The design criterion in physics internal assessment

Aspect 1 of the design criterion requires students to formulate a focused problem or research question and to identify independent and dependent variables, and relevant controlled variables. It is essential that the teacher gives the student an open-ended prompt. The topic must allow for a variety of different approaches.

There are two types of appropriate teacher prompts.

- The first is where the **dependent variable is given** and the student must select the independent variable as well as appreciate the controlled variables. An example here is when the teacher tells the student to investigate one factor that affects the deflection of a cantilever.
- The second type of prompt is where **neither the dependent nor independent variables are given**. An example of an open-ended teacher prompt would be “Investigate a leaking can of water”. The student must identify and select the variables. Some variables in this example include the liquid depth, temperature or viscosity, the can size, shape or location, the time to drain the can, the distance the water squirts, the air pressure above the liquid level, and so on.

A student’s research question is appropriate when it asks for a **relationship** or **function** between two quantities, for example, “How does the length of a pendulum relate to the period?”

Inappropriate research questions often look for a specific value, for example, “What is the value of gravity?” or “What is the specific heat capacity of an unknown liquid?” Teacher prompts that ask for the verification of a known law or theory are also inappropriate, for example, “Confirm Newton’s second law of motion” or “Verify the equation $PV = nRT$”. Teacher prompts that give both the dependent and independent variables are also inappropriate, for example, “Investigate the relationship between the period of a pendulum and the length of the pendulum”.

Examples of appropriate teacher prompts

Here is a list of appropriate teacher prompts for aspect 1 of the design criterion, and a possible student research question response. Students must carefully define the variables and appreciate the controlled variables.

Batteries and lemons

Electrical cells can be produced using lemons or potatoes, along with electrolytes and electrodes of different metals. Investigate the factors affecting the voltage produced by such a cell.	
Dependent:	The dependent variable is given.
Student might ask:	How does the spacing between electrodes affect the voltage?

Bicycle stopping

Investigate one factor that affects the stopping distance of a moving bicycle.	
Dependent:	The dependent variable is given.
Student might ask:	How does the total weight of the bike relate to the stopping distance?

Big splash

Investigate the splash of water when a ball falls into a bucket of water.	
Dependent:	The dependent variable is given, but only in a vague way. The student must define what a “splash” is.
Student might ask:	How does the drop height of a ball affect the range (as measured from the centre of the bucket) of the water splashing out?

Bouncing ball

Investigate some physical property of a bouncing ball.

Dependent:	Students must decide on the dependent and independent variables here.
Student might ask:	Is there a constant relationship between the drop height and the rebound height over a reasonable range of drop heights?

Bungee jumps

Bungee jumping can be simulated in the laboratory in different ways. Investigate one factor that affects the bungee jump.	
Dependent:	Students must not only decide on the dependent and independent variables, but also define clearly what the variables are.
Student might ask:	How does the maximum rebound height of a bungee jump depend on the length of the elastic string?

Cantilever deflection

Investigate one factor that affects the declination of a cantilever.	
Dependent:	The dependent variable is given.
Student might ask:	How does the hanging mass at the end of a cantilever affect the declination?

Cantilever oscillation

Using a hacksaw blade, investigate one factor that affects the oscillation of the blade.	
Dependent:	The dependent variable is given.
Student might ask:	How does the period of oscillation depend on the length of the blade?

Catapult

Investigate one variable affecting the range of a toy catapult.	
Dependent:	The dependent variable is given.
Student might ask:	How is the range of a catapult’s projectile affected by the mass of the projectile object?

Coffee and milk

Investigate the effects of mixing cold milk with hot coffee.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between the cooling rate of coffee and the amount of milk added?

Conductive paper

Investigate some electrical property of conducting paper.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between the effective resistance of a square of conducting paper and the paper’s total surface area?

Craters

In the laboratory, a ball can be dropped into a box of sand or modelling clay. Investigate the formation of craters.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between the depth of a crater and the drop height of a ball?

Dominoes

Investigate the domino effect with a set of dominoes.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between spacing of consecutive dominoes and the effective speed of the domino effect?

