Additional comments (based on common errors encountered when correcting the exam):

- Since it is a understaturated oil reservoir (reservoir pressure is above the bubble point pressure), the GOR of reservoir fluid equal to the solution gas-oil ratio (Rs) at saturation. When examining the Black oil table, the Rs at reservoir temperature increases with pressure until it reaches 253 bara, at which point it remains constant (and equal to 100). Since the table has a discrete number of pressure points, in principle it could be possible that the bubble point pressure is another pressure value between 248.7-253 bara, that is not reported in the table (although this is not good practice, the bubble point pressure value should always be included in the BO table). The bubble point pressure cannot be 248.7 bara, since the Rs is still not equal to 100 yet. For the purposes of this exercise, it is fine to assume the bubble point pressure is 253 bara, since no additional information is provided. At current reservoir pressure, the inflow from the reservoir will always have a GOR = 100, regardless of the value of the flowing bottom-hole pressure used (even if pwf < pb).
- At natural equilibrium conditions, the available pressure value (calculated co-current from the reservoir) and the required pressure value (calculated counter-current from the wellhead) at the same point should be identical.
- When performing equilibrium calculations at the bottom-hole, you can use directly the equations and table provided to calculate available pressure (IPR equation) and required pressure (interpolation in TPR table). There is no need to generate points with the equation and table, fit polynomials, and they use the polynomials in the equilibrium calculations, since you already have the equation/table.
- Flow equilibrium calculations are always performed on the "dominant" phase (standard conditions oil, or standard conditions gas). The amounts of the secondary phase are usually calculated after performing equilibrium using the flowing GOR.
- To solve the question about skin, since permeability, layer height, oil viscosity, volume factor and radius ratio do not change, it is possible to find the new J (Jnew) by dividing the equation of J for the new skin by the J equation with the old skin. Many of the constant values cancel out, giving Jnew = Jold *(ln(re/rw)-0.75+s)/(ln(re/rw)-0.75). Some of you have solved this exercise by assuming values of k, h, Bo, muo. This is also ok, but you should always check that your choice of assumed values does not affect the results, since they will ultimately cancel out in the equation.
- The rate used to estimate pump power must be the local volumetric rate at the pump suction, not the standard conditions rate. The standard conditions rate is always lower than the local volumetric rate and can give wrong estimations of required pumping power.
- When using gas lift, the GOR of the tubing will be higher than the GOR of the reservoir. If you want to have a GOR in the tubing equal to x, calculate first the total amount of gas needed (qo_sc*x) and then subtract how much is coming from the reservoir (qo_sc*x-qo_sc*GOR_res). The amount of lift gas required is then qo_sc*(x-GOR_res).
- The VBA equation provided called "ffriction", as the descriptive text provided indicates, is the Darcy friction factor used to calculate the frictional pressure drop in pipes for single phase flow. See more information here: https://en.wikipedia.org/wiki/Darcy_friction_factor_formulae . This factor has

NOTHING to do with holdup, void fraction, etc. This VBA function is used when estimating frictional pressure drop for two phase flow.

- The non-slip liquid gas volumetric fraction is qg/(ql+qg) were q is volumetric rate of the phase (g-gas or l-liquid) at local pressure and temperature. This value gives what fraction of the pipe cross section is occupied by gas ASSUMING the gas and liquid travel at the same velocity. By definition, the non-slip volume fraction of a phase should always be between 0-1 (the phase occupies either all of the pipe cross section or none of the pipe cross section).
- The slip gas volumetric fraction, gas hold-up or void fraction is the fraction of the pipe cross section occupied by gas. By definition, the slip volume fraction of a phase should always be between 0-1 (the phase occupies either all of the pipe cross section or none of the pipe cross section). The slip volume fraction is usually different from the non-slip volume fraction because gas and liquid DO NOT typically travel at the same speed. The slip volumetric fraction must be calculated using auxiliary equations, for example a correlation, or implicitly by solving additional conservation equations.
- The slip gas volumetric fraction is required to estimate the gravitational pressure drop term in multiphase flow, because it allows to calculate how much of the pipe is occupied by liquid and gas during flowing conditions and then calculate the effective density and ultimately the hydrostatic pressure gradient.
- Regarding the dp/dl equation provided in the exam, this equation has a negative sign in front of the hydrostatic and frictional terms. This means that, as we progress in distance (distance increases), there will be a reduction in pressure. You can think of it as pressure should decrease when moving from bottom-hole to wellhead. In this equation, "l" is increasing from bottom to up (for example, we set l=0 at the bottom-hole). If you would have defined dl in the opposite direction (from example from top to bottom) then dp/dl would be positive (pressure increases with depth).
- When integrating the dp/dl equation along the tubing, from top to bottom, for the point below the wellhead (1) we use $p_1 = p_{wh} + (dp/dl) \bullet dl$. By definition, dl should be negative, since l_1 is smaller than l_{wh}, and $dl = (l_1 - l_{wh})$. When using TVD, TVD = (2500-l) (vertical well, TVD is measured from the top), then this gives $p_1 = p_{wh} + (dp/dl) \bullet (TVD_{wh} - TVD_1)$. This gives the correct result that p1 > pwh, since the negative sign of dp/dl cancels out with the TVD difference.
- It is often not necessary to do the analysis mentioned in the last two points, if you use logic and common sense (e.g. think about which sign does the dp/dl has and in which direction you are conducting the integration). But this analysis is VERY important for cases where there are non-intuitive configurations (e.g. downward sections in deviated wells).
- For future exams, I recommend you read well (several times) the exam text and check all the information provided before getting stressed and asking questions. During the exam there were several of you that asked questions that had clear answers in the exam material.
- During the exam, there was a student that indicated that didn't know how to make a plot in Windows Excel, because he/she had been working with Mac during the course. I was asked to send a short text explaining how to do the plot in Windows. The procedure to make the plot was very similar in the two versions of Excel, so probably the student didn't require my input to make them. Also, I indicated days before the exam that you

were going to use NTNU computers with Excel (which are typically running Windows). I attribute this to the fact that the student was nervous, tired, or stressed out.