Mock Full Paper 1   Worked answers

You should attempt all the questions in the mock paper first, before looking at the worked answers.

1. A

A Vessel outside the territorial limit is not in any of the four UK Nations so no RSL is appropriate. The suffix /MM is optional but is helpful especially if your contact should not be beaming towards the UK.

2. C

The relevant licence clause is 3(3)(c). The pass certificate is valid indefinitely so it is possible the holder either hasn't yet obtained a licence and callsign or is disqualified as defined in clause 17(1)(i). Note the wording is 'whom the Licensee has reasonable grounds to believe is not a Disqualified Person'. Simply not knowing either way is not sufficient.

3. B

The relevant licence clauses are 11(2)(b) and 11(3). Codes such as Q-codes or Morse code are not secret and are intended to aid communication. Option B in this question is intended to obscure the real message and may only be used when assisting a User Service or disaster situations as described in clauses 1(2) and 1(3)

4. A

All the answers might seem sensible but clause 7(1)(b) shows that the 1% limit applies to the nominal modulated carrier bandwidth.

That bandwidth is that actually required to successfully transmit the required information. It comes from the International Telecommunication Union Radio Regulations (ITU RR) as does the 1% limit.

5. C

Note (f) to the licence confirms the answer.

The note to the licence is a reminder that commercial communications companies may have restrictions on your use of their facilities. Also note that the non-encryption requirement {clause 11(2)(b)} only applies to RF transmissions in an amateur band.

6. B

Clause 9(5) requires that you must comply both with your licence schedule and the bands allocated to amateur radio in the ITU region concerned. The frequency must be in both documents.

Note this is not the same as operating in another country where you must comply with the licence conditions and licence schedule of that country. That may prohibit bands you can use in the UK and allow bands that are not in the UK schedule.

7. D

This condition is in note (g) to Schedule 1 of the licence.

8. B

The 50Ω ‘load resistor on the right is in series with the last resistor in the ladder, making 100Ω. That is in parallel with the last 100Ω resistor giving an effective resistance of 50Ω. The latter collapses stage by stage until the last stage which in then 2 100Ω resistors in parallel and an input resistance of 50Ω

Not relevant to the question but if a voltage is applied to the input the voltage at each section, i.e. the top of each 100Ω resistor, is exactly half the voltage of the previous stage. This is technique can be used in digital to analogue converters.

9. B

Some analysis of the question is required. C is not an answer since capacitors are not responsible for harmonic distortion. Breakdown voltage is always a factor but the question deliberately states a Foundation level device so there is no indication of high voltages; option A is unlikely. There is no suggestion the capacitors are used in a tuning circuit so D is also an unlikely answer but the fact that it is VHF is relevant. At VHF dielectric losses can be high for some materials and should be avoided. Answer B.

10 B

The back EMF always opposes a change. If the applied PD is increased to increase the current then the back EMF opposes that and slows the increase. If the source EMF is removed then the back EMF tries to maintain the current thereby slowing its fall.

11. D

When the switch is closed the capacitor starts to charge at a current limited by R. As the capacitor charges the PD across it rises leaving less PD across R so the current falls. The shape of the graph shows either the current or the PD across R. Only the latter is available as an answer.

12 A

In the absence of C3 some 99% of the AC signal at the base is present at the emitter – as if it were an emitter follower. The DC and the signal current in R3 and R4 are almost identical so the output signal voltage depends on the ratio of R3 and R4. If R3 is five times the value of R4 then the voltage gain of the circuit will be five. Adding C3 removes the AC signal across R4 provided the reactance of C3 is lower than the resistance of R4 by an adequate margin. That increases or restores the voltage gain of the circuit. It decouples R4.

13 C

The Fourier Transform is a mathematical process that takes a stream of samples of an analogue waveform (that is the time domain) and calculates all the different frequencies present – which is the frequency domain.

14 C

The power supplied by the PSU is 13.8V × 25A = 345W. With an 80% efficient PSU the input power is 345/0.8 = 431.25W. At 230V the input current is 431.25/230 = 1.875A. Giving three decimal places in the answer implies we know the input values to the same level of accuracy, which is not the case. At best we can say 1.9A.

