MATERIALS SCIENCE

NEW YORK STATE SCIENCE OLYMPIAD
LAKE ERIE/NIAGARA 2013 REGIONAL COMPETITION
FEBRUARY 2, 2013 – CANISIUS COLLEGE

Directions:
You may use ONE nonprogrammable calculator and ONE 3-ring binder for this test.

You may remove your goggles and lab coats when completing the test portion of this event.

Answer all questions in the test book. A periodic table is included as the last page of this test. You may separate the pages of this test and the answer booklet, however, if you choose to do so, please ensure that your team name and number is written at the top of each page. Failure to include this information on each page of the answer booklet may result in a scoring error.

You have 50 minutes to complete this event. The event is composed of two short lab experiments as well as test questions. The event has a maximum score of 100 points – 50 for questions related to intermolecular forces, and 50 for questions related to material performance. The points available for each question are indicated.

Answer all questions in the provided answer booklet. You may write on the test, however, any work done in the test booklet will not be scored.

Team Name: _____ Team Number: _____

Part I: Material Performance (50 points)

Questions 1 and 2 must be performed over a 30 minute interval, so start this section first. You should work on other sections of this test while completing these questions.

A. Creep Rate

1. You have been provided a container of Silly Putty, a sheet of wax paper, a ruler, a stopwatch, and a sheet of grid paper. Form the Silly Putty into an inverted cone shape – like that of a witch's hat or Hershey Kiss, with a circular base. Place the wax paper on top of the grid paper, and the Silly Putty on top of the wax paper. Draw a circle around the base of the Silly Putty or note its diameter from the grid paper. Each line on the grid paper is spaced 1 mm apart.

   At approximately five minute intervals, draw another circle around the base of the kiss, or record its diameter based on the grid paper. Record the time (from the stopwatch) at which each circle was drawn. The intervals should be close to five minutes, but need not be exact so long as the actual time is recorded for each circle.

   After a minimum of 30 minutes, remove the Silly Putty from the wax paper and return it to its container. If you traced on the wax paper, save it – you will need it to complete this section.

   Construct a data table that includes time and the corresponding value of creep for that time. In this experiment, the value of creep is defined as the percent enlargement in the area of the base. You can obtain this value from the circles drawn on your wax paper or the corresponding diameter measurements. You may choose to include any intermediate calculations performed in your table if desired. Show all calculations.

   Place your table and calculations on the supplied answer booklet.

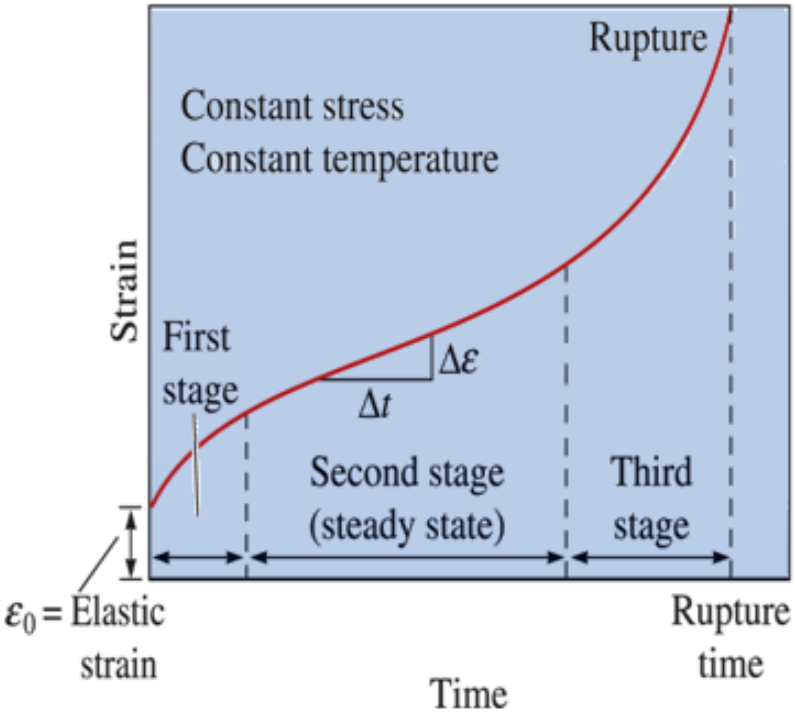
   [5 points]

2. Construct a graph of creep vs. time, and using the graph, provide an estimated value of the creep rate.

   Please construct your graph on the grid provided in the answer booklet.

