State of Iowa Physics Competition

OFFICIAL 2014-15 RULES

FOR REGIONAL (AEA) AND STATE COMPETITIONS

Rules/Advisory Committee

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Overview

The Physics Competition is a series of 5 competitive physics events for high school (Grades 9-12) students. The competition stresses creativity and ingenuity as well as an understanding of physics related principles and is intended to stimulate interest in Science, Technology, Engineering, and Mathematics (STEM). The competition emphasizes the scientific and engineering practices found in the Next Generation Science Standards (NGSS) and participation in the competition integrated with appropriate instruction can address the Iowa Core.

Each participating school shall form one or more school teams who will organize themselves into event teams and compete at a Regional Area Education Agency (AEA) Physics Competition. Regional AEA Physics Competition winners and runners-up advance to the State of Iowa Physics Competition.

The events include:

1. Catapult
2. Mousetrap Car
3. Bridge Building
4. Soda Straw Arm
5. Challenge Problem

Contact Information

Regional AEA Physics Competition

Contact your AEA representative for information about the competition in your region. Questions related to the UNI/267 Regional Competition should be directed to Larry Escalada (319-273-2431 or Lawrence.Escalada@uni.edu).

State of Iowa Physics Competition

Questions related to the State of Iowa Physics Competition should be directed to Larry Escalada (319-273-2431 or Lawrence.Escalada@uni.edu).

Regional AEA Definitions and Clarifications

1. An **individual school** is defined as a building within a school district. If a school district has multiple high schools, each building is considered a separate individual high school.
2. A **school team** is defined as one consisting of 2 students for each event entered and whose event scores count towards the school team's total score. The school team does not have to enter all events but a score of 0 will be entered in the team score for events in which 2 students fail to compete. A school team may consist of 5 to 10 students. Each school team may enter only one device in each event.
3. An **event team** is defined as one consisting of 2 students whose scores do not count towards the

school team total score. An event team must consist of two students. Each event team may enter only one device in each event.

4. An individual student may be a member of only school team or a maximum of 2 event teams.
5. An individual school may enter multiple teams. It will be up to the individual AEA competition organizer(s) to determine how many teams from a school may compete at the regional competition. Only one school team from any school may advance to the state competition.
6. All students, competing and observing, must be accompanied by a school representative.

State Competition Definitions and Clarifications

1. The definitions of individual school, school team, and event team provided previously apply to state competition.
2. The qualifying school teams finishing first and second at each regional competition advance to the state competition. An individual school invited to send a school team to the state competition may enter a maximum of 10 students for the 5 events.
3. The qualifying event team finishing first for any event who is NOT part of a school team qualifying for the state competition also advances to the state competition.
4. All students, competing and observing, must accompanied by a school representative.
5. If there is no regional competition in an AEA region, two schools per AEA region may compete at the State Competition with a maximum of one school team or 5 event teams per school. If there is no regional competition, the AEA consultant should be contacted to let him/her know that a school is interested in participating in the State Competition. The school should also contact a neighboring AEA to determine if it is possible to compete in their regional competition in order to qualify. Teachers, in communication with their AEA consultant, may organize and facilitate a regional competition to determine the teams who will represent their area at the state competition. AEA consultant should notify Larry Escalada of these plans.

Device Rules - All Competitions

1. Each team (school or event) will enter ONLY ONE DEVICE in each event.
2. If a device qualifies for a state event and the student responsible becomes ineligible, the device may still be entered in competition by a substitute student.
3. All catapults, cars, and bridges must be labeled with the names of the competing student(s) and school.
4. Unless otherwise stated in the event rules, only that event's team members may manipulate the team's device during the event.
5. Accommodations will be allowed for participants with disabilities where a 3rd person will be allowed to move the device for that participant under the direction of the participant, if necessary. It is the responsibility of the coach or participant to inform the judges of accommodations ahead of time.
6. Each teacher will sign a compliance form certifying that their students constructed their own devices from scratch for the current year of competition, with only materials as specified in these rules, and without the use of a commercial kit. It is the responsibility of the sponsoring teacher to assure student compliance with all of the applicable rules as well as appropriate moral and ethical behavior.

Scoring - All Competitions

Each event is scored separately with the top three places being declared for each event. **The overall school team score will be the sum of the 5 event scores with the highest scoring school team being declared the <u>Physics Competition Grand Champion</u>.**

Individual Event Scoring

1. A maximum of 10 points will be awarded for each event.
2. All teams that enter and compete in an event without being disqualified will score a minimum of 1 point.

3. If fewer than 10 competing teams, points will be awarded only for those places. If more than 10 teams compete, those in 10th place and lower each receive 1 point.
4. In the event of a tie, the teams will share points from the 2 places. For example, tie for 2nd place, split 2nd and 3rd place with no 3rd place points awarded.
5. Teams that enter a device in an event but receive a default, will have their place points divided equally between all the defaulting teams for that event.
6. Teams that register for an event but do not enter a device, will receive zero points for that event. Each event is scored separately with a winner and runner-up being declared.
7. The overall school team score will be the sum of the event team scores. The school team with the highest sum of the 5 events scores will be declared the Physics Competition Grand Champion.

Placement	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Points Awarded	**10 pts**	**9 pts**	**8 pts**	**7 pts**	**6 pts**	**5 pts**	**4 pts**	**3 pts**	**2 pts**	**1 pt**

If a device qualifies, but the student becomes ineligible or unavailable, the device may still be entered in the competition.

