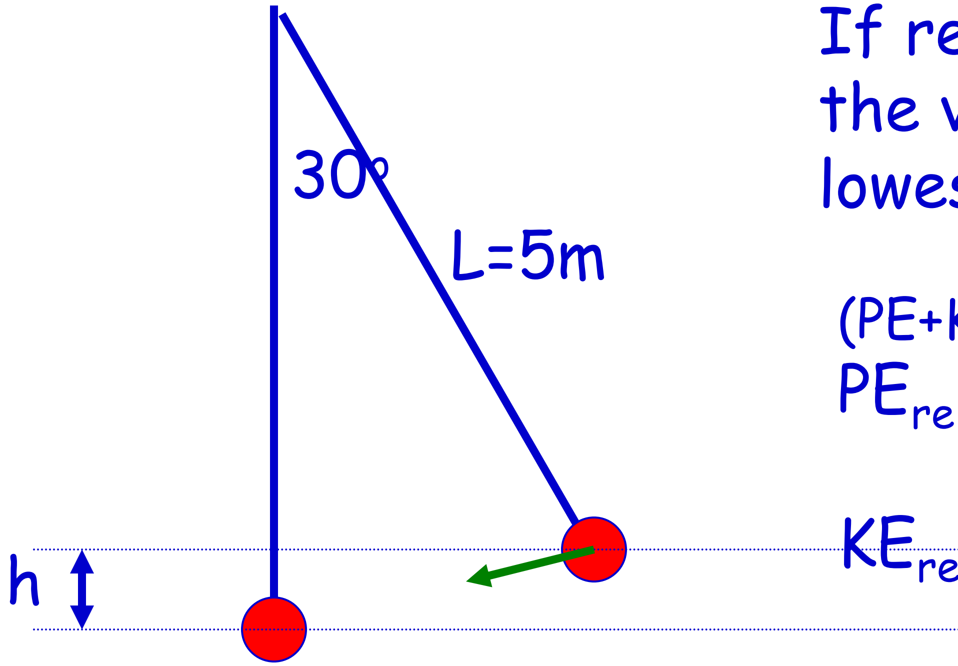


With friction




KE
PE
TME
Height = 72.0 m
Speed = 0.0 m/s

A swing



If relieved from rest, what is the velocity of the ball at the lowest point?

(PE+KE)=constant

$PE_{release}$=mgh (h=5-5cos(30°))