   [5 points]

3. The creep curve for a typical metal is shown in the figure below.



Which condition likely caused this metal to "creep"?

a. Cryogenic conditions
b. High weight
c. Salt water conditions
d. High temperatures

4. In the first stage of creep, the creep rate decreases with increasing time. What is the scientific origin of this behavior?

a. Annealing
b. Strain hardening
c. Elastic deformation
d. Fracture

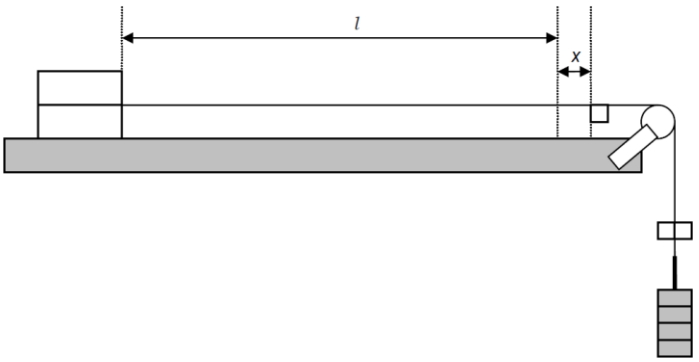
5. The metal melts at 1240°C. Estimate the temperature above which creep will occur.

a. 413°C
b. 504°C
c. 231°C
d. 1240°C

[#3-5: 2 points each]

B. Stiffness of material

6. The following set up has been provided:



A wire is held at one end of a long plank, and is hung over a pulley at the other end and loaded in the downward direction by the addition of masses.

A point on the wire, corresponding to the length "*l*", is marked using a small piece of masking tape. Underneath this point is a millimeter ruler. Note the position of the tape on the ruler, estimating to the nearest 0.1 mm. In this experiment, ***l*=1.9000 m**.

A container with a fixed mass is hung from the end of the wire. Do not include this mass in your calculations – the length is calibrated against this fixed mass, which is necessary to keep the wire from sagging. A series of 500 gram masses has been provided. Place in the first mass, and record the current position of the masking tape in order to determine the distance "x." In this experiment, "x" is the distance that the masking tape has moved with the addition of the loading – or its initial position subtracted from its current position.

Add each additional 500 gram mass until a total mass of 2.5 kg has been loaded, and record the value of "x" for each, estimated to the nearest 0.1 mm.

Construct a data table that includes the **stress** in the wire and the **strain** of the wire. You may choose to include any intermediate calculations performed in your table if desired. Show all calculations. Place your table on the supplied answer sheet.

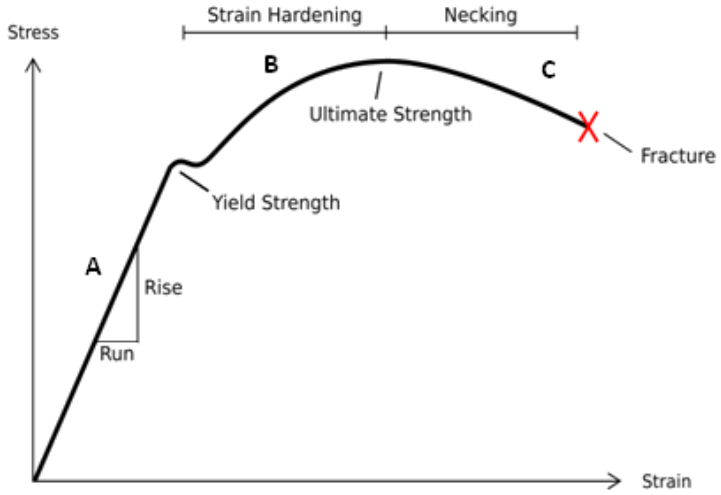
[5 points]

7. Construct a plot of stress vs. strain on the grid provided in the answer booklet. Use this table to estimate Young's Modulus for the wire.

