NCEA Level 2 Physics, final mechanics assignment

This assignment is entirely made up of questions that cover precisely the material that you **need** to know for the mechanics topic. Thus, unlike the earlier assignments, I expect this one (a) to requre less deep thinking on your part, and (b) to be done completely. It is a little longer than the other assignments as well: since none of the questions should require any clever thinking, you should be able to get through them faster than normal.

Several of the questions ask for explanations; what you are being marked on is clarity and understanding. That is, you need to write clearly and precisely (using correct English grammar, and with minimum waffling).

Example. *State the law of conservation of momentum.* The law of conservation of momentum states that if no external forces act on a system then the total momentum of the objects in that system does not change.

Draw diagrams and explain your reasoning!!!

Part A

Short answer questions — you should be able to do all of these without too much thought. If you find any of them difficult, please let me know so we can revise the relevant material.

1. A stone is thrown straight up with an initial speed of $20\,\mathrm{m\,s^{-1}}$. If the only force acting on it is gravity:
   (a) How high does the stone go?
   (b) How long does it take to reach that maximum height?
2. How large a horizontal force must be exerted on a $920\,\mathrm{kg}$ car in order to give it an acceleration of $3.0\,\mathrm{m\,s^{-2}}$ along a flat road, assuming that friction is negligible?
3. What net force must act on a $950\,\mathrm{kg}$ car to accelerate it from rest to a speed of $60\,\mathrm{km\,h^{-1}}$ in $8.0\,\mathrm{s}$?
4. State the law of conservation of energy.
5. A piano, mass $270\,\mathrm{kg}$, is dropped from a window $12.0\,\mathrm{m}$ above the ground.
   (a) What speed is it travelling when it hits the roof of a car $170\,\mathrm{cm}$ above the ground?
   (b) What is the momentum of the piano at the instant of impact?
   (c) How long did the piano take to fall?
6. It is found experimentally that a force of $4.9\,\mathrm{N}$ is needed to extend a spring by $0.05\,\mathrm{m}$ from its equilibrium position. The spring is then hung vertically with an unknown mass attached to the end, and the extension from equilibrium length is measured to be $27\,\mathrm{cm}$. Assume the spring is massless.
   (a) Draw a force diagram, showing all the forces acting on the mass.
   (b) What is the size of the mass?
7. A merry-go-round is observed to take $360\,\mathrm{s}$ to complete a full rotation. The radius of the merry-go-round is $5\,\mathrm{m}$.
   (a) Zavana is sitting on the edge of the spinning disc. How fast is she travelling?
   (b) Calculate the centripetal force felt by Zavana, if she has a mass of $65\,\mathrm{kg}$.

Part B

Long answer questions — in order to pass this standard at merit/excellence level, you must be able to do all of these problems.

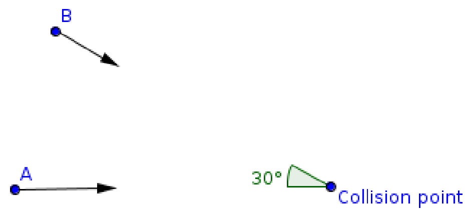
1. *Circular motion.* The earth is orbiting the sun at a constant speed, in a roughly circular orbit.
   (a) Explain, with physical arguments, why the net force on the earth must be directed towards the centre of the sun.
   (b) The earth has mass 5.97×10^{24} kg, orbits the sun once every year (365.25 days), and is on average a distance 1.496×10^{11} m from the centre of the sun. Calculate the strength of the gravity force exerted **on the earth** by the sun.
   (c) What is the strength and direction of the gravity force exerted **on the sun** by the earth?

2. *Energy.* Many swimming pools have diving boards. Suppose such a board is fixed at one end, and the board is flexible (so if a person sits on the end it bends down). Mark (mass: 74 kg) is sitting on the end of a diving board, 2.0 m away from the fixed pivot point. We can model the end of the flexible diving board as a spring that roughly follows Hooke's law.
   (a) State Hooke's law.
   (b) If the end of the diving board has dipped down by 2.5 cm from the horizontal, calculate the spring constant of the board.
   (c) Mark jumps into the air and lands back on the board; the board is now dipping 3.4 cm from the horizontal. How high **above the equilibrium point of the board** did Mark jump?
   (d) Some of the energy which enabled Mark to jump to this height came from the elasticity of the board. How much **additional** work K did Mark have to do in order to reach this height?
   (e) Mark now jumps again, this time landing in the water. He is travelling at a speed of $20\,\mathrm{m\,s^{-1}}$ when he hits the water. Assuming that the energy which enabled this jump came from the two same sources as before — the elastic energy of the board and a new input of energy K by Mark — calculate the height of the equilibrium point of the board above the water.

3. *Forces.* I pull a trolley of mass 20 kg along the ground at a constant speed of $5\,\mathrm{m\,s^{-1}}$. The handle of the trolley makes an angle $30°$ with the horizontal.
   (a) State the magnitude and direction of the **net** force on the trolley. Explain your answer.
   (b) Calculate the magnitude of the tension force in the handle of the trolley.
   (c) How much work do I do in pulling the trolley a distance of 50 m along a flat surface?

4. *Torques.* A rod, of mass 500 g, is pivoted at a point $\frac{2}{5}$ of the distance from one end and is free to rotate about this point.
   (a) If the rod is horizontal at a given instant, calculate the torque about the pivot point due to the rod's own mass.
   (b) In order to keep the rod balanced horizontally, a mass of 30 g is hung at the short end of the rod. What is the length of the rod?

5. *Collisions.* Two toy cars A and B, travelling at constant speeds, with respective masses 300 g and 200 g, approach each other at an angle of 30° as depicted here.



The two cars collide and stick together, moving off together as one unit with speed $1.932\,\mathrm{m\,s^{-1}}$.

(a) Draw a vector diagram depicting the conservation of momentum.

(b) Car A was originally travelling at a speed of $1.67\,\mathrm{m\,s^{-1}}$. What was the initial speed of car B?

(c) Show that the collision was inelastic (i.e. kinetic energy was **not** conserved).

6. *Projectiles.* A tennis ball is fired from the roof of a 10 m tall building at an angle of 20° to the horizontal with an initial velocity of $20\,\mathrm{m\,s^{-1}}$.

(a) Explain in detail what assumptions we make in order to model the ball as a projectile, and justify whether these assumptions are reasonable.

(b) Calculate the following:

- The maximum height above the ground reached by the ball.
- The vertical speed with which it is travelling when it hits the ground.
- The time taken to hit the ground.
- The range of the ball (i.e. the horizontal distance it travels before it hits the ground).