Constructing Integrated Testlets Across Disciplines

RALPH SHIELL and AARON SLEPKOV
ralphshiell@trentu.ca aaronslepkov@trentu.ca

PHYSICS AND ASTRONOMY DEPARTMENT,
TRENT UNIVERSITY

Hand-out package to accompany STLHE-2015 workshop,
June 18, 2015
Three questions from mathematics:

Question 1 - Numeracy-based

Last summer John ran his household air conditioner continually from 9 am until 9 pm for seven consecutive days. The cost of electricity is shown in the figure below. Assume the air conditioner operated constantly at 5000 watts and that the prices shown do not include the harmonised sales tax of 13%. How much was John charged (including harmonised sales tax) for this week?

![Electricity prices](http://www.ontarioenergyboard.ca/OEB/Consumers/Electricity/Electricity+Prices)

Question 2 - Algebra-based

A box to hold sand is formed by cutting out squares of side \( x \) cm from each corner of a rectangle with dimensions \( \ell = 30 \text{ cm} \) and width \( w = 20 \text{ cm} \) as shown in the figure, and then sticking the adjacent cut edges together. The area of the base of the completed box is 416 cm\(^2\). What is the volume of this box?

![Box diagram](image)

Question 3 - Calculus-based

Using an appropriate substitution, determine the value of the integral shown below.

\[
\int_{-5}^{10} \frac{7x}{1 + 3x^2} \, dx
\]
Testlet 1— Mathematics; Numeracy

Last summer John ran his household air conditioner continually from 9 am until 9 pm for seven consecutive days. The cost of electricity is shown in the figure below. Assume the air conditioner operated constantly at 5000 watts and that the prices shown do not include the harmonised sales tax of 13%.

![Electricity Price Chart](http://www.ontarioenergyboard.ca/OEB/Consumers/Electricity/Electricity+Prices)

1) For how many off-peak hours was John’s air-conditioner on during this week?
   A. 34 hours  B. 32 hours  C. 30 hours  D. 20 hours  E. 10 hours

2) For how many mid-peak hours was John’s air-conditioner on during this week?
   A. 44 hours  B. 14 hours  C. 20 hours  D. 12 hours  E. 4 hours

3) How many kWh were used by John’s air conditioner at the mid-peak rate during this week?
   A. 5 kWh  B. 17 kWh  C. 10 kWh  D. 100 kWh  E. 170 kWh

4) How much to the nearest dollar was John charged (including harmonised sales tax) for this week?
   A. $5  B. $6  C. $56  D. $50  E. $9
Testlet 2— Mathematics; Algebra

A box to hold sand is formed by cutting out squares of side \( x \) cm from each corner of a rectangle with dimensions \( l = 30 \text{ cm} \) and width \( w = 20 \text{ cm} \) as shown in the figure, and then sticking the adjacent cut edges together. The area of the base of the completed box is 416 cm\(^2\).

5) Which of the following expressions in \( x \) best represents the area of the base of the completed box?
A. \((20 - 2x)\)
B. \((30 - 2x)\)
C. \((30 - x)(20 - x)\)
D. \((30 - 2x)(20 - 2x)\)
E. \(600x^2\)

6) Which of the following equations does \( x \) satisfy?
A. \(30 - 2x = 20 - 2x\)
B. \(600 - 100x + 4x^2 = 0\)
C. \(4x^2 + 100x + 184 = 0\)
D. \(x^2 - 125x + 46 = 0\)
E. \(x^2 - 25x + 46 = 0\)

7) What is the length \( x \)?
A. 1 cm  
B. 1.5 cm  
C. 2 cm  
D. 10 cm  
E. 23 cm

8) What is the volume of this box?
A. 332 cm\(^3\)  
B. 600 cm\(^3\)  
C. 832 cm\(^3\)  
D. 932 cm\(^3\)  
E. 1200 cm\(^3\)
Testlet 3— Mathematics; Calculus

Consider the following expressions for \( w \) and \( y \):

\[
w = \int_a^b \frac{dx}{x} \quad \text{and} \quad y = \int_a^b \frac{7x}{1+3x^2} \, dx
\]

9) What does integral \( w \) evaluate to?