[5 points]

8. Which class of materials generally has the highest Young's Modulus?
    a. Metals
    b. Polymers
    c. Ceramics
    d. Composites

Questions 9 makes use of the figure below, which shows a stress-strain curve for an unknown material.



9. Based on this curve, the material is most likely
    a. Ductile
    b. Brittle

10. Write the following in order of *increasing* Young's Modulus: **Aluminum, Diamond Pine, Rubber**.

[#7-10: 2 points each]

C. General properties and material characterization

11. The main types of materials are metals, ceramics, polymers, and composites. For each of the materials listed below, indicate the type to which it belongs.
    a. Aluminum reinforced with silicon carbide particles.
    b. Polytetrafluoroethylene ("Teflon")
    c. Silicon dioxide
    d. Carbon fiber reinforced epoxy
    e. Copper
    f. Polyvinyl chloride

[1 point each]

12. Yield strength is defined as the strength at which a material
    a. Experiences tensile failure
    b. Fails under cyclic loading
    c. Fails under a suddenly applied load
    d. Experiences permanent deformation

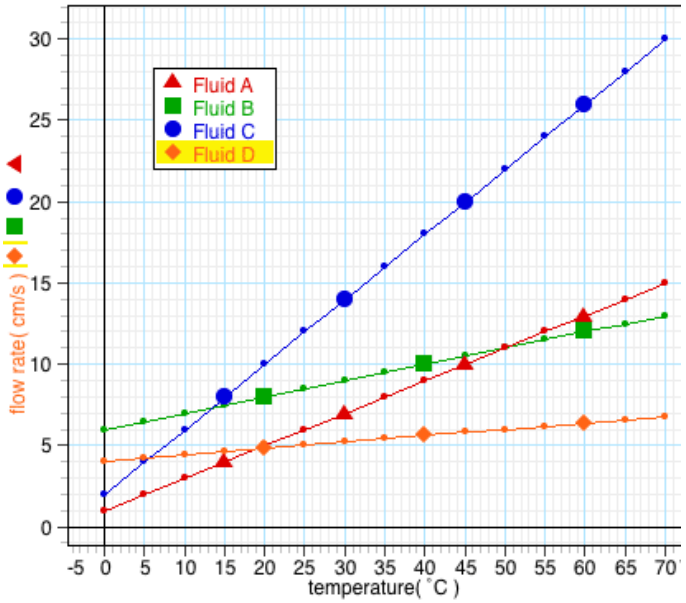
13. Magnesium has an atomic number Z=12. The electron configuration for a Magnesium ion with a +2 charge is:
    a. $1s^2 2s^2 2p^6 3s^2$
    b. $1s^2 2s^2 2p^6$
    c. $1s^2 2s^2 2p^5 3s^1$
    d. $1s^2 2s^2 2p^6 3s^2 3p^2$

14. Modern bronze is made of
    a. Copper and zinc
    b. Copper and silver
    c. Copper and tin
    d. Copper and magnesium

15. What would be the hybridization in a single bond between C-Cl in a molecule of CCl_4?
    a. $s\text{-}sp^3$
    b. $s\text{-}sp^2$
    c. $p\text{-}sp^2$
    d. $p\text{-}sp^3$

16. If a viscous fluid flows steadily in a pipe, the fluid speed
    a. Is the same at the pipe wall and center, but is greater in between.
    b. Is the same at the pipe wall and center, but is smaller in between.
    c. Is least near the pipe wall, but increases toward the center.
    d. Is greatest near the pipe wall, but decreases toward the center.
    e. Must be uniform across any cross section.