Rulings and Appeal

In the case of any clarification or contention of an event or another team's entry, within one minute of being informed of the judges' decision or the completion of the other entry's trials respectively, a student team member may appeal to the event judges without outside influence or input (i.e. coaches, parents, other students, etc.). Any device ruled by the judges that does not comply with the rules will be given a time interval (determined by the judges) to be modified to comply. The resolution is up to the judges. The event judges may confer with head judges and/or competition director if necessary. **The decision of the judges is final.**

Awards

Medals will be provided for the top **3** places in each individual event and trophies will be provided for the Grand Champion School Team, First Runner-Up School Team, and Second Runner Up School Team for the state competition. **Awards will be determined by each regional competition**.

Schedule, Costs, and Information

AEA Regional Competition

Contact your AEA consultant for information about schedule, costs, and information for the competition in your region. The UNI/AEA 267 Regional Competition will be held on Thursday, March 26, 2015 at the UNI McLeod Center. Information about the UNI/AEA 267 Regional Competition may be found at http://www.physics.uni.edu/outreach/uni-physics-olympics. For questions related to the UNI/AEA 267 Regional Competition, call 319-273-2431 or email Larry Escalada at Lawrence.Escalada@uni.edu.

State Physics Competition

The State Physics Competition will be held on Thursday, April 16, 2015 at the UNI McLeod Center. Information about the state competition may be found http://www.physics.uni.edu/outreach/uni-physics-olympics. For questions related to the State Competition, call 319-273-2431 or email Larry Escalada at Lawrence.Escalada@uni.edu.

Teams that enter 2 events or less would pay $20
Teams entering 3 or more events would pay $40

All payments for the State Physics Competition should be sent directly to the UNI Physics Department. Checks and P.O.'s will be accepted. P.O.'s can be sent to Becky Adams via email at: becky.adams@uni.edu or you can fax (319-273-7136), or mail the P.O. to Becky at: 215 Begeman Hall, Department of Physics, University of Northern Iowa, Cedar Falls, IA 50614-0150. Please use the same address for payment by check. For questions related to payment, contact Becky Adams via phone (319-273-2420) or email provided above.

THE SCORED EVENTS

1. Catapult
2. Mousetrap Car
3. Bridge Building
4. Soda Straw Arm
5. Challenge Problem

1. CATAPULT. Each team will submit one **stationary** "Catapult," built by both members to launch a ping-pong or table tennis ball from a starting line to 3 given targets. The device shall **NOT** exceed the following dimensions: **40** cm in length, **20 cm** in width, and **40 cm** in height. Teams may place their devices in either cocked or uncocked position prior to the judges' measurements of the device's dimensions. The energy sources shall consist of any elastic storage device (rubber bands, bungee cords, leaf springs, etc.) **and/or gravity-powered device**. No other mechanical or chemical device may provide energy the propulsion of the ball. The judges will provide the ping-pong balls. Once the catapults are found to be in compliance with the construction parameters, the students may not handle their catapults until they compete.

The Competition –The official competition ping-pong ball will be a 40 mm table tennis ball. This replaces the former 38 mm (1.5") diameter ball. Teams will use ping-pong balls supplied by the judges. Each device will be placed behind a starting line. After being given the ping-pong ball to be placed on their device, teams may trip or release a switch, object, or some other device that activates the catapult.

1. A target will be marked on the floor **3** meters from the **starting line**. The distance measured radially from the center of the target to the point where the ball first contacts the floor, will be the launch distance. Each team gets one trial at this distance.
2. Another target will be marked on the floor **5** meters from the **starting line**. The distance measured radially from the center of the target to the point where the ball first contacts the floor, will be the launch distance. Each team gets one trial at this distance.
3. A target will be marked on the floor **8** meters from the **starting line**. The distance measured radially from the center of the target to the point where the ball first contacts the floor, will be the launch distance. Each team gets one trial at this distance.

The distances will vary from year-to-year with at least two of the distances changing.

Once the competing student places the catapult behind the starting line, he/she will have a maximum of one minute to launch the ping-pong ball. Exceeding the 1-minute time frame will result in a default score of **4** meters. No student may not enter the competition zone once the ping-pong ball has been given to the team. Students who want to line up their device before launching the ball must do so within the 1 minute time limit and before being given the ping-pong ball.

Each device entered will be allowed one trial at each distance. Scores will be based on the total of the three trials. The team with the smallest launch distance will be declared the winner. A default or failure to launch will be assigned a distance of **4** meters.

The target distance and/or other parameters may change each year.

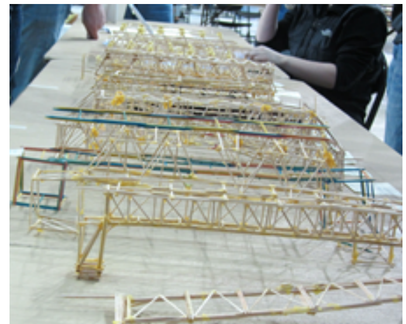
2. MOUSETRAP CAR. Each team will enter one mousetrap-powered car, built by both team members. The car shall not include any parts from a commercial mouse trap car kit. The car must meet the following requirements:

