Physics 1021

Spring 2012 Ch.10a

ConcepTest 10.1-post Prof Lewin

Does Prof. Lewin lose his life?

1) Yes
2) No
3) Not enough information is given?

PHYS 1021: Chap. 10, Pg 2

ConcepTest 10.1 Prof Lewin

Does Prof. Lewin lose his life?

1) Yes
2) No
3) Not enough information is given?

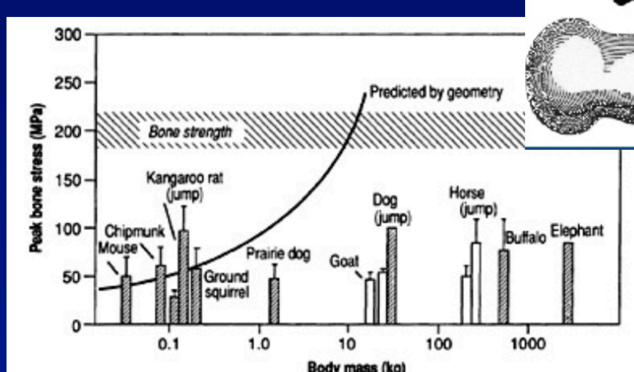
Energy is conserved so the ball just touches his chin.

Follow-up: Why does the ball not quite reach him?

PHYS 1021: Chap. 10, Pg 3

Of Mice and Elephants
Force considerations of size ….
How big are their legs?

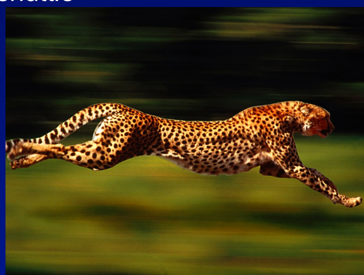
- 200 MPa is the greatest material stress that bone can take before breaking
- Bones for large animals have to be huge and eventually, they can't even support their weight while running



PHYS 1021: Chap. 10, Pg 4

Of Mice and Elephants
Force considerations of size ….
How big are their legs?

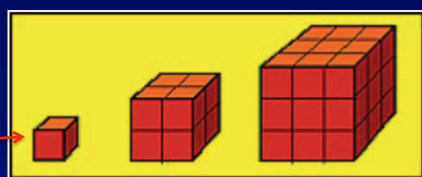
- What is the resolution? Animals change their stride.
- Humans, horses, and elephants are more upright
- Fleas and mice use high accelerations to jump … for a flea to jump a few inches, it needs an acceleration of 140 times gravity or 50 times the space shuttle

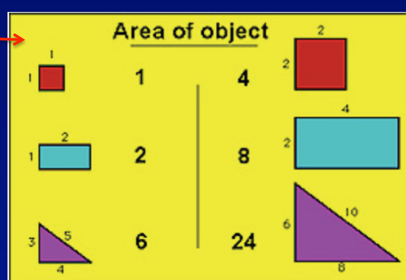


PHYS 1021: Chap. 10, Pg 5

Of Mice and Elephants
Energy considerations of size ….
How much is used?

- Heat generated is proportional to the number of cells … the mass or volume of an organism … 1,8,27,64
- Heat loss is proportional to surface area 1,4,9,16
- Ratio of volume to surface area ~ r^3/r^2 ….
- For a given rate of cellular activity,
  - ➢ a smaller animal loses more heat
  - ➢ Needs a higher metabolism to replace heat





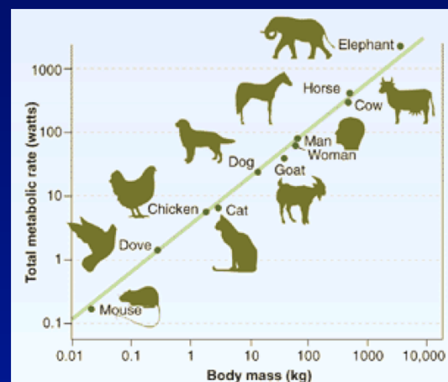
PHYS 1021: Chap. 10, Pg 6

Of Mice and Elephants
Energy considerations of size ….
How much is needed?

- Graph is a log-log plot
  - log(mass)~log(metabolism)
  - log(metabolism) = A x log(mass)
    (A = 4/5.5 ~1/1.1)
  - From the slope …

    metabolism ~ $mass^{0.7}$

    What is the metabolic rate per unit volume?
- Good agreement with scaling laws



PHYS 1021: Chap. 10, Pg 7

Why study energy?

