Physics 221, February 2

Key Concepts:

- Projectile motion
- Hooke's law
- Friction
- Uniform circular motion

Electronic Devices

Please separate your professional from your social life

Do not use social media during class time.

Permit yourself to think and participate.

Forces

On macroscopic scale, the most common forces (interactions) we experience on a daily basis are gravity and contact forces.

Gravity near the surface of Earth:

- proportional to mass
- constant as a function of position
- pointing straight downward

$F_g = mg$

constant force → constant acceleration

Motion with constant acceleration

Kinematic equations:

Assume **a** = constant, a_x = constant, a_y = constant, a_z = constant.

For the x-component of the motion the kinematic equations are

$v_{xf} = v_{xi} + a_x \Delta t$,
$x_f = x_i + v_{xi}\Delta t + (1/2)a_x\Delta t^2$,
$v_{xf}^2 = v_{xi}^2 + 2a_x (x_f - x_i)$.
This includes $a_x = 0$.

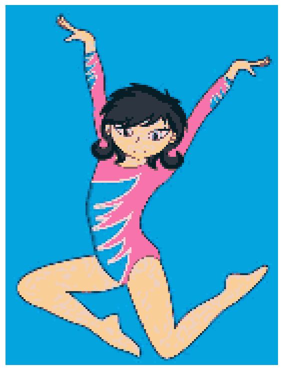
The position x_f versus time Δt graph is a section of a parabola.
In the limit $a_x = 0$ it becomes a straight line.

Similarly for the other components!

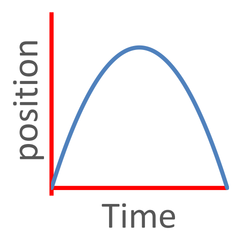
Assume g = 10 m/s^2 .

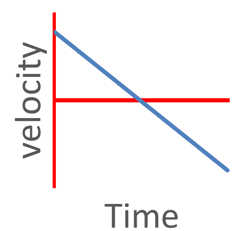
A gymnast jumps upward with an initial speed of 10 m/s. She is in the air for a total time of

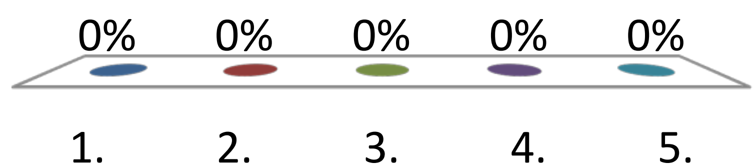
1. 1.6 s.
2. 2 s.
3. 4 s.
4. 0.8 s.
5. 1.2 s.



Hint: The time moving upward equals the time moving downward.







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At the highest point the velocity of the jumper is zero.

$v = v_{0y} - gt$, let $g = 10\ m/s^2$.

$0 = v_{0y} - gt_{top}$,

t_{top} is the time it takes the ball to reach the highest point.

It takes the ball the same amount of time to come back down, so its time in the air is $t = 2t_{top}$.

or

The final position is equal to the initial position.

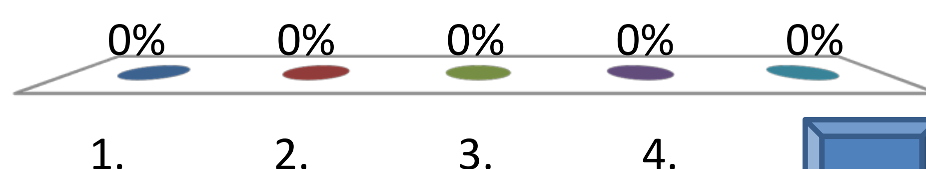
$y_f - y_i = v_{0y}t - (1/2)gt^2$

$0 = v_{0y}t - (1/2)gt^2$

A rock is dropped from a height of 40 m above the ground. How long does it take the rock to fall the last 10 m before it hits the ground?
Let $g = 10\ m/s^2$.

