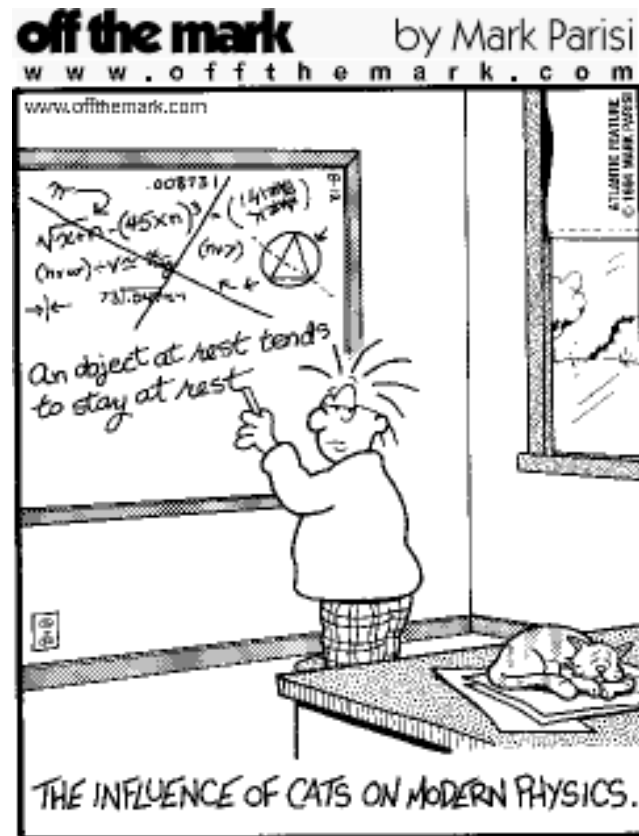


PHYSICS 231

Lecture 7: Newton's Laws



Isaac Newton (1642-1727)

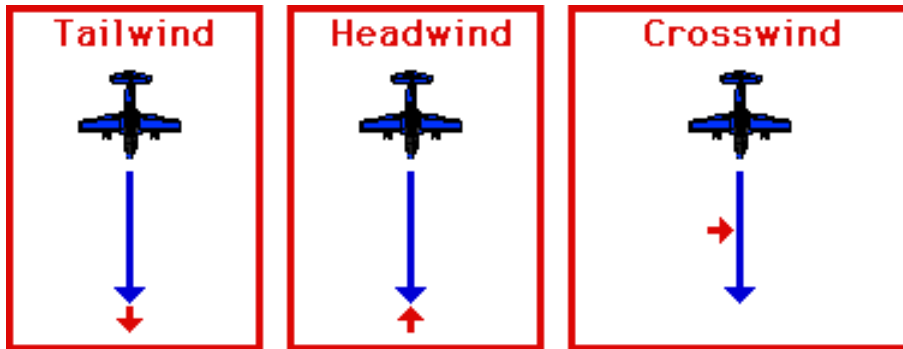
"In the beginning of 1665 I found the...rule for reducing any dignity of binomial to a series. The same year in May I found the method of tangents and in November the method of fluxions and in the next year in January had the Theory of Colours and in May following I had the entrance into the inverse method of fluxions and in the same year I began to think of gravity extending to the orb of the moon...and...compared the force requisite to keep the Moon in her orb with the force of Gravity at the surface of the Earth."