- Considering the conversion of energy from one form to another potential to kinetic simplifies many problems
- Energy – chemical, work, electrical – is essential to life.
- Energy efficiency is a major fitness criterion for evolution
- Energy efficiency makes better machines

chemical

mechanical

configurational

potential

conserved

electromagnetic

ATP->ADP

thermal

kinetic

dissipative

PHYS 1021: Chap. 10, Pg 8

•Chap. 10 •Energy

- Energy Conservation
- Kinetic Energy
  - Kinetic-Energy Principle
- Potential Energy
  - Gravitational
  - Elastic

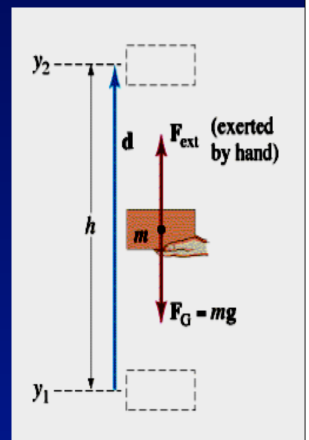
Phys 1021: Chapter 10, Pg 9

Potential Energy

New Topic

Potential Energy

- An object is moved to increase or decrease its potential to do work
- Important points to appreciate:
  - PE is measured with respect to some reference level
    - table top, ground, ceiling, etc.
  - only ***changes*** in PE actually have physical meaning
  - ΔPE does not depend on path



Conservative and Nonconservative Forces

- **Conservative** force: work **does not** depend on path taken
  - example: gravity, spring, electric force
  - such a force can be related to a *potential energy*

$$F_x = -\frac{dU}{dx}$$

$$U(x) = -\int F_x dx$$

$$U(x) = -\int -mgdy = mgy = mgh$$

Gravitational potential energy

- **Nonconservative** force: work **does** depend on path taken
  - example: friction (work is proportional to path length)
  - potential energy **cannot** be defined

Conservation of Energy (accounting in physics)

$K = {}^{1}/_{2}\, mv^2$

- Define Total Conserved Energy (sum of PE and KE):

$$E_{cons} = K + U$$

- Define *Total Energy* (sum of all forms):

$$E_{tot} = K + U + \textit{all others}$$

i.e. heat

- If no friction is present, we say that $E_{mech}=E_{cons}$ is conserved

$$\Delta E_{cons} = \Delta K + \Delta U = 0$$

$E_{cons} = K + U$ is *constant !!!*

Both K and U can change, but their sum, $E_{cons} = K + U$ remains constant

ConcepTest 10.2-post Speeding Up I

A car starts from rest and accelerates to 30 mph. Later, it gets on a highway and accelerates to 60 mph. Which takes more energy, the 0→30 mph, or the 30→60 mph?

1) 0 → 30 mph
2) 30 → 60 mph
3) both the same

ConcepTest 10.2 Speeding Up I

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1) 0 → 30 mph
2) 30 → 60 mph
3) both the same

The change in KE ($1/2\ mv^2$) involves the *velocity squared*.

So in the first case, we have: $1/2\ m\ (30^2 - 0^2) = 1/2\ m\ (900)$

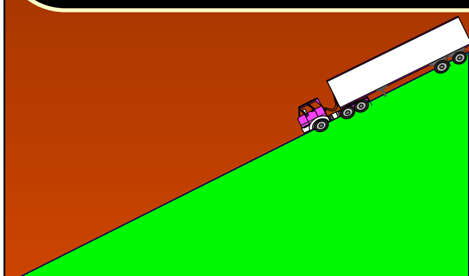
In the second case, we have: $1/2\ m\ (60^2 - 30^2) = 1/2\ m\ (2700)$

Thus, the bigger energy change occurs in the second case.

ConcepTest 10.3-post Runaway Truck

A truck, initially at rest, rolls down a frictionless hill and attains a speed of *20 m/s* at the bottom. To achieve a speed of *40 m/s* at the bottom, how many times higher must the hill be?