17. An experiment was performed that measured the flow rate of four different liquids as the temperature was increased.



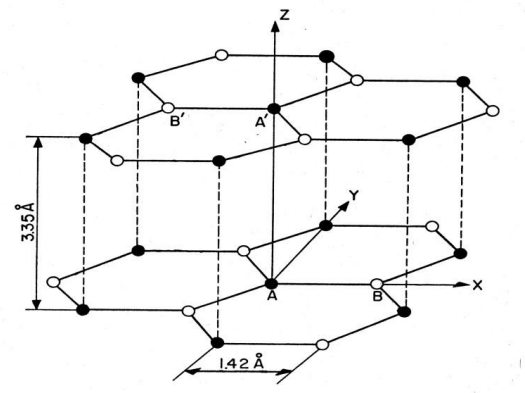
According to the graph, which of the liquids had the greatest viscosity at a temperature of 30°C?

a. Fluid A
b. Fluid B
c. Fluid C
d. Fluid D

[#12-17: 2 points each]

Part II: Intermolecular Forces and Surface Chemistry (50 points)

The figure below shows the atomic arrangement in graphite. Use this figure to answer problems 18 and 19.



18. Which of the following explains why graphite is a good solid lubricant?
    a. In-plane bonding in graphite is only van der Waals' forces.
    b. Out-of-plane bonding in graphite is only van der Waals' forces.
    c. In-plane bonding in graphite is covalent and metallic.
    d. Out-of-plane bonding in graphite is covalent and metallic.

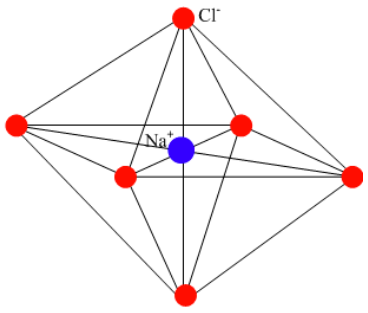
19. Which of the following explains why graphite is a good electrical conductor?
    a. In-plane bonding in graphite is only van der Waals' forces.
    b. Out-of-plane bonding in graphite is only van der Waals' forces.
    c. In-plane bonding in graphite is covalent and metallic.
    d. Out-of-plane bonding in graphite is covalent and metallic.

20. What is the coordination number for the Body-Centered Cubic (BCC) structure?
    a. 6
    b. 8
    c. 10
    d. 12

21. What is the shape of the primitive unit cell of the Body-Centered Cubic (BCC) structure?
    a. Cubic
    b. Tetragonal
    c. Rhombohedral
    d. Hexagonal

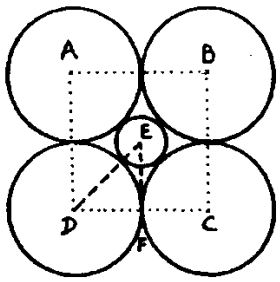
[#18-21: 2 points each]

22. The figure below shows octahedral coordination, in which six nearest atoms of radius R surround an atom of radius r, with R being larger than r. This coordination is often known as the rock-salt structure and is found in compounds such as sodium chloride.



Calculate the minimum r/R ratio for this coordination to be stable. Show your calculation and the final answer in the answer book.

Hint: Use the following diagram.



[5 points]

23. On what Bravais lattice is the structure in problem 22 based?
    a. FCC
    b. BCC
    c. HCP

24. The reason that vacancies are always present in the lattice is
    a. They are equilibrium defects.
    b. Crystals are not perfect.
    c. They are easy to form.
    d. There is an activation energy for their formation.

25. If a liquid wets the surface it falls on (like water on glass), what is the approximate contact angle?
    a. Less than 90°
    b. Exactly 180°
    c. More than 90°
    d. 45°

26. The bonding between the molecules of liquid hydrogen is
    a. Hydrogen bonding.
    b. Network bonding.
    c. Van der Waals' forces.
    d. Non-polar bonding.

