Use of Calculators in MEI Pure, Mechanics and Decision A Level Examinations

Calculators are not allowed in the MEI C1 unit; this is the same as for other A Level examinations in Mathematics. Graphical calculators are *allowed* for other units and *required* for two optional questions: investigation of curves in FP2 and Markov chains in FP3.

Calculators have become increasingly sophisticated in recent years; this applies to scientific calculators as well as graphical calculators. This document is intended as advice to teachers and their students to understand better how to use calculators in examinations appropriately. Although the regulations concerning calculator use are the same for all awarding bodies, different exam boards may have different expectations of how much working candidates need to show in order to gain marks. The advice in this document relates to the MEI AS and A Level pure, mechanics and decision units. There is a separate document for the statistics units.

Solving a mathematical problem as part of a job or research might involve using appropriate ICT. However, solving a mathematical problem in an examination has a slightly different purpose; the candidate needs to demonstrate to the examiners that the necessary techniques have been acquired and can be used appropriately and accurately.

Which calculators are allowed?

General regulations concerning calculator use are the responsibility of the Joint Council for Qualifications (JCQ); they can be found in the document "Instructions for Conducting Examinations". The latest version can be found on the JCQ website www.jcq.org.uk There is no list of banned or allowed calculators; it would be difficult to compile such a list due to new models coming on the market and old models being discontinued.

The instructions include the information that candidates cannot use calculators which are able to perform symbolic algebra manipulation or symbolic differentiation or integration. However, calculators which have numerical quadratic equation solvers or numerical integration built in (as many graphical calculators do) are allowed.

Some general advice

All MEI A Level papers include the following general instruction on the front cover.

> "You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used."

Showing working is especially important for questions where the answer is given and candidates are required to show that the answer is correct. Candidates need to show enough detail to enable examiners to decide whether they have acquired the skills being tested and are able to use them correctly. The amount of detail needed for this varies. To help candidates understand how much detail of the working needs to be shown, it is helpful to refer to the examiners' reports from past papers.

Candidates should not round before they reach the final answer to avoid losing accuracy. However, the final answer should be given to a suitable degree of accuracy.

Pure Mathematics units

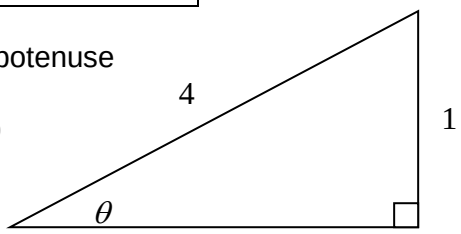
Candidates should be able to demonstrate that they have acquired the competences in the specification. For example, techniques of integration are part of the competence statements of pure units and so, if candidates are asked to find the value of a definite integral, examiners will expect to see the algebraic form of the integral first. It is not sufficient to do the definite integral on a calculator which has a facility for numerical integration and get the answer. Of course, candidates who have a calculator which performs numerical integration can use the definite integral function on their calculators to check their answer, if they have time to do so.

Giving an exact answer

Some candidates lose marks because they do not understand the meaning of the word *exact*. An example of this occurred in question 3 of the June 2006 C2 paper, however, the principles apply to all units.

> θ is an acute angle and $\sin\theta = \frac{1}{4}$. Find the exact value of $\tan\theta$.

Candidates were expected to draw a right-angled triangle, with hypotenuse 4 units and the side opposite the angle θ 1 unit, and then to use Pythagoras' theorem to show that the length of the third (adjacent) side is $\sqrt{15}$. So the exact value of $\tan\theta$ is $\frac{1}{\sqrt{15}}$.



Many candidates, however, used their calculators to find arcsin(0.25) and then used them again to find tan of the answer. Candidates who did this commonly gave their answers as 0.258 or 0.2581988897, neither of which is the exact answer which was asked for in the question.

The examiners' report for this paper says "It must be made clear to candidates, as part of the preparation for this paper, that a request for ' the exact value' of anything usually implies that calculators must not be used."

