An analysis of applied mechanics contest for senior high school students in Taiwan

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Abstract

The applied mechanics education contest hosted by STAM (Society of Theoretical Applied Mechanics) has been held in Taiwan for several years. The contest pattern has been changed from a simple written test to an experiment-oriented test after the NSTM (National Science and Technology Museum) proceeded to hold the competition in 2005. The major change of the contest is to merge theory with a practical experiment. The NSTM set up well-designed video shows and materials packs for hands-on experiments at the contests. Visiting related mechanics exhibits at NSTM was highly recommended by the contestants and teachers. Statistical analyses of the contest scores over the past four years shows no significant correlation between the medals and the areas where the contestants are from, and there was no significant difference among the contestants' final scores for different areas. Since 2004, the outstanding students at the competition were selected to attend the annual cross-strait mechanics field academic exchanges, and this academic exchange will continue to help extend the influence of mechanics education in Taiwan and China.

Keywords: applied mechanics education, mechanical contest

Origin

The NSTM innovated contests for students have become more and more important in showcasing students' innovative talents in China. Tang and Sun analysed the students' learning science and technology innovation contest in China and made several suggestions and countermeasures on the team's construction, system ensure, funds and educational reform (Zhao-Ping Tang, Jian-Ping Sun, 2007). Several of the students' after-school technology activities were conducted in a laboratory that was open to the students and was set up especially for students to organize after-school technology activities (Song-Wu Wang, Wen-Zhi Liu and Hai-Bo Li, 2007). Liu and Yu gave introductions at the Electronic Design Contest at the University of Electronic Science and Technology of China. The contest's organization and impact on strengthening educational reform as well as developing students' innovative and practical abilities were also discussed (Yun Liu and Mei Yu, 2007). In Taiwan, Huang and Chuang (2005) studied the scientific knowledge and creativity of high school students and described the process of contest judgement. They found training programs could be helpful in improving students' knowledge. Through the in-depth interviews and analysis, they also found that the creativity contest helps students to think creatively (?) (Jun-Fu Huang, Mei-Chen Chuang, 2005). Hsu explored the problem of high school students' abilities in mechanics (?), and the research showed that basic physical knowledge of the subject is very important in predicting students' ability to find problems. In addition, only logical reasoning ability is related to problem finding ability (Yu-Chang Hsu, 1999). STAM (Society of Theoretical Applied Mechanics) has been hosting the mechanics contest in Taiwan for senior high school students in order to stimulate the learning intention of the mechanics field since 2002. It was originally given as a written test. Taking a written test was fair and time-saving, but the disadvantages included difficulty in screening elite competitors and obtaining government subsidies as written tests are commonly taken. . The educational authority encouraged the related mechanics tests to include hands-on experiments so as to encourage the students to explore, to observe, to experiment and to discuss. Therefore, STAM searched help from NSTM (National Science and Technology Museum) to overcome the challenges.

Approaches and Primary Test

In order to initiate circumstances to provide an equitable, education-oriented and entertaining mechanics test, NSTM set up a multi-steps mechanics contest for all senior high school students in Taiwan. There are two major stages for the mechanics contest. One is the primary test and the other is the final test. Several physics teachers from different senior high schools are invited to establish a test database, and professors of the National Cheng Kung University form an exam committee to revise and select the proper questions. Every April, the primary test is held in four main areas including Northern Taiwan, Taoyuan Hsinchu Area, Middle Taiwan and Southern Taiwan. More than 1200 students attend the primary test (see Pic. 1) every year. Around 200 candidates are selected, based on their primary test grades, to take the final test that is held in May. The primary tests of year 2006, 2007 and 2008 are posted on the NSTM website(Appendix A shows three examples of the primary tests).

