TWO-STAGE EXAMS: DESIGNING EFFECTIVE EXAM QUESTIONS

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THE TWO-STAGE EXAM

A two-stage exam[†] is a process in which students complete an exam in two parts, first independently and then as part of a peer learning group. In principle, the two-stage exam:

- Reinforces the importance and the benefits of collaborative learning
- Demonstrates that learning can and should take place throughout the entire semester not just in compartmentalized chunks
- Provides immediate feedback on exam performance

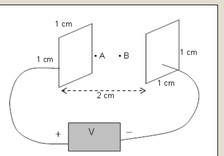
COLLABORATIVE GROUPS

- Groups of 3-4 students
- Students select group members
- Instructor approves groups before exam
- Majority of students chose nearest neighbors

Questions Tied To Part One

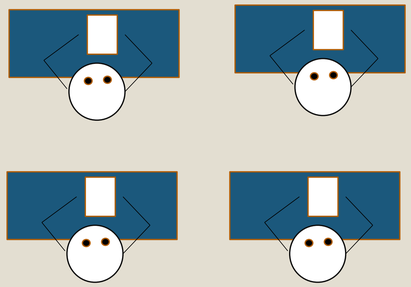
On Part One of the exam, students were asked to calculate the battery potential and the magnitude of the electric field between the plates. These answers are given in the text of the problem in Part Two. The question also requires students to consider the problem in a novel way.

A parallel plate capacitor consisting of two 1 cm^2 square plates separated by a distance of 2 cm is connected to a 3V battery. The electric field between the plates is 150 V/m. All questions refer to the original scenario.



The terminals of the battery are reversed so that the left plate becomes negatively charged and the right plate becomes positively charged (but the physical dimensions are not changed). Circle the quantities listed below that will also change.

a. The magnitude of the total charge on the plate
b. The surface charge density of the plate
c. The potential difference of the capacitor ΔV_c
d. The magnitude of the electric field
e. The direction of the electric field
f. The potential energy of an electron on the – plate
g. The trajectory of a + charge that enters the capacitor from above.



Exam – Stage One

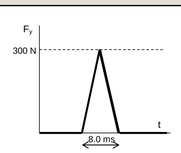
- Completed independently
- Exam Time = 50-60% of class period
- Point Allocation = 85-90% of exam grade

Questions that are Conceptual

On Part One of the exam, students were asked to calculate the rebound speed of the ball. The same question is asked on Part Two; the majority of students answer the question incorrectly independently and correctly in their collaborative groups.

Questions b-d were generally covered in class but never explicitly connected to this exam problem.

A 200 g rubber ball is dropped from rest from a height of 1.0 m onto a hard floor. The ball reaches the floor at a speed of 4.4 m/s and the floor provides an impulse of 1.2 Ns to the ball.

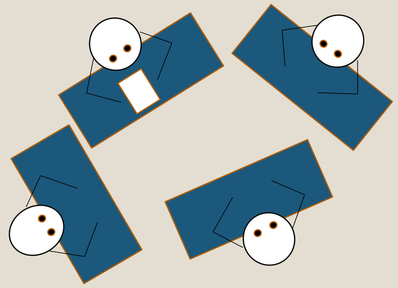


a. Find the rebound speed of the ball.

b. During the collision of the ball with the floor, is the *energy of the ball* conserved? Briefly explain your answer.

c. During the collision of the ball with the floor, is the *momentum of the ball* conserved? Briefly explain your answer.

d. If the ball were to land on a squishier floor, what would happen to the shape of the graph? Make a quick sketch to illustrate your answer.



Exam – Stage Two

- Completed collaboratively
- Exam Time = 20-30% of class period
- Point Allocation = 10-15% of exam grade
- Each group submits <u>one</u> solution

Questions Tied to Misconceptions

Before the exam, students were asked to consider the scenario below (left panel) in which a fisherman is to throw a spear to hit a fish below the surface of the water. Considering the refraction of the light rays, students realize that the man should aim below the image of the fish.

The right panel shows the same fisherman using a laser ray gun on Part Two of the exam. This particular question was identified by 80% of the class as one in which they learned something during the exam.

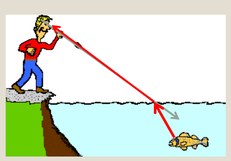


Figure from considerable class discussion; fisherman with spear.

Figure from Two Stage Exam; fisherman with laser ray gun.

EFFECTIVE EXAM QUESTIONS

The exam question effectiveness was determined through an assessment of student interview responses and by comparing student scores on questions before and after completion of the exam.

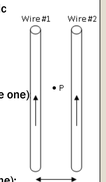
The most effective two-stage exam questions have the following characteristics:

- Stage Two questions are tied to questions on Part One of the exam.
- Stage Two questions are conceptual in nature rather than computationally oriented.
- Stage Two questions include the more difficult or misconception-laden topics, particularly those that have been part of Think-Pair-Share questions in class discussion.
- Stage Two questions require reasoning and extrapolation beyond previously covered content.

Questions Requiring Novel Thinking

In this class, students had been introduced to the magnetic field produced by a current-carrying wire and the force experienced by a current-carrying wire but had not explicitly been introduced to the force between two current-carrying wires.

Two long parallel wires carry currents of 100 A and 150 A in the same direction. The wires are separated by a distance of 1cm. The magnetic field at Point P is 0.002 T.



At P, the direction of the magnetic field due to Wire #1 is (circle one):
up *down* *left* *right* *in* *out*

The direction of the magnetic force on Wire #2 due to Wire #1 is (circle one):
up *down* *left* *right* *in* *out*

At P, the direction of the magnetic field due to Wire #2 is (circle one):
up *down* *left* *right* *in* *out*

The direction of the magnetic force Wire #1 due to Wire #2 is (circle one):
up *down* *left* *right* *in* *out*

Based on your answers, what happens when two wires carry currents parallel to each other?

[†]G.W.Reiger and C.E. Heiner, Journal Of College Science Teaching, Vol 43, No. 4, pg 41

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