Section 2: Newton's second law

Exercise level 3 (Extension)

Where necessary, take $g = 10$.

1. The diagram shows an instrument called a spring balance. It works by hanging an object to the hook with the instrument firmly suspended from a bench or ceiling. The hook is connected to the instrument by a spring with a pointer attached which moves along the scale. When a supermarket chicken pack is suspended from the hook, the reading from the scale is 255.
   (i) What reading would you expect it to show if you repeated the experiment on the moon (where acceleration due to gravity is $\frac{g}{5}$)?
   (ii) What reading would you expect it to show if it were suspended from a fixed point of the ceiling of a lift compartment when the lift is accelerating upwards (on earth) at $\frac{g}{5}$ ms^{-2}?

2. A submersible of mass 900 kg and volume 1 m^3 falls into water and is found to descend 1 metre until it comes to rest. Assume that there is a buoyancy force equal to the weight of its displaced volume of water, and that resistance to downward motion owing to its flaps is constant.
   (i) What is the resistance to motion generated by the flaps if its speed on leaving the surface is 2 ms^{-1}? (The mass of 1 m^3 of water is 1000 kg).
   Once it reaches rest the flaps adjust automatically to give the same resistance to upward motion. At the same time it jettisons 100 kg of its mass.
   (ii) How soon does it reach the surface again and how fast is it travelling then?

3. A bus of mass 12 tonnes (including the driver) is powered by a diesel engine which drives through a four-stage torque convertor. When the driver's foot is fully depressing the accelerator in any stage the forward force is a constant $\frac{P}{2^n}$ kN, from moving off or entering that stage to reaching the engine's maximum governed speed, where $n = 1, 2, 3$ or 4 is the stage.
   At maximum speed in any stage, power automatically falls to zero to protect the engine. When the engine is at maximum governed speed in the first stage, the bus is travelling at 15.5 kmh^{-1}. The maximum speed in succeeding stages is 30.5 kmh^{-1}, 58.5 kmh^{-1} and 118.5 kmh^{-1}. The bus is streamlined so that a constant resistance model is considered appropriate.
   The bus takes 5 seconds to reach maximum speed from rest in the first stage. The second stage takes over immediately at that threshold, whereupon the bus accelerates to the second threshold value of 30.5 kmh^{-1} and takes a further 10 seconds to do so.
   (i) What value should be assumed for the resistance in this model?
   (ii) How long does it take to reach its maximum speed of 118.5 kmh^{-1}?
   (iii) Comment on the assumption that resistance is constant.