Phys2006 Classical Mechanics June 2019

Although many students answered this paper well, plenty of marks were lost for lack of rigour, failure to show adequate working, and inconsistent use of vectors. There was little sign of students picking up slips by checking their working. Draughtsmanship and hand writing seemed significantly poorer than in recent years.

The mean exam mark was 57.2%, with 61.9% for the course overall, which was failed by 12 students, 3 of whom didn't take the exam.

Section A **mean 12.3/20**

A1 Moment of inertia theorems **mean 2.2/4**

In general, this question was executed reasonably. Most students knew both theorems. Students dropped marks when assessing the conditions under which these theorems apply. Some students simply neglected to answer that section or got confused between the two theorems.

A2 Kepler's laws **mean 3.7/4**

Very successfully answered, with most students scoring full marks. Most students knew the laws and were able to write assumption/ conditions under which they hold.

A3 Torque and angular momentum **mean 3.0/4**

Students again performed pretty well, with most able to define torque and remember the definition in terms of the derivative of the angular momentum, though some forgot that $\mathbf{r} \times \mathbf{F} \neq \mathbf{F} \times \mathbf{r}$, i.e. the cross product of two vectors does not commute. Most marks were dropped in showing that $\mathbf{r} \times \mathbf{F}$ was 0: many simply asserted that $\mathbf{F}$ itself was 0 without realising the two vectors are parallel.

A4 Reduced mass **mean 2.2/4**

Students had more difficulty tackling this question. Although most were able to recall the reduced mass equation, few could explain when it applies. Troublingly, a huge proportion of students dropped marks by failing to write down units.

A5 Buys Ballot's law **mean 1.3/4**

Most were able to identify that Buys Ballot's law is a result of Coriolis acceleration, but many struggled to reason any further. A remarkable number seem to think that in a given hemisphere the wind only blows in one direction i.e. east to west. Many tried to answer the question for specific cases i.e wind going east to west, but didn't generalise from their conclusion.

Section B **mean 22.3/40**

B1 Normal modes of a compound pendulum **23 attempts** **mean 10.6**

The basic methods of normal mode analysis were generally well understood. However, poor diagrams – and overlooking the instruction to indicate the rotation point – meant that some students lacked enough understanding of the specific system to be able to derive its particular equations, and simple errors of arithmetic (factors and minus signs) lost further marks.

B2 Gyroscopic motion **80 attempts** **mean 10.2**

There was little consistency with this question: between them, students managed to answer or muddle all parts similarly, the only overall themes being that scene-setting diagrams were often poor, and that a general lack of methodical rigour, thought and care caused many to go adrift. Marks were lost for not defining terms, fudging derivations, muddling vectors and scalars, plenty of numerical errors (especially factors of 2π and 60), not using the moment of inertia of part (b), and forgetting that gyroscopes show precession. Almost all calculated the torque upon the bomb, rather than the reaction upon the aircraft, though as many declined to give the direction of the angular momentum and torque this mattered little. Propagated numerical errors were not penalized. A distressing number portrayed the Dam Buster aircraft as swept-wing jets.

B3 Orbital dynamics **100 attempts** **mean 11.4**

This popular question was often answered well throughout. Some students however assumed that the orbit was circular, or that the velocity at the apogee was zero; some tried to use conservation of linear, rather than angular, momentum; and several thought that the total energy, rather than its variation, was zero. Many gave up when they reached a quadratic expression for r_a, although even without factorization it yielded easily to standard methods; but there were also some elegant innovative solutions. Those who wrote the target expression at the end of unsuccessful derivation attempts narrowly escaped punitive marks for thinking that their working wouldn't be checked.

B4 Coriolis force and the vibrating structure gyroscope **77 attempts** **score 12.9**

Although few could remember all the initial derivation, this question was largely answered well, with marks lost mainly for inadequately detailed explanations and failure to show sufficient working towards the requested results; some stopped at part (e) and hence missed the easy number-plugging of part (f). Students confused the oscillation frequency ω with the rotational angular velocity Ω, or more generally abandoned all rigour and logic to muddle vectors and scalars. A couple of students tried to apply the GCSE result for steady acceleration to this dynamic example; and several curiously assumed the result for the instantaneous quasi-static force balance in a harmonic potential – quite different from the inertial motion of a free mass. Factors of 2π frequently went awry.