For this Tutorial, while still aiming to grasp the concept of "program correctness", we would delve into Logical Equivalence and verify if select propositions are **tautology** or **contradiction**

We would be given a program already designed but with some lines of code redacted. The program would give an output based on the proposition we feed into it.

We would also engage our conditional **for, if and else-if** statements.

Consider the truth table for tautology below with a proposition **p∨ ¬p **

p	$\neg p$	$p \vee \neg p$
True	False	True
False	True	True

Practice 1

The code below is designed to recieve the right syntax for (p $\vee$ q) $\vee$ (q $\implies$ p) and check if the logical expression is a tautology or contradiction while drawing the truth table for verification

In [3]:
```
%pip install pandas
```

```
^C
Note: you may need to restart the kernel to use updated packages.
```

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Downloading tzdata-2024.2-py2.py3-none-any.whl (346 kB)
Installing collected packages: pytz, tzdata, numpy, pandas
Successfully installed numpy-2.1.1 pandas-2.2.3 pytz-2024.2 tzdata-2024.2
  WARNING: The scripts f2py.exe and numpy-config.exe are installed in 'c:\Users\bist
r\AppData\Local\Programs\Python\Python312\Scripts' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning,
use --no-warn-script-location.
```

In [ ]:

In [2]:
```
import pandas as pd
import itertools
```

In [5]:
```
print(pd.__version__)
```

```
2.2.3
```

In [7]:
```
# Define a function to evaluate the logical expression (p ∨ q) ∨ (q → p)
def evaluate_expression(p, q):
    return (p or q) or (p ** q)

# Create a list of all possible truth values for p and q
possible_truth_values = [(p, q) for p in [True, False] for q in [True, False]]

# Create a table to store the truth values and the results of the expression
table_data = []

# Evaluate the expression for each combination of truth values
for p, q in possible_truth_values:
    result = evaluate_expression(p, q)
    table_data.append((p, q, result))

# Create a DataFrame to display the truth table
df = pd.DataFrame(table_data, columns=['p', 'q', '(p ∨ q) ∨ (q → p)'])

# Display the truth table
print(df)

print()
# Determine whether the logical expression is a tautology, contradiction, or neithe
if all(df['(p ∨ q) ∨ (q → p)']):
    print("(p ∨ q) ∨ (q → p) is a tautology.")
elif not any(df['(p ∨ q) ∨ (q → p)']):
    print("(p ∨ q) ∨ (q → p) is a contradiction.")
else:
    print("(p ∨ q) ∨ (q → p) is neither a tautology nor a contradiction.")
```

```
       p      q (p ∨ q) ∨ (q → p)
0   True   True              True
1   True  False              True
2  False   True              True
3  False  False                 1

(p ∨ q) ∨ (q → p) is a tautology.
```

Exercise 1

Complete the code below and state if the logical expression (p $\implies$ q) $\vee$ p is a tautology or contradiction.

In [14]:
```python
# Define a function to evaluate the logical expression (p → q) ∨ p
def evaluate_expression(p, q):
    # Return the expression
    # complete the code below
    #return (q ** p) or p #This ocde returns 1 for every time it evaluates
    return (not p or q) or p


# Create a list of all possible truth values for p and q
possible_truth_values = [(p, q) for p in [True, False] for q in [True, False]]

# Create a table to store the truth values and the results of the expression
table_data = []

# Evaluate the expression for each combination of truth values
for p, q in possible_truth_values:
    result = evaluate_expression(p, q)
    table_data.append((p, q, result))

# Create a DataFrame to display the truth table
df = pd.DataFrame(table_data, columns=['p', 'q', '(p → q) ∨ p'])

# Display the truth table
print(df)

print()
# Determine whether the expression is a tautology, contradiction, or 9neither
if all(df['(p → q) ∨ p']):
    print("(p → q) ∨ p is a tautology.")
elif not any(df['(p → q) ∨ p']):
    print("(p → q) ∨ p is a contradiction.")
else:
    print("(p → q) ∨ p is neither a tautology nor a contradiction.")
```