A. \( w = \ln(b) - \ln(a) \)  
B. \( w = e^b - e^a \)  
C. \( w = \frac{1}{b} - \frac{1}{a} \)  
D. \( w = \frac{2}{b^2} - \frac{2}{a^2} \)  
E. \( w = \frac{b^2}{2} - \frac{a^2}{2} \)

10) Which substitution is most useful to evaluate integral \( y \)?

A. \( u = x^2 \)  
B. \( u = 1 + 3x^2 \)  
C. \( u = 7x \)  
D. \( u = 1 - x \)  
E. \( u = \frac{7x}{1 - 3x^2} \)

11) Use the appropriate substitution in Question 10 to get an expression of the form \( y = \int_a^b f(u) \, du \). Then if the original expression for \( y \) has \( a = -5 \) and \( b = 10 \), what are \( a' \) and \( b' \) after this substitution?

A. \( a' = 76 ; b' = 301 \)  
B. \( a' = 57 ; b' = 104 \)  
C. \( a' = 25 ; b' = 100 \)  
D. \( a' = 10 ; b' = -5 \)  
E. \( a' = -9 ; b' = 4 \)

12) What is the value of \( y \)?

A. 1.6  
B. 2.4  
C. 5.7  
D. 14.5  
E. 15.7
Integrated testlets in other disciplines

The following integrated testlets (ITs) cover a range of subjects. They are presented in order of increasing concept integration, with the initial ones minimally integrated, and the last ones substantially integrated.

- Items have been keyed to the supplied scratch card. Pay careful attention to the exact item number before making a selection on the card.
- A correct response is denoted by a star located within the hidden bounding box.
- An answer-until-correct approach is used and partial marks are therefore possible. We often adopt: **100%** granted for a first-selection correct response; **50%** granted for a second-selection correct response, and **10%** for a third-selection response.
- If you do not get the correct answer after three tries, scratch off the remaining boxes to reveal the correct answer. You can then use this knowledge to help with subsequent items within an IT.

**Testlet 4 —Weakly Integrated: Art History**

Consider the photograph of a famous piece of art on the right, and answer the following four related questions

13) During which of the following years was this piece created?

A. 1890-1920  
B. 1940-1970  
C. 1830-1860  
D. 1770-1800  
E. 1720-1750

14) What is the name of this piece?

A. American Gothic  
B. The Red, White, And Blue  
C. Flags of our forefathers  
D. Stars and Stripes Forever  
E. Three Flags

15) What movement/period is represented by this piece?

A. Art Deco  
B. Pop Art  
C. Cubism  
D. Post Modernism  
E. Dada

16) Which of the following artists was most contemporary with (i.e. worked at the same time as) the piece’s creator?

A. Marie Cassatt  
B. Winslow Homer  
C. James McNeill Whistler  
D. Frida Khalo  
E. Roy Lichtenstein
Testlet 5—Weakly Integrated: 20th Century Literature

Consider the following excerpt from a famous poem, and answer the following four related questions:

You will not be able to stay home, brother
You will not be able to plug in, turn on and cop out
You will not be able to lose yourself on skag
And skip out for beer during commercials
Because the revolution will not be televised
.
.
.
The revolution will not be right back after a message
About a white tornado, white lightning, or white people
You will not have to worry about a dove in your bedroom
The tiger in your tank or the giant in your toilet bowl
The revolution will not go better with Coke
The revolution will not fight the germs that may cause bad breath
The revolution will put you in the driver's seat

The revolution will not be televised, will not be televised
Will not be televised, will not be televised
The revolution will be no re-run brothers
The revolution will be live

