Developing New Superhero/Villain Characters for Teaching Activities

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Abstract. Superhero themes have been increasingly used in the teaching of a range of topics including business, humanities and science in recent years. Typically, characters from existing popular media are adopted for the teaching activities. On the other hand, customised characters that are developed from scratch allow the educator to have more control of the characters' features so that the learning objectives can be achieved more effectively. In this work, new fictitious characters have been created as cases for students to perform their engineering materials selection assignment. The motivation for using the superhero theme was to increase the students' excitement in the assignment. This paper shares the approach taken and the teaching experience after running the superhero theme with two cohorts of students.

> "*They don't match any artefacts from our codex. What do you think?*
> *I'm not sure. They're not vibranium. Chitauri?*
> *How long did your dad have them before he gave them to you?*
> *Um… About a thousand years.*
> *Their thermoluminescence indicates they're older than that. By a lot*."
>
> Extracted from *Shang-Chi and the Legend of the Ten Rings* (Feige & Schwartz, 2021)

Superheroes/villains narratives have been widely used as case studies or teaching themes in a wide range of disciplines. Particularly in business and humanities pedagogy, superheroes have been used to teach issues such as ethics (Burton, 2008; Gerde & Foster, 2007), economics (Knudsen & Duncan, 2018; O'Roark, 2017), sociology (Hall & Lucal, 1999) as well as racial and gender discrimination (Cho & Johnson, 2020). The ability to transcend "normal" human powers has been used to instigate discussion on human anatomy, physiology, genetic engineering and wearable technologies (Brown et al., 2017; Fitzgerald, 2018a; Zehr, 2008, 2011). Sabín et al. (2008) developed comic characters to introduce elementary aspects of quantum physics and the quark model while Fitzgerald (2018b) proposed using superheroes such as Hawkeye, Wonder Woman and the Invisible Woman to teach physics concepts in the classroom. Full teaching modules or courses based on superhero themes have also been created (e.g., Peppard, 2020; Pflueger-Peters, 2021; Robichaud, 2013; Treat, 2009; Wolpert, 2019). Grachan & Quinn (2021) described how the Ohio State University–Columbus campus developed a superhero-based introductory anatomy and physiology course called "SuperAnatomy," where elements of superheroes were embedded through the course.

There are a few reasons why superheroes are used to enhance the teaching and learning experience. First, they offer a visual portrayal of the application of abstract theories and concepts in situations that can be related to reality (Champoux, 1999). Second, superheroes are culturally popular and students most likely already have a

base understanding of and interest in them (Grachan & Quinn, 2021). In fact, superhero themes are often used by organisations for promotional activities, an example being the UNICEF's global campaign to #ENDviolence in schools (Rahimi, 2019). Third, when students role-play the characters, they are using metaphors through which they can enhance their existing ways of thinking and possibly transform their new knowledge into behaviour (Burton, 2008). Fourth, the diverse stories that superheroes are told allow for opportunities to connect to a wide range of topics, from humanities to science and technology (O'Roark, 2017). These stories lend themselves easily to case-based or simulation-based teaching since their depth can be easily tuned. The stories can also be used to substitute real experiences with guided ones that induce or reproduce substantial aspects of real work situations (Duchatelet et al., 2022).

In science and engineering courses in particular, students need to have a greater level of engagement in the subjects and to appreciate how science can impact their lives (Grachan & Quinn, 2021). Whilst introducing active learning strategies in the classroom can help increase student engagement (Prince, 2004), it is equally important that the technical content is grounded in accurate scientific laws and principles. In superhero stories, however, there is no limit to what characters can do: "bodies perform impossible feats of strength, explode into flame, dissipate into vapor, flow like water, morph into animals, merge with machines, and perhaps most resonantly, defy the law of gravity, soaring effortlessly into the heavens" (Saunders, 2011, p. 3). Indeed, the delineation between science and fiction of superheroes has been explored in a number of publications (e.g., Kakalios, 2019). Thus, the incorporation of superhero themes into science and engineering classrooms requires creativity on the part of the educator to balance the excitement with what is scientifically acceptable. This is so that students can more effectively connect science to personal experience and address scientific misunderstandings (Matuk et al., 2021).

