CHAPTER 16

U-VALUES

U-Values

- U-values refer to how well building materials conduct heat.
- The U-value is a measurement of the amount of heat lost from a material.
- The U-value is:

  "The heat transfer of 1 Kelvin through 1m^2 of a building material"

Or

U-value = W/m^{2}K

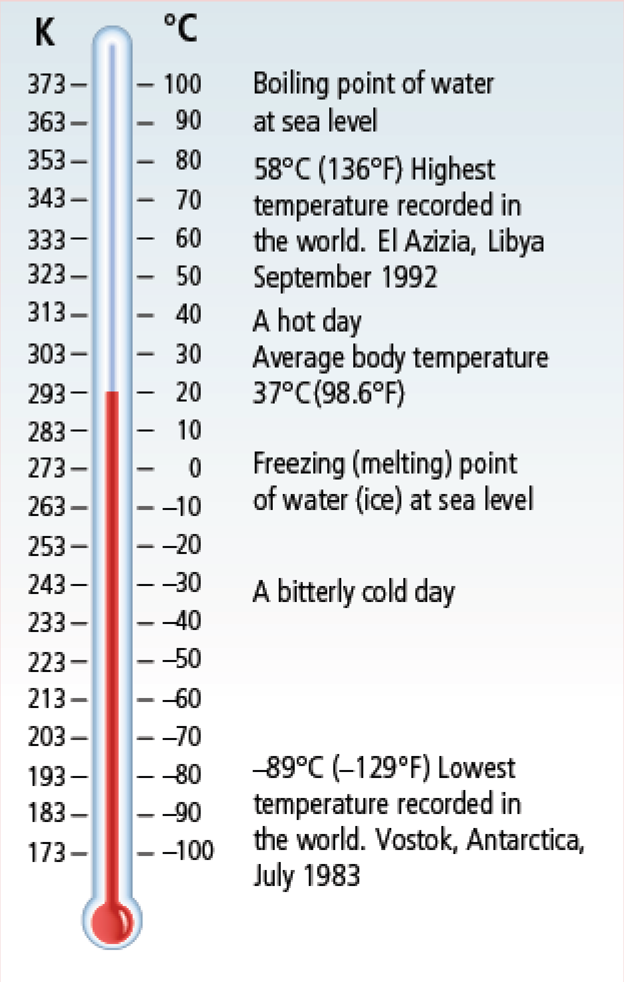
U-Values

U-value = W/m²K

W = Watt (unit of electricity)

m = metre

K = Kelvin (unit of temperature)



U-Values

- The lower the U-value, the less heat that is lost through the building materials.
- U-values vary according to the following:
  - The materials used in the building
  - The building's location
  - The temperature difference between the outside and the inside

Building Element Values

Building regulations set out the maximum U-values for each element of the building. The current values can be seen in the table below.

TABLE 16.1 CURRENT (2011) BUILDING REGULATIONS

Building element	Maximum acceptable U-value (W/m^2k)
Roof (pitched with horizontal insulation)	0.16
Roof (pitched with parallel insulation)	0.16
Roof (flat)	0.2
Wall	0.21
Floor	0.21
Window/Door/Rooflight	1.6

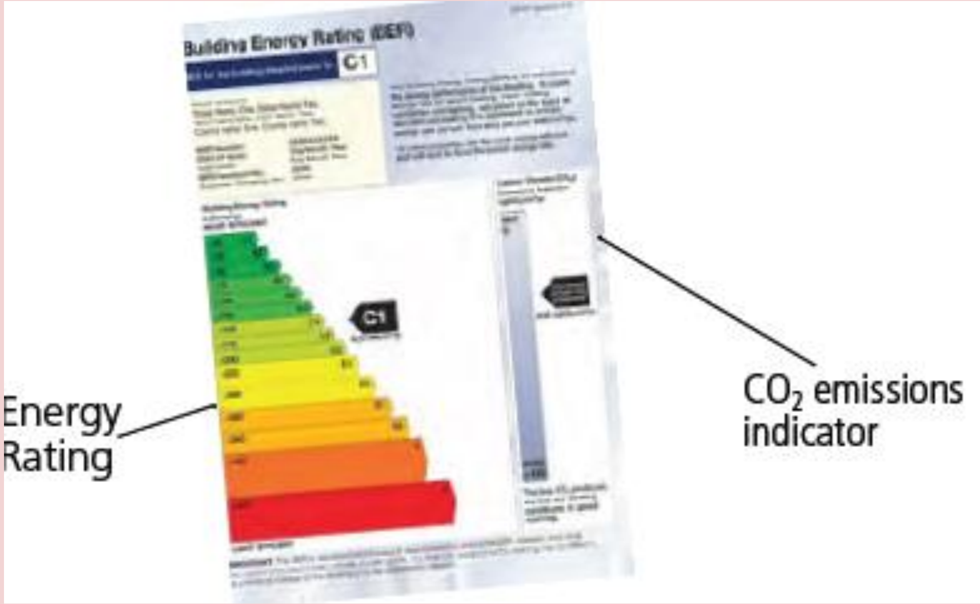
Building Energy Rating (BER)

