KNOX GRAMMAR SCHOOL

STATE

DA VINCI DECATHLON 2018

CELEBRATING THE ACADEMIC GIFTS OF STUDENTS IN YEARS 7 & 8

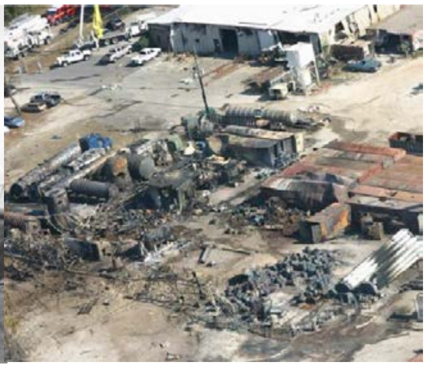
SCIENCE ANSWERS

TEAM NUMBER _______________

1	2	3	4	5	6	Total	Rank
/12	/9	/9	/5	/12	/4	/51	

DISASTERS AND DISCOVERIES





Scientists often follow careful methods and procedures in order to conduct their testing. This ensures the safety of everyone involved in the experiment and that of the general public. However, if the scientists involved don't fully understand what they are experimenting with, it can often have unexpected results. If these results are positive, then history shows many examples of unexpected discoveries of new drugs, new imaging techniques and many other miraculous findings. However, if the results are negative, they can often have disastrous consequences for various groups.

Read the following articles describing three man-made disasters and then answer the following questions:

Fukushima

The Great East Japan Earthquake of magnitude 9.0 at 2.46 pm on Friday 11 March 2011 did considerable damage in the region, and the large tsunami it created caused very much more. The earthquake was centred 130 km offshore the city of Sendai in Miyagi prefecture on the eastern cost of Honshu Island (the main part of Japan), and was a rare and complex double quake giving a severe duration of about 3 minutes. An area of the seafloor extending 650 km north-south moved typically 10-20 metres horizontally. Japan moved a few metres east and the local coastline subsided half a metre. The tsunami inundated about 560 sq km and resulted in a human death toll of about 19,000 and much damage to coastal ports and towns, with over a million buildings destroyed or partly collapsed.

Eleven reactors at four nuclear power plants in the region were operating at the time and all shut down automatically when the quake hit. Subsequent inspection showed no significant damage to any from the earthquake. The operating units which shut down were Tokyo Electric Power Company's (Tepco) Fukushima Daiichi 1, 2, 3, and Fukushima Daini 1, 2, 3, 4, Tohoku's Onagawa 1, 2, 3, and Japco's Tokai, total 9377 MWe net. Fukushima Daiichi units 4, 5 & 6 were not operating at the time, but were affected. The main problem initially centred on Fukushima Daiichi units 1-3. Unit 4 became a problem on day five.

The reactors proved robust seismically, but vulnerable to the tsunami. Power, from grid or backup generators, was available to run the Residual Heat Removal (RHR) system cooling pumps at eight of the eleven units, and despite some problems they achieved 'cold shutdown' within about four days. The other three, at Fukushima Daiichi, lost power at 3.42 pm, almost an hour after the quake, when the entire site was flooded by the 15-metre tsunami. This disabled 12 of 13 back-up generators on site and also the heat exchangers for dumping reactor waste heat and decay heat to the sea.

Tacoma Narrows Bridge

The collapse of the 1940 Tacoma Narrows Bridge stunned everyone, especially engineers. How could the most "modern" suspension bridge, with the most advanced design, suffer catastrophic failure in a relatively light wind?

In March 1941 the Carmody Board announced its findings. "Random action of turbulent wind" in general, said the report, caused the bridge to fail. This ambiguous explanation was the beginning of attempts to understand the complex phenomenon of wind-induced motion in suspension bridges.

"The fundamental weakness" of the Tacoma Narrows Bridge, said a summary article published in Engineering News Record, was its "great flexibility, vertically and in torsion." Several factors contributed to the excessive flexibility: The deck was too light. The deck was too shallow at 8 feet (a 1/350 ratio with the center span). The side spans were too long, compared with the length of the center span. The cables were anchored at too great a distance from the side spans. The width of the deck was extremely narrow compared with its center span length, an unprecedented ratio of 1 to 72.