15 A

This is a straightforward resonant frequency question. From the supplied formula sheet:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Square both sides

$$f^2 = \frac{1}{4\pi^2 LC}$$

Multiply both sides by L and divide both sides by f^2

$$L = \frac{1}{4\pi^2 f^2 C}$$

Inserting the numbers

$$L = \frac{1}{4\pi^2 \times 14^2 \times 10^{12} \times 140 \times 10^{-12}}$$

The calculator gives 9.231e-7 which is **0.92µH**

16 B

The graph is the characteristic of the Zener diode; see Fig 5.8 on page 32 of the Full manual.

17 C

The drawing shows a common source configuration. See Figs 5.20, 5.26 and 5.27 to piece the various bits of information together.

18 A

A significant feature of a switched mode power supply is the potential for a high harmonic content of the 50-100kHz (approx.) switching of the mains input. Fast switching is needed to minimise power dissipation in the switching transistors and that causes harmonics into the VHF band if not filtered. There is no series pass transistor – that is for linear PSUs. The transformer has a ferrite core and is much smaller and lighter.

Most switch mode mains PSUs are good for inputs from 100V to 250V but always check the specification of the individual device.

19 C

Frequency multipliers cannot be used on SSB or AM transmitters. If the audio is 1kHz and 1.2kHz on a USB carrier at 12MHz then the sideband signals will be at 12001 and 12001.2kHz. Fed to a frequency double gives 24002 and 24002.4kHz. Note the two signals are now 400Hz apart, not 200Hz as in the original audio. The 12MHz modulated signal must be mixed up to 144MHz by either a 132MHz oscillator or a 156MHz oscillator.

Not part of the question but in the numerical example using an oscillator at 156MHz is taking the difference frequency, 156-12 = 144, not the sum. An upper sideband at 12MHz becomes a lower sideband at 144MHz.

20 A

The transmitted signal occupies the frequency range 145987.5kHz ± 6kHz, i.e. 145986.5kHz to 145993.5kHz which is 6.5kHz from the band edge.

The maximum error as a proportion is 6.5/145987.5 which is 4.452e-5. That is 44.52ppm rounded to 44ppm.

21 C

The direct digital synthesiser has a table of the amplitude of a sinewave at several points over the cycle which is sent to a digital to analogue converter at an appropriate rate to re-create the sinewave.

A phase lock loop synthesiser uses a variable frequency oscillator locked to a crystal oscillator reference.

22 C

The formula, from the supplied sheet is Bandwidth = 2×(peak deviation + max audio frequency) giving 2 × (5 + 3.5) = 17kHz.

23 B

PEP is defined in the licence document (supplied) as the power averaged over one RF cycle at the crest of the modulation envelope. The heat dissipation is effectively averaged over many seconds. AM and SSB vary in amplitude so the average power over time will be less than the PEP. CW is at the peak for several RF cycles on key-down and zero on key up. The average heating will be around half the key-down peak. FM is at the peak all the time for the entire duration the PTT is pressed irrespective of any audio modulation.

24 B

The comment ‘correctly operating’ is significant on two counts. One, it will be lower sideband, LSB, in accordance with amateur convention. Two it is not faulty in any way apart from the audio being too high. That will distort the audio introducing audio harmonic frequencies above 3kHz. These frequencies are created in the modulator, after any frequency limiting filters in the microphone amplifier.

Since it is LSB, the carrier is at 7.050MHz, the audio goes down to 7.047MHz and the audio harmonics a bit further below that, including 7.045MHz.

7.065MHz is where the upper sideband would be but will be removed by the sideband filter. There is no reason to assume the RF signal will be distorted which would give rise to harmonics of the RF (rather than the audio).

25 B

The box above the Local Oscillator is the Mixer and the one to its right is the IF Amplifier. The box above the box marked X is the demodulator, in this case for CW, making box X the Beat Frequency Oscillator, BFO.

The demodulator could equally be for SSB making box X the Carrier Insertion Oscillator, CIO, but that option wasn't available to pick. Note the description Second Local Oscillator is reserved for the double superhet architecture.

26 B

When the receiver is tuned to 8.7MHz the 7.1MHz signal is now on the image frequency of the receiver. The LO will now be midway between them at 7.9MHz and the IF is 800kHz.

Initially the LO was at 6.3MHz so a signal at 7.1MHz would mix to 800kHz.

27 C

The HF bands, especially the lower ones are noisy, noisier than the internal receiver noise. All a preamp will achieve is to make the signal and natural RF noise stronger, the signal won't be any clearer.