1) half the height
2) the same height
3) $\sqrt{2}$ times the height
4) twice the height
5) four times the height



ConcepTest 10.3 Runaway Truck

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Use energy conservation:

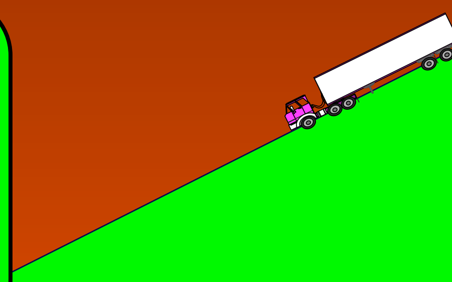
- *initial energy:* $E_i = U_g = mgH$
- *final energy:* $E_f = K = 1/2\, mv^2$

Conservation of Energy:

$$E_i = mgH = E_f = 1/2\, mv^2$$

therefore: $gH = 1/2\, v^2$

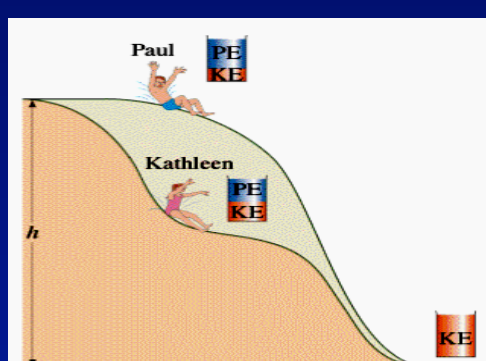
So if v doubles, H quadruples!



ConcepTest 10.4-post Water Slide II

Paul and Kathleen start from rest at the same time on frictionless water slides with different shapes. Who makes it to the bottom first?

1) Paul
2) Kathleen
3) both the same

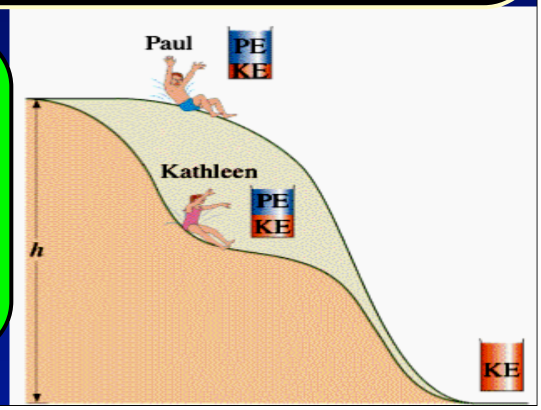


ConcepTest 10.5 Water Slide II

Paul and Kathleen start from rest at the same time on frictionless water slides with different shapes. Who makes it to the bottom first?

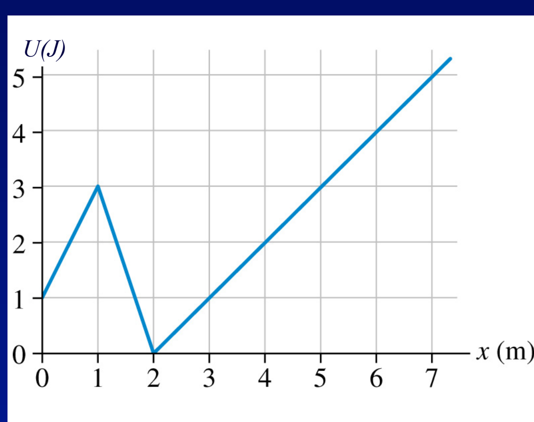
1) Paul
2) Kathleen
3) both the same

Even though they both have the same *final velocity*, **Kathleen is at a lower height than Paul for most of her ride.** Thus she always has a *larger velocity* during her ride and therefore arrives earlier!



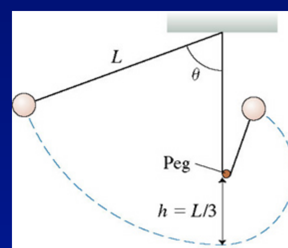
Ponderable: Turning around

A particle with the potential energy shown in the graph is moving to the right. It has 1 J of kinetic energy at x = 1 m. At what distance does it stop?



Example: Funny Pendulum

A pendulum is formed from a small ball of mass m on a string of length L. As the figure shows, a peg is height h above the pendulum's lowest point. From what minimum angle θ must the pendulum be released in order for the ball to go over the top of the peg without the string going slack?



Ponderable: Loop the loop

A roller coaster car may be approximated by a block of mass *m*. The car, which starts from rest, is released at a height *h* above the ground and slides along a frictionless track. The car encounters a loop of radius R , as shown. Assume that the initial height, *h,* is great enough so that the car never loses contact with the track. What is the minimum height, *h*, which will allow the car to execute a successful loop?