AP Physics Review Sheet
Chapter 5: The Laws of Motion

AP Physics
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Background:

Motion, one of the most fundamental parts of mechanics, is described mainly by Newton's three laws of motion. This chapter introduces them and their meanings in mechanics.

Major Topics:

1. Force

   A force is something that "pushes or pulls on an object." It is the only way to cause motion in an object, though, if there are equal and opposite forces that cancel out, forces do not always have to cause motion.

2. Mass and weight

   Mass is a measure of the resistance to a change in motion that an object has. Alternatively, it is a measure of an object's inertia. Weight is the measure of the effect that the force of gravity of the Earth has on an object. Or, how much the Earth pulls on an object.

3. Newton's First Law

   Newton's first law of motion states that an object in motion will stay in motion and an object at rest will remain at rest unless acted upon by an outside force. This means that without any external force, an object will have no change in its motion, whether existent or zero.

4. Newton's Second Law

   Newton's second law of motion states that the net force acting on an object is equivalent to its mass multiplied by its net acceleration. This is represented by the equation:

   $$F_{net} = ma$$

5. Newton's Third Law

   Newton's third law of motion states that for every force exerted on an object, there is an equal and opposite force acting on the object that applied the force. This means that for every push or pull on an object, there is an opposite push or pull of an equal magnitude on the other object.

6. Free body diagrams

   Free body diagrams are a way to visualize the forces acting on an object. The diagram contains the object, usually a sphere representative of the object or a depiction of it, and vectors that show the direction and approximate magnitude of the force.

Formulae:

The only relevant formula for this chapter is the formula from Newton's second law:

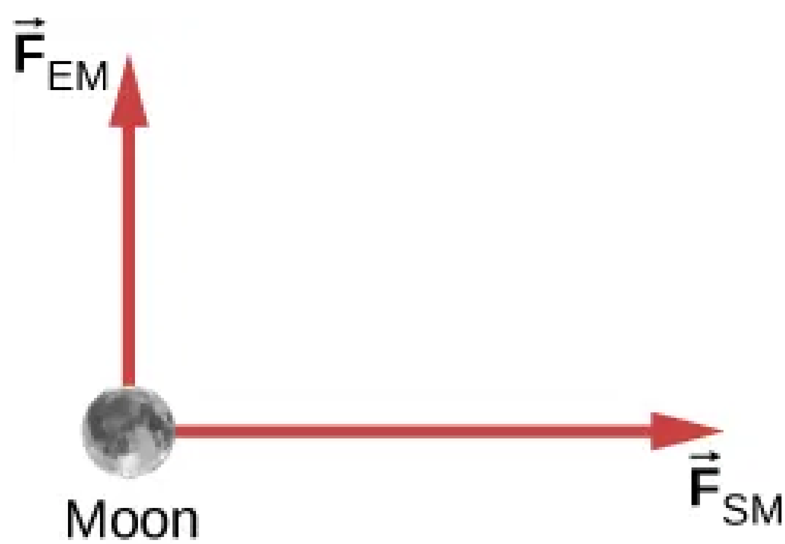
$F_{net} = ma.$

All other formulae are simple derivations of this (such as F_g and $F_\perp$).

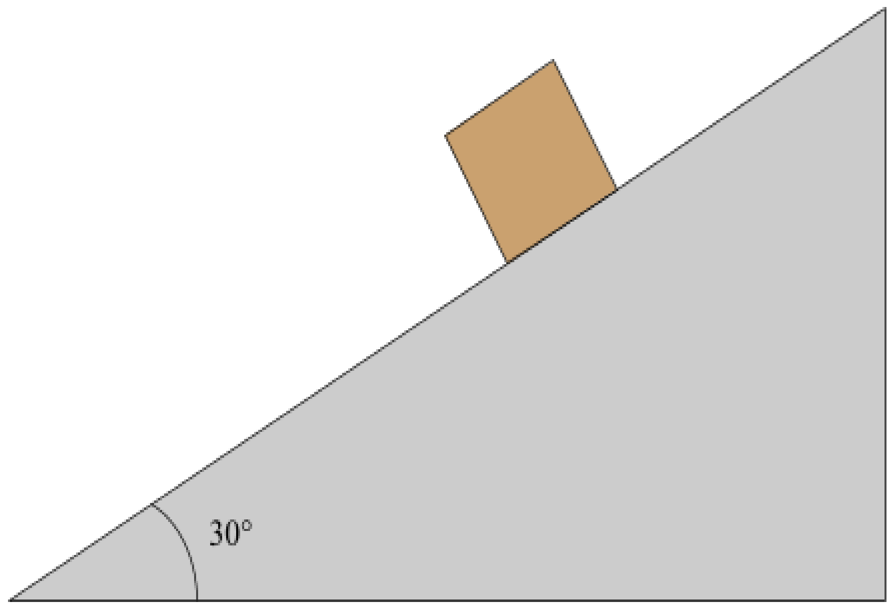
Practice Problems:

1. (Easy) A 70-kg sprinter takes off running, accelerating at 5 m/s^2. Calculate the force that the sprinter exerts and draw a free body diagram of all of the forces acting on the sprinter.

2. (Medium) When the Moon is directly overhead at sunset, the force by Earth on the Moon, F_{EM}, is essentially at 90° to the force by the Sun on the Moon, F_{SM}, as shown below. Given that $F_{EM} = 1.98 \bullet 10^{20} N$ and $F_{SM} = 4.36 \bullet 10^{20} N$, all other forces on the Moon are negligible, and the mass of the Moon is $7.35 \bullet 10^{22} kg$, determine the magnitude of the Moon's acceleration.