a. The car shall have a minimum of two (2) wheels, **and only wheels**, in contact with the testing surface at all times. **If any portion of the device (other than a string) makes contact with testing surface during the trial, the device scored as a default of 550 cm. String may touch the surface at any given time without disqualification.**
b. The sole power source of the car shall be a mousetrap (about 2” x 4”) as a part of the car. Rattraps may NOT be used.
c. Only the following changes are allowed for the mousetrap:
 -Heat may be used to change the tension of the spring.
 -The trip mechanism may be removed.
 -A string may be attached to the bow.
d. No other string, wire, materials, or system may be used including to link the device to another object during the trials.
e. In the cocked position the only part of the car that may touch the trap is the frame and the string.
f. Each device must conform to the following maximum dimensions: **30 cm in length x 15 cm in width x 15 cm in height**. **Teams may place their devices in either cocked or uncocked position prior to the judges’ measurements of device dimensions.**
g. The car must travel within a **300 cm** wide lane. The lane will also extend 50 cm before the start line to form a start zone. The front edge of the car must start within the designated start zone defined by the interior edge of the line.
h. The target line will be **550 cm** from the launch line. **The students will clearly mark the front edge of their car that will act as the point from which the measurement(s) will be taken. Once identified with a permanent marker, this point may not be changed.**
i. Once **the competitor steps** behind the line, **there will be** a maximum of two minutes to launch. Exceeding the 2-minute time frame will result in a default for that trial and will be scored as a default of **550** cm.
j. Any attempt in which the car breaks the plane of either side boundary line will be declared a fault and will be assigned the default distance of 550 cm.

<u>**The Competition**</u> - The car will be allowed two trials to determine the best distance. The car may be launched from any point within the start zone. The distance will be measured perpendicularly from the center of target to the point **designated by the students (Not the judge or scorer)** on the front edge of the car. No false starts will be allowed. Cars <u>must</u> be self-starting - no pushing for starts. The shortest perpendicular distance from the front edge as determined by the students to the center of the target line determines the car with the best score. A car stopping point can be on either side of the target line. In the case of a tie, the results of the other trial score will break the tie. Next best scores will determine runners-up.

The target distance and/or other parameters will change each year.

3. BRIDGE BUILDING. Each team will submit one toothpick bridge for testing, built by both team members. The bridge will be constructed from Diamond or Forster flat, round, or square wooden toothpicks approximately 6.5 cm in length from a box labeled accordingly: Flat, Round, or Square Toothpicks; and **Elmer's™ white glue** may be used. **NO other glue may be used. Any off-white color for dried glue found on the bridge will result in a disqualification.** Each bridge <u>must</u> satisfy the following requirements:



a. While resting on a table the bridge shall allow for a 5 cm x 5 cm x 30 cm board to pass under the bridge with its broadest side vertical and parallel to the length of the bridge, and with the movement of the board perpendicular to the roadway along the table top.
b. The roadway of the bridge shall be a minimum of 4 cm wide along the maximum length of the bridge and at a height from the tabletop of not more than 10 cm. The roadway shall consist of at least a rail along each side, which is continuous along the maximum length of the bridge. It need not have a travelable surface. When a 3.5-cm wide by 50-cm long 3/4" board is laid along the roadway, there shall not be more than a 1.0-cm vertical gap between the board and roadway on either end.
c. The bridge shall allow for a test rod (wooden block with the dimensions of 2 cm x 4 cm x 15 cm) to be placed across the bridge at the roadway level and with both bottom 15 cm edges within 3 cm horizontally of the center of the 30 cm span roadway. If student teams can easily remove toothpicks from their bridge for this to be done, they may do so at the discretion of the judges. Teams, however, are NOT allowed to remove significant sections of their bridge and re-glue any of their components.
d. The maximum bridge height shall be 22 cm.
e. The bridge must be "free standing".
f. Specified toothpicks and glue are the only materials to be used.

<u>**The Competition**</u> - The bridges will be tested as follows:

a. The bridge shall be placed on a testing stand, by the student(s), which will consist of two flat level surfaces level with respect to each other and separated by approximately 25 cm.
b. The testing apparatus will be placed over the bridge, by the student(s), with the test rod placed on the roadway as specified above. (Maximum bridge height is 22 cm.)
c. Force will be applied slowly by the student via the lever to the test rod (by twisting the turnbuckle) while one scorer continuously calls the scale reading until the other scorer detects a deflection of 0.5 cm. The scale reading last called is the measured force applied or bridge strength.
d. The team with the **largest ratio of measured force applied divided by the mass of the bridge** will be declared the winner.

Other devices may be used. Photographs of a testing apparatus that may be used at regional and state competitions are available at http://www.physics.uni.edu/outreach/uni-physics-olympics. Other devices may be used.

4. SODA STRAW ARM - each team will be given 15 jumbo plastic, clear straws, 10 straight pins and one #1 paper clip. The straws used in the competition will be 7¾" or 10" straws. **Straws will be provided for the actual competition only. No straws will be provided for event preparation.** The purpose of the competition is, with only the above materials, to construct the longest arm from their own team design that will support a 50-gram mass. Construction time will be **20 minutes** with testing by the team allowed during the construction. The paper clip, bent to an "S" shape, is to be used only for attaching the 50-gram mass. It must be attached by looping it over a single straw or pin. It may not be used in any way to strengthen or help construct the arm.

a. **Students are required to bring and show the judges a sketch of their design prior to the competition to guide their construction.** No physical models will be allowed at the competition.

b. Straws, pins and the mass will be provided at the competition. The mass will be attached to a string (approximately 30-cm from the paper clip to the top of the mass). **Scissors and pliers will be allowed as tools but they will NOT be provided.**

c. **If students wish to cut pins, they must bring and wear chemical splash goggles and gloves and move to the "pin cutting station" to complete this process. Goggles and gloves will NOT be provided.** Students will not be allowed to cut pins without wearing goggles and gloves. If no goggles are

d. All construction must be done during one **20-minute** time period at the competition site. If pins bend or break during construction, they will not be replaced. At the end of the **20-minute** period all arms will be labeled and placed on the judge's second table. The team members will pick up the arm only when they are called to compete. **No modifications are allowed after the 20-minute construction period.** This prohibition includes replacing straws or pins, which have pulled loose from the arm.