Teaching Engineering Materials Selection

One could have mistaken the conversation (minus the "thousand years") in the prologue to have taken place between materials scientists or engineers. Instead, the conversation was enacted at the final scene of the movie *Shang-Chi and the Legend of the Ten Rings* (Feige & Schwartz, 2021), where the superheroes were gathered around a holographic projection of an unknown material. Indeed, materials have played a significant role in the Marvel universe, and their history, sources, properties and applications have been documented extensively (Marvel Database, 2021). Recent movies in the Marvel series have included scenes portraying elements of materials science, such as the creation of a new element by Tony Stark in *Iron Man 2* and the casting of Thor's axe in *Avengers: Infinity War*.

The use of powerful armoury and extraordinary abilities in superhero stories provides an opportunity to bring the superheroes theme into a materials engineering course. Whilst literature on the science of superheroes makes reference to a range of scientific principles, much less has been written specifically about the materials engineering aspects of superheroes and the tools they work with. In this article, I would like to share the creation of new superhero/supervillain characters to teach engineering materials selection in mechanical engineering programmes. Although existing characters in popular media could have been adopted in class, the creation of new

fictitious characters allowed for customisation to suit the intended le arning outcomes. The link between the characters and the learning outcomes is important as it differentiates between any other activity with one that focuses on the task of learning and whose learning outcomes are explicitly identified (Sauvé et al., 2007). Furthermore, it is important that the pedagogical approach be designed to guide and help students gain the skills to critically analyse the relevant points of interest (Cook & Frey, 2017). In this case, by restricting the students to use real materials, their experiential understanding of what an actual engineer does is anchored in the practical world despite the fantasy theme.

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Module Information

I have been involved in delivering a common first year, second trimester module called Material Selection for Engineering Structures (hereafter referred to as the "materials module") within two Mechanical Engineering based programmes. The materials module has been delivered since 2015 to the first cohort of students in both programmes. Like many other introductory materials science and engineering modules in engineering programmes (e.g., Qamar et al., 2020), the materials module is generally more descriptive than other mathematical-based modules. The major assessment components include quizzes, laboratory assessments and a final examination.

In engineering processes, selecting the right materials that meet the functional and design requirements is an important step, and this competency is important for students to learn. In the materials module, the learning outcome for this competency is assessed through a team project assignment. The assignment has a weightage of 25% of the total grade.

Before the superhero theme was introduced, the engineering systems used for the assignment were similar to those that the students had studied in a prior solid mechanics module. These systems, like a scooter or a trolley, require relatively simple stress analysis such as bending, bearing, shear and axial stresses. Since the systems contain a number of components, each member of a team could work on a different component.

While systems like the scooter or the trolley provide manageable, real-life examples for students to work on, they did not exactly increase the excitement level. In the search for "experiences that are both academically challenging and creatively engaging" (Burton, 2008, p. 2), a superhero theme was thus explored. The idea was initiated during the Covid pandemic, since students had to rely significantly on electronic gadgets during lessons. The prevalence of such gadgets has been associated with a growth in mobile games (e.g., Wang et al., 2019) and quite a number of such games involve players playing with and developing their heroes. Furthermore, the recent series of Marvel movies has also increased the exposure to the superheroes theme, as the series "will keep 'on trending' in social medias, people's daily talks and other fields in daily life, …especially in the youth groups" (Zhu et al., 2021, p. 694).

Hence, I believed that a superhero theme would pique the interest of the students in an otherwise rather staid assignment.

