NCEA Level 2 Physics, assignment on energies

Note. Some of these questions may appear to give less information than you think you need. Nonetheless, they are all possible! This is illustrative of the power of energy conservation as a tool. You will find it particularly useful, for each scenario, to begin by thinking about any forces that are acting and any energy changes that are taking place. Diagrams are often helpful; as well as pictures of the scenario and force diagrams, you might also want to draw rough flowcharts showing energy changes.

1. Describe as many energy changes as you can that are associated with an aeroplane during a flight, from the moment the doors close at one airport to the moment the doors open at the destination. *Do not perform any calculations.* (Hint: every time a force acts, there is an energy change going on.)
2. Suppose I have a spring of (unstretched) length 5.00 cm.
   (a) I hang my spring vertically, so the top is fixed and the bottom is free to move up and down; I hang a 100 g mass on the bottom. The new length of the spring is 6.50 cm.
      i. Draw a diagram showing both forces acting on the hanging mass. Given that the mass is not accelerating (it is stationary), what can you say about these two forces?
      ii. Show that the spring constant of the spring is $k = 65.4\,\mathrm{kg\,s^{-2}}$.
   (b) Suppose now I align the *same* spring horizontally, with the *same* mass still attached at one end and the other end fixed. The mass is lying on a frictionless surface and is free to move backwards and forwards. I pull the mass a distance 3.00 cm from its resting place, stretching the spring; I then let the mass go.
      i. Draw a diagram showing the direction of the forces on the mass and the velocity of the mass at various points in time. (Hint: the only force acting is the elastic force, and it always acts in the opposite direction to the velocity.) In particular, note on your diagram the point where the velocity of the mass is largest.
      ii. Show that the maximum velocity of the mass is $4.43\,\mathrm{m\,s^{-1}}$.
3. Petrol, as used in cars, has an energy content of roughly $46.7 \times 10^6\,\mathrm{J\,L^{-1}}$.*
   (a) A car (mass 1350 kg) accelerates smoothly from rest to a speed of $50\,\mathrm{km\,h^{-1}}$. Assuming that only negligible energy is lost to friction, how many litres of petrol did the car burn? (You should obtain a number that is very small. One litre of petrol has a rough mass of 1 kg, so the amount of mass lost by burning the petrol is very small compared to the total mass of the car, and so we don't need to take it into account.)
   (b) The car travels in a straight line for 100 kilometres, at a constant speed of $50\,\mathrm{km\,h^{-1}}$ (i.e. it does not accelerate at all); it burns 5.3 L of petrol.
      i. Assuming that the only energy loss is due to friction, how much energy is converted from chemical energy to heat and sound energy by the friction force? (In other words, how much work does the friction force do to the car?)
      ii. Assuming the friction force is constant, calculate its magnitude.
      iii. The engine cuts out suddenly. How long does it take for the car to coast to a halt?
4. Two toy cars are initially moving in the same direction at different speeds. One has a mass 100 g and is moving at a speed $1.0\,\mathrm{m\,s^{-1}}$, the other, behind it, has a mass 50 g and is moving at a speed $2.0\,\mathrm{m\,s^{-1}}$. When the faster car catches up and the two cars collide, they stick together and move as one mass.
   (a) Using conservation of momentum, show that the final speed of the clumped cars is $1.3\,\mathrm{m\,s^{-1}}$.
   (b) Show that kinetic energy is *not* conserved in this collision. How much kinetic energy is lost during the collision?
   (c) Explain why we have not just disproved the law of conservation of energy.

*This is something that one would measure in chemistry: if you have done the level 2 chemistry topic on chemical reaction rates, this is the standard enthalpy of combustion of petrol. It can be measured by burning a set amount of petrol under a beaker containing water and measuring the temperature change of the water. As physicists, we just care what the number is, not the way we get it!

Useful facts

Newton's laws

1. If the total force on an object is zero, then the object has no acceleration (its speed and direction of movement are constant).
2. The acceleration felt by an object of mass m when acted upon by a force F is $a = F/m$. Equivalently, if a constant force F acts for a time t on an object then the change in momentum is $\Delta p = Ft$.
3. If an object A exerts a force on an object B, then object B exerts an equal and opposite force on object A.

Force laws

- Gravity: $F = mg$, towards the centre of the earth.
- Elastic (Hooke's law): $F = kx$, opposing the displacement.

Other forces: normal, friction/air resistance, electromagnetic, ...

Conservation laws

- In a closed system (i.e. a system where no external forces act), the total momentum is conserved.
- In a closed system (i.e. a system where no external forces act), the total energy is conserved.

Energy laws When a force F acts over a distance d, the energy transferred is $W = Fd$.

- Gravity potential: $\Delta E = mg\Delta x$.
- Elastic potential: $\Delta E = \frac{1}{2}kx^2$.
- Kinetic: $E_K = \frac{1}{2}mv^2$.

Other types of energy: heat, light, sound, electromagnetic, rotational kinetic, ...