*"Nature and Nature's Laws lay hid in night:
God said, Let Newton be! And all was light."*

Alexander Pope (1688-1744)



quiz for extra credit

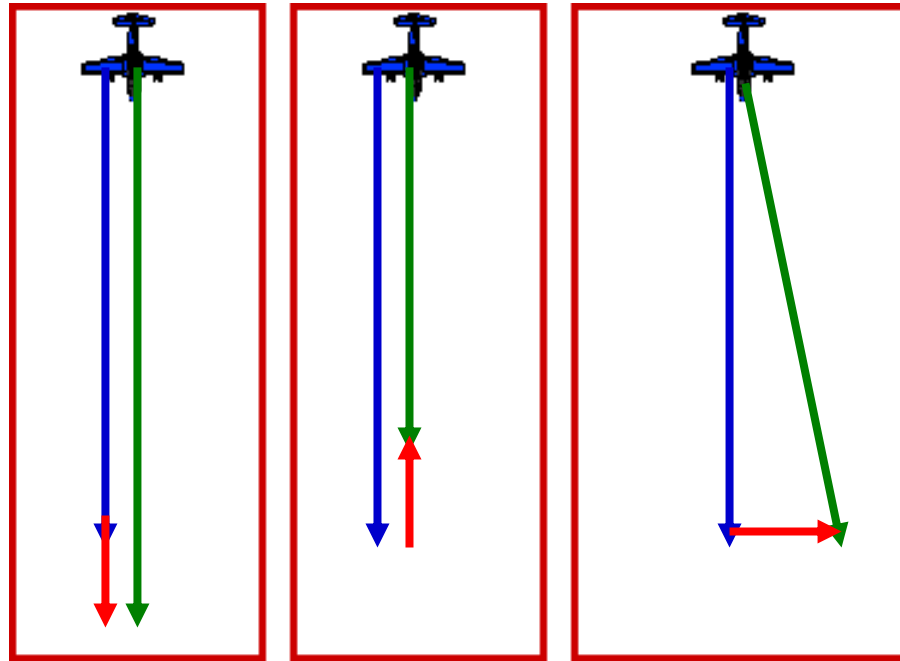


Three planes are traveling with equal motor power to the south, as indicated by the blue arrow. At $t=0$, a wind starts to blow in different ways but with equal strength as indicated by the red arrows. The pilots do not correct speed or steering.

Which plane has the largest displacement after 1 hour of flying, and 2nd and 3rd?

- a) C largest displacement, then A then B
- b) A largest displacement, then C then B
- c) C largest displacement, then B then A
- d) A largest displacement, then B, then C

answer



A) $L = A + B = \sqrt{(A+B)^2} = \sqrt{A^2 + B^2 + 2AB}$

B) $L = A - B$

C) $L = \sqrt{A^2 + B^2}$

largest displacement

3rd

2nd

So right answer: A,C,B (answer b)

Newton's Laws

- **First Law:** If the net force exerted on an object is zero the object continues in its original state of motion; if it was at rest, it remains at rest. If it was moving with a certain velocity, it will keep on moving with the same velocity. (Demo)
- **Second Law:** The acceleration of an object is proportional to the net force acting on it, and inversely proportional to its mass: $F=ma$ (Demo)
- **If two objects interact**, the force exerted by the first object on the second is equal but opposite in direction to the force exerted by the second object on the first: $F_{12}=-F_{21}$

Identifying the forces in a system

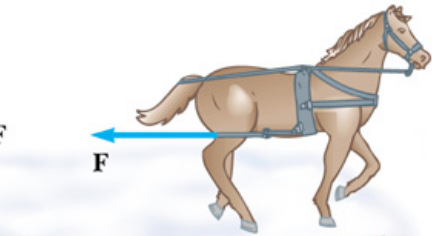
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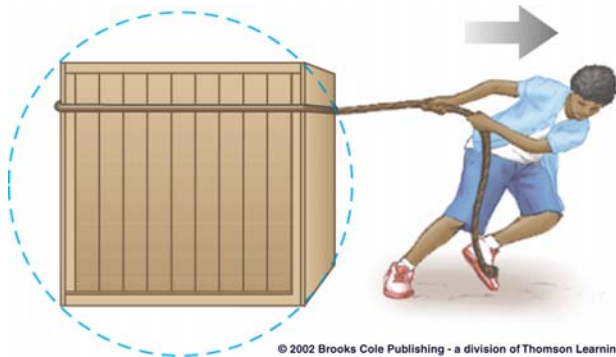
(a)



