P2211K
9 / 14 / 2010

(Excerpt from updated syllabus on-line at my website.)

POLICY ON CALCULATORS AND CELL PHONES FOR EXAMS: ***Programmable calculators, graphics calculators, hand held computers and any type of cell phone are not allowed for tests and exams. For these, you need to have a simple "scientific" calculator that has roots and trig functions. (These are available at Walmart, Office Depot, etc., for $10 - $15. An example is the TI-30 series.)***

POLICY ON CELL PHONES IN CLASS: ***Anyone texting or talking on a cell phone during class will be asked to leave.***

Re-cap of where we stand:

- Have worked on the description of motion (kinematics) and have developed the concept of ***equations of motion***.
- Kinematical equations of motion:

$$\vec{\boldsymbol{r}} = \vec{\boldsymbol{r}}\boldsymbol{(t)} = x(t)\hat{\boldsymbol{i}} + y(t)\hat{\boldsymbol{j}} + z(t)\hat{\boldsymbol{k}} \quad \textit{(the position is a function of time)}$$

$$\vec{\boldsymbol{v}}\boldsymbol{(t)} = \frac{\boldsymbol{d\vec{r}}}{dt} \quad \textit{(velocity is the rate of change of position)}$$

$$\vec{\boldsymbol{a}}\boldsymbol{(t)} = \frac{\boldsymbol{d\vec{v}}}{dt} \quad \textit{(acceleration is the rate of change of velocity)}$$

etc.

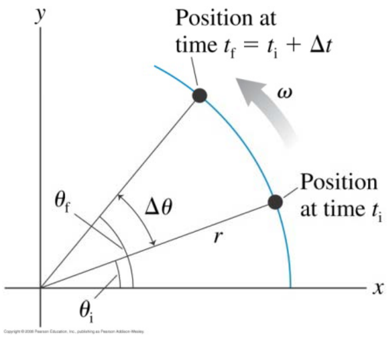
For constant acceleration, these lead to:

$$x(t) = x_0 + v_{x0}t + \tfrac{1}{2}a_x t^2$$

$$y(t) = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2$$

$$z(t) = z_0 + v_{z0}t + \tfrac{1}{2}a_z t^2$$

- Have emphasized that the description of position and velocity depend on the coordinate system (frame of reference) chosen. This led to the concept of relative motion and coordinate transformation (but only for cases where the relative motion does not involve acceleration).
- Have introduced the special case "uniform circular motion," where the acceleration is not constant. Specifically, for this motion:



$$\vec{r} = r(\cos\omega t\ \hat{i} + \sin\omega t\ \hat{j})$$

$$\vec{v} = \frac{d\vec{r}}{dt} = \omega r(-\sin\omega t\ \hat{i} + \cos\omega t\ \hat{j})\ \ (\perp \vec{r}\ \&\ \textit{tangent to the path})$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \omega^2 r(-\cos\omega t\ \hat{i} - \sin\omega t\ \hat{j})\ \ (\| \text{-} \vec{r}\ \&\ \textit{towards the path's center})$$

$$\textit{Also, because } v = \omega r$$

$$a = \omega^2 r = \frac{v^2}{r}$$

- Have introduced the concept of ***rotational kinematics***, the ***rotational equations of motion*** and have emphasized the correspondence between these and those above for ***xyz*** (rectilinear) motion:

$$\theta = \theta(t) \quad \textit{(the angular position is a function of time)}$$

$$\omega(t) = \frac{d\theta}{dt} \quad \textit{(angular velocity is the rate of change of angular position)}$$

$$\alpha(t) = \frac{d\theta}{dt} \quad \textit{(angular acceleration is the rate of change of angular velocity)}$$