27. The adhesion of a gas or liquid to a surface is called
    a. Adsorption.
    b. Bonding.
    c. Meniscus.
    d. Absorption.

28. As water temperature increases from 0°C to 100°C, what happens to the surface tension?
    a. Increases
    b. Decreases
    c. Stays the same

29. The body-centered cubic (BCC) and face-centered cubic (FCC) latties
    a. Have different packing factors.
    b. Both contain close-packed planes.
    c. Have the same stacking sequences of the close-packed planes.
    d. All of the above.

30. Hexagonal Close Packed (HCP) metals include
    a. Magnesium.
    b. Zinc.
    c. Titanium.
    d. All of the above..

31. The number of atoms in a unit cell of BCC, FCC, and HCP metals are
    a. 4, 2, 6 respectively
    b. 6, 4, 2 respectively
    c. 2, 4, 6 respectively
    d. None of the above

[#23-31: 2 points each]

Use the following information to answer questions 32 and 33:

Copper exhibits the FCC structure. Its atomic radius is 1.28 Å.

32. Calculate the lattice constant (in Å) of copper, i.e., the length of an edge of the conventional cubic unit cell.

[5 points]

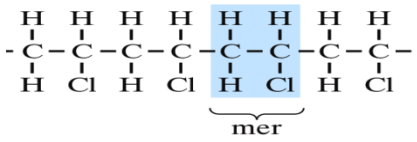
33. Calculate the packing factor of copper, i.e., the fraction of space that is occupied by atoms. [5 points]

34. Give the Miller indices of the family of close-packed planes in copper. Use the conventional notation for indicating a family of planes (e.g. {0 0 0}).

[1 point]

35. What causes the different physical properties between graphite and diamond?
    a. Diamond is harder.
    b. Location where each is formed.
    c. Internal arrangement of carbon and hydrogen atoms.
    d. Internal arrangement of carbon atoms.

36. The figure below shows a molecule of Polyvinyl Chloride (PVC).



A molecule of PE is the same in composition as that of PVC except that each Cl (chlorine) atom is replaced by an H (hydrogen) atom.

Which of the following best explains why PVC is stiffer than PE?
    a. PE exhibits ionic bonding, while PVC exhibits covalent bonding.
    b. Hydrogen bonding occurs in PVC.
    c. Hydrogen is lighter than chlorine, so PE is less dense than PVC.
    d. PVC tends to form longer chains than PVC.

37. Four sigma bonds emanate from the central atom "M" to four atoms of element "X". What is the most probably structure for the compound MX_4?
    a. Tetrahedral
    b. Trigonal pyramidal
    c. Planar
    d. Octahedral

38. What allows the molecular flexibility of an organic polymer?
    a. Alternating single and double bonds between the carbon atoms
    b. Single bonds involving a single pair of electrons
    c. Multiple covalent bonds involving two or more electron pairs
    d. Triple bonded carbon atoms

[#35-38: 2 points each]

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.179
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.938	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **§** (269)	111 **§** (272)	112 **§** (277)						

§Not yet named

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Materials Science Answer Sheet