Hint:
Find time for the rock to fall 40 m.
Find time for the rock to fall 30 m.
Subtract t(40 m) – t(30 m) to get the time to fall the last 10 m.

1. 2 s
2. 1.44 s
3. 0.45 s
4. 6 s
5. 0.38 s



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Let $g = 10\ m/s^2$.

$y_f - y_i = v_{0y}t - (1/2)gt^2$.

Here $v_{0y} = 0$.

$40\ m = ½\ (10\ m/s^2)\ t_{40\ m}{}^2$.

Solve for $t_{40\ m}$.

$30\ m = ½\ (10\ m/s^2)\ t_{30\ m}{}^2$.

Solve for $t_{30\ m}$.

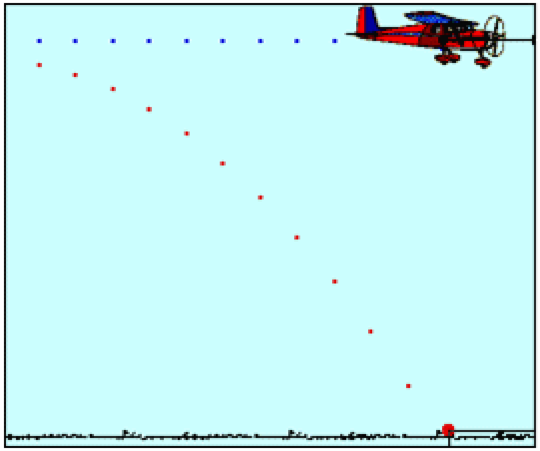
$t_{diff} = t_{40\ m} - t_{30\ m}$.

Projectile motion

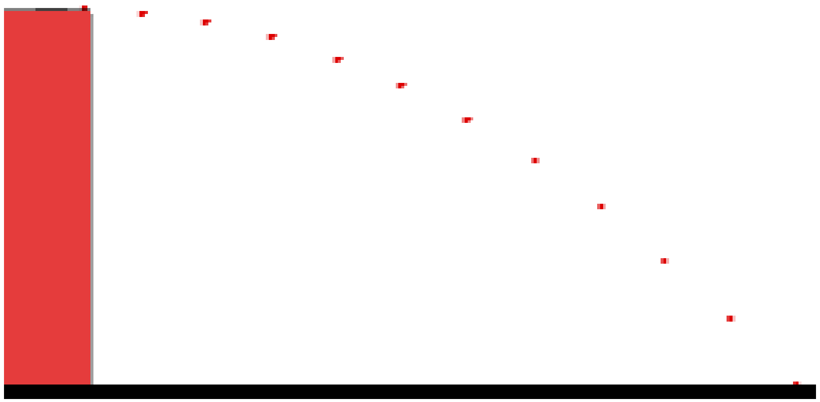
Projectile motion is motion of a particle through a region of space where it is subject to **constant acceleration**.
Let the acceleration be along the y-direction and let the trajectory lie in the xy-plane.
Then $v_x = v_{0x}$, $\Delta x = v_{0x}\,\Delta t$, $v_y = v_{0y} + a_y\Delta t$, $\Delta y = v_{0y}\Delta t + (1/2)a_y\Delta t^2$.

The motion along the x-direction is independent of the motion along the y-direction.

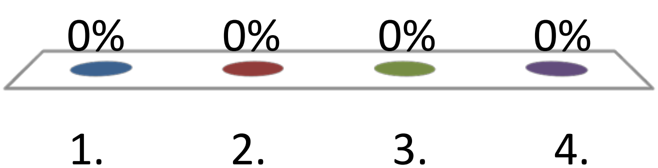
If $a_y = -g$ then
$v_x = v_{0x}$, $\Delta x = v_{0x}\,\Delta t$,
$v_y = v_{0y} - g\Delta t$, $\Delta y = v_{0y}\Delta t - (1/2)g\Delta t^2$.



A ball is thrown horizontally from the roof of a 25 m tall building with a speed of 20 m/s. What is its acceleration just before it hits the ground?