Mechanic Contest for Final Test

For the final test, the exam committee's goal is to merge mechanics theories into a practical hands-on experiment and conduct the final test for nearly 200 contestants at the same time all in one day. The exam committee found a solution by using:

1. Video Show: Some experiments related to the final test were recorded beforehand. The video shows are played in front of the contestants so that they can observe the entire experimental process (Pic. 2 and Pic. 3).
2. Materials Pack: Packs of materials are provided to the contestants, if necessary, so that they can conduct the experiments at the table near their seats. (Pic. 4-Pic.7)
3. Questions: The test questions are designed in conjunction with the video shows. The tests are divided into several parts including multiple choice questions and short answer questions.
4. Corrections: The test sheets are scored by the exam committee, the standardized answers ” are minimized.
5. Visiting: Testers are taken to the exhibition hall inside NSTM to visit the exhibits related to the mechanics field. (Pic. 8)

Pic.1: The primary test

Pic. 2: Video show

Pic. 3: Experiment exam video show for the final test

Pic. 4: Experiment material pack for the final test

Pic. 5: Materials packs for hands-on learning

Pic. 6: The final test set-up (I)

Pic.7: The final test (II)

Pic. 8: Visiting exhibits

(Photos of Pic 1 to Pic. 8 by Nelson Cheng-Chih Chen)

The final tests of 2006 and 2007 are posted on the NSTM website (Appendix B shows three examples of the primary tests).

Statistical Analysis

Since 2004, the NSTM has been conducting the projects. At first, both the primary test and the final test were written tests. In 2005, the test mode was changed; the primary test kept the same written test pattern, and the final test was changed to merge theory and practical hands-on activities. The descriptive statistics about the final contestants and their primary and final scores are shown in Table 1. In 2005, there was a huge gap between the primary and the final test scores. The difference for the two average test scores almost reached 36(=94.20-58.24), and the reason may be because the testers were not accustomed to the newly changed test pattern.

Table 1: The descriptive statistics of the primary test and final test

Year	Primary test			Final test		
	Number of contestants	Average score	Standard deviation	Number of contestants	Average score	Standard deviation
2004	226	73.47	8.88	209	60.27	13.96
2005	210	94.20	4.07	210	58.24	11.10
2006	201	77.46	6.94	198	62.75	11.02
2007	203	77.59	8.58	200	57.97	14.05
2004-2007	840	80.60	10.91	817	59.78	12.74

Note 1: The number of primary test contestants is not the original competition attendance number; the number shown is representative of those permitted to join the final test after the primary test was held.

Note 2: Full score is 100.

Table 2: The correlation analysis of various tests between 2004 -2007

Year	Test method		Pearson correlation coefficient (r) for primary and final test scores	p value
	Primary	Final		
2004	Written	Written	0.36	0.00*
2005	Written	Hands-on	0.09	0.19
2006	Written	Hands-on	0.26	0.00*
2007	Written	Hands-on	0.51	0.00*

* Means p value < 0.05

The correlation analysis between the primary and the final test scores for each year is shown in Table 2. In 2004, the Pearson correlation coefficient between the primary test and the final test is 0.36. Statistical test results showed that there was significant correlation between the two tests. When the test method for the final test was changed to a hands-on approach in 2005, the correlation coefficient among the two tests dropped to 0.09. It appears that the primary test was not significantly linearly correlated with the final test. The reason might be that the testers were not familiar with the newly created tests. Nevertheless, the correlation gradually increases during 2006 and 2007, and the testers may be getting used to the changes.

The one factor ANOVA test about the final scores for different areas where contestants are from is shown in Table 3. The testing results show that from 2004 to 2007, there is no significant difference among the final scores for the different areas; the contestants from different areas seem to have equal ability in such applied mechanics contests.

Table 3: Final score analysis from different regions from 2004 to 2007

Area	Final test			F test	
	Testers' number	Average score	Standard deviation	F value	p value
Northern	186	59.56	12.72	0.33	0.80
Taoyuan Hsinchu	115	60.77	13.41		
Middle	157	59.29	12.37		
Southern	359	59.80	12.73		
Total	817	59.78	12.74		

The frequency distributions from 2004 to 2007 for various medals and areas where contestants from are shown in Table 4 to Table 7, respectively. Table 8 shows the correlation analysis among the medal types and the areas during the four years. Testing results suggested there was no significant correlation among the medal types and the areas where the contestant was from; the mechanics contest contestants seemed to have an equal ability in obtaining medals no matter where he/she came from.