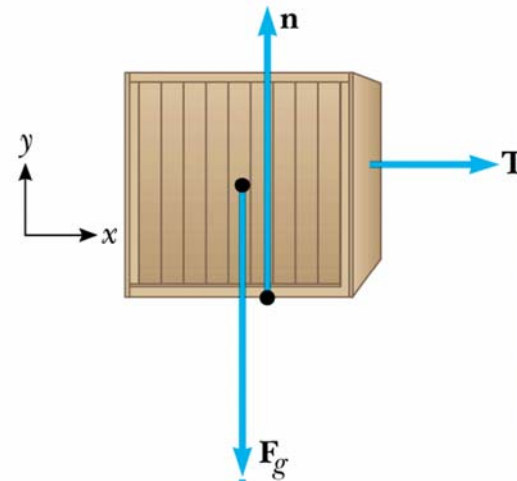
(b)



(c)



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Force

- Forces are quantified in units of *Newton* (N).

$$1 \text{ N} = 1 \text{ kgm/s}^2$$

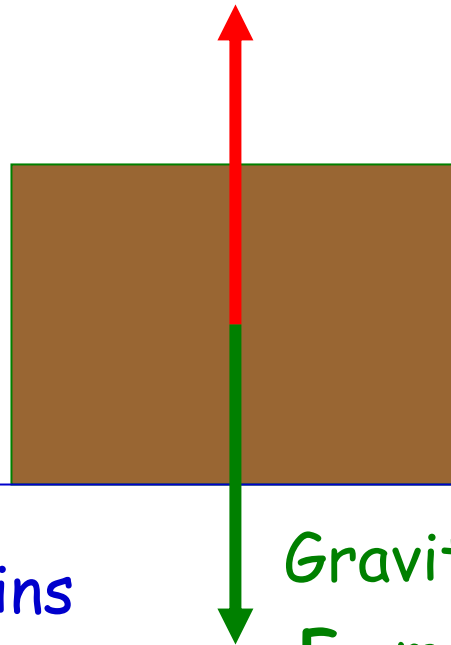
$$F = ma$$

- A force is a **vector**: it has direction.

Two Forces that luckily act upon us nearly all the time.

Normal Force: elastic force acting perpendicular to the surface the object is resting on.