The pivotal event in the bridge's collapse, said the Board, was the change from vertical waves to the destructive twisting, torsional motion. This event was associated with the slippage of the cable band on the north cable at mid-span. Normally, the main cables are of equal length where the mid-span cable band attaches them to the deck. When the band slipped, the north cable became separated into two segments of unequal length. The imbalance translated quickly to the thin, flexible plate girders, which twisted easily. Once the unbalanced motion began, progressive failure followed.

T2 Labs

The co-owner of Jacksonville’s T2 Laboratories spent his life’s last frantic minutes trying to stop a runaway chemical reaction he didn’t fully understand, a draft report by federal investigators says. Robert Scott Gallagher waved for employees to get away from a reactor chamber, telling one worker a fire was about to start, according to the assessment by the U.S. Chemical Safety Board. Then Gallagher, a 49-year-old father of five, went back inside the reactor’s concrete block control room and tried to stop the disaster. Within minutes, he and three others were killed as the blast wiped out the Northside plant and wrecked neighboring businesses on Faye Road. Another 32 people were injured in the explosion on Dec. 19, 2007, that threw heavy steel columns and other shrapnel up to 1,000 feet. And investigators doubt anyone saw it coming.

“None of the T2 employees appreciated the potential for a catastrophic explosion,” says the draft that will be presented this evening in Jacksonville to the presidential appointees who sit on the safety board. The report suggests they should have. There were past scares, some as soon as the plant opened, when the chemical reaction raced ahead unexpectedly as employees made earlier batches of the same product. It concludes that Gallagher, a chemical engineer, and co-owner Marion “Mike” Wyatt didn’t prepare well enough for a catastrophic mishap.

More basically, it suggests that despite both men having college degrees and long careers in the chemical industry, they didn’t see the real dangers in production of a gasoline additive they called Ecotane. The explosion happened during the plant’s 175th time making Ecotane, but the report says heat and pressure built up unexpectedly during the very first batch made at the new plant. It happened again several more times after that, the draft report says.

But the company's owners just adjusted their recipe and procedures, the draft says, and didn't recognize that one day the chemical reaction could get completely out of control. "The owners had these warning signs. They had these near misses," board investigator Robert Hall told reporters Tuesday. "But the reaction was not to investigate what caused the problem. ... Just to make another batch." The investigators say that reflects a poor understanding of reactive chemicals in the entire chemical industry. They urge industry groups and college chemical engineering programs to put more attention on those dangers.

The draft also says a pressure-relief device on the reactor only could have prevented the explosion if it was set to vent pressure much earlier than it did. By the time the device took effect, heat and pressure were building inside the chamber so fast there was no stopping the disaster, the draft says. The report says Wyatt, a chemist, practiced making the gasoline additive in tiny batches more than 100 times before the company leased space on Faye Road in 2001. It was January 2004 before the plant there produced its first commercial batch of Ecotane. The draft describes Eccotane, whose scientific name is methylcyclopentadienyl manganese tricarbonyl, as one of many reactive chemicals whose properties aren't widely understood. The report's authors wrote that they searched for published studies on the chemical and found very little - none of it about reactive hazards.

Extracts from the following:
http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-accident.aspx
https://www.wsdot.wa.gov/TNBhistory/Machine/machine3.htm
http://www.jacksonville.com/news/metro/2009-09-15/story/report_owners_of_jacksonvilles_t2_lab_never_knew_risks_of_deadly_explosi

Disasters

1. For each disaster described above, provide a concise description of the exact reason for why the disaster occurred, giving scientific explanations for your reasoning. (4 marks each)

a)

2 marks each for describing the reason behind the disaster
e.g. Tacoma Narrows occurred due to the action of turbulent wind which vibrated the particles in the bridge so much that the entire bridge started to wobble