There is no point in having more gain than needed to bring the natural atmospheric noise up to full volume. Easy at HF and even a budget priced receiver are likely to achieve that.

At VHF the atmospheric noise is much lower and the internal circuit noise of mid-priced receivers is greater. It may now be worthwhile getting a low internal noise pre-amplifier to bring weak signals up to a level which overcomes the internal noise of the receiver. Weak signals, previously drowned by the internal noise, can now be heard. The signal to noise ratio is improved.

It is better to replace the RF front end of the receiver with a lower internal-noise, front end amplifier. That is not always a practicable option.

The more practical and common option is to obtain a low noise pre-amp. That brings the weak signals (still stronger than the atmospheric noise) up by, say, 10dB, so now they can be heard over the high internal noise of the receiver itself.

Adding a preamp will reduce the maximum signal that can be handled without overloading. It may be advantageous to be able to switch out the preamp when there are strong signals and the preamp is not needed.

28 C

The aim of the AGC is to keep the level of the signal out of the IF amplifier stages as constant as practicable. The level monitoring circuit could be either in the final IF amp stage or at the input of the demodulator – electrically the same place.

29 A

Analogue signals can occupy any amplitude or phase as long as it is within upper limits. Data signals can only occupy pre-set values defined by the modulation scheme being used. The IQ or constellation diagram shows the amplitudes and phases that a data signal may occupy. In this instance there are 8 options all different phases but because the all lie on a circle centred on the zero of both the I and Q axes it can be seen the all have the same amplitude.

Option D, QPSK, quadrature phase shift keying, would be shown by four dots or positions on the diagram and would then also likely be at 90° intervals.

It is a phase modulated system, adopting 8 phase positions. That may involve frequency changes but they are as a consequence of the phase modulation so FM modulation is not a correct description.

RTTY using two different frequencies to represent the data 1's and 0's is a frequency modulated system; any phase changes of the carrier are simply a consequence of the different frequencies.

30 C

RIT, receiver incremental tuning, provides a limited tuning change to a transceiver without changing the transmit frequency. It is used to allow fine tuning when several people are in an SSB net but are not all on exactly the same frequency.

31 A

The drawing shows a choke balun made up of a number of ferrite rings round a coaxial cable.

If the cable was connected directly to a dipole then RF currents would be present on the outside surface of the coax screen. That risks causing interference and susceptibility to picking up unwanted signals. The inductance of the ferrite rings suppresses or chokes off such currents thereby acting as a balun.

32 B

The current at the open (unconnected) end of an antenna will be zero so options 3 & 4 can be immediately discarded. A low current point is normally accompanied by a high voltage so option 1 goes too. Option 2 is correct.

33 D

Read this one carefully. The question gives the reflected *power* and asks for the *voltage* standing wave ratio.

If half the power is reflected then that is 70% of the voltage. (Strictly 70.71%).

The formula sheet shows $SWR = \frac{V_{max}}{V_{min}} = \frac{V_f + V_r}{V_f - V_r}$

where V_f is the voltage of the forward wave and V_r the voltage of the reflected wave.

Inserting the numbers: $SWR = \frac{1 + 0.7}{1 - 0.7} = 5.67$

6:1 is about as close as we can reasonably say. SWR meters are not precision instruments.

34 A

The circuit shown is that of an Antenna Matching Unit.

This circuit can cope with antenna impedances both above and below 50Ω. The parallel tuned circuit can have quite high circulating currents and voltages, i.e. a high Q-factor. With the antenna acting as a load the loaded Q will be rather lower but when poorly matched the loading effect will be lower. Components should be generously rated!

35 C

Right-handed circular polarisation is defined as rotating clockwise when seen from behind.

36 C

The critical frequency is the highest frequency that will be returned from the ionosphere on a vertical path, that is co-located transmitter and receiver. As the path length increases the required angle of refraction reduces (from 180°) so the MUF increases.

37 B

An Earth-Moon-Earth path has very high losses. Only a small fraction of the transmitted signal actually hits the moon, most bypasses it. The moon is also a poor reflector. High gain antennas and high powers are needed along with very low noise receivers.

New digital modulation schemes make contacts easier but it is still quite an achievement.

38 B

Even good quality equipment can be compromised by poor installation. The EMC standards apply to the equipment itself, there are no standards on the quality of installation or ongoing maintenance checks.