3. (Hard) A 2.0-kg block is on a perfectly smooth ramp that makes an angle of 30° with the horizontal. What is the block's acceleration down the ramp and the force of the ramp on the block?



Solutions:

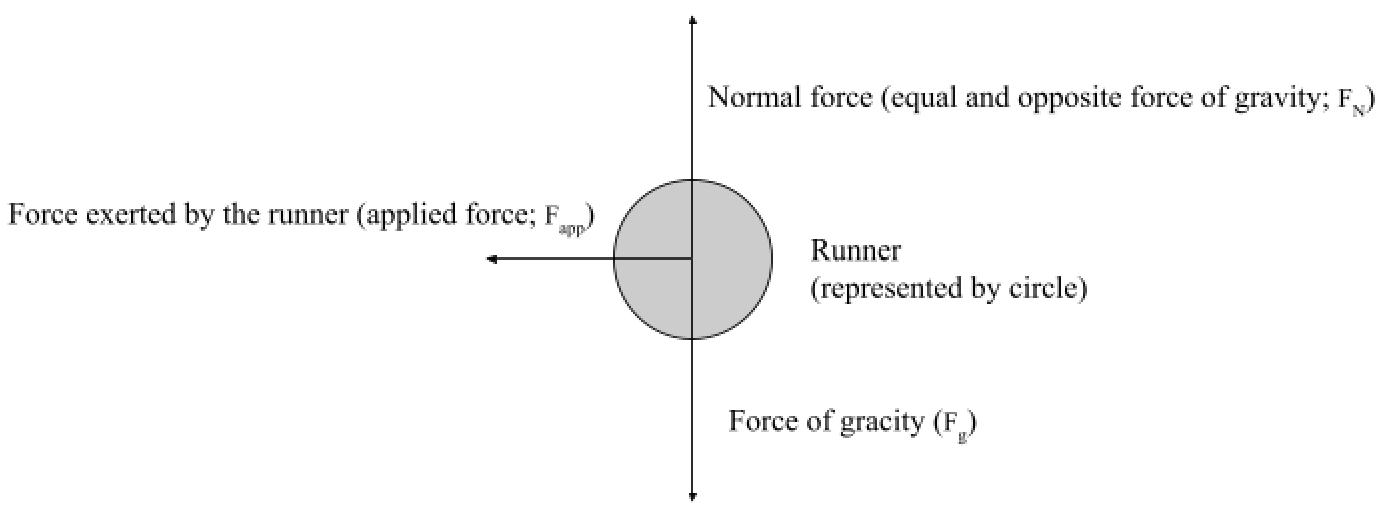
1. Given the formula:

$$F_{net} = ma,$$

we can calculate the force exerted by the athlete as such:

$$5\ m/s^2 \bullet 70\ kg = 350\ N = F_{net}.$$

Next, the free body diagram can be shown as such:



2. These two forces acting on the Moon give it a net force vector of:

$$F_{net} = 4.36 \bullet 10^{20}\,\hat{\imath}\ N + 1.98 \bullet 20^{20}\,\hat{\jmath}\,N.$$

With this and basic trigonometry, we can find the magnitude of the net force vector:

$$F_{net} = \sqrt{\left(4.36 \bullet 10^{20}\right)^2 + \left(1.98 \bullet 20^{20}\right)^2} = 4.79 \bullet 10^{20}\,N$$

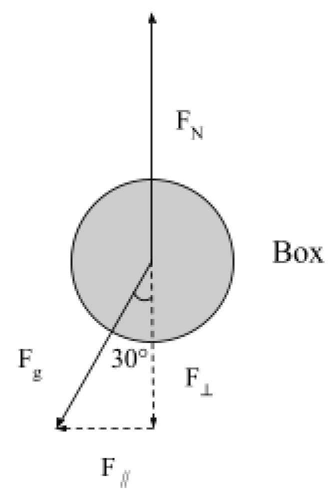
Next, with Newton's second law:

$$F_{net} = ma; \quad \frac{F_{net}}{m} = a$$

and the given mass of the Moon, we can calculate the acceleration of the Moon:

$$\frac{4.79 \bullet 10^{20}\,N}{7.36 \bullet 10^{22}\,kg} = 0.0065\,m/s^2$$

3. First, we must make a free body diagram with the appropriate component vectors to visualize the forces acting on the crate. Next, we must note that the F_N cancels out with the $F_\perp$, or the component of the force of gravity perpendicular to the acceleration of the object, leaving zero net force vertically and thus zero net acceleration. To find the horizontal acceleration, we must calculate the $F_{/\!/}$, or the component of the force of gravity parallel to the acceleration of the object. This is done by taking the horizontal, or parallel, component of the gravity vector using basic right-angle trigonometry and Newton's second law:



$$F_\parallel = F_g \bullet sin(\theta); \quad F_g = mg.$$

Combining these gives us our parallel component:

$$F_\parallel = mg \bullet sin(\theta).$$

Now, combining this with Newton's second law:

$$F_{net} = ma,$$

we find that:

$$ma = mg \bullet sin(\theta) \Rightarrow a = g \bullet sin(\theta)$$

If we plug in our values, we can arrive at our final answer of:

$$a = 9.81 \bullet sin(30°) = 4.91\,m/s^2.$$

The process is similar for the perpendicular force, which, as we know, is equal and opposite to the normal force, or the force of the ramp on the block:

$$F_\perp = F_g \bullet cos(\theta) \Rightarrow F_\perp = mg \bullet cos(\theta).$$

By plugging in our values for the final time, we find the force of the ramp on the block:

$$F_\perp = 2 \bullet 9.81 \bullet cos(30°) = 17.0\,N = F_N$$