- BER gives an assessment of the efficiency of the home.
- It considers:
  - The energy used by the building
  - The CO_2 output of the building
- It is expressed as primary energy use per unit of floor area per year

$kWh/m^2/yr$

Building Energy Rating (BER)

- Energy ratings are scaled between A-G.
- Every house sold or rented must have a BER.
- BER certification lasts for 10 years.



U-Value Calculations

- Each material has a different U-value. This should be supplied by the manufacturer.
- They are collected together in a table of thermal conductivity.
- When calculating the U-value of a building element such as a wall, the total thermal resistance of each material are added together.

Terminology for Calculations

Conductivity (k)	$k = \frac{1}{r}$	(W/mK)
Resistivity (r)	$r = \frac{1}{k}$	(mK/W)
Thickness (T) measured in metres		(m)
Resistance (R)	$R = r \times T$ or $R = \frac{T}{k}$	(m^2K/W)
U-value	$= \frac{1}{R^T}$	(W/m^2K)

U-Values

CALCULATION #1

Calculating U-Values

Calculation

Leaving Certificate Higher Level 2010 Question 5 (a)

Calculate the U-value of an uninsulated external solid concrete wall of a dwelling house built in the 1950s given the following data:

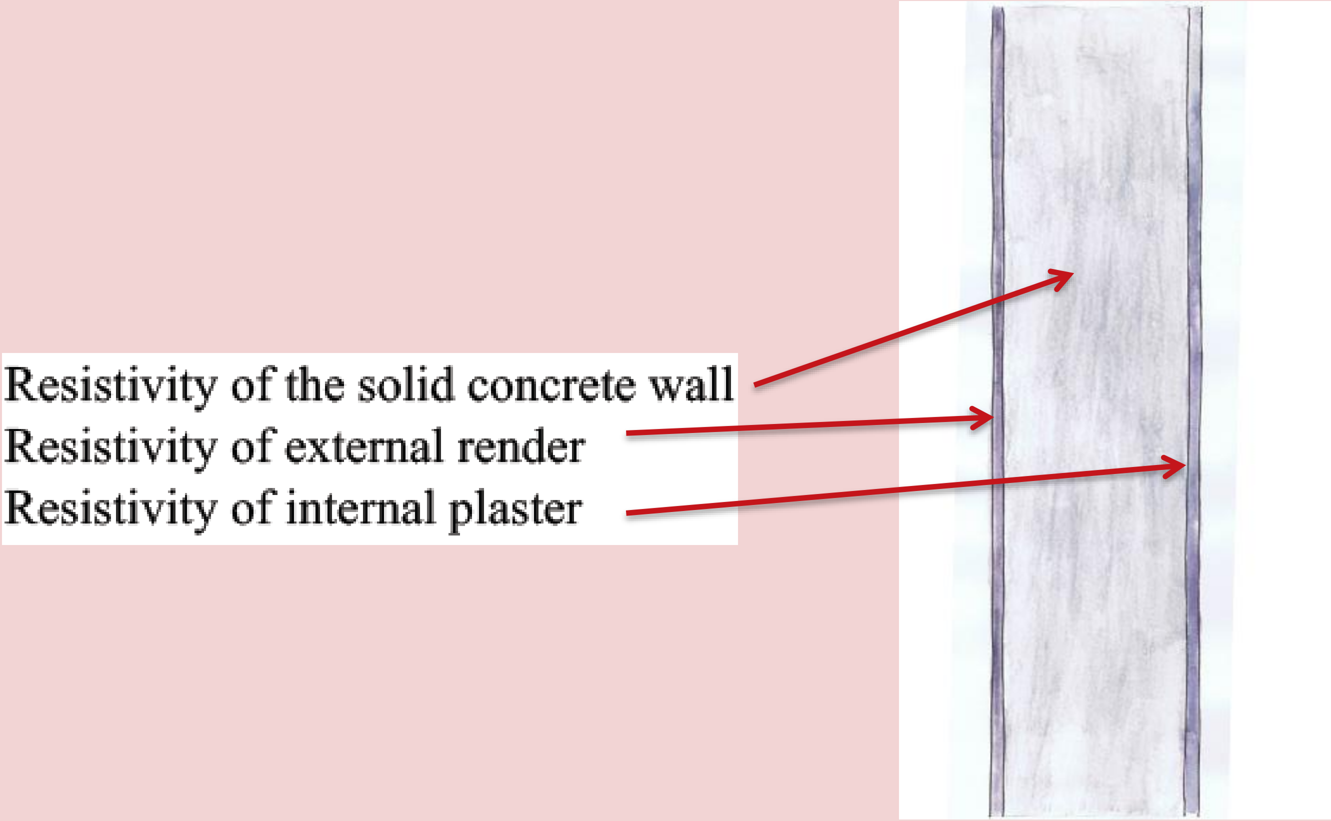
External render	thickness	16 mm
Solid concrete wall	thickness	225 mm
Internal plaster	thickness	13 mm

