1.1

Given:	
- part drawing with two views	- dimensions in mm

a) The stock must have a larger OD than the largest OD of the part, a smaller OD than the smallest OD of the part, and length greater than that of the part by enough that it can be held in a lathe chuck. Therefore, an appropriate choice would be an tube of 125-mm OD and 30-mm wall thickness (or 65-mm ID). This would be best done with a long bar from which the appropriate length would be parted off once all other lathe-work is complete.

b) The operations required to machine the part are listed below. Each is broken into multiple individual processes as needed to create the respective feature.

Op-1 Create outer axisymmetric surfaces

1. Fixturing: Extend 275 mm or slightly more from the chuck of a lathe.
2. OD turn entire length (260 mm minimum) to 120 mm outer diameter in two passes: one rough (to 121 mm diameter) and one finish (to 120 mm diameter).
3. OD turn right-hand portion to 80 mm outer diameter in seven passes: six rough passes of equal depths of cut down to 81 mm diameter and one finish pass to 80 mm diameter; create chamfer at diameter transition.

Op-2 Create inner axisymmetric surfaces

1. Fixturing: Keep chucked in lathe.
2. Bore/ID-turn entire length (260 mm minimum) to 70 mm inner diameter in two passes: one rough (to 69 mm diameter) and one finish (to 70 mm diameter).

Op-3 Cut-off

1. Fixturing: Keep chucked in lath.
2. Part/cut-off to remove 260-mm length from raw tube stock to remain in lathe chuck.

Op-4 Create slot and drilled holes

1. Fixturing: transfer cut-off part to a machining center with a rotary clamp.
2. Cut slot with 20-mm diameter end cutting (for plunging) end mill.
3. Drill first hole in line with slot.
4. Drill three additional holes with a 90° part rotation between each.
5. Using four additional part rotations, orient and tap each of the four holes.

The six processes are:

(1) OD turning (2) Boring/ID-turning (3) Cut-off (4) Slot end milling (5) Drilling (6) Tapping

---

2.3

Given:

- orthogonal cutting
- orthogonal rake angle, $\gamma_o = 10°$
- uncut chip thickness, $h = 0.20$ mm
- cutting speed, $V = 50$ m/min
- chip thickness ratio, $r_h = 0.5°$

a) By definition, the chip thickness ratio is

$$r_h = \frac{h}{h_c}\ .$$

Therefore,

$$h_c = \frac{h}{r_h}\ .$$

Substituting the given value for uncut chip thickness *h*, the final result (in mm) is

$$h_c = \frac{0.20}{0.5} = \boxed{0.40}$$

b) The chip velocity is related to the cutting velocity by the chip ratio as

$$V_c = r_h V\ .$$

Substituting known values, the final result (in m/min) is

$$V_c = (0.5)(50) = \boxed{25}\ .$$

c) The chip thickness ratio can also be written in terms of the shear angle and rake angle as

$$r_h = \frac{\sin\phi_o}{\cos(\phi_o - \gamma_o)}\ .$$

Rearranging,

$$\sin\phi_o = r_h \cos(\phi_o - \gamma_o)\ .$$

The shear angle can be found in two ways as follows:

The $\cos(\phi_o - \gamma_o)$ terms can be transformed, using an angle-difference trigonometric identity, to

$$\cos(\phi_o - \gamma_o) = \cos\phi_o \cos\gamma_o + \sin\phi_o \sin\gamma_o\ .$$

Therefore,

$$\sin\phi_o = r_h \left(\cos\phi_o \cos\gamma_o + \sin\phi_o \sin\gamma_o\right).$$

Dividing through by $\cos\phi_o$ yields

$$\tan\phi_o = r_h \left(\cos\gamma_o + \tan\phi_o \sin\gamma_o\right).$$

Grouping coefficient of $\tan\phi_o$ then results in

$$\tan\phi_o \left(1 - r_h \sin\gamma_o\right) = r_h \cos\gamma_o\ .$$

The final expression for shear angle is

$$\phi_o = \tan^{-1}\left[\frac{r_h \cos\gamma_o}{1 - r_h \sin\gamma_o}\right].$$

Substituting known values, the final result is

By taking the inverse sine of each side, an expression for ϕo in terms of ϕo results as

$$\phi_o = \sin^{-1}\left[r_h \cos(\phi_o - \gamma_o)\right].$$

Substituting known values yeilds

$$\phi_o = \sin^{-1}\left[0.5\cos(\phi_o - 10°)\right].$$

The result can then be found by simple iteration. It is known that shear angle cannot be greater than the minimum-energy result of

$$\frac{90° + \gamma_o}{2} = 50°\ .$$

Therefore, a good guess may be slightly below that, such as 45°. The first iteration is

$$\phi_o = \sin^{-1}\left[0.5\cos(45° - 10°)\right] = 24.17°\ .$$

Subsequent iterations are

$$\phi_o = \sin^{-1}\left[0.5\cos(24.17° - 10°)\right] = 29.00°$$

$$\phi_o = \tan^{-1}\left[\frac{0.5\cos(10°)}{1-0.5\sin(10°)}\right] = \boxed{28.3°}\,.$$

$$\phi_o = \sin^{-1}\left[0.5\cos(29.00° - 10°)\right] = 28.21°$$

$$\phi_o = \sin^{-1}\left[0.5\cos(28.21° - 10°)\right] = 28.36°$$

$$\phi_o = \sin^{-1}\left[0.5\cos(28.36° - 10°)\right] = 28.33°$$

$$\phi_o = \sin^{-1}\left[0.5\cos(28.33° - 10°)\right] = 28.34°$$

The final result is

$$\phi_o = \boxed{28.34°}\,.$$

For the remainder of the problem, assume the answer to part (c) is ϕ_o = 30°.

d) The shear velocity is related to the cutting velocity as

$$V_s = \frac{\cos\gamma_o}{\cos(\phi_o - \gamma_o)} V\,.$$

Substituting known values, including the value given for shear angle of 30°, the final result (in m/min) is

$$V_s = \frac{\cos(10°)}{\cos(30° - 10°)} 50 = \boxed{52.4}\,.$$

e) The Lee and Shaffer model is

$$\phi_o = 45° + \gamma_o - \beta\,.$$

Solving for β and substituting known values, the final result is

$$\beta = 45° + \gamma_o - \phi_o = 45° + 10° - 30° = \boxed{25°}\,.$$