Table 4: The cross table about medals and areas in year 2004

Area	Counts for medal rank				
	gold	silver	bronze	excellent	total
Northern	1	0	15	33	49
Touyuan Hsin-Chou	3	1	9	10	23
Middle	1	4	10	28	43
Southern	5	14	15	60	94
Total	10	19	49	131	209

Table 5: The cross table about medals and areas in year 2005

Area	Counts for medal rank				
	gold	silver	bronze	excellent	total
Northern	2	4	10	30	46
Touyuan & Hsin-Chou	4	4	12	26	46
Middle	1	1	10	18	30
Southern	3	11	18	56	88
Total	10	20	50	130	210

Table 6: The cross table about medals and areas in year 2006

Area	Counts for medal rank				
	gold	silver	bronze	excellent	total
Northern	3	9	16	29	57
Taoyuan & Hsinchu	3	2	4	12	21
Middle	1	2	10	25	38
Southern	3	7	20	52	82
Total	10	20	50	118	198

Table 7: The cross table about medals and areas in year 2007

Area	Counts for medal rank				
	gold	silver	bronze	excellent	total
Northern	1	3	11	19	34
Taoyuan & Hsinchu	0	3	5	17	25
Middle	4	3	16	23	46
Southern	5	11	18	61	95
Total	10	20	50	120	200

Table 8: The correlation analysis about medals and areas from year 2004~2007

Area	Counts for medal rank					Chi-Square test	
	gold	silver	bronze	excellent	total	Chi-Square value	p value
Northern	7	16	52	111	186	14.88	0.09
Taoyuan & Hsinchu	10	10	30	65	115		
Middle	7	10	46	94	157		

Southern	16	43	71	229	359		
Total	40	79	199	359	817		

Exchange and Contest between Taiwan and China

After the competitions in 2004, STAM chose 10 to 30 outstanding students to join the mechanics exchange and contest between Taiwan and China to help each other promote the related mechanics knowledge. From 2004 to 2007, the communication and applied mechanic contest for senior high school students in Taiwan and China, sponsored by the Society of Cross-Strait Applied Mechanics for Taiwan and China and the Chou Pei-Yuan Foundation, was held and the attending situations are recorded in Table 9 and in Pic. 9 to Pic. 11. The Cross-Strait applied mechanics tests of the year 2004, 2005, 2006 and 2007 are posted on the NSTM website.

Table 9: The mechanics field academic exchange from 2004 to 2007

Date	Undertake University	Coordinator	Number of attendants
2004/7/10 to 2004/7/16	Feng Chia University, Taichung, Taiwan		Taiwan: 30 students China: 15teachers 15 students
2005/7/15 to 2005/7/24	Hunan University, Hunan Changsha, China	The High School attached to Hunan Normal University	Taiwan: 14 teachers 10 students China: 37students
2006/7/16 to 2006/7/26	National Cheng Kung University, Tainan, Taiwan	National Science and Technology Museum	Taiwan: 27 students China: 15 teachers 15 students
2007/7/16 to 2007/7/23	Xi'An Jiaotong University, Shensi Sian, China	The High School to Xi'An Jiaotong University	Taiwan: 15 teachers 15 students China: 10 teachers 39 students
2008/7/14 to 2008/7/21	National Tsing Hua University, Hsinchu, Taiwan	National Science and Technology Museum	<to be held>

Pic. 9: The 2005 Mechanics Exchange and Contest in Hunan University, China

Pic.10: The 2006 Mechanics Exchange and Contest in National Cheng Kung University, Taiwan

Pic.11: The 2007 Mechanics Exchange and Contest in Xi'An Jiaotong University, China

(Photos of Pic. 9 to Pic.11 by Nelson Cheng-Chih Chen)

Conclusion and Suggestion

Technology learning is based on students' technological cognition, and it affects students' technology learning either directly or indirectly. Huang found that the effect of the students' experience after attending the competition on technological recognition. The students changed their recognition makes the researchers aware the continuity in technology education (Yi-Feng Huang, 2006).