17) Who wrote this piece?
A. E.E. Cummings
B. Gil Scott-Heron
C. Maya Angelou
D. Allen Ginsberg
E. Walt Whitman

18) During what time period was this poem written?
A. 1965-1980
B. 1935-1950
C. 1980-1995
D. 1950-1965
E. 1995-2010

19) What pervades this poem, as a tool for ridiculing and trivializing the average TV-watching American?
A. references to couches and potatoes
B. references to wild animals
C. the term “brother”
D. advertising slogans
E. metaphors for fat people

20) What musical genre is this work thought to have helped inspire?
A. Rap
B. Funk
C. Trip-hop
D. Acid Jazz
E. Heavy Metal
You are studying a disease that you suspect is hereditary. You have compiled a pedigree chart for a particular family with a high occurrence of affected individuals. Use the pedigree chart on the right to answer the following questions.

21) You have determined that the chart is consistent with autosomal dominant inheritance with a dominant allele A and a recessive allele a. As such, what are the genotypes of individuals 5 and 6?

A. Individual 5 is aa; Individual 6 is either Aa or AA  
B. Individual 5 is either Aa or aa; Individual 6 is AA  
C. Individual 5 is Aa; Individual 6 is aa  
D. Individual 5 is aa; Individual 6 is AA  
E. Individual 5 is either AA or aa; Individual 6 is Aa

22) Considering autosomal dominant inheritance and the family pedigree chart, what are the odds that a new (sixth) offspring of individuals 3 and 4 would be affected?

A. 0 %  
B. 100 %  
C. 25 %  
D. 1/6 (or 17%)  
E. 50 %

23) Can you use the given pedigree chart to estimate the rate of incidence of the disease in the population? If so, what is the best estimate for the prevalence of affected individuals in the population?

A. Yes, the chart suggests that approximately 50% of both men and women in the population is afflicted.  
B. Yes, the chart suggests that less than 10% of the population is afflicted, and that the disease is more common in females.  
C. Yes, the chart suggests that approximately 2/7 (or 29%) of the current population is afflicted.  
D. Yes, the chart suggests that anywhere between 30% and 49% of the population is afflicted.  
E. No estimate can be made of the prevalence of the disease in the population based on the chart.

24) Consider instead the possibility that the pedigree chart suggests an X-linked recessive inheritance? Which of the following statements is most true?

A. Individuals 7, 8, 9 and 11 would all need to be affected for X-linked recessive inheritance to be a possibility.  
B. The pedigree chart is already consistent with X-linked recessive inheritance.  
C. Individual 10 would need to be affected for X-linked recessive inheritance to be a possibility.  
D. Individual 6 would have to be unaffected for X-linked inheritance to be a possibility.  
E. All 3 generations in the pedigree table make it entirely inconsistent with X-linked recessive inheritance.
Consider the following reaction: $2\text{H}_2\text{S}(g) + 3\text{O}_2(g) \rightarrow 2\text{SO}_2(g) + 2\text{H}_2\text{O}(g)$

Consult the following table of Standard Thermodynamic Quantities for substances at 25 ºC and answer the following five related questions.

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H_f^\circ$ (kJ/mol)</th>
<th>$S^\circ$ (J/mol·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}_2\text{S}(g)$</td>
<td>-20.6</td>
<td>205.8</td>
</tr>
<tr>
<td>$\text{O}_2(g)$</td>
<td>0</td>
<td>205.2</td>
</tr>
<tr>
<td>$\text{SO}_2(g)$</td>
<td>-296.8</td>
<td>248.2</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(g)$</td>
<td>-241.8</td>
<td>188.8</td>
</tr>
</tbody>
</table>

25) Consider the expression for Gibb’s free energy, $\Delta G = \Delta G^0 + RT \ln Q$. Which of the following statements is most generally true about reaction spontaneity?