1. 0
2. 25 m/s^2, horizontal
3. 9.8 m/s^2, downward
4. greater than 9.8 m/s^2 to the right and downward.



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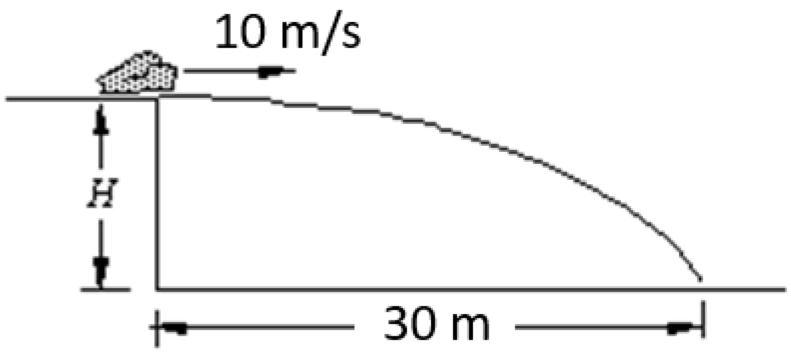
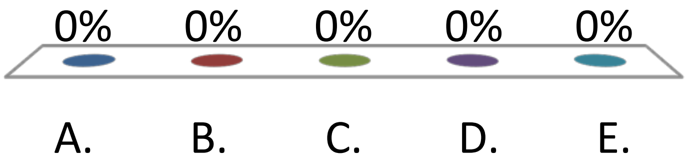
A rock is kicked horizontally at 10 m/s off a cliff.
The rock strikes the ground 30 m from the cliff as shown in the figure.
What is the approximate height of the cliff H?



A. 27 m
B. 300 m
C. 15 m
D. 45 m
E. 90 m



Hint:

$a_x = 0$, $a_y = -g$.

The horizontal component of the velocity does not change.

$v_x = 10$ m/s

The time it take the rock to travel $\Delta x = 30$ m horizontally is

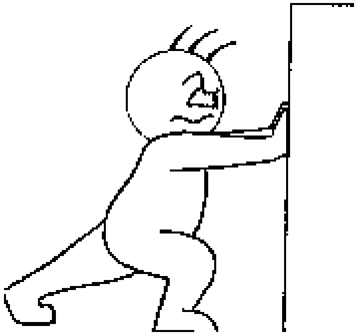
$\Delta t = \Delta x / v_x$

During this time the rock falls a distance $\Delta y = \frac{1}{2} a_y \Delta t^2$.

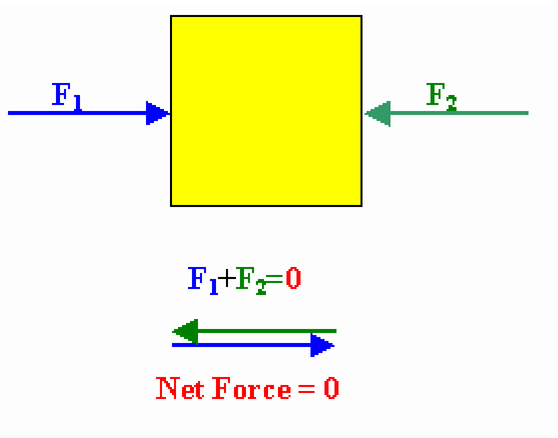
$|\Delta y| = \frac{1}{2} g * \Delta t^2$.

Contact forces

pushes, pulls, normal forces, friction, drag



If an object is at rest, then the net force on the object is zero.
Several forces may be acting on different parts of the object, but there vector sum is zero.



The material acted on by several forces whose vector sum is zero is under tension or compression. It deforms by some amount. It bends, expands or contracts.