2 marks each for giving detailed reasoning
e.g. The bridge started to wobble at the same frequency with which the bridge was moving

b)

c)

2. Write a risk assessment for each situation that should have been undertaken before the disaster occurred. (3 marks each)

a)

2 marks for providing at least 3 reasonable features of safety that should have been implemented depending on the situation.
E.g. installing supports to the bridge to stabilise it in the initial phases of its use

1 mark for a structured response – either using a table, or providing some kind of link between the safety measure and its effect

b)

c)

3. For each disaster, propose two solutions that could prevent similar disasters in the future. Write a scientific method for each solution that could be used by the people running each project in the future (3 marks each)

a)

2 marks for the two solutions
e.g. research into stronger building materials for bridges

1 mark for a scientific method for each solution
e.g. a method for experimenting with different materials in scale model bridges

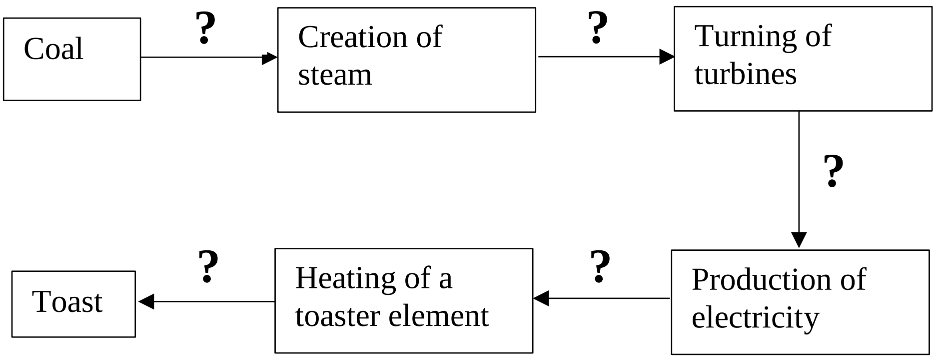
b)

c)

Energy Transformations

Another area of science where unexpected connections can be made is in the study of energy. Transforming energy from one form to another is a very important task for scientists and engineers, to convert fuels or other types of stored energy into useful work.

4. For the below flowchart, describe how each energy form can be transformed into the other. (5 marks)



1 mark per step described

1. Burning of coal to heat water until it boils to steam (thermal energy)
2. Rising of steam to turn the blades of a turbine (kinetic energy)
3. Motion of wires in a magnetic field produces a current (electrical energy) (TRICKY – a reasonable attempt deserves a mark)
4. Electricity through a wire produces heat, so lots of electricity creates lots of heat
5. Heat passes through the air to cook the bread

5. Given the following start and end points, construct a path using various forms of energy to transform the starting form of energy in to the final form. You must identify at least one form kinetic energy (movement) and one form of potential energy (stored) in each path. (6 marks each)

Part	Starting point	End Point
a)	Solar Energy	A cyclists thigh muscles
b)	Geothermal Energy	The heating of food in a pot

a)

For each question:
3 marks, with 1 mark for each reasonable step (at least 3)
2 marks for providing at least one kinetic and one potential form of energy
1 mark for having all steps in a correct and accurate sequence

For example:

a)

Solar energy -> plants produce sugars and other compounds to store the light energy -> animals eat the compounds in the plants releasing the chemical potential energy -> the cyclist eats those animals/plants releasing the chemical potential energy -> the cyclist moves their legs using kinetic energy in their muscles

b)

Geothermal energy heats water to steam -> steam turns a turbine producing kinetic energy -> the rotations of the turbine become electrical potential energy -> the electrical energy powers a cooktop to heat the food in the pot, providing it with thermal energy

b)

6. Propose two specific reasons why the above flowcharts and systems may not work to 100% efficiency. That is, identify where energy could be lost in the above systems. (4 marks)

1 mark for each reason and 1 mark for a detailed description of that reason

Answers may include:

- Chemical potential energy may be lost due to waste processes in the human body
- Electrical energy can be lost due to having to transmit it through wires
- Heat energy is very easily lost to surrounding areas