```
       p      q  (p → q) ∨ p
0   True   True          True
1   True  False          True
2  False   True          True
3  False  False          True

(p → q) ∨ p is a tautology.
```

Practice 2

Recall that for two propositions to be logically equivalent, their truth values must be same regardless of the truth values of individual propositions.

Consider the proposition $(p \implies q) \wedge (r \implies q)$ **AND** $(p \wedge r) \implies q$. A program has been designed to check if the two propositions are logically equivalent or not.

In [7]:
```
# Define the symbolic variables p, q, and r
p_values = [True, False]
q_values = [True, False]
r_values = [True, False]

# Create a table to store the truth values and results
table_data = []

# Generate all possible combinations of truth values for p, q, and r
for p, q, r in itertools.product(p_values, q_values, r_values):
    # Evaluate the expressions
    expr1_result = (not p or q) and (not r or q)# (q ** p) and (q ** r)
    expr2_result = (not (p and r) or q) #q ** (p and r)

    # Determine if they are equivalent
    equivalent = expr1_result == expr2_result

    # Append the values to the table
    table_data.append((p, q, r, expr1_result, expr2_result, equivalent))

# Create a DataFrame to display the truth table
import pandas as pd
df = pd.DataFrame(table_data, columns=['p', 'q', 'r', '(p → q) ∧ (r → q)', '(p ∧ r

# Check if the expressions are equivalent for all rows
equivalent = all(df['Equivalent'])
# Display the truth table
print(df)
# Determine the result
if equivalent:
    print("The expressions are logically equivalent.")
else:
    print("The expressions are not logically equivalent.")
```

```
       p      q      r  (p → q) ∧ (r → q)  (p ∧ r) → q  Equivalent
0   True   True   True               True         True        True
1   True   True  False               True         True        True
2   True  False   True              False        False        True
3   True  False  False              False         True       False
4  False   True   True               True         True        True
5  False   True  False               True         True        True
6  False  False   True              False         True       False
7  False  False  False               True         True        True
The expressions are not logically equivalent.
```

Exercise 2

Using the same concept as above complete the code below to check if the two propositions $p \wedge (p \implies q)$ **AND** $p \wedge q$ are logically equivalent. Also complete the code to draw the truth table

In [9]:
```
# Define the symbolic variables p and q
p_values = [True, False]
q_values = [True, False]


# Create a table to store the truth values and results
table_data = []

# Generate all possible combinations of truth values for p and q
for p, q in itertools.product(p_values, q_values):
    # Evaluate the expressions
    # complete the code code below
    expr1_result = (p and (not p or q))
    expr2_result = (p and q)

    # Determine if they are equivalent
    equivalent = expr1_result == expr2_result

    # Append the values to the table
    table_data.append((p, q, expr1_result, expr2_result, equivalent))

# Create a DataFrame to display the truth table
import pandas as pd
df = pd.DataFrame(table_data, columns=['p', 'q', 'p ∧ (p→ q)', 'q ∧ p', 'Equivalen

# Check if the expressions are equivalent for all rows
equivalent = all(df['Equivalent'])

# Determine the result
if equivalent:
    print("The expressions are logically equivalent.")
else:
    print("The expressions are not logically equivalent.")

# Display the truth table
# insert code below
print(df)
```

```
The expressions are logically equivalent.
       p      q  p ∧ (p→ q)  q ∧ p  Equivalent
0   True   True        True   True        True
1   True  False       False  False        True
2  False   True       False  False        True
3  False  False       False  False        True
```

Practice 3

Consider the following statement in English " **The square of every number is at least 0.**". A logical expression with the same meaning could be written as ∀x (x**2 ≥ 0)

Write a program to to check if the value holds true for a range of numbers between -10 to 10

In [ ]:
```
# Define a function to check the condition for a given number
def check_condition(x):
    return x ** 2 >= 0

# Define the range of numbers to check (for example, from -10 to 10)
# Reason for the range is to save calculation time
for x in range(-10, 10):
    if not check_condition(x):
        print(f"The statement does not hold for {x}.")
        break
else:
    print("The statement holds for all numbers in the range.")
```