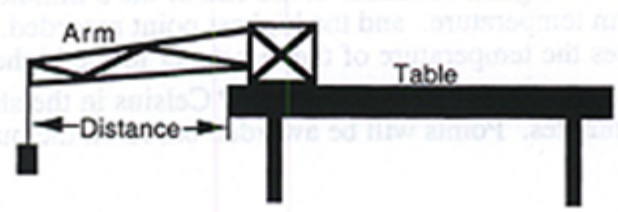
e. The arm apparatus must be in contact with (not secured to) the top surface only of the table.

e. The arm must support the mass above the floor for 10 seconds without any straws "crimping". Crimping is a fold line across the straw and will be allowed in the original construction before testing.

f. A team member is responsible for holding the straw arm and sliding it out from the edge of the table to the desired position. This person may not touch any part of the apparatus that extends beyond the table once timing has begun. Once the straw arm is in the selected position and tension has been supplied by the 50-gram mass, the 10-second period begins, and manipulation of the arm by the holder must stop.

g. The distance will be measured along a horizontal line perpendicular to the table edge from the point directly above the point of attachment of the weight. The distance to be recorded will be the distance at the end of the 10-second time period.

h. If the arm design is such that the arm end is higher than the tabletop, the 30 cm string must extend below the top of the table so the judge can accurately measure the length using a meter stick at table-top height.



The Competition - One of the team members will hold the arm in the desired test position against the tabletop with no part of the team member's body extending beyond the test edge of the table and with both palms touching the tabletop. No other part of the body may touch the arm or be attached to it. The other team member will attach the weight by placing the loop of the string attached to the 50-gram mass over the hook end of the paper clip. As soon as the team member hooks the string and immediately removes his/her hand from the string, the 10-second period will begin. This team member may not touch the arm, string, or mass during the 10 second time period. During this time the holding team member may not manipulate the arm. At the end of the 10-second time period, the judge will measure the length**. Each team whose arm successfully holds the 50-gram mass for ten seconds will be immediately given a second trial. No changes may be made to the arm except for desired repositioning on the tabletop.** The winner is the team with the arm having the longest recorded distance, which held the mass successfully for 10 seconds.

5. CHALLENGE PROBLEM

<u>Directions for students</u>

1. Students should come to the event with their understanding of physics. Each team should consist of two students.
2. Each team will have a separate set-up on a bench to work with. Benches may or may not be separated with partitions, but should be sufficiently separated so that teams cannot easily follow each other's work.
3. There will be at least one judge for every two participating teams.
4. The set-up will be physics laboratory equipment. The equipment **may or may not** include the following items (<u>the list is neither inclusive or exclusive and may change from one year to the next</u>):
    a. Two wooden rulers, graded in millimeters.
    b. Two metal hangers with clamps and hooks.
    c. A metal or plastic prism about 5-7 cm on the side.
    d. A graduated beaker with spout that can contain 0.5 l of liquid.
    e. A graduated beaker with spout that can contain 0.25 l of liquid.
    f. A roll of string.
    g. A hollow metal or plastic tube.
    h. A vessel containing clean water (at least 1 liter).
    i. A protractor of 1-degree accuracy.
    j. A small, light pulley.
    k. A flexible metal ruler.
    l. Metal or plastic spring(s).
    m. A stopwatch.
    n. A pair of scissors.
    o. A roll of kitchen paper towels.

5. The following items will *always* be included:
    a. A set of calibrated masses with **100 g resolution** (hanger or slotted -style, 100-g and 500-g masses only). Each team may bring their own masses for the *regional* competition, but must show them to the judges first. For the *state* competition the masses will be provided. **All masses including those brought by any team must have 100g resolution.**
    b. A notepad, checked graph paper, and several pencils.
    c. A pocket non-programmable calculator.
    d. A laminated formula sheet that includes constants
    e. An unknown mass (test object), like a sphere, cylinder or cube with a hook **possibly** attached to it (the unknown mass need not be the same for all team.)
6. During the competition, each team should devise at least one technique to measure the unknown mass, and carry out the necessary experiment(s) to do so.
7. All work done by the team, including formulas used, measurements, calculations, sketches of the apparatus, graphs, and results should be kept. Teams may choose to use the notepad for early work before summarizing their results on the reporting worksheet, but should append these pages to the submitted worksheet.
8. DO NOT damage, alter, or mark the equipment in any way except for cutting strings and paper.
9. Teams will be given **30 minutes** to complete their work.

10. Each team shall present the judges with the following (at the end of the **30 minute** period or earlier):
    a. Challenge problem worksheet, containing
        i. Team members' names and school;
        ii. Best estimate of the unknown mass in grams (to an accuracy of 0.1 g);
        iii. Two values, representing the highest and lowest estimate of the mass due to measurement uncertainty;
        iv. Absolute value of the difference between the highest and lowest estimates, divided by 2. This will be quoted as the uncertainty (error) in the measurement.
    b. any additional sheets displaying measurements, calculations, and other work, and any graph paper (if used). <u>The team's name should be written on every notepad page and piece of graph paper used by the team</u>.