Team Name: _____ Team Number: _____

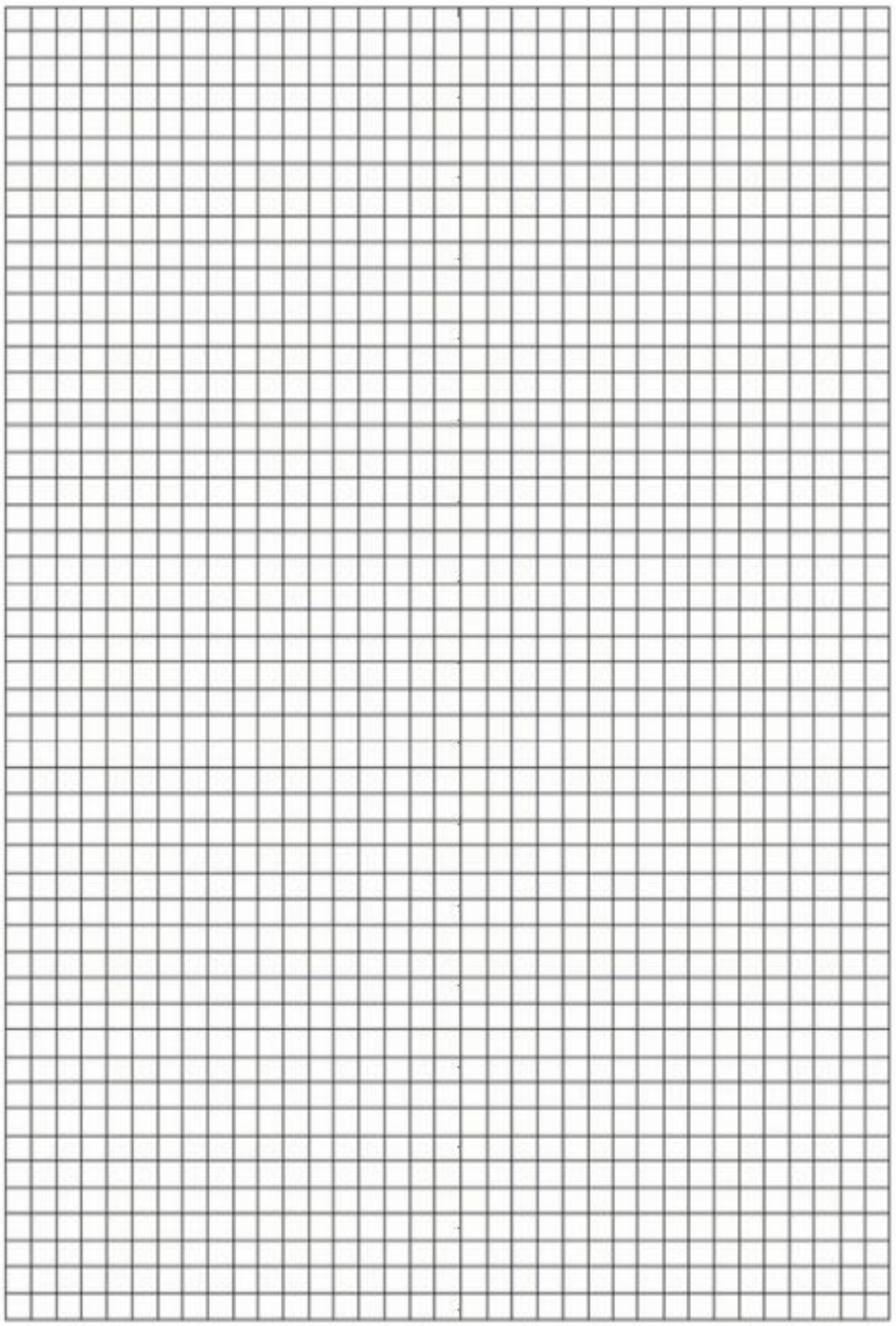
Team Member Names: 1. _____

2. _____

1.

Time	**Creep**

2.