```
The statement holds for all numbers in the range.
```

Check if the program holds true when x is 2

In [ ]:
```
check_condition(-2)
```

Out[ ]:
```
True
```

In [1]:
```
%pip install nbconvert
```

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ing\python\python312\site-packages (from nbclient>=0.5.0->nbconvert) (8.6.3)
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5.7->nbconvert)
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Requirement already satisfied: tornado>=6.2 in c:\users\bistr\appdata\roaming\python
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(6.4.1)
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Downloading bleach-6.1.0-py3-none-any.whl (162 kB)
Downloading jinja2-3.1.4-py3-none-any.whl (133 kB)
Downloading MarkupSafe-2.1.5-cp312-cp312-win_amd64.whl (17 kB)
Downloading mistune-3.0.2-py3-none-any.whl (47 kB)
Downloading nbclient-0.10.0-py3-none-any.whl (25 kB)
Downloading nbformat-5.10.4-py3-none-any.whl (78 kB)
Downloading pandocfilters-1.5.1-py2.py3-none-any.whl (8.7 kB)
Downloading beautifulsoup4-4.12.3-py3-none-any.whl (147 kB)
Downloading defusedxml-0.7.1-py2.py3-none-any.whl (25 kB)
Downloading jupyterlab_pygments-0.3.0-py3-none-any.whl (15 kB)
Downloading tinycss2-1.3.0-py3-none-any.whl (22 kB)
Downloading fastjsonschema-2.20.0-py3-none-any.whl (23 kB)
Downloading jsonschema-4.23.0-py3-none-any.whl (88 kB)
Downloading soupsieve-2.6-py3-none-any.whl (36 kB)
Downloading webencodings-0.5.1-py2.py3-none-any.whl (11 kB)
Downloading attrs-24.2.0-py3-none-any.whl (63 kB)
Downloading jsonschema_specifications-2023.12.1-py3-none-any.whl (18 kB)
Downloading referencing-0.35.1-py3-none-any.whl (26 kB)
Downloading rpds_py-0.20.0-cp312-none-win_amd64.whl (214 kB)
Installing collected packages: webencodings, fastjsonschema, tinycss2, soupsieve, rp
ds-py, pandocfilters, mistune, markupsafe, jupyterlab-pygments, defusedxml, bleach,
attrs, referencing, jinja2, beautifulsoup4, jsonschema-specifications, jsonschema, n
bformat, nbclient, nbconvert
Successfully installed attrs-24.2.0 beautifulsoup4-4.12.3 bleach-6.1.0 defusedxm
l-0.7.1 fastjsonschema-2.20.0 jinja2-3.1.4 jsonschema-4.23.0 jsonschema-specificatio
ns-2023.12.1 jupyterlab-pygments-0.3.0 markupsafe-2.1.5 mistune-3.0.2 nbclient-0.1
0.0 nbconvert-7.16.4 nbformat-5.10.4 pandocfilters-1.5.1 referencing-0.35.1 rpds-p
y-0.20.0 soupsieve-2.6 tinycss2-1.3.0 webencodings-0.5.1
Note: you may need to restart the kernel to use updated packages.
```

```
  WARNING: The script jsonschema.exe is installed in 'c:\Users\bistr\AppData\Local\P
rograms\Python\Python312\Scripts' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning,
use --no-warn-script-location.
  WARNING: The script jupyter-trust.exe is installed in 'c:\Users\bistr\AppData\Loca
l\Programs\Python\Python312\Scripts' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning,
use --no-warn-script-location.
  WARNING: The script jupyter-execute.exe is installed in 'c:\Users\bistr\AppData\Lo
cal\Programs\Python\Python312\Scripts' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning,
use --no-warn-script-location.
  WARNING: The scripts jupyter-dejavu.exe and jupyter-nbconvert.exe are installed in
'c:\Users\bistr\AppData\Local\Programs\Python\Python312\Scripts' which is not on PAT
H.
  Consider adding this directory to PATH or, if you prefer to suppress this warning,
use --no-warn-script-location.
```