Material Selection Assignment

For the assignment, the students were divided into four-member teams. Briefly, each team was required to report on the material selection for four chosen characters, and each character was to be analysed by a separate team member. For each selected material, a simplified Mill Test Certificate was to be completed and submitted. The selection matrix would be based on the methods taught in class, such as the Pugh method or the weighted performance index method (Farag, 2006). Together with other information such as the metal grade, the chemical composition, values of relevant properties and typical microstructure, the students had to fill in and submit a simplified Mill Test Certificate for each chosen character. The purpose of the Mill Test Certificate was to expose students to actual practice where metals are supplied together with an accompanying Mill Test Certificate. The students were given approximately five weeks to finish the assignment. No dedicated workshop or discussion sessions were allocated, although students were free to consult about the project. The full description of the assignment can be found in the Appendix.

Story Structure

The assignment was set against a brief story so that students could role-play their tasks. The story was prepared based on the Hollywood Three-Act structure (Novak, 2011). The story at the Beginning (Act I) provided some background events about new superhero/villain characters being created. In the Middle of the story (Act II), the "complication" about materials selection was introduced, which led to the End (Act III) where the students had to resolve the "complication."

Character Development

Egri (1972) proposed a checklist called a "bone structure" to define a character – the bone structure has three dimensions: physiology, sociology and psychology. The physiology dimension defines the physical make-up of the character and influences how the character approaches the world. For example, a tiny character can squeeze through the keyhole of a door, but a large character needs to move through the whole doorway opening. The sociology dimension is related to the environment and background of the character, while the psychology dimension, being the product of the other two dimensions, is related to the attitudes and mental state of the character.

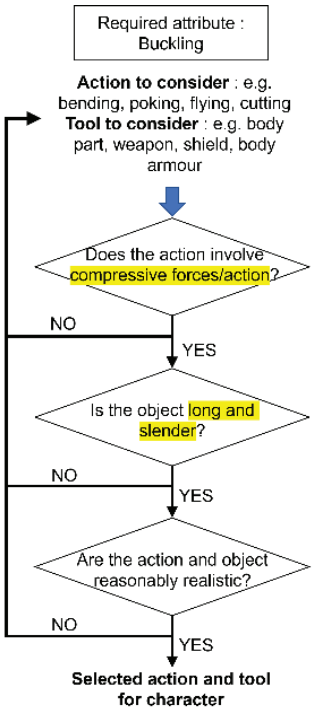
For the assignment, the new characters were developed mostly on the physiology dimension and for some cases, on the psychology dimension (e.g., likings). Egri (1972) listed a few items to be considered for the physiology dimension: sex; age; height and weight; color of hair, eyes and skin; posture; appearance; defects; heredity features. Most of these items were not critical for the assignment, but each character had an embedded key attribute that was intentionally designed to be related to a unique engineering property.

Lankoski (2004) suggested that each character should have a goal (of the actions) and as a result, conflict and action will arise. An iterative process was therefore

applied to each character to determine what action could be associated with the character and how conflict might arise from the action. The conflict would then require the consideration of the relevant attribute in the materials selection process.

Figure 1 shows an example of such a consideration for the buckling attribute, which requires the application of axial compressive forces on long, slender bodies. Various parts of the character may be considered for buckling; for example, the character may have a tall and slim body shape. However, having a tall and slim body shape as well as being compressed do not quite form a reasonably realistic phenomenon or utility. Hence, after the iteration process, a rod used for poking action was selected. Further description, in association with the poking action, was then added to provide a short background of the character. In addition, the required task that needs to be worked upon by the students was also included. Overall, the complete description was crafted to carry a degree of ambiguity so that students needed to exercise some judgement and assumptions in their analysis. Material selection is typically an open-ended process (Leary, 2011) and it is important that the students' tasks embrace the open-ended nature of the process. Lastly, a short name was assigned to the character.

Figure 1



Note. Iterative process to determine the action and tool that would be relevant to the key attribute of each character. The highlighted criteria may be swapped for different attributes. In this case, the example is shown for Pokedot whose key attribute is to resist buckling and buckling tends to occur due to compressive forces in long, slender objects.