A. At $\Delta G^0 = 0$ the reaction ceases to be spontaneous
B. At $\Delta G = 0$ the reaction ceases to be spontaneous
C. At $T = 0$ the reaction ceases to be spontaneous
D. At $Q = 0$ the reaction ceases to be spontaneous
E. At $Q = 1$ the reaction ceases to be spontaneous

26) What is the net change in reaction enthalpy ($\Delta H_{\text{rxn}}^\circ$) for the above reaction?

A. -1036 kJ/mol
B. +1036 kJ/mol
C. +518 kJ/mol
D. -518 kJ/mol
E. 0 kJ/mol

27) At what temperature does this reaction either become spontaneous or cease to become spontaneous?

A. Ceases to be spontaneous above 298 K
B. The reaction is spontaneous at all temperatures
C. The reaction is non-spontaneous at all temperatures
D. Ceases to be spontaneous above 6760K
E. Ceases to be spontaneous above 159 K

28) Rank the following equilibrium constants, $K_T$, at various temperatures T, for this reaction in order of increasing magnitude?

A. $K_{2000} < K_{298} < K_{150}$
B. $K_{298} = K_{150} = K_{2000}$
C. $K_{298} < K_{2000} < K_{150}$
D. $K_{298} < K_{150} < K_{2000}$
E. $K_{150} < K_{298} < K_{2000}$

29) What is the equilibrium constant for the reaction at 2000 K?

A. $3.6 \times 10^{-3}$
B. 60
C. $7.7 \times 10^{13}$
D. 44
E. $1.3 \times 10^{19}$
Testlet 8—Strongly Integrated: Physics; Kinematics and Forces in 2-Dimensions

Two people are attempting to pull a crate of mass 50 kg using massless ropes held parallel to the floor. The crate is initially at rest and the coefficient of static friction between the crate and the floor is 0.3. Person A exerts a force $F_A = 60$ N in a direction $\theta_A = 37^\circ$ above the horizontal as shown in the figure. Let the force applied by person B have magnitude and direction $F_B$ and $\theta_B$, respectively.

30) Which of the following is the most correct free body diagram for the crate while at rest and viewed from the side? (Looking along y-axis)

A. $N$  
B. $N$  
C. $N$  
D. $N$  
E. $N$

31) With what force (magnitude and direction) should person B pull in order to just barely make the crate move, exclusively in the positive x-direction?

A. $F_B = 36.1$ N and $\theta_B = 70^\circ$ below x-axis  
B. $F_B = 60.0$ N and $\theta_B = 37^\circ$ below x-axis  
C. $F_B = 99.0$ N and $\theta_B = 0^\circ$; i.e. along x-axis  
D. $F_B = 105$ N and $\theta_B = 20^\circ$ below x-axis  
E. $F_B = 120$ N and $\theta_B = 67^\circ$ below x-axis

32) If the total force applied by the two people remains the same as in question 23, what will be the acceleration of the crate if the coefficient of kinetic friction between the crate and the floor is 0.20?

A. $0$ m/s$^2$  
B. $0.98$ m/s$^2$  
C. $1.9$ m/s$^2$  
D. $3.0$ m/s$^2$  
E. $4.3$ m/s$^2$

33) How long would it then take the two people to pull the crate a distance of 12 meters in the x-direction?

A. 3.1 s  
B. 3.8 s  
C. 4.9 s  
D. 2.4 s  
E. 24 s
Testlet 9—Strongly Integrated: Behavioural Sciences; Hypothesis Testing & Statistics

One of your employees believes that recent installation of wireless technology in your large company is negatively affecting the health of workers. To test this hypothesis, you obtain the absence records of employees with last names beginning with the letters R and S, and find that among these 150 employees, the mean number of sick days taken last year was 5.4, with a standard deviation of 2.3. A company-wide census taken two years before the installation of the wireless routers reports a mean of 5.2 sick days taken per year, with a standard deviation of 2.1. Use this information and the table shown to answer the following related set of questions.