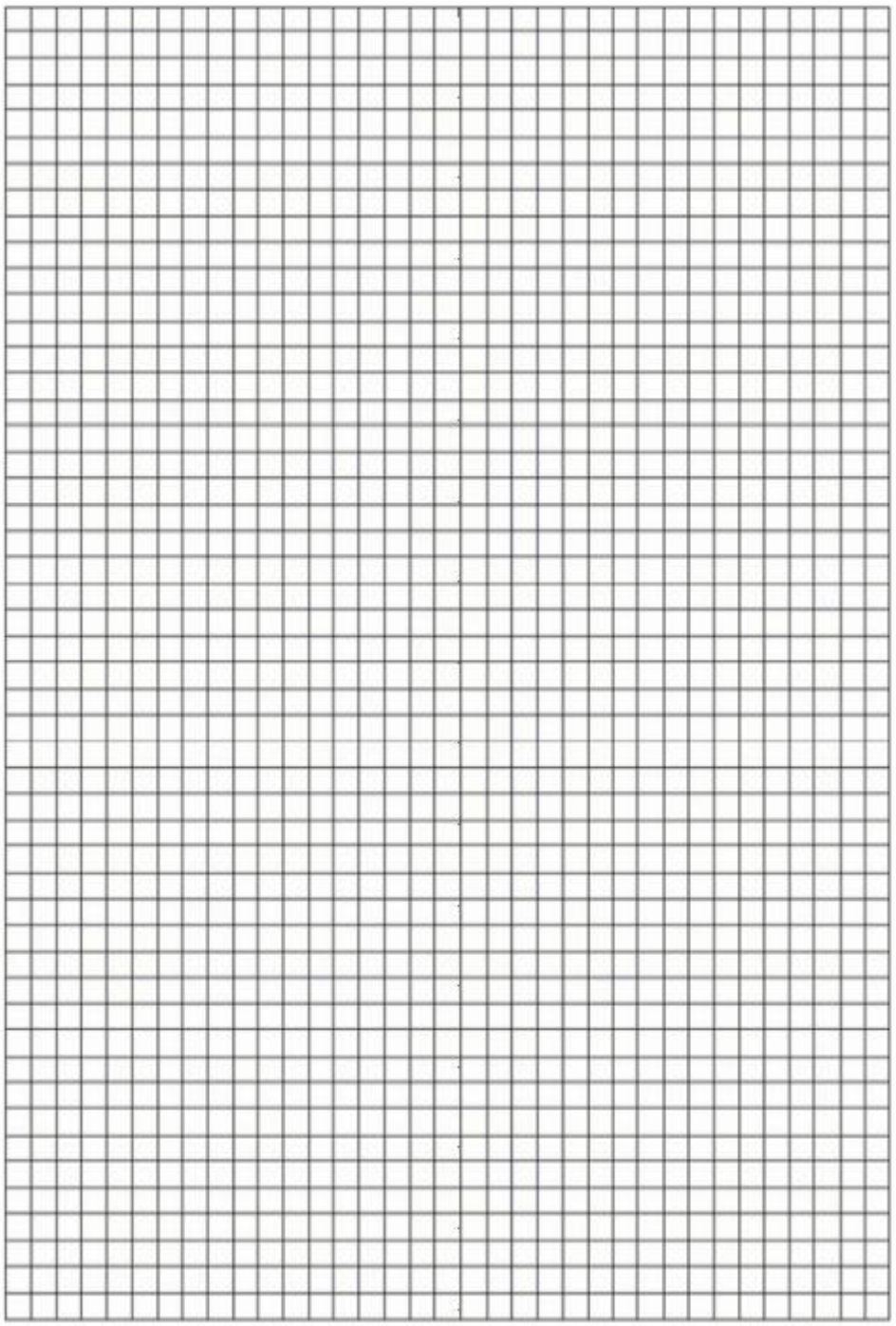
Creep Rate: _____

Team Name: _____ Team Number: _____

3. _____ 4. _____ 5._____

6.

7.



Young's Modulus: _____

Team Name: _____ Team Number: _____

8. _____ 9. _____

10. _____

11. a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

12. _____ 13. _____ 14. _____

15. _____ 16. _____ 17. _____

18. _____ 19. _____ 20. _____

21. _____

22.

Answer: _____

23. _____ 24. _____ 25. _____

26. _____ 27. _____ 28. _____

29. _____ 30. _____ 31. _____

32.

Answer: _____

33.

Answer: ______________________________

34. ____________________________________

35. ________________ 36. ________________ 37. ________________

38. ________________