A mechanics contest is an alternative and essential way for students to become familiar with mechanics. Correlation analysis results show that those who performed well in the primary test also had good performances in final test in 2004, 2006 and 2007. Statistical analyses of the test scores in the past four years show that contestants who came from different areas seemed to have equal abilities in their final scores and ability to obtain medals. The students not only use knowledge, passion and put bolts together, but the activity may possibly spark an interest in science and technology. Students' ability to find and solve problems still needs great improvements, , and it remains a big issue for educators to provide adequate teaching materials and methods to help cultivate high school students thinking and ability to solve mechanical problems. As more and more people attend the cross-strait mechanics field academic exchanges, the influence of mechanics education in Taiwan and China will continue to grow.

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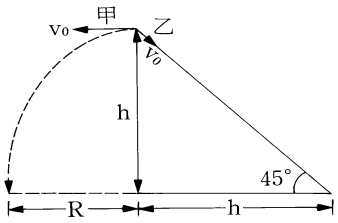
Appendix A: Three examples of the primary written test

Example 1:

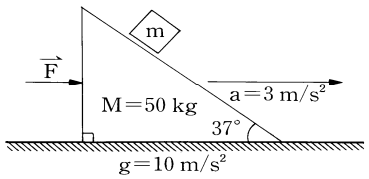
在距地面高度h處有甲、乙兩物體。物體甲以初速v_0水平射出，物體乙也同時以初速v_0沿一斜角爲45°之光滑斜面以直線軌跡滑下。如甲、乙兩物體同時到達地面，則 v_0爲何？

(A) $\frac{1}{2}\sqrt{gh}$ (B) $\sqrt{gh}$ (C) $\frac{3}{2}\sqrt{gh}$ (D) $\frac{1}{2}\sqrt{2gh}$ (E) $2\sqrt{gh}$



Example 2:

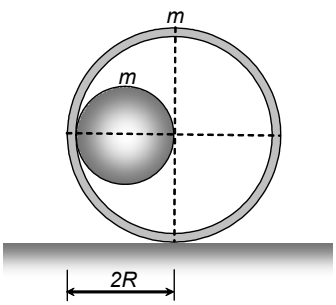
質量 m=10kg 的塊狀物體置於斜角爲 37°的三角形木塊 M 上，三角形木塊以 3.0 米／秒 ^{2} 的加速度向右運動，如圖所示。欲使物體不沿斜面滑動，且設 g=10 米／秒 ^{2}，試求物體與斜面間之最小靜摩擦係數 μ_s 爲多少(已知 $\sin 37^o = 3/5$，$\cos 37^o = 4/5$) (A) 0.6 (B) 0.8 (C) 0.37 (D) 0.63 (E) 0.57



Example 3:

質量 m，半徑爲 R 的球放在同質量、半徑爲 2R 的薄球殼內，並靜置於水平光滑桌面上，如右圖(3)所示。然後球被釋放並在球殼內來回滾動，最後靜止於底部；同時球殼也會左右移動，最後靜止於某一位置。請問最後球殼與桌面的接觸點與原來的接觸點相差了多少？

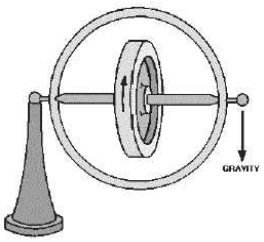
（A） R（B）R/2（C）R/4（D）3R/8（E）R/8。



Appendix B: Three examples of the hands-on experiment for the final test

Example 1 (2006)

陀螺儀(Gyroscope top)在水平軸旋轉，其左端點 pivot 固定，右端點可以自由運動沒有拘束，請問它會做甚麼樣的運動呢？請說明



Example 2 (2005)

念力單擺(2005)

本題組請使用材料包內之 2 枚鈴噹、2 條長短不一細繩、衛生筷，並依先前影片示範內容動手做做看

2-1、複選題(題分 4 分，全答對給 4 分，答錯不倒扣)

有關「念力單擺」的實驗影片中，下列敘述何者正確?