39 B

Options C and D are easily discarded but both A and B appear credible. Radio broadcasts come from a number of transmitters so the likelihood of all of them being weak is not high. The radio is also stated as particularly sensitive suggesting others are not so badly affected. That points towards B.

There is room for argument and in practice the situation in ‘A’ could happen. However the question reflects real life EMC problems which are seldom clear cut. There may be one or two questions where the best answer needs to be selected and few options are simply wrong or impossible.

40 A

This question is best tackled by considering all four options.

Cross-modulation occurs when the wanted signal is affected by the modulation on any unwanted one. Clearly a potential answer.

Blocking is where a very strong signal drives the receiver out of its usable range such that the wanted signal effectively disappears. Not a correct option.

Capture effect in an FM discriminator is a valid condition where the discriminator tends to capture or lock-on to the strongest signal even when the weaker one would be perfectly good on its own. It is the opposite of the effect described and is also outside the syllabus.

Non-linearities in the loudspeaker sounds like rubbish and not an answer.

41 C

There could be a number of routes of ingress and many do not require the victim equipment to have radio receiving capability. The licence requirement is to not cause interference to other wireless telegraphy – meaning in the WT Acts any form of radio communication. However there are also limits on the RF field strength in neighbouring properties so ‘hard luck’ is not socially acceptable and may not be legally acceptable.

The choice is between the CD head and the speaker leads. The leads act as an antenna and the audio stages of the equipment have transistor and diode junctions to demodulate the RF if there is any form of amplitude modulation, typically AM and SSB, but possibly data and CW if the transmitter is poorly set up or operated. C is the better option by some margin.

42 A

An MW receiver tunes from 526.5 kHz - 1.6065 MHz. With a 465 kHz IF the LO can tune from 61.5 kHz to 1141.5 kHz or 991.5 kHz to 2071.5 kHz. To reduce the proportionate range the LO is on the high side of the wanted signal. Consequently the image frequency ranges from 1456.5 kHz to 2536.5 kHz. That covers the entire of the amateur 160m ‘top’ band from 1.81 MHz to 2.00 MHz. Domestic radios are more susceptible to pickup on image frequencies.

43 C

The device is a mains filter to be connected in the supply radio and other equipment.

Note this type of filter does not filter the earth wire so may be of limited use. It is better fitted on items such as electric drills which can cause interference. Such items should have an integral filter but additional filtering might prove advantageous in some circumstances.

44 D

Reducing power to a comfortable minimum is the best all round option. Option B is obviously sensible if there is still a risk to the neighbour but the question included problems to your own home so beam heading is not the answer.

45 B

The coax and end-fed antenna are both unbalanced so might seem OK. However end-fed antennas can cause high RF currents in the RF earth (or mains earth). There may also be high voltages depending on the exact layout and frequency. Upstairs it will be difficult to achieve a good RF earth so the transmitter may be a a high RF potential, painfully high even at 50-100W.

In some instances getting a good SWR may be tricky but it is achievable and does not solve the problem of high RF voltages on the transmitter case and maybe AMU case.

46 C

Code of Practice FCS 1362 advises on fitting radio equipment in vehicles. The positive lead should be fused direct to the vehicle (12V) battery and the negative lead unfused to the chassis adjacent to the connection from battery negative to the chassis.

The old arrangement of taking the negative lead (fused) to the battery is now deprecated since it will provide a route from battery negative, via the transceiver and antenna leads (and possibly audio or control leads) to the chassis. Thus a failure of the battery negative to chassis strap, which may be subject to corrosion, may go un-noticed until a heavier current is drawn.

A fuse in the negative lead may well not be adequate protection since a 100W transmitter will draw 20A and a 20-25A fuse would not protect such incidental connections perhaps via tracks on a printed circuit board or other thin leads.

47 D

Weak TV signals and interference all have a similar effect on digital TV, the bit error ratio of the data stream increases causing pixilation, momentary freezes of the picture and possibly complete loss. The best bet is to be as helpful as you can and carry out tests with the neighbour's co-operation to check if it is your activities that are causing the problem and exactly what causes the problem.

48 C

Operating from a rare and sought after location can attract large numbers of callers all on top of each other making it difficult to identify any one callsign. A common technique is to operate 'split frequency' by listening on a different frequency to the one used for transmit. In this instance about 5 kHz higher than transmit. That spreads out the callers allowing a better chance of successful contacts.