34) You are specifically looking for a directional H1, because you hypothesize that wireless radiation negatively affects health, and furthermore you want to test your hypothesis at the 99% confidence level. Which of the following parameters will you use for looking-up a critical value for your main test statistic?

A. $\alpha$ (2 tail) = 0.01  
B. $\alpha$ (1 tail) = 0.05  
C. $\alpha$ (1 tail) = 0.01  
D. $\alpha$ (2 tail) = 0.05  
E. $\alpha$ (2 tail) = 0.10

35) Which is the most sensitive test with which to analyze your data?

A. z-test  
B. unsigned-rank test  
C. signed-rank test  
D. ANOVA  
E. t-test

36) What is the finding of your statistical test?

A. The obtained value > critical value ; reject $H_0$  
B. The obtained value < critical value ; reject $H_0$  
C. The obtained value < critical value ; accept $H_0$  
D. The obtained value > critical value ; cannot reject $H_0$  
E. The obtained value < critical value ; cannot reject $H_0$

37) What can be said about the size of effect for this study?

A. 0.0 ; no effect  
B. 0.095 ; small effect  
C. 0.095 ; medium effect  
D. 0.87 ; medium effect  
E. 0.87 ; large effect
Selected student feedback on integrated testlets from course evaluations/surveys:

Over the past four years we have used integrated testlets in all 1st-year physics midterm and final exams at Trent University. Student response is overwhelmingly positive. Examples of student comments from anonymous surveys and course evaluations are included below. The only negative comments mention a perception of increased anxiety for some students who do not like knowing that they are doing poorly on an exam, and comments about minor procedural difficulties with the scratch-cards themselves.

Integrated Testlets and concept integration:

“I personally strongly prefer [IT] over constructed response. I would be very happy with a 100% [IT] tests. I have done 100% [IT] tests before in PHYS 1060H and much preferred them. I prefer [IT] because I find when I am doing a constructed response question, I spend too much time thinking about what I need to write down on my exam sheet (all the assumptions and rationale that are taking place in my head). I find this a major burden in an exam …[because] you have to come up with a way to explain this fact on paper…[while] this fact is only one small part of the problem you are solving. I find that I end up wasting time on little parts of the problem clearly stating my rationale, which reduces the amount of time I spend actually thinking about the underlying [concepts]…

“Yes I like this, immediate feedback helps me to better figure out other related questions.”

“[ITs are] good for allowing questions that can build on themselves… I [also] liked the fact that it helped to build confidence, in that you knew that you were right and there wasn't that nigging self doubt that always makes you change your answers at the last minute to something silly.”

“It's great knowing how you're doing as you're going through a test. And also, if you make a mistake in the previous question, it helps you to correct yourself before attempting subsequent questions, which is very helpful.”

Formative assessment qualities:

“I love the fact that you can walk away with knowing what your mark on the final exam is and not have to wait … to see your mark. Knowing the right answer after you made a mistake definitely does stay in ones memory for a long time.”

“IT WAS AWESOME! Yes. It was cool that I got the second chance and even if I got that wrong I knew the answer to the question and I feel like it helped me learn better”

“Knowing your mark as you leave the test is great having the feedback during the test is better.”

Aligns assessment with learning objectives:

“This was a great technique! It is very similar to the style of the lectures when we would do iclicker questions. If you are incorrect you are given a chance to rethink the question and try to better understand it. I think this is a great technique and very helpful in better understanding the material.”

Helps with student engagement during assessment

“I would recommend it to be used in other courses. I found that, knowing I would see whether my answer was correct or not, made me focus more on the question and less likely to guess if I was presented with a question that I did not immediately understand.”
Further Reading on Multiple-Choice Testing

**Research articles on Integrated Testlets**


**Articles examining the Immediate Feedback Assessment Technique (IF-AT)**


**Articles examining guidelines for writing multiple-choice items**


**Books that focus specifically on multiple-choice testing**


**Assessing higher-order thinking**