Showing that a given answer is correct

An example of the kind of question which asks candidates to show that a given answer is correct is given below. This example is based on the FP2 specification but the principles apply to all units.

$$\text{Show that } \int_{-\ln 2}^{\ln 2} \cosh 2x \, \mathrm{d}x = \frac{15}{8}$$

Having done the first step correctly $\int_{-\ln 2}^{\ln 2} \cosh 2x \, \mathrm{d}x = \left[\frac{1}{2}\sinh 2x\right]_{-\ln 2}^{\ln 2}$ and got full credit for it, candidates might turn to their calculators and complete the question thus:

$$\left[\frac{1}{2}\sinh 2x\right]_{-\ln 2}^{\ln 2} = \frac{1}{2}\sinh(2\ln 2) - \frac{1}{2}\sinh(-2\ln 2) = \frac{15}{8}.$$

Typing $\frac{1}{2}\sinh(2\ln 2)-\frac{1}{2}\sinh(-2\ln 2)$ into many scientific calculators does give the exact answer $\frac{15}{8}$ but no credit can be given for this part of the question because the answer was printed and candidates could just have copied it down. Candidates are expected to show working, for example:

$$\sinh(2\ln 2)=\frac{e^{2\ln 2}-e^{-2\ln 2}}{2}=\frac{e^{\ln 4}-e^{-\ln 4}}{2}=\frac{1}{2}\left(4-\frac{1}{4}\right)=\frac{15}{8} \qquad \sinh(-2\ln 2)=-\frac{15}{8}$$

So $\left[\frac{1}{2}\sinh 2x\right]_{-\ln 2}^{\ln 2}=\frac{1}{2}\left(\frac{15}{8}\right)-\frac{1}{2}\left(-\frac{15}{8}\right)=\frac{15}{8}$.

The examiners' reports for the hyperbolic functions questions on FP2 show students often drop marks on this kind of question because they do not show sufficient working.

Solving simultaneous equations

Candidates attempting the Markov chains option in FP3 are expected to use a calculator which can handle matrices. Candidates are expected to be able to calculate equilibrium probabilities; one way of doing this is by solving a system of simultaneous equations. It is acceptable for candidates to solve the equations using a solver on their calculator but they should write down the equations being solved, to make their method clear.

However, for FP2, where a question asks candidates to solve simultaneous equations, they will generally be expected to solve them without using a calculator solver to do so.

Curve sketching

Candidates are allowed graphical calculators in C2 and FP1. However, a graphical calculator is best used in conjunction with analytical techniques. A calculator can quickly show many of the general features of a curve and then analytical techniques can be used to fill in the details.

Exam questions asking candidates to sketch the graph of a given function will normally ask candidates to work out significant features of the curve; for example, turning points and intersections with axes. Once candidates have done this, they will be able to sketch the curve with an appropriate level of detail.

It is good practice for candidates to annotate sketches of graphs to show equations of asymptotes and to put numbers on axes at turning points and intersections. Candidates are not expected to do an accurate plot when they are asked to sketch a curve and it is not good use of their time to do so.

When sketching curves in DE, candidates will have found some of the features of the curve in their working. It will often be difficult to see all these features of the curve using a graphical calculator so candidates should not rely solely on such a calculator but should refer back to their previous working when they are asked to sketch the curve.

Mechanics units

When solving a mechanics problem, students will sometimes need to solve a pair of simultaneous equations or a quadratic equation. It is acceptable for candidates to use numerical solvers on their calculators to do so. It will often save candidates time if they are able to use their calculators efficiently.

Candidates should be aware that although there may be two distinct real roots of a quadratic equation, these roots may not fit in with the situation being modelled. For example, when finding a time which needs to be positive, candidates are expected to show that they have considered both possible roots before rejecting the negative one as inappropriate. In general, they should write down both roots of the quadratic equation and then discuss which, if either, is appropriate for the situation being modelled.

Decision units

When solving a linear programming problem graphically in D1, candidates can use simultaneous equation solvers to find the exact coordinates of the vertices of the feasible region if they wish to do so.