Problem Set #1

Measure Theory, Jan Ertl
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Solution 1. (1.3)

1. Suppose $s \in \mathbb{R}$ open. So $s \in \mathbb{G}_1$ by definition. Take $s^c \in \mathbb{R}$ is close by properties of open/closed sets.
   $\Rightarrow s^c \notin \mathbb{G}_1$ by definition of $\mathbb{G}_1$
   $\Rightarrow$ not closed under complements. So G1 is not a sigma-algebra.

2. **WTS:** G2 algebra

   - $\emptyset \in (a, b] \Rightarrow \emptyset \in \mathbb{G}_2$
   - Suppose $A_j = \cup_{i=1}^{N_j}((a_i, b_i] \cup (-\infty, b] \cup (a, \infty))$
     So then $\cup_j^M A_j = \cup_j^M(\cup_{i=1}^{N_j}((a_i, b_i] \cup (-\infty, b] \cup (a, \infty))) \in \mathbb{G}_2 \quad \square$

   So G2 is an algebra.

3. **WTS:** G3 sig-alg

   - $\emptyset \in (a, b] \Rightarrow \emptyset \in \mathbb{G}_3$
   - Suppose $A_j = \cup_{i=1}^{N_j}((a_i, b_i] \cup (-\infty, b] \cup (a, \infty))$
     So then $\cup_j^\infty A_j = \cup_j^\infty(\cup_{i=1}^{\infty}((a_i, b_i] \cup (-\infty, b] \cup (a, \infty))) \in \mathbb{G}_3 \quad \square$

   So, G3 is a sigma algebra

Solution 2. (1.7)
Suppose $\mathcal{A}$ is an algebra. **WTS:** $\{\emptyset, X\} \subset \mathcal{A} \subset \mathcal{P}(X)$

Solution 3. (1.10)
i) $\emptyset \in S_\alpha \forall \alpha$ by definition of sig-alg. $\Rightarrow \emptyset \in \cap^\alpha S_\alpha$
ii) suppose $A_1, ... \in \cap^\alpha S_\alpha$ this implies $A_1, ... \in S_\alpha \forall \alpha$
So the union of $A_i \in S_\alpha$ for every alpha.

So $\cup A_1, ... \in \cap^\infty S_\alpha$ Therefore intersection is a sigma algebra.

Solution 4. (1.17)
i) We know

$$\mu(A \cup B)) = \mu(A) + \mu(B)$$

if

$$A \cap B = \emptyset$$

[1]worked with Arpan Chakrabarti and Arushi Saksena

. Now suppose $A \subset B$ and $B = A \cup B$.
So,

$$\mu(A \cup U) = \mu(A)\mu(U) \geq \mu(A)$$

because measure is valued on positive reals.

ii) We know,

$$\mu(\cup_{i=1}^{\infty} A_i) = \sum_{i=1}^{\infty} \mu(A_i) - \mu(\cap_i A_i)$$

So,

$$\mu(\cup_{i=1}^{n} A_i) + \underbrace{\mu(\cap_i^{\infty} A_i)}_{\geq 0} = \sum_{i=1}^{\infty} \mu(A_i)$$

Solution 5. (1.18)
WTS:

$$\lambda(A) = \mu(A \cap B)$$

Pf:

$$A, B \in S \Rightarrow (A \cap B) \in S. \Rightarrow \emptyset \cap B = \emptyset$$

So, i)

$$\lambda(\emptyset) = \mu(\emptyset) = 0$$

And because intersection is in S and ,

$$\lambda(A) = \mu(A \cap B) \Rightarrow \lambda(\cup^{\infty} A_i) = \mu(\cup^{\infty}(A_i \cap B)) = \sum^{\infty} \underbrace{\mu(A_i \cap B)}_{\lambda(A_i)} = \sum^{\infty} \lambda(A_i)$$

Solution 6. (1.20)