After running the assignment over two cohorts, eight characters have so far been developed:

- Pokedot – ability to prevent buckling
- Mallea – ability to undergo large plastic deformation without breaking
- Shash – ability to resist crack propagation
- Vibrash – ability to withstand fluctuating stresses
- Jowel – ability to cut without yielding or breaking
- HeatKO – ability to maintain properties at high temperatures
- Nitrog – ability to withstand nitric acid corrosion
- Cryom – ability to maintain properties at low temperatures.

The list of unique properties is not exhaustive and other new characters may be introduced. The descriptions of the characters are found in the Appendix while that for Pokedot is shown here:

> Pokedot may seem small and cute, and its thin, long rod seems, at first instance, to be a utility tool for Pokedot to reach for greater heights. But don't let its appearance fool you. Pokedot has mastered the action of thrusting with the long rod that no other creature has ever done. Thrusting with the long rod (or poking – as what Pokedot fondly refers to) breaks all things that come into contact with the tip of the rod. Nothing gets near Pokedot without coming into force with the poking rod—making Pokedot a commanding melee superpower!
>
> Select a material to make Pokedot's rod. The rod has a dimension of 2 metres with a diameter of 20mm. The tips of the rod must be hardened.

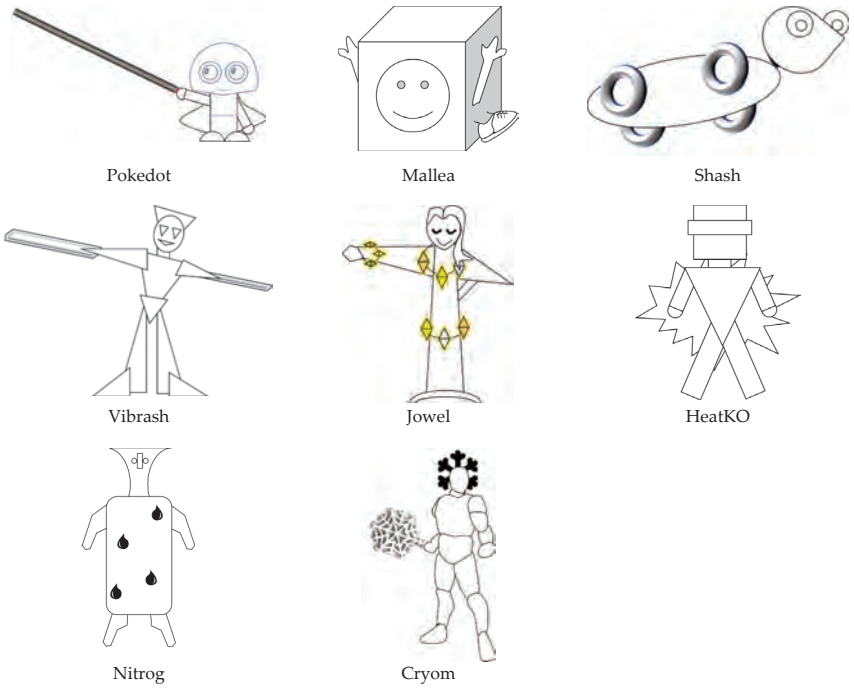
One of the reasons for having a diverse range of characters was so that different engineering properties could be analysed. Another reason was to provide sufficient variation between teams and between each team member to address. The teams had the liberty to choose their desired characters so that they could better develop agency over their own learning (Matuk et al., 2021).

Visual Appearance of Characters

Although a visual embodiment of the characters was not critical for the assignment, research suggests that visual appearance of game characters can have a positive influence on the motivation, enjoyment, performance and feelings of users (e.g., Rahill & Sebrechts, 2021; Sierra Rativa et al., 2020). Solarski (2012) suggested that combining primary shapes – the circle, square and triangle – could be useful to generate various possibilities for the design of the head, body and legs of a character. More complex shapes could be incorporated by finding images that may be considered as visual metaphors of the character's attributes and turning these images into black and white silhouettes (Solarski, 2012). Following these simple approaches, illustrations of

the characters were created using simple 2D and 3D shapes as well as clip arts in Microsoft PowerPoint. The illustrations of the characters are shown in Figure 2.