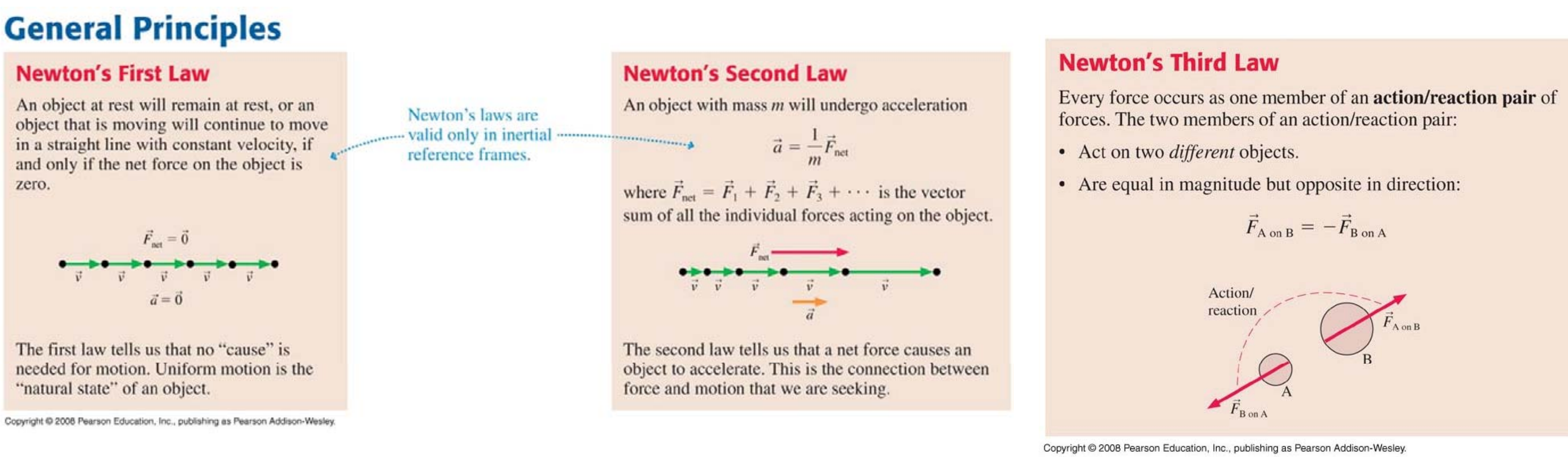
etc.

TABLE 4.1 Rotational and linear kinematics for constant acceleration

Rotational kinematics	Linear kinematics
$\omega_f = \omega_i + \alpha \Delta t$	$v_{fs} = v_{is} + a_s \Delta t$
$\theta_f = \theta_i + \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2$	$s_f = s_i + v_{is} \Delta t + \frac{1}{2} a_s (\Delta t)^2$
$\omega_f^2 = \omega_i^2 + 2\alpha \Delta\theta$	$v_{fs}^2 = v_{is}^2 + 2a_s \Delta s$

These lead us to the discussion of interactions that "cause" acceleration, or ***Forces.***

- **Assignment: Read Chapter 5 for an intuition-level discussion of forces.**
- For our working purposes, we need to know that
  - ***Force*** "causes" an object to accelerate;
  - The amount of acceleration is inversely proportional to the object's mass;
  - Mass is proportional to weight, but is not the same thing as weight;
  - Forces are vectors;
  - The object's acceleration is the ***vector*** result of ***ALL*** forces acting it.
- Also, from the nature of ***Forces,*** we can conclude that
  - If an object accelerates, the ***net force*** on it is non-zero;
  - If the ***net force*** on an object is non-zero, it will accelerate.
- Newton's 1st and 2nd laws describe the quantitative nature of ***Forces***:



Focus on Newton's 2^{nd} Law:

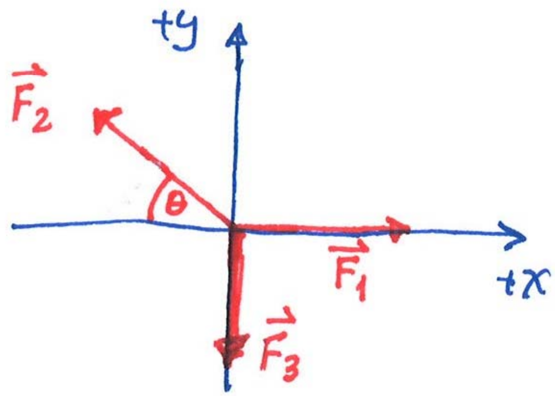
- The amount of acceleration is inversely proportional to the object's mass;
  - Mass somehow describes the amount of "stuff" in an object;
  - The international (SI) unit for mass is defined as the ***kilogram***;
  - From this, the units of force are the product (mass) x (acceleration), which gives the combination**: [F] = [mass] X [acceleration] = kg (m/s^2)**. This combination is named the ***Newton*** and is abbreviated by the symbol ***N***. In other words, 1 N is the amount of force that will accelerate 1 kg at the rate $1 m/s^2$.
- Mass is proportional to weight, but is not the same thing as weight;
  - So what is the difference between mass and weight? ***Mass*** is a basic property of an object while ***weight*** depends on the nature of ***gravity*** at its location. For example, this is why objects can become weightless in space and why an object weighs less on the moon than on earth. The object's mass isn't different, but the effect of gravity is different on the moon than on earth.
  - How does the ***pound*** fit into the mass picture? A pound is a measure of weight so that a pound is not a pound on the moon, for example. However, a kilogram is still a kilogram on the moon.
- Thus, weight is a specific force, that due to gravity:

$$W = mg, \quad \text{and 1kg } \textit{weighs} \text{ 9.8 N}$$

Working with Newton's 2nd Law:

An object of mass = 9kg has forces acting on it as shown in the sketch. F_1 = 9 N, F_2 = 6 N at θ = 30°, and F_3 = 12 N.