A.造成擺錘搖動的原因是念力集中的能量傳遞

B.造成擺錘搖動的原因是身體局部周期性振動力的傳遞

C.擺錘會搖動是因爲振動力的頻率接近單擺的自然振動頻率

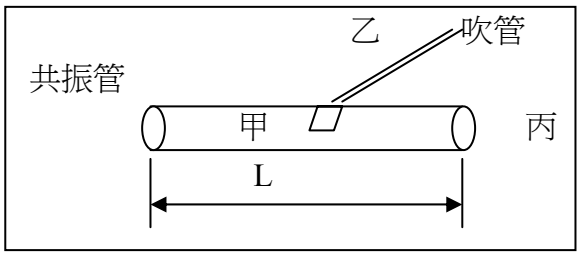
D.角頻率等於 π 乘以頻率

E.無論擺動幅度的大小，單擺擺動的頻率皆爲一定值。

Example 3 (2005)

黃鶯笛 (2005)

本題組請利用材料包內之粗、細吸管與電工膠布，並依先前影片示範內容動手做做看



6-1、單選題(題分 2 分)

輕微改變幾個不同的吹管角度，有些角度比較不容易發出共鳴聲，由此結果可推測發聲的振動部位是

A. 嘴唇　B.共振管壁　C.共振管氣柱　D.吹管壁。

6-2、填空題(題分 3 分)

若一個兩端開口的共振管之管長爲 L，其可發出的最低音（稱爲「基音」）之波長爲_____(填入幾個 L 單位)

6-3、填空題(題分 4 分)

若一支一端開口另一端閉口的共振管之管長爲 L，其可發出的最低音之波長爲____(填入幾個 L 單位)

6-4、填空題(題分 4 分)

承上題 6-3，次低音（稱爲「第一泛音」）之波長爲 _____(填入幾個 L 單位)

6-5、單選題(題分 2 分)

若在共振管開口端(甲)與靠近吹管的洞(乙)之間，約正好一半距離的地方再開一個洞，則可以發出的最低音的頻率比沒有開洞前 A.高　B.低　C.一樣高　D.可能高也可能低，由其他因素決定

6-6、填空題(題分 4 分)

在音樂中，各種可能的音的頻率之間有一定的比值才能構成適當的音階。規定這些頻率比值的律法稱爲「音律」。音律有很多種，目前樂器演奏時最常用的是巴哈(Bach)發明的「十二平均律」，他將頻率相差兩倍的兩音（八度）間平均分爲頻率比相等的十二個半音。但是這樣會使得八度音以外的音之間，頻率並不會構成簡單的整數比，也就不符合樂器振動時由於力學緣故而自然形成的泛音頻率比。相對而言，「純律」就可以保持音階中各音的頻率呈現簡單整數比，如下表所示：

度數	1	2	3	4	5	6	7	8
範例音名	c^1 (Do)	d^1 (Re)	e^1 (Me)	f^1 (Fa)	g^1 (So)	a^2 (La)	b^2 (Si)	c^2 Do
與基音之頻率比	1	9/8	5/4	4/3	3/2	5/3	15/8	2

若根據「純律」來討論上述一個一端開口另一端閉口的共振管可發出的聲音，則其第一泛音比「基音的八度音」（基音頻率兩倍的音）高或低幾度？

6-7、填空題(題分 4 分)

承上題 6-6，請問基音的第二泛音將比「基音的十六度音」（基音頻率四倍的音）高或低幾度？_____

Please refer to website http://www.nstm.gov.tw/mechanics for questions concerning the mechanics contest held from 2005 to 2008