HOOKE'S LAW

No material is perfectly hard. As long as the external pushes or pulls are not too strong, displacement x due to the bending, contraction or expansion is proportional to the magnitude of the pushing or pulling forces.

$$F_{ext} = kx$$

The material pushes back with force

$$F = -kx$$

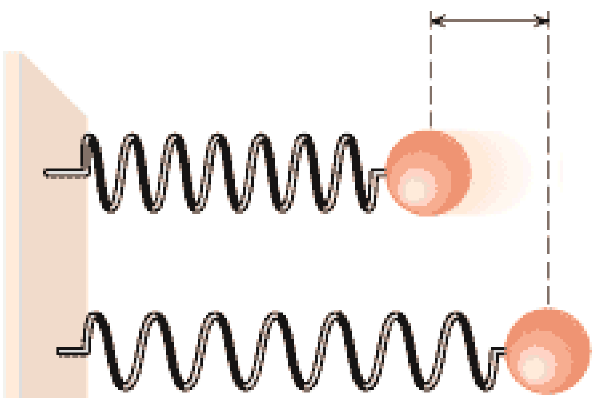
This is Hooke's law.

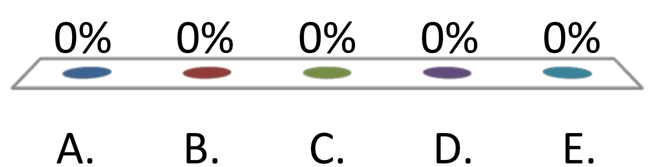
Hooke's law is NOT a law of nature.

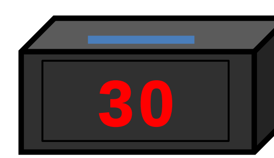
It is a rule of thumb that often holds over a limited range of bending, expansion and contraction.

A force of magnitude 15 N compresses an ideal spring by 4 mm. How much force is needed to stretch the same spring by 8 mm?

A. 30 N
B. 15 N
C. 20 N
D. 7.5 N
E. impossible to know

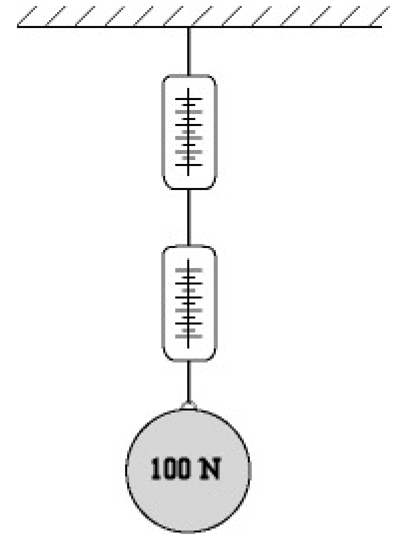




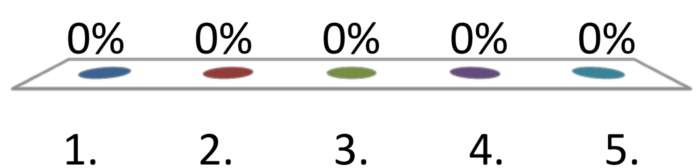


In the figure, a 100 N weight is suspended from two spring scales, each of which has negligible weight. What is the reading of the scales?

1. The top scale will read zero, the lower scale will read 100 N.
2. Each scale will read 100 N.
3. The lower scale will read zero, the top scale will read 100 N.
4. Each scale will read 50 N.
5. Each scale will show a reading between one and 100 N, such that the sum of the two is 100 N. However, exact readings cannot be determined without more information.



Hint: How much weight is pulling on each scale?



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Friction

The frictional force always acts between two surfaces, and opposes the **relative motion** of the two surfaces.