Name: n

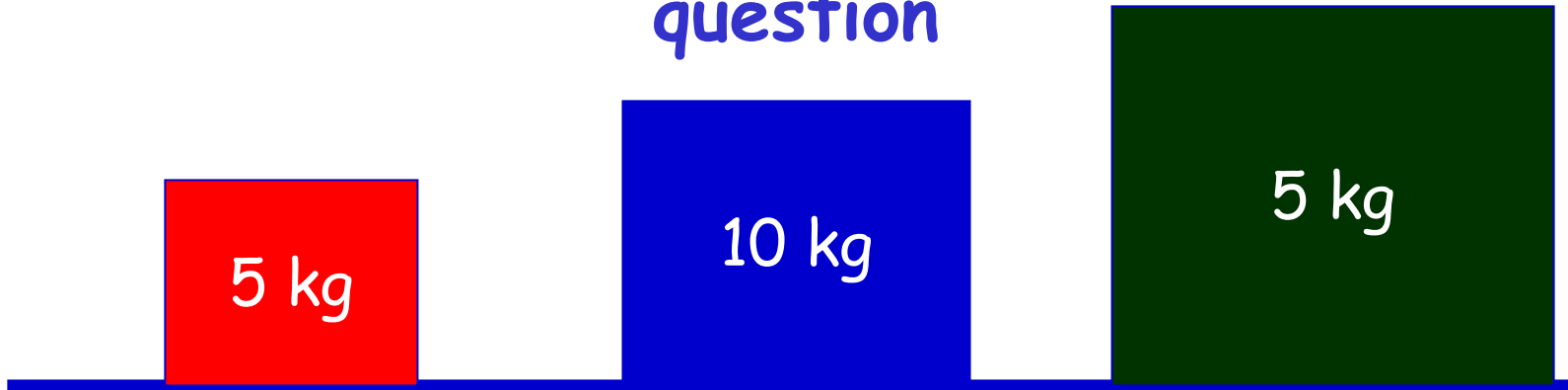


Gravitational Force

$F_g = mg$ (referred to as weight)
 $g = 9.81 \text{ m/s}^2$

1. No net force: remains at rest.
2. $F_g = mg = n$
3. $F_{\text{mass-ground}} = -F_{\text{ground-mass}}$

question

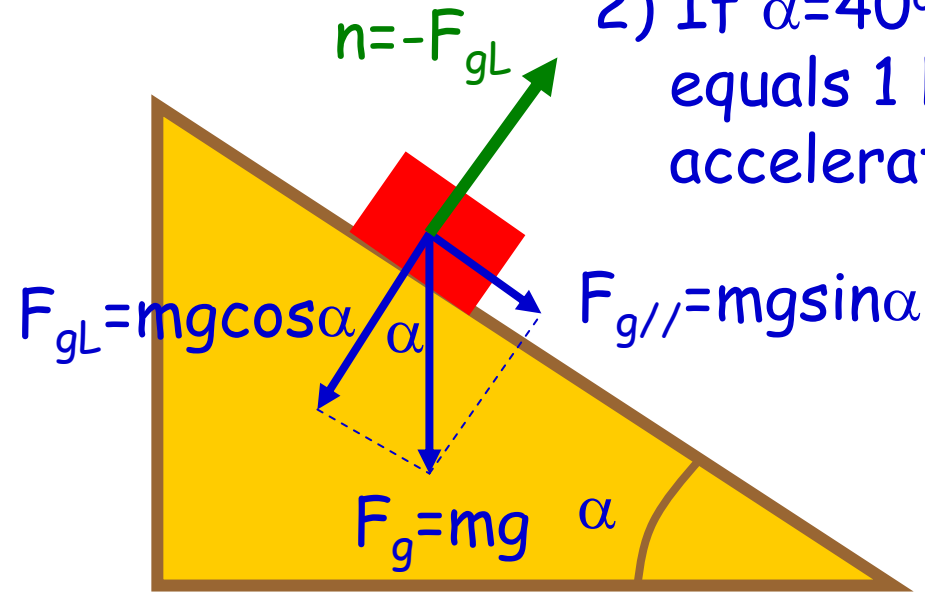


3 cases with different mass and size are standing on a floor. which of the following is true:

- a) the normal forces acting on the crates is the same
- b) the normal force acting on crate b is largest because its mass is largest
- c) the normal force on the green crate is largest because its size is largest
- d) the gravitational force acting on each of the crates is the same
- e) all of the above

A first example

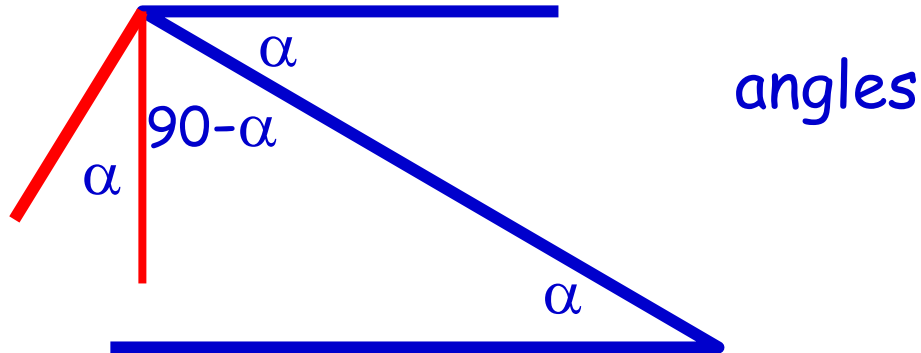
- 1) Draw all Forces acting on the red object
- 2) If $\alpha=40^\circ$ and the mass of the red object equals 1 kg, what is the resulting acceleration (no friction).