Drinking fountain

Investigate one factor affecting the distance travelled by the water from a rubber tube connected to a tap.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the water range and the water pressure?

Electric motor

Investigate one factor that affects the efficiency of a small electric motor.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the load on an electric motor and its efficiency?

Electrical play dough

Investigate an electrical property of a chunk of play dough.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between the diameter of a cylinder of play dough and its resistance?

Electromagnetic strength

Build an electromagnet and investigate one factor affecting its strength.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the current in the electromagnet and the number of paper clips that the electromagnet can hold?

Evaporation

Investigate factors affecting the rate of evaporation.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the surface area of a container of water and the rate of evaporation?

Fluid resistance

Fluid resistance can be studied in the laboratory with different fluids and small balls falling through them. Investigate one factor affecting the terminal speed of balls falling through a liquid.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between terminal speed and the temperature of a given fluid?

Margarine tub

Investigate one factor affecting the distance travelled by a weighted margarine tub when it is propelled along a

runway.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the mass of the tub and the distance travelled?

Paper helicopter

Construct a paper helicopter by cutting paper into a “T” shape, folding over (in opposite ways) the hat (blades) of the “T”, and adding a paper clip. Investigate some property of the toy helicopter.	
Dependent:	Students must define all the variables and look for a relationship.
Student might ask:	What is the relationship between the helicopter blade area and the time it takes to drop a given height?

Pool depth

Submerge balls of various sizes to the bottom of a swimming pool. Investigate any relationship between some physical property of the ball and the time it takes to rise back to the surface.	
Dependent:	The dependent variable is given.
Student might ask:	What is the relationship between the size of a ball and the time it takes to rise up to the surface?

Slinky spring

Investigate the oscillation of a toy slinky spring.	
Dependent:	The dependent variable is given.
Student might ask:	How does the period of oscillation relate to the number of slinky turns?

Example of a design experiment

Teacher prompt: “Investigate the domino effect using a set of dominoes”

The teacher shows the students the domino effect by lining up a number of dominoes and then lightly pushing the first one, so producing the domino chain reaction. Students have studied mechanics and waves. This is an open-ended investigation where the students must decide on both the dependent and independent variables.

Students would satisfy **aspect 1** of design (defining the problem and selecting variables) if they:

- state a clear research question, for example, “How does the separation between a fixed number of dominoes affect the time it takes for all the dominoes to fall?”
- identify the relevant variables correctly, for example, the dependent variable as the pulse speed or time to fall, the independent variable as the separation of the dominoes, and the control variables as the number of dominoes and the surface upon which the dominoes rest.

Under **aspect 2** of design (controlling variables) students would earn a “complete” if they addressed the following.

- The method of starting the domino motion: for example, a student might use a small inclined plane of fixed length and roll a ball down the incline in order to hit the first domino with the same impulse for the various trials of the experiment.
- A method for timing: for example, a student might use two photo-gate timers, one at the start and one at the end of the domino chain, which would be activated by a falling domino. The timer would start when the first domino moves and stop when the last domino moves. They could also just use a stopwatch.
- Standardization: students would explain how they would keep the domino chain in a straight line.
- Details of controlling the independent variable: there should be discussion as to how the distance between the dominoes is altered and how the distance between consecutive dominoes is made the

same for each trial. This would involve stating the two points between which the separation is measured.

- A list of materials: this would include a box of dominoes, photo-gate timers or stopwatch, a ramp and small ball for the incline, a metre rule to keep the domino chain at a constant 2.00 m length, and a 30 cm rule for measuring domino separation.

Under **aspect 3** of design (developing a method for collection of data) students would earn a “complete” if they addressed the following.

- Repeated measurements: students would realize that repeated measurements for the same domino separation are required. An average time would then be calculated.
- Scope and limit: students would realize that the minimum separation of the dominoes is when they are touching, face to face, that is, zero separation. Students would also realize that there is a maximum separation that is more or less equal to the height of a domino. Students would ensure that a suitable range of values is chosen between these limits.
- Changing the number of dominoes one at a time allows for ample data within the allowed range.