11. The judges will measure the exact mass of the test object(s) with an accurate laboratory scale. This result will be recorded as the REAL VALUE of the mass. The judges will also keep track of the total time each team takes to complete their work, which should not exceed 30 minutes.

<u>Evaluation</u>

The evaluation of each team's work will consist of 2 parts: (1) a score of the measurement and (2) a score of the work done. Both scores will be produced by the judges. The final score will be the SUM of the measurement and the work scores.

1. The score of the measurement must be a measure of the closeness to the actual value as well as the precision of the measurement. The following formula will be used to evaluate this score:

$$\text{Measurement Score} = 100 - \text{fractional abs. error} - \text{fractional uncertainty} - \text{statistical success}$$

where

$$\text{fractional absolute error} = \frac{|\text{real value} - \text{best estimate}|}{\text{real value}} \times 100$$

and

$$\text{fractional uncertainty} = \frac{\text{measurement uncertainty}}{\text{best estimate}} \times 100$$

and

$$\text{statistical success} = |\text{high est.} - \text{real value}| + |\text{real value} - \text{low est.}| - (\text{high est.} - \text{low est.})$$

The bigger the uncertainty the more likely it is that the measurement will include the actual value of the mass. On the other hand the bigger the uncertainty the less valuable the measurement is.

Using this formula a team that produces an estimate that is closer to the actual value AND has smaller uncertainty in their measurements will get a higher score, <u>provided that the real value lies within the reported uncertainty of the reported estimate</u>. The highest possible score of the measurement is 100.

2. The score of the work done will be given based on the following criteria:
    a. Does the team use a valid experimental approach, and are they able to describe it? (30 points maximum)
    b. Has the team taken all necessary measurements and performed any required calculation? (40 points maximum)

c. Does the team account for reasonable experimental uncertainty, given their chosen approach? (30 points maximum)

Specific criteria examined by the judges are provided within the judging section of the challenge problem worksheet, included in this document.

The evaluation of the work done certainly includes some subjectivity. To minimize this subjectivity and ensure that all teams are treated equally this part of the evaluation will be done by the entire team of judges who will convene after the event for this purpose.

In the case of a tie the team who finishes in the shortest time will be ranked higher.

NOTE: No measurement will be accepted without a measurement error estimate. If a team reports a measurement without an error estimate they will be disqualified.

CHALLENGE PROBLEM WORKSHEET

Team Members' Names:____

School:____

Best Estimate of the Mass:__________

High Estimate of the Mass (accounting for experimental uncertainty):__________

Low Estimate of the Mass (accounting for experimental uncertainty):__________

Experimental Uncertainty ($(high\ estimate - low\ estimate) \div 2$):__________

Experimental Approach. Briefly describe, in paragraph form, the technique(s) used to determine your measurement of the mass.

Experimental Approach Score (judges use only)	Points
Could the method described be used to determine mass? (Yes = 10 pts, No = 0 pts)	
Is the description free from error? (Yes = 10 pts, No = –2 pts per error)	
Overall, rate the description. (Excellent: 10 pts Good: 7 pts Fair: 4 pts Poor: 1 pt)	

Measurements and Calculations. Please include all measurements and calculations used to determine your reported values. Use additional paper if necessary.

Measurements and Calculations, continued.

Measurements and Calculations Score (judges use only)	Points
Do the measurements and calculations support the previously described experimental approach? (Yes = 10 pts, No = 0 pts)	
Are the calculations error-free? (Yes = 20 pts, No = –5 pts per error)	
Do the calculations support the reported mass value? (Yes = 10 pts, No = 0 pts)	

Experimental Uncertainty. Briefly describe, in paragraph form, justify how you determined or estimated the uncertainty in your measurements.

Experimental Uncertainty Score (judges use only)	Points
Rate the justification (Excellent: 10 pts Good: 7 pts Fair: 4 pts Poor: 1 pt)	
Is the reported uncertainty value reasonable? (Yes = 10 pts, No = 0 pts)	
Does the reported uncertainty agree with the description? (Yes = 10 pts, No = 0 pts)	

TOTAL WORK DONE SCORE:________

Challenge Problem Example

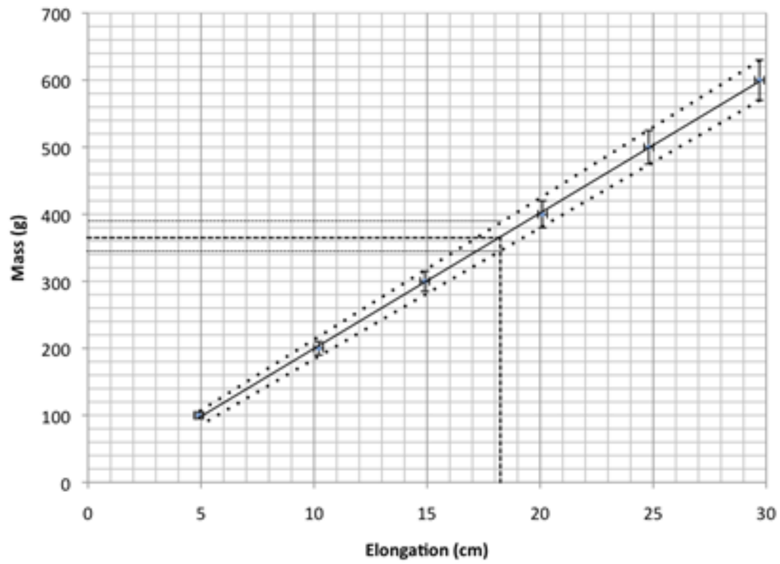
Suppose that on the bench you find, among other items, a set of masses, a metal spring, a ruler, and a hanger with a horizontal bar from which the spring can be suspended. The first idea that may come to mind is use Hooke's law for springs to measure the unknown mass.