Static friction: $f_s \leq \mu_s N$

Kinetic friction: $f_k = \mu_k N$

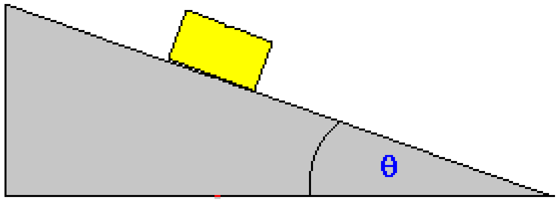
N = magnitude of the force pressing the surfaces together

What is the direction of the frictional force on the block if

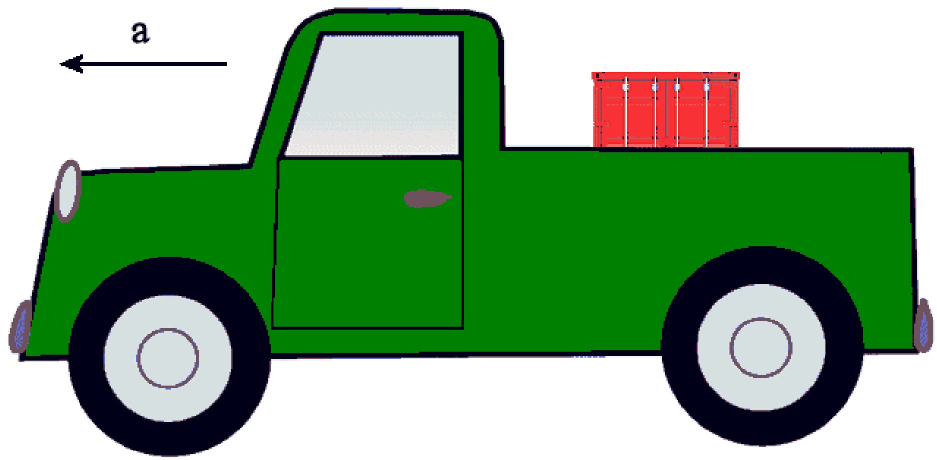
i) the block is at rest on the ramp?

ii) the block moves up the ramp?

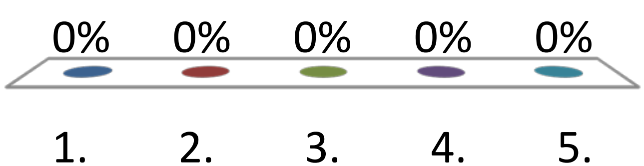
iii) the block is moves down the ramp?



A heavy box sits in the back of a pickup truck. The truck and the box are accelerating towards the left.
What is the direction of the frictional force on the box?



1. Towards the right
2. Towards the left
3. Up
4. Down
5. Down and towards the left



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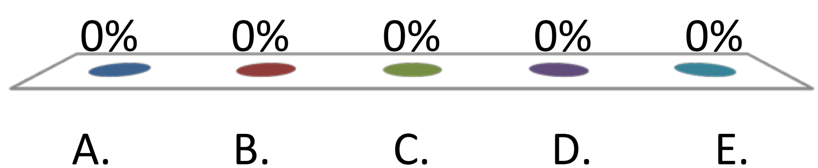
A horizontal external force of 5 N acts on a 2 kg box that slides across a surface with constant velocity.

What is the coefficient of kinetic friction μ_k between the box and the surface?

(Let $g = 10\ m/s^2$.)

Hint:
constant velocity ←→ no net force

A. 0.25
B. 5
C. 1
D. 0.5
E. 0.1



Circular motion

An object moving in a circle of radius r with speed v is accelerating.

This acceleration is called radial acceleration or centripetal acceleration.

This acceleration, $\mathbf{a_c}$, points **towards the center of the circle**.

The magnitude of the centripetal acceleration vector is

$$a_c = v^2/r.$$

A force is required to make an object move in a circle.

This force is called the centripetal force, with magnitude

$$F_c = m\,v^2/r.$$

$\mathbf{F_c}$ points **towards the center of the circle**.