Balance forces in directions where you expect no acceleration; whatever is left causes the object to accelerate!

$$ma = mg \sin \alpha = 6.3 \text{ N}$$
$$a = 6.3 \text{ m/s}^2$$

Some handy things to remember.



Choose your coordinate system in a clever way:
Define one axis along the direction where you expect
an object to start moving, the other axis perpendicular
to it (these are not necessarily the horizontal and
vertical direction).

question



- A ball is rolling from a slope. If the angle α is decreased:
- a) the normal force on the ball increases
 - b) the magnitude of the normal force gets closer to that of the gravitational force
 - c) the ball rolls slower
 - d) all of the above

Gravity, mass and weights.

Weight=mass times gravitational acceleration

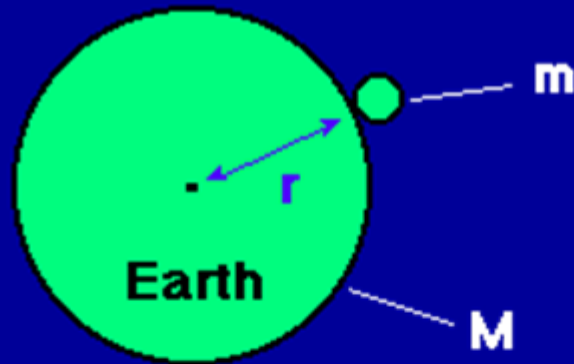
$$F_g(\text{N})=M(\text{kg}) g(\text{m/s}^2)$$

Newton's law of universal gravitation:

$$F_{\text{gravitation}}=Gm_1m_2/r^2$$
$$G=6.67 \cdot 10^{-11} \text{ Nm}^2/\text{kg}^2$$

For objects on the surface of the earth:

- $m_1=m_{\text{earth}}=\text{fixed}$
- $r=\text{"radius" of earth}=\text{fixed}$



$$\text{Weight} = F_g = G \frac{Mm}{r^2} = mg$$

M is the mass of the Earth

m is the mass of the object

r is the radius of the Earth

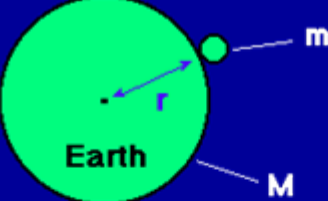
g is the acceleration due to gravity at the Earth's surface

Measuring mass and weight.

Given that $g_{\text{earth}}=9.81 \text{ m/s}^2$, $g_{\text{sun}}=274 \text{ m/s}^2$, $g_{\text{moon}}=1.67 \text{ m/s}^2$, what is the mass of a person on the sun and moon if his mass on earth is 70 kg? And what is his weight on each of the three surfaces?

- The mass is the same on each of the surfaces
- On Earth: $w=686.7 \text{ N}$
- On the Moon: $w=116.7 \text{ N}$
- On the Sun: 19180 N

question



Weight = $F_g = G \frac{Mm}{r^2} = mg$

M is the mass of the Earth
m is the mass of the object
r is the radius of the Earth
g is the acceleration due to gravity at the Earth's surface

Buck Rogers travels from earth to a planet which has a radius that is 2 times larger than that of earth and has a mass 6 times that of earth. By what factor does his weight change relative to earth?

- a) 1/3
- b) 2/3
- c) 1
- d) 1.5
- e) 3

$$F_g \sim 1/r^2 \sim 1/4$$

$$F_g \sim M \sim 6$$

$$F_g \sim M/r^2 = 6/4 = 1.5$$

His weight is 1.5 times larger.

Next lecture

- Other forces: Tension & Friction
- Many, many examples.