Recall that if a mass is suspended from a vertical and very light spring the elongation, x, of the spring from its natural length is proportional to the weight, W, of the mass, *i.e.*, $W = kx$, where k is the spring constant. Now, $W = mg$, where m is the mass and $g = 9.8\ \text{m/s}^2$ is the acceleration due to gravity. Therefore, $m = (k/g)x$. This means that the mass m and the elongation x are proportional to each other. If m is plotted versus x on graph paper it will look like a straight line passing through zero. The slope of the line (rise over run) is simply k/g.

One procedure that could be followed is to simply record several values of the elongation when known masses are suspended and produce the m-versus-x plot. Then one can suspend the unknown mass, measure the elongation it produces (always from the low-end of the spring) and use the plot to find the unknown mass. Each known mass has an uncertainty (error) associated with it. For this example, we'll assume that each provided 100-g mass has an uncertainty of +/– 5 g. Similarly reading the spring elongation with a ruler includes an error, typically taken as the smallest division the ruler can measure. The measurements can be summarized in the table.

	elongation (x) in cm	mass (m) in grams	x-error in cm	m-error in g
	4.9	100	0.2	5
	10.2	200	0.2	10
	14.9	300	0.2	15
	20.1	400	0.2	20
	24.8	500	0.2	25
	29.7	600	0.2	30

The plot of m versus x for these data is shown below. The central line can be drawn by eye to best fit the data. The two other lines represent the two extreme limit lines that could be drawn and can be used to estimate the error in the measurement of the unknown mass.



Now the unknown mass is suspended and, say, an elongation of 18.2 cm is measured with the error of +/– 0.2 cm. On the same graph we draw a line perpendicular to the x-axis at 18.2 cm. This intercepts the three lines drawn earlier. The central line gives a value of m = 365 g. Similarly the upper line gives m_{max} = 390 g and the lower line gives m_{min} = 345 g. Therefore, the experimental uncertainty in the mass measurement is given by (390 g - 345 g) ÷ 2 = 22.5 g.

A sample challenge problem worksheet with scoring comments is included.

SAMPLE SUBMITTED CHALLENGE PROBLEM WORKSHEET

Team Members' Names: A Einstein and I Newton

School: Anytown, Iowa High School

Best Estimate of the Mass: 365 grams

High Estimate of the Mass (accounting for experimental uncertainty): 390 grams

Low Estimate of the Mass (accounting for experimental uncertainty): 345 grams

Experimental Uncertainty ($(high\ estimate - low\ estimate) \div 2$): 22.5 grams

Experimental Approach. Briefly describe, in paragraph form, the technique(s) used to determine your measurement of the mass.

We used a spring and stretched it out with various masses.

Experimental Approach Score (judges use only)	Points
Could the method described be used to determine mass? (Yes = 10 pts, No = 0 pts)	**10**
Is the description free from error? (Yes = 10 pts, No = –2 pts per error)	**10**
Overall, rate the description. (Excellent: 10 pts Good: 7 pts Fair: 4 pts Poor: 1 pt)	**1**

{Comments: A spring can be used to determine the mass, as shown in the example. With what little is said by the students, there are no errors in the explanation. However, the great lack of detail led the judges to score this description of experimental approach as "poor."}

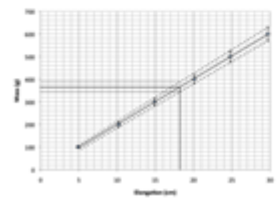
Measurements and Calculations. Please include all measurements and calculations used to determine your reported values. Use additional paper if necessary.

Here is what we measured:

	elongation (x) in cm	mass (m) in grams	x-error in cm	m-error in g
	4.9	100	0.2	5
	10.2	200	0.2	10
	14.9	300	0.2	15

	20.1	400	0.2	20
	24.8	500	0.2	25
	29.7	600	0.2	30

We stopped taking data at 600 grams because the spring was getting pretty stretched out at this point. We then made a graph of the mass vs. elongation of the spring, and figured out the slope of the graph.



Measurements and Calculations, continued.

Since the slope of the graph is 20 g/cm, and this is equal to *k/g*, then the spring constant of the spring must be 20 × 9.8 = 196 N/m. When we hung the unknown mass from the spring, it stretched to 18.2 cm, which is 0.182 m, the unknown mass should be 35.7 grams.

Measurements and Calculations Score (judges use only)	Points
Do the measurements and calculations support the previously described experimental approach? (Yes = 10 pts, No = 0 pts)	**10**
Are the calculations error-free? (Yes = 20 pts, No = –5 pts per error)	**15**
Do the calculations support the reported mass value? (Yes = 10 pts, No = 0 pts)	**0**

{Comments: The measurements and calculations are consistent with using a Hooke's law approach to finding the unknown mass. However, the calculations are not error-free; the group failed to convert from g/cm to kg/m when finding the spring constant. Also, the result of the calculations does not agree with the value reported at the top of the worksheet.}

Experimental Uncertainty. Briefly describe, in paragraph form, justify how you determined or estimated the uncertainty in your measurements.