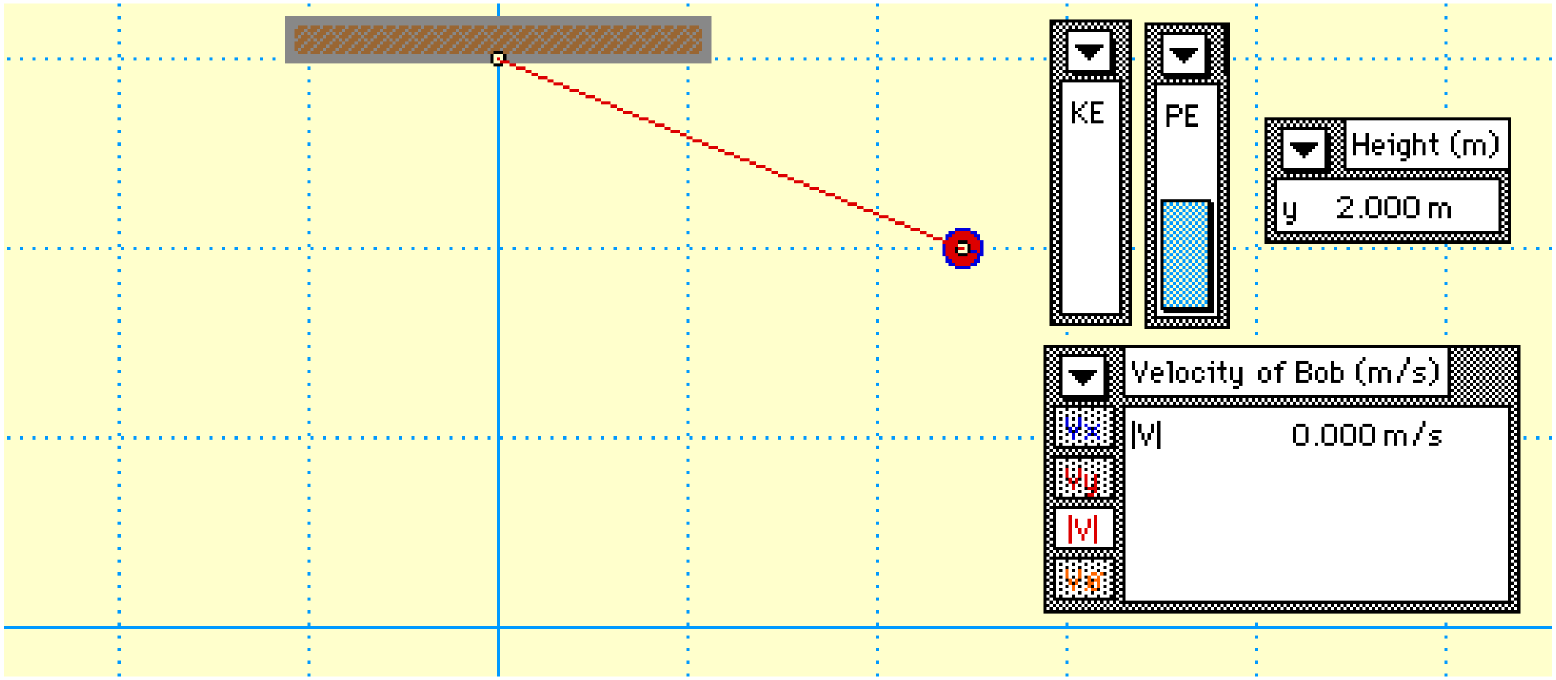
=6.57m J

$KE_{release}$=0

PE_{bottom}=0

$KE_{bottom}=\frac{1}{2}mv^2$

$\frac{1}{2}mv^2$=6.57m so v=3.6 m/s


KE
PE
Height (m)
y 2.000 m
Velocity of Bob (m/s)
Vx
Vy
|V|
|V| 0.000 m/s

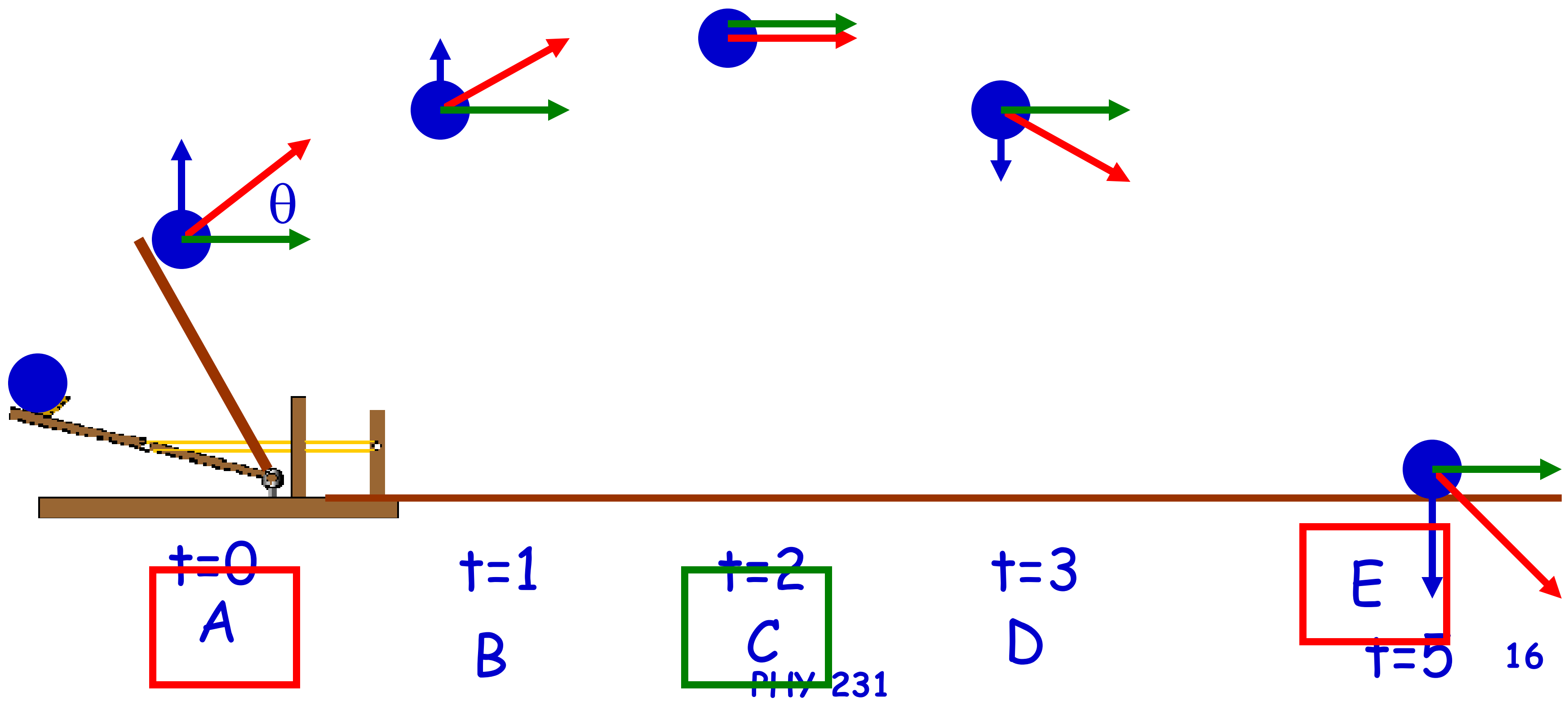
Where is the kinetic energy…

1) highest?
2) lowest ?

Assume height of catapult is negligible to the maximum height of the stone.

Parabolic motion

And what about potential energy?




KE
PEg
PEs
TME
Height = 1.0 m
Speed = 0.0 m/s

question

An outfielder throws a baseball of 0.15 kg at a speed of 40 m/s and angle of 30 degrees with the field. What is the kinetic energy of the baseball at the highest point, ignoring friction?

a) 0 J
b) 30 J
c) 90 J
d) 120 J
e) don't know

Horizontal component of velocity at start:
$v_x = v_o \cos 30 = 34.65$ m/s

At highest point: only horizontal velocity
$v_{x,highest} = 34.65$ m/s
kinetic energy: $0.5mv^2 = 90$ J

question