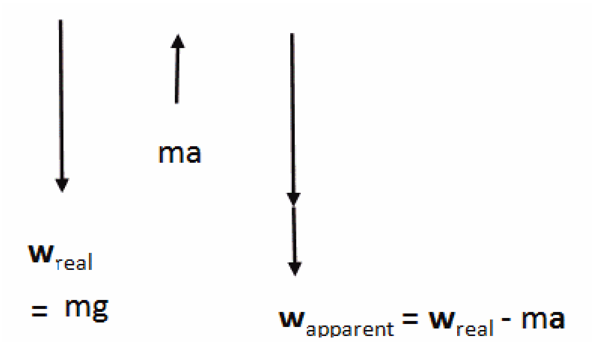
Apparent weight

When you stand on a bathroom scale in an inertial frame, such as this room, its reading is proportional to your real weight.

When you stand on a bathroom scale in an accelerating frame, such as an elevator accelerating upward, its reading is proportional to your apparent weight.

$\mathbf{w}_{apparent} = \mathbf{w}_{real} - m\mathbf{a}$.

For the elevator accelerating upward:



In every accelerating frame we have

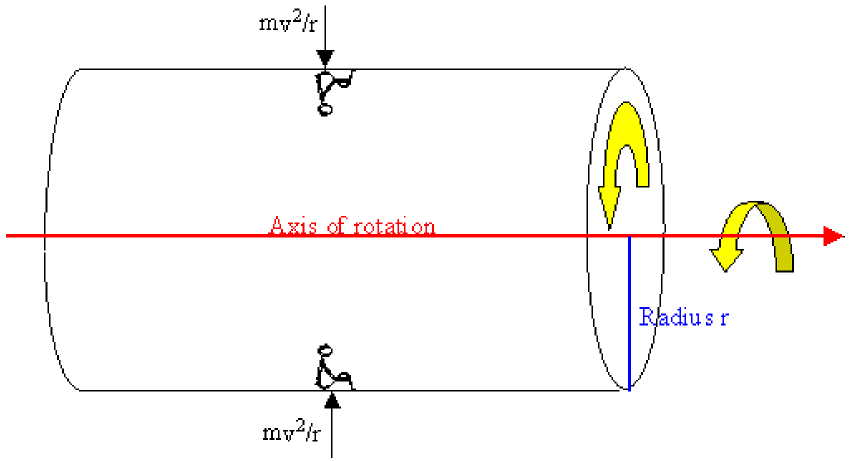
$$\mathbf{w}_{apparent} = \mathbf{w}_{real} - m\mathbf{a}$$

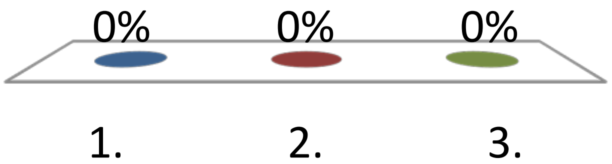
The apparent weight of a mass m is its real weight minus its mass times the acceleration of the frame (vector addition).

In outer space, where $\mathbf{w}_{real} = 0$,
$\mathbf{w}_{apparent} = - m\mathbf{a}$

Some engineers have suggested that we can simulate gravity in outer space by having a circular rotating space station where persons feel an outward-directed fictitious force due to the rotation of the station. The reason they feel such a force is because

1. their velocity is toward the center of the space station and their inertia tends to keep them moving outward.
2. they are accelerating toward the center of the space station and the walls of the space station provide the centripetal force, which they experience as an apparent weight.
3. their velocity is away from the center of the space station and their inertia tends to make them move in towards the center.





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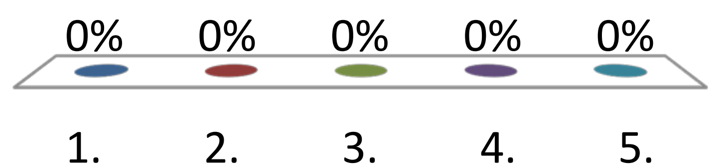
A ring shaped space station with a radius of 2 km is spinning, so that the speed of the rim is 100 m/s. A 50 kg woman sits on the inside of the rim. What is the magnitude of his apparent weight?

1. 5000 N
2. 350 N
3. 250000 N
4. 500 N
5. 250 N



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