We think we can measure to within ± 0.2 cm with the ruler. Also, we estimated that each 100 g mass had an uncertainty of ± 5 g. Since our best estimate of the mass is 365 g, this would be between 300 g (± 15 g) and 400 g (± 20 g), so we guessed that the uncertainty in mass is about ± 18 g.

Experimental Uncertainty Score (judges use only)	Points
Rate the justification (Excellent: 10 pts Good: 7 pts Fair: 4 pts Poor: 1 pt)	**7**
Is the reported uncertainty value reasonable? (Yes = 10 pts, No = 0 pts)	**10**
Does the reported uncertainty agree with the description? (Yes = 10 pts, No = 0 pts)	**0**

{Comments: The estimated uncertainties in length measurements and mass values seem reasonable, but the reported uncertainty given earlier in the worksheet does not agree with this description, but rather with values gleaned from the graph. This justification was deemed "good," as it represents a reasonable number based on estimated uncertainties, though the final result could be determined more precisely rather than being guessed.}

TOTAL WORK DONE SCORE: **63 pts**

Suppose a very accurate electronic scale gives 371.2 g; this is considered the real value of the mass for scoring purposes. Based on the values reported on the challenge problem worksheet, we can determine the measurement score:

$$fractional\ absolute\ error = \frac{|371.2\,g - 365\,g|}{371.2} \times 100 = 1.67$$

and

$$fractional\ uncertainty = \frac{22.5\,g}{365\,g} \times 100 = 6.16$$

and

$$statistical\ success = |390\,g - 365\,g| + |365\,g - 345\,g| - (390\,g - 345\,g) = 0$$

(Statistical success is always 0 if the real value lies within the reported uncertainty of the best estimate.)

This means the measurement score would be

$$Measurement\ Score = 100 - 1.67 - 6.16 - 0 = 92.17$$

The measurement score combined with the work score produces the total score for the challenge problem event. In this example, the total score would be 155.17.

IOWA PHYSICS COMPETITION
2014-15

CATAPULT

Judge and Event Director Checklist

1. Check each device to assure that **only** elastic storage device (rubber bands, bungee cords, springs) and/or a gravity powered device are used.

2. Check for size compliance of the device (**40 cm x 20 cm x 40 cm**).

3. Complete 1 and 2 above for all contestants before proceeding

4. After each device has been checked in, place it on a table and **assure that students do not handle the device** until it is time for that team to compete.

5. Mark the point where the ball first contacts the floor for each distance (3 m, 5 m, 8 m).

6. When all contestants have completed their three trials, measure and record each **distance from the center of the target to the point of ball contact with the floor. Do not do any calculations.** These are done with a computer.

7. Record a distance of **4** meters for any device that does not complete its trial or takes longer than **1 minute** to launch after the student has been given the ping-pong ball.

8. Please mark the "Device Entered" column on your score sheet (Y or N) for each team to aid the scorers in distinguishing between a fault and a no-show. Be sure to explain to the Physics Competition Director any **confusing data**.

9**. Please make sure that the two table tennis balls (40 mm) official ping-pong balls are ready. Please note that the 40 mm ball replaces the 38 mm ball previously used.**

IOWA PHYSICS COMPETITION
2014-15

MOUSETRAP CAR

Judge and Event Director Checklist

1. Check each car for **size** using the size gauge provided.

2. Check the mousetrap to see that a rattrap is NOT used and for allowed **changes** (rules 2b & 2c).

3. Check that only one string is used and attached to the bow with no other string, wire, materials or system being used including to link the device to another object during the trial.

4. Complete 1 through 3 above for all contestants before proceeding. After each car has been checked in, place it on a table and **assure that students do not handle the car** until it is time for that team to compete.

5. For each trial, the front edge of the **entire device (including the wheels)** must start within the designated "start zone" defined by the interior edge of the tape. T**he students (NOT the judge or scorer)** designate the front edge of the car from which measurements are to be made.

6. As each car competes, the front edge of the car designated by the students is immediately marked by tape on the floor and the distance is measured to the closest edge of the line. The measurement will be the perpendicular distance from the center of the target line to the front edge of the car. A car stopping point can be on either side of the target line.

7. Please mark the "Device Entered" column on your score sheet (Y or N) for each team to aid the scorers in distinguishing between a fault and a no-show. Be sure to explain to the Physics Competition Director any **confusing data**.

IOWA PHYSICS COMPETITION
2014-15

BRIDGE BUILDING

Judge and Event Director Checklist

1. Measure the **mass** of each bridge.

2. Check for the **under bridge clearance** with the provided gauge**.**

3. Check the **roadway height** (not more than 10 cm above the tabletop) and the **roadway width** (minimum of 4 cm).

4. Check for the **placement of the test rod** (edge within 3 cm of the center of the 30 cm span).

5. The **height of the bridge** shall not exceed 22 cm.

6. Check the **roadway for flatness with the board provided**. (no more than 1.0 cm gap at either end)

7. Check that the only **construction materials** are flat, round or square wooden tooth picks; and Elmer's white. **NO other glue allowed**.

8. Complete 1 through 7 above for all contestants before proceeding.

9. After each bridge has been checked in, place it on a table and **assure that students do not handle the bridge** until it is time for that team to compete.