Calculate the object's acceleration:



$$\vec{\mathbf{F}} = m\vec{\mathbf{a}} \Rightarrow \vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}}{m} = \frac{\sum \vec{\mathbf{F}}}{m}$$

$$a_x = \frac{\sum F_x}{m} = \left(\frac{1}{m}\right)\left[F_{1x} + F_{2x} + F_{3x}\right]$$

$$= \left(\frac{1}{9\text{ kg}}\right)\left[+9 + 6\cos\left(150°\right) + 0\right]\text{N} = 0.423\text{ m/s}^2$$

$$a_y = \frac{\sum F_y}{m} = \left(\frac{1}{m}\right)\left[F_{1y} + F_{2y} + F_{3y}\right]$$

$$= \left(\frac{1}{9\text{ kg}}\right)\left[0 + 6\sin\left(150°\right) - 12\right]\text{N} = -1.00\text{ m/s}^2$$

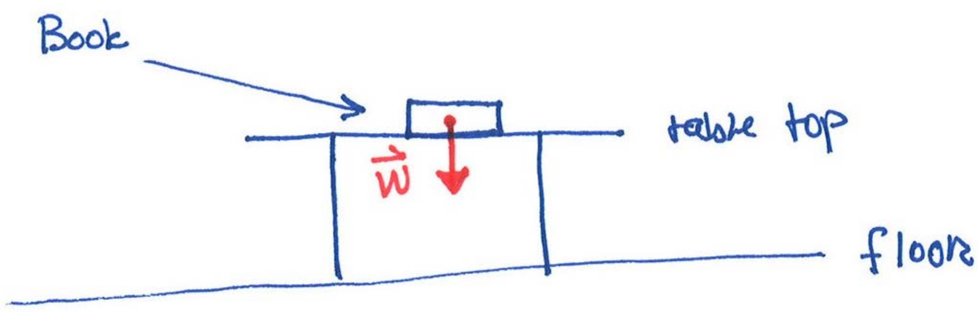
$$\vec{\mathbf{a}} = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}} = \left(0.423\hat{\mathbf{i}} - 1.00\hat{\mathbf{j}}\right)\text{ m/s}^2$$

$$= 1.09\text{ m/s}^2 \text{ @ } -67.1°\text{from} + x$$

Thus, the calculation comes down to finding the vector sum of the forces and then calculating the acceleration. The major challenge is to identify all the forces acting on the object.

Possible conceptual issues with forces:

- The term ***"Normal"*** force typically refers to one due to contact with another. ("Normal" in this case means "perpendicular to" and is not the opposite of abnormal!!)
- Friction is a force that arises due to contact between two objects and is directly related to the "Normal" force: ***the greater the force of contact, the greater the frictional force.***
- Force of contact: Why doesn't the book fall due to the force of gravity?



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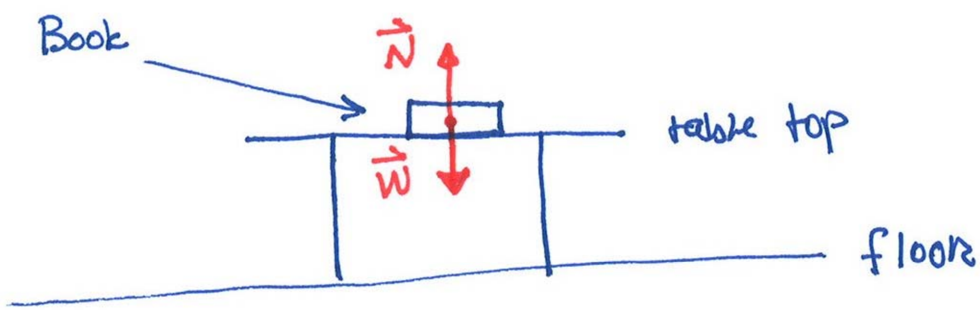
- Force of contact: ….Because the table supports it with an opposing force.



- Also, because a = 0 in the vertical direction (y-direction) for the book, we conclude that $\vec{\mathbf{N}} + \vec{\mathbf{W}} = \mathbf{0}$, and that the magnitude of N = W (=mg).

Assignment: Read Chapter 5 for an intuition-level discussion of forces.