49 C

The UK 7 MHz band is 7.00 to 7.20 MHz so a reply on 7.205 MHz is out of band and a breach of the licence terms. All you can do is to reply on 7.20 MHz lower sideband, as is the convention below 10 MHz, and hope the American amateur is familiar with the UK amateur frequencies and is listening there – eg a panoramic display.

50 C

All four options are factually correct but the one that matters is C, the high voltage. You might not get a second chance.

51 B

Static charges can collect on disconnected antennas even when the thunderstorm does not present an imminent risk. The antenna may remain charged when it is considered safe to resume operating, resulting in damage to the equipment.

52 A

The ICNIRP, the International Commission on Non-Ionising Radiation Protection, advises of the safe levels of exposure the electromagnetic fields. The UK authority, currently Public Health England (for all four UK nations) simply points to the ICNIRP.

PHE is expected to become the National Institute for Health Protection early in 2021. As a formal change both names will be regarded as correct in the meantime.

53 C

The extinguisher should be sufficiently far away from the generator and fuel store that it remains accessible in a fire. That removes positions 1 & 2. It should also be visible and not too far away. In the layout shown that is position 3. Position 4 is not naturally in view being somewhat behind the operating tent door. The 80m dipole gives some indication of scale.

54 B

The key point in this question is that the meter will influence the circuit. The potential divider comprises the 220 kΩ top resistor and the 120 kΩ and 100kΩ resistance of the meter in parallel as the bottom resistor. That gives 54.54 kΩ.

The actual PD at the gate is then 10V × 54.54/(220+54.54) = 1.98V. Option B at 2V

It is good enough to take the parallel pair as midway between 120/2 and 100/2, ie 55 kΩ. That is a quarter of 220 kΩ giving a 5:1 potential divider. A glance at the four options will show they are all sufficiently different that a precise calculation is not required.

55 D

The signal generator has an output resistance of 50Ω so connecting the receiver, which represents a 50Ω load will halve the terminal voltage at the signal generator. The oscilloscope typically has an input resistance of 1 MΩ or 10MΩ if a ×10 probe is used. It won't affect a 50Ω circuit. Removing the receiver connection but leaving the oscilloscope attached will result in the oscilloscope doubling in amplitude.

Care should always be taken to be sure whether specifications or meter readings are EMF (open circuit- no load) or PD (50Ω load). With oscilloscopes at RF it is also necessary to consider the input capacitance, typically 20 to 30 pF plus any extra capacitance of the lead. Using a ×10 probe also drops the input capacitance to around 2to 3 pF. X10 probes also have a small built-in variable capacitor to ensure the capacitance division ratio is he same as the resistance ratio.

56 D

The device is an SWR meter, see Fig 14.7 in the manual. This question uses a single meter and a switch to swap between the forward and reverse signals.

57 B

283 V peak to peak is 141.5 V peak which is $^{141.5}/_{\sqrt{2}}$ = 100 V rms.

100 V, 50 Ω gives 2 A and 200 W.

You may recognise 200 W as 23 dBW but the schedule in the licence shows the 5 MHz band as 100W and 20dBW so 200 W is 23dBW.

1 W is 30 dBm so 200 W is 23+30 = 53 dBm.

58 A

The inductor temperature coefficient is 10 ppm/°C so for 10°C this is 100 ppm change.

The formula for the resonant frequency is $f = \frac{1}{2\pi\sqrt{LC}}$

The L is in the denominator so an increase in L will cause a decrease in frequency.

Less obvious is the effect of the square root sign.

Without the square root a 100 ppm increase in L will be a 100 ppm decrease in frequency.

A 100 ppm change at 10MHz would be a 1 kHz frequency change.

The square root of numbers greater than 1 results in a smaller number.

We are, therefore looking for a decrease in frequency less than 1 kHz. ‘A’ at 500 Hz is the only available option.

To better understand the effect of the square root lets first consider squaring numbers.

1.01^2 is 1.0201; 1.02^2 is 1.0404

Notice the relationship between the underlined digit and at same digit before squaring, it has (approximately) doubled.

$\sqrt{1.02}$ is 1.00995, very close to 1.01 as we now expect.

Applying this change to the original question does show that a 500Hz change is the correct answer. The actual number is 499.98 (to two decimal places) so the error is so small as to be irrelevant.