10. **Supervise as student(s)** test each bridge for strength. The event director should **verbally call out the reading of the scale or the Force plate** at each 1.0 kg, 1.0 lb, or 1.0 N or agreed upon kg, lb, or N (by the judges) increment. The recorder should watch for the indicator light signaling the 0.5 cm deflection and then record the largest kg, lb, or N reading as the bridge strength or measured force applied.

11. Determine the ratio of the measured force applied over mass of the bridge. The highest ratio of bridge strength to mass of bridge will be designated the winner.

12. Please mark the "Device Entered" column on your score sheet (Y or N) for each team to aid the scorers in distinguishing between a fault and a no-show. Be sure to explain to the Physics Competition Director any **confusing data**.

IOWA PHYSICS COMPETITION
2014-15

SODA STRAW ARM

Judge and Event Director Checklist

1. **Students are required to bring and show the judges a sketch of their arm design prior to the start of the event.** Make sure there are **no model arms brought with student teams**.

2. **Distribute** the straws, pins and the paper clip. It is recommended that the students be given several minutes to count the pins and straws and also to exchange any items they consider defective. Then **start timing**. Notice that students may provide their own scissors and/or pliers only. Other tools should not be allowed.

3. If students wish to cut pins they must bring and wear chemical splash goggles and gloves and move to the "pin cutting station" to complete this process.

4. At the end of **20 minutes** call time. Collect and label all arms and place them on a table.

5. After each arm has been checked in, place it on a table and **assure that students do not handle the arm** until it is time for that team to compete.

6. As each arm is tested, **check** for appropriate positioning and use of **hands while sliding and holding**.

7. If an arm holds the mass on the first trial the team is immediately given a second trial. If the arm does not hold the mass on the first trial the team receives a fault and **does not get a second trial**.

8. Measure and record the **length** of each arm. Circle the length for the top five teams.

9. Please mark the "Device Entered" column on your score sheet (Y or N) for each team to aid the scorers in distinguishing between a fault and a no-show. Be sure to explain to the Physics Competition Director any **confusing data**.

IOWA PHYSICS COMPETITION
2014-15

CHALLENGE PROBLEM

Judge and Event Director Checklist

Before the event starts
1. Make sure that all set-ups have the same items available.
2. Identify all teams. Each team must have 2 students. The event may occur in two or more installments if there are more than 4 or 5 teams.
3. For the regional competition the students may bring their own masses. Check them in advance because their masses may not be allowed. Mass sets will be provided for the regional and state competitions. **Please note that the masses used for the event including those brought by any team must have a resolution of no smaller than 100 grams.**

During the event
1. Start your stopwatch to count the time the teams will take to finish their work. **Please note that each team has 30 minutes to complete the event.**
2. Make sure the teams do not copy from one another.
3. Make sure that the teams do not break or alter the equipment (except for cutting paper and strings).

Collecting student results
1. When a team finishes, record their time, and collect their challenge problem worksheet, additional notebook pages (if any), graph paper(s) (if any). Ensure that the names of team members are included on any additional papers. Also, ensure that an uncertainty estimate is reported. Teams not including uncertainty estimates are disqualified.
2. Using the laboratory scale, determine the "real" value for each mass in grams.
3. Calculate the measurement score for each team, using the following formula:

$$Measurement\ Score = 100 - fractional\ abs.error - fractional\ uncertainty - statistical\ success$$

where

$$fractional\ absolute\ error = \frac{|real\ value - best\ estimate|}{real\ value} \times 100$$

and

$$fractional\ uncertainty = \frac{measurement\ uncertainty}{best\ estimate} \times 100$$

and

$$statistical\ success = |high\ est. - real\ value| + |real\ value - low\ est.| - (high\ est. - low\ est.)$$

Note that if the "real" value lies within the reported uncertainty of the reported estimate, the statistical success will be 0. (This portion was added to penalize teams when the "real" value lies outside of reported uncertainty, and to discourage teams from reporting unreasonably small uncertainties.)

A spreadsheet for automating calculations of the measurement score can be obtained from Jeff Morgan (jeff.morgan@uni.edu).

4. Evaluate the work done by each team. If possible, all judges should collectively score the work done by each team. If this is not possible, the judges should meet and discuss criteria for scoring prior to beginning. After completion of scoring, judges should again discuss any ambiguities or questions to ensure that all judging is as equitable as possible.
    a. Use the questions provided on the challenge problem worksheet to judge the description of the experimental approach. Is this approach valid? Do the students describe the approach correctly and thoroughly? (Maximum score of 30 points. If left blank, score a 0.)
    b. Use the questions provided on the challenge problem worksheet to judge the measurements and calculations presented on the worksheet, as well as on additional papers submitted. Do they support the technique(s) previously described? Are they correct? Do they agree with the reported value? (Maximum score of 40 points. If left blank, score a 0.)
    c. Use the questions provided on the challenge problem worksheet to judge the description of the determination of experimental uncertainty. Does the team justify their estimates? Are they reasonable? Are they in agreement with values reported elsewhere on the sheet? (Maximum score of 30 points. If left blank, score a 0.)
    d. Determine a work done score for each team.
5. Determine the team score by summing the measurement score and the work done score.
6. In the case of a tie, the time taken to complete the task will be used. The faster team will rank higher than a team that took more time.
7. Rank the top 10 teams in descending order, giving 10 points to the first place team, 9 points to the second place team, etc. Report these results to the event coordinator.