Figure 2



Note. Illustration of the different characters. The illustrations have been made almost entirely using Microsoft PowerPoint.

Discussion

Much has been written about the use of superheroes in teaching pedagogical approaches, but much less informs of why an educator should consider creating custom superhero characters and how the characters may be created. Custom-created characters can offer simpler models that allow both educators and students to specifically target the desired features without being too distracted by unnecessary details (Coll, 2006; Cook & Frey, 2017). For example, there is no need for characters to "wear… their underwear on the outside and proudly [display] their exaggeratedly hard and sensuous curves inside revealing, skin-tight costumes" (Peppard, 2020, p. 3) if the class does not need to discuss sexuality. Since the characters are new and the narrative is designed from scratch by the educator, there is little to no personal biasness or pre-judgement from the students (Nohria, 2021) as compared to the possible reaction to known stories. There are also no concerns about prior knowledge by students who are "comic aficionados" that they may "call you [the educator] out on some minor details or bog the class down with questions" (O'Roark, 2017, p. 54). There is also a

much lower probability of having to deal with copyright infringement regulations (Kealy, 2022) at all levels, be it institutional, regional or international.

Whilst the assignment was not developed to be a full-fledged case study, simulation, or game, the assignment did incorporate some characteristics of these didactic methods. Sauvé et al. (2007) listed five essential attributes of an educational simulation:

- it is a model of reality in which variables are clearly specified and their behaviour around a phenomenon is similar to that of the system being modelled
- it reproduces, to some extent, the behaviour of a real system in real time through the movement of its components
- it simplifies reality through the removal of certain elements to highlight others
- it is a precise and valid representation of relevant phenomena in reality
- and lastly, it directly addresses the learning objectives.

Meanwhile, Herreid (2005) listed key characteristics for a good discussion case: the case tends to be short, be controversial, have dialogue, have interesting characters, be relevant to the student, have a dilemma to be solved, be contemporary, be real rather than fabricated and have learning objectives.

Out of these two lists, the driving attribute for the current assignment was that the characters must be linked to the learning objectives. From the materials selection point of view, this meant that the primary material properties of concern formed the basis of the character design, and students must be engaged in selecting appropriate engineering materials for the characters.

How superheroes will be used in the classroom greatly influences the story structure and the quantity, depth and breadth of the superhero characters. For example, let's assume that the Mallea character is used in class to instigate discussion on recycling, reuse and upcycling. It may be sufficient to use the current description as is to develop discussion points for a single class session. Additional guiding questions may be developed, such as, "Can all types of objects be recycled/reused or upcycled?", "What kind of energy is required to change the shapes of objects?", or "How may objects which consist of different parts be managed for recycling?". However, for a longer-term project requiring quantitative analysis, such as the economics for recycling, then more data and information would be required.

One of the challenges faced when setting similar assignments for different cohorts is the possibility of one cohort copying the work of the previous cohorts. Some strategies may be practised to prevent the occurrence of copying:

- Having a pool of characters, from which a smaller number of characters are selected randomly each year, would help prevent direct copying.
- Alternatively, swapping tools between characters or selecting a different part of a character, can also create differentiation between cohorts.
- For the materials selection assignment specifically, using a different pre-selected starting material (represented by 'XX' in the preamble to the

assignment – see the Appendix) that the students have to compare their candidate materials with, would ensure the need for a new analysis.

- Cataloguing the solutions considered for each character, and comparing the database with new submissions, would also provide some checks. However, setting up, appending and using the database can be time consuming; hence, a good plan needs to be thought through before implementation.
- Requesting each team to create a new character and perform a material selection process for that character. This would ensure uniqueness in the work, as long as the process for developing the new character does not detract from the focus on the learning outcomes.