A worker pushes a sled with a force of 50 N over a distance of 10 m. A frictional force acts on the wheelbarrow in the opposite direction, with a magnitude of 30 N. What net work is done on the wheelbarrow?

a) don't know
b) 100 J
c) 200 J
d) 300 J
e) 500 J

$$W_{friction} = F\Delta x = (50-30)10 = 200\ J$$

question

Old faithful geyser in Yellowstone park shoots water hourly to a height of 40 m. With what velocity does the water leave the ground?

a) 7.0 m/s
b) 14 m/s
c) 20 m/s
d) 28 m/s
e) don't know

At ground level:
$E=0.5mv^2+mgh=$
$0.5mv^2+0=0.5mv^2$
At highest point:
$E=0.5mv^2+mgh=$
$0+m*9.8*40=392m$
Conservation of energy:
$0.5mv^2=392m$ so $v=28$ m/s

question

A ball of 1 kg rolls up a ramp, with initial velocity of 6 m/s. It reaches a maximum height of 1 m (I.e. velocity 0 at at that point). How much work is done by friction?

a) 0.
b) 8.2 J
c) 9.8 J
d) 18 J
e) 27.8 J

initial: $E=0.5mv^2$ (kinetic only)=18J
final: $E=mgh$ (potential only)=9.8 J
$W_{nc}=18-9.8=8.2$ J

kinetic energy: $0.5mv^2$
potential energy: mgh $g=9.8\ m/s^2$