Thermal data of external wall of house:

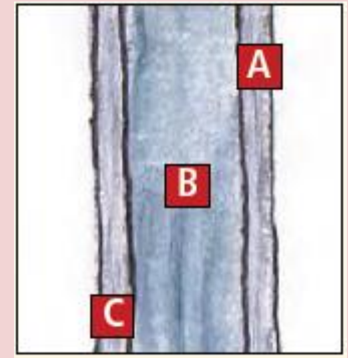
Resistivity of the solid concrete wall	(r)	1.190 m °C/W
Resistivity of external render	(r)	2.170 m °C/W
Resistivity of internal plaster	(r)	6.250 m °C/W
Resistance of external surface	(R)	0.048 m^2 °C/W
Resistance of internal surface	(R)	0.122 m^2 °C/W

Draw a sketch of the building element which you are calculating.

STEP 1



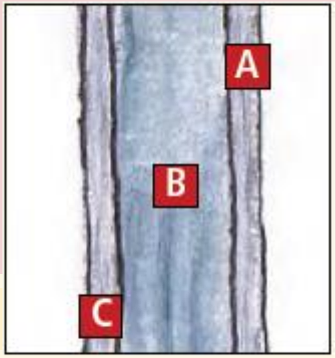
Draw the table as below.



STEP 2

Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
Internal surface	–	–	–	0.122
A Internal plaster		6.250	0.013	
B Solid concrete wall		1.190	0.225	
C External render		2.170	0.016	
External surface	–	–	–	0.048

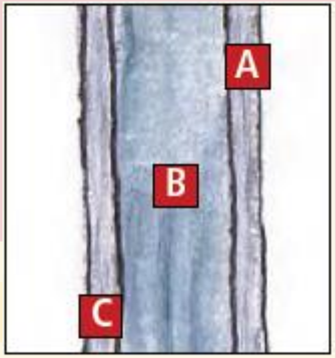
Fill in the resistance values.



STEP 3

Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
Internal surface	–	–	–	0.122
A Internal plaster	0.16	6.250	0.013	0.08125
B Solid concrete wall	0.84	1.190	0.225	0.26775
C External render	0.46	2.170	0.016	0.03472
External surface	–	–	–	0.048

Add the total resistance.



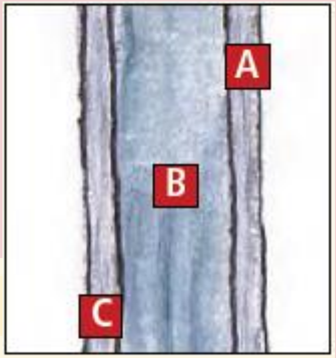
STEP 4

Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
Internal surface	–	–	–	0.122
A Internal plaster	0.16	6.250	0.013	0.08125
B Solid concrete wall	0.84	1.190	0.225	0.26775
C External render	0.46	2.170	0.016	0.03472
External surface	–	–	–	0.048

Find R^T by adding all values in the resistance column.

$R^T = 0.55372$

Draw the table as below.



STEP 5

- U-value is found by getting $\frac{1}{R_T}$
- U-value = 1.8 W/m^2K
- This does not fit with modern building regulations as per table below.

TABLE 16.1 CURRENT (2011) BUILDING REGULATIONS

Building element	Maximum acceptable U-value (W/m^2k)
Roof (pitched with horizontal insulation)	0.16
Roof (pitched with parallel insulation)	0.16
Roof (flat)	0.2
Wall	0.21
Floor	0.21
Window/Door/Rooflight	1