Lesson 5 – Newton's Laws

Recap: Newton's three laws

I. Any object not under the influence of a *net* force will remain at rest or travel at constant velocity

II. Force acting on an object is proportional to its mass and acceleration. i.e. $\vec{F} = m\vec{a}$

III. Forces exist in action and reaction pairs. The reaction force is equal in magnitude but opposite in direction to the action force. The action and reaction force acts on different objects.

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0. What is the unit for force? After that, express it in terms of *kg, m* and *s*.

1. Draw a free body diagram for the following objects
   a. A box being pushed by a man **on rough ground**
   b. An ice hockey sliding across **an ice-skating rink**. (treat ice as frictionless)
   c. An object falling mid-air, under the effect of air resistance
   d. A car sliding down a slope
   e. The Earth and the sun (ignore effects of all other celestial bodies)
   f. A spacecraft flying through deep space with its engine turned off.

2. A rollercoaster, with mass 500kg has propellers along the track which gives it a force to accelerate forward.
   a. What is the *weight* of the rollercoaster?
   b. Suppose the rollercoaster accelerates uniformly at 9 ms^{-2} (nearly 1G), what is the force applied to the rollercoaster?
   c. Now suppose that we want an even more violent rollercoaster that accelerates at 18ms^{-2} (nearly 2G), what is the force that we need to apply to it?
   d. Of course our rollercoaster cannot go on forever, at the end of the track there are brakes which apply a 2500N force to decelerate the rollercoaster. Draw a free body diagram for the rollercoaster, indicating the direction of its velocity when it is being stopped.
   e. The rollercoaster enters the braking region with an initial velocity of 40 ms^{-1}. Suppose the braking region is 175m, is it long enough to bring the rollercoaster to a complete stop?

3. A steel ball falls through the air with no air resistance. A rubber ball falls along side it also without the effect of air resistance. (take g = 9.8 ms^{-2})
   a. What is the acceleration of both balls?
   b. Suppose both balls were originally dropped from rest at the same time, do they both reach the ground at the same time? If so, why is it so much more painful to be hit by the steel ball, despite both having the same speed on impact?

c. From now on we only consider the steel ball. The steel ball falls through air for 3s after being released from rest and enters a column of oil. First find the speed of the steel ball when it just enters the column of oil.
d. The oil provides a resistive force to the steel ball's motion. The resistive force is 90N, and the mass of the steel ball is 10kg. Draw a free body diagram and hence find the resulting acceleration of the steel ball while it is inside the column of oil.
e. How long does it then take for the steel ball to travel through the column of oil, which is 80m tall.

4. Explain the following phenomena with the use of action reaction forces

    a. We exert a backward force on the ground to walk forwards
    b. A rocket launches its fuel downwards in order to propel itself upwards
    c. Tides on the Earth (Hint: think about the moon)

5. We are now conducting crash tests on a new model of car.
    a. Brand A has created a car with a frame that is very rigid and does not get deformed during crashes while Brand B has created a car whose frame will crumple in crashes. Which car would you rather be in?
    b. Both cars A and B approach the obstacle at 30 kmh^{-1}. Car A, being very rigid, stops within 0.1s upon colliding with the wall while car B takes 0.64s to come to a complete stop. Find the acceleration (or deceleration) of both cars.
    c. Hence find the force exerted on our driver, who has a mass of 60kg under both scenarios.
    d. Answer question (a) again.