Phys2006 Classical Mechanics January 2020

Marking these exam scripts led to a growing suspicion that there had been a muddle in the exam office, and that a despairing geology colleague was somewhere battling with our physics students' perplexed attempts to explain metasomatism or geomorphology. Few scripts showed significant recognition of the difference between scalars and vectors, or familiarity with the chain rule of differentiation – especially when applied to second derivatives; and rather too many students could not state correctly the length of an arc or the volume of a sphere. It would be mild to refer to a lack of rigour: many answers were 'not even wrong': many an answer was a Pliny-like jumble of facts, half-truths, hearsay and wildly improbable speculation, and spotting logical connections between the scattered jottings of a given answer made *Only Connect* seem like a walk in the park. Bad handwriting, a preference for working backwards from the target expression, and some bizarre representations of the character θ, added to the challenge.

This is the first time, at least in recent memory, that this course has been run in the second year's first semester, and it is clear that students are less prepared for it than they were by the second semester. There is clear discomfort with the underpinning maths of vectors and calculus, and uncertainty about tackling longer, structured questions – even though these aspects were emphasized during lectures. The value of visualizing the situation through a clear diagram also seems too little recognized. Many marks were lost by skipping whole sections of questions, answering a different question from that asked – though the physics of the situations was generally well identified – or failing to show adequate working. There was little sign of students picking up slips by checking their answers, though the slender answer books suggested no lack of time.

Few sections seemed consistently well or poorly answered: different students found different bits tricky. While few students seemed to have mastered the course material as a whole, there were nonetheless some very competent and insightful answers and inspired solutions. Indeed, even when analysis was poor, the physics of the situations was often picked up well.

For the 119 students who sat the exam, the mean exam mark was 51.1%, with 56.0% for the course overall, which was failed by 16 students. A further 5 students were registered for the course but didn't take the exam.

Section A **mean 12.7/20**

A1 Central forces **mean 2.8/4**

For the most part this question was answered well. Most students knew what a central force is (although many believed that it must be SO(3) symmetric) and could give 2 examples. However, most of the marks were lost when trying to explain why central forces cannot affect angular momentum. Many did not refer to torque at all or could not define it.

A2 Kepler's laws **mean 3.4 /4**

The students performed strongest on this question as most had memorised Kepler's laws and could recall the assumptions upon which it depended.

A3 Rockets **mean 3.2 /4**

Students again performed well on this question. Almost all could solve the differential equation to give the rocket equation. However, many marks were dropped by failing to construct the initial set up of the rocket before and after the rocket has begun ejecting fuel. Many tried to work back from the final answer.

A4 Spacecraft rotation **mean 1.0 /4**

This question caused far more grief than the others in this section. Many tried to explain the resultant motion by some gyroscopic precession but failed to include the second force required to produce this effect. They also struggled to calculate the angle required to rotate. Many didn't even try. Of those who did, many forgot that the angular velocity could be a function of time and therefore failed to integrate properly with respect to time.

A5 Coriolis force **mean 2.1 /4**

Students also struggled with this question. Most lost marks by defining their coordinate system incorrectly and thus seeing the wrong deflection.

Section B **mean 18.0/40**

B1 Precession of a spinning coin **49 attempts** **mean 9.5**

The fundamentals of rotations, their vector representation and rate of change expression, all proved disappointingly elusive for such core material; and there were many mistakes in calculation of the moment of inertia, including too many errors in expressions for the circumference or area of a circle or the angular range of integration. Marks were lost for failing to read the question or to appreciate what is required of a formal derivation. Few students consistently handled vectors correctly.

B2 Precession of the equinoxes **53 attempts** **mean 6.7**

This question tested students' understanding of vectors, and often revealed it to be poor. Almost no-one wrote Newton's law of gravitation in the requested vector form with the correct sign; and those who tackled b(i) forgot all they knew about vector products, with several inventing the vector ratio as its inverse. Several students did not know the expression for the volume of a sphere.

The requested two sketches varied in quality; those who took the effort to produce clear, accurate diagrams generally showed fewer misunderstandings elsewhere in the question. Few made use of the scalar gravity gradient that was the object of part (a), and almost no-one combined the expressions given in the question to find the precession period in c(ii).

B3 Coupled piano strings **66 attempts** **mean 10.5**

This question was often answered well, though the initial definitions sometimes proved surprisingly elusive. Matrices were generally handled correctly, despite odd difficulties with the identity matrix, and bar the odd slip the determinant was computed correctly. Many however assumed that $d^2x_{2,3}/dt^2$ were accelerations in the inertial frame, which a clear diagram would have shown to be incorrect since they were measured from an accelerating reference: there were lots of attempts to fudge the subsequent derivation. Surprisingly few realised the value of the stated assumption that $k_0 << k$. Failures to use brackets around long expressions led to some trouble.

There was common confusion about the symmetric and asymmetric modes and, while pretty recognizable in this example, marks were given provided the modes were described consistently. Regrettably, many descriptions were based upon imperfect recall of lecture examples, rather than examination of the specific situation.

B4 Cometary orbit **70 attempts** **score 8.9**

Although many parts of the question gave clear instructions on how to proceed, this didn't deter students from bold attempts to find alternative approaches, which sadly only occasionally worked. The vector nature of the orbital velocity clearly troubled a number of students – but not as many as were confused by the chain rule, second derivative, and sometimes differentiation in general. Several students thought that the total energy was the difference between the kinetic and potential energies.