Like other educators who have introduced superheroes in their classes and had used the word "fun" (e.g., Brown et al., 2017; O'Roark, 2017), running this assignment for the past two years has allowed me to introduce "playful" (Whitton, 2018) strategies to a rather mundane topic. The "playfulness" could be observed in some of the opening statements of the student reports, of which two examples are extracted here:

> Student 1:
> Just because you don't see them, doesn't mean that they do not exist! A group of undercover superheroes that has been secretly protecting our city has approached us, the material specialists, to upgrade their outdated weapon/suit arsenal.

> Student 2:
> With the new age of villains comes a thirst for domination. Reincarnated and summoned by the menacing king of the underworld Professor **, 4 villains were summoned to form The Infinities…. However, before the start of world domination, the villains had to figure out what materials to use for their weapons.

From these opening statements, it also appears that setting the tasks against a superhero backdrop allowed the students to consider the roles of imaginary characters and operate with some degree of freedom in an imaginary environment (Simpson & Elias, 2011). This would hopefully permit the students to explore, observe and analyze from a new perspective (Burton, 2008; Simpson & Elias, 2011). Indeed, students have shown willingness for a deeper exploration in topics that were not covered in class. These topics include thermal properties and wear resistance coatings as well as material behavior at low and high temperatures. In fact, no student has so far complained about having to explore more than what could be found in the class notes.

Not only have I been encouraged by the engagement of the students, but importantly, I have had a lot of "fun" in the process of creating the characters and running the assignment. After all, it is not often that I can be excited about opening a report and be able to chuckle at what students write (about their super-teams).

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Appendix: Project Brief

THE BACKGROUND

The *Avengers: Endgame* may have marked the end of an era, but a new dawn is arising, with new superhero or villain characters to unveil.

More importantly these new characters make use of real materials that exist presently (real alloys or polymers) and are backed by real and current science. They are not fictitious materials like *adamantium* or *vibranium*, nor exist only in science fiction.

THE BRIEF

Six characters have been developed and require your contribution to make them complete.

As SPECIALISTs in materials engineering and selection, you and your team are to identify the best materials to adorn the characters.

Out of the six proposed characters, choose four to form a new superheroes or villains team. Give the superheroes/villain team a name, and select the best material for the items identified for each character.

An initial screening exercise has been performed by the character designers.

Due to the need for easy access to raw materials and manufacturing processes in all parts of the world, the character designers have narrowed the potential candidates to be just steel and aluminium, both of which are commonly used metals.

The internal fabrication workshop has proposed XX as it is easily available in the workshop and worldwide.

The character designers have asked if your team, as the Materials Specialists, agree with the workshop's proposal.

YOUR TASKS

For each of the four chosen characters:

1. Translate design requirements into relevant properties, and rank the requirements (output: Table of requirements)
    i. Consider the list of properties covered in the lecture
    ii. Consider other relevant physical properties or chemical degradation, e.g., environmental degradation and/or corrosion
    iii. Consider possible manufacturing process
        a) bulk shape
        b) surface modification
        c) joining, if relevant
2. Shortlist 4 other candidate materials, with relevant processing (cold work, heat treatment, etc.) history
    i. The candidate materials are limited to steel and aluminium alloys only.
    ii. These candidate materials should show superior performance to the critical properties identified in step 1.
    iii. Each candidate material must be of a different grade, e.g., if you select AISI 1005, you are not allowed to include both AISI 1005 annealed and quenched conditions as two candidate materials.

3. Apply the material selection method to identify your selected material, i.e., develop a decision matrix to compare your 5 candidate materials, with the preselected AISI 304 as one of the candidate materials, and identify the best material.
4. Create a Mill Test Certificate (using the template given) for the recommended material.
5. Compile your recommendations into a single proposal for your team characters.

CHARACTERS

Mallea

Is it a box? Is it a stool? No, it is Mallea (pronounced Moll-y)! Mallea isn't easily recognisable because it changes shape and retains its new shape easily, allowing it to disguise or move around with little restrictions. Mallea would have been a welcomed addition to the Incredibles family, complementing Elastigirl's stretching but elastic abilities. Unlike T1000 (in Terminator) which turns from solid into liquid form to change shape, Mallea does not turn into a liquid but deforms in the solid state. Mallea relies on the common phenomenon of plastic deformation and continuous recrystalisation to remain ductile.

Select a material to make Mallea's costume. The costume can be deformed to different shapes without breaking to adjust to Mallea's changing shapes.

Shash

Need a speedster for the mission? Behold the new Shash character, which can swish around on its maglev discs. When Shash moves, hardly anything else can chase after it. A lightweight, nimble character, yet a battlefield tank too, with a shell that can sustain heavy blows and blunt cracks with ease. A featherweight by class, but zippy and tough by might!

Select a material to make Shash's shell. The shell must be durable to sustain heavy blows and be resistant to crack propagations.

Vibrash

Vibrash is an unconventional character that can cause serious damage. Traditional characters of similar nature use brute strength, with stronger, sharper weapons, to reduce objects into pieces. But Vibrash does not smart sharp weapons. Instead, Vibrash has the ability to apply ultrasonic vibration to its tools to cut and slice things along the way. Its favourite tool is a large rectangular bevelled plate with bevelled edges. The weight of the plate is just nice for the ultrasonic vibration to work effectively. The edges are gentle to touch, unless Vibrash unleashes the ultrasonic vibration which turns the plate into a deadly cutter.

Select a material to make Vibrash's plate. The plate has a dimension of 600mm by 100mm and a thickness of 5mm. The edges are bevelled.

Jowel

Jowel loves glitter and adorns colourful metal jewelries all the time. Its favourite shape is a quadrilateral that looks like a bisected kite. The metal jewelries aren't just shimmer and shine though. Their edges are highly sharpened and hardened, making them powerful weapon when necessary. You see, Jowel is a specialist weapon thrower and the metal jewelries are to Jowel just like batarangs are for Batman.

Select a material to make Jowel's metal jewelries. The jewelries have three different sizes, with a thickness of 3mm. The edges are hardened and sharpened.

HeatKO

There have been so many superheroes/villains using fire and flames. But hey, no one likes burning fires nowadays, what with toxic fumes, global warming and haze to deal with. So, let's welcome HeatKO, a new character which uses heat to cause indirect damage without any open flames. HeatKO heats things up to around 600-800°C, enough to make many things melt, disintegrate or weakened, which then allows HeatKO to easily KO them (Heat + KO).

Select a material to make HeatKO's costume. The costume must maintain its properties despite HeatKO's temperature going to as high as 800°C.

Nitrog

Wonder if superheroes/supervillains ever sweat? Well sweat not, because Nitrog is an amazing creature. It sweats off concentrated nitric acid freely as and when needed. Nitrog's favourite home is in the green plains, where it uses its nitric acid sweat to help make fertilisers to enrich the land. But when called upon, it converts its nitric acid sweat into something more devastating – explosives. Want to capture it? Well, its nitric acid sweat will corrode most metals quickly – Nitrog's nickname is 'slippery nitrog' and for good reasons!

Select a material to make Nitrog's costume. The costume must maintain its properties even as Nitrog sweats its nitric acid.

Cryom

Frozone deals out ice at 0°C but Cryom is comfortable with temperatures as low as -150°C. At this temperature, many things are turned into brittleness so Cryom can cause damage with ease. Not forgetting that the colder temperatures can provide more utility – storing and transporting vaccines during emergencies! Cryom sports an ice-crystal shaped shield – a cool (pun intended) tool indeed as it is as strong at cryogenic temperatures as it is at room temperature, without being more brittle.

Select a material to make Cryom's costume. The costume must maintain its favourable properties despite Cryom's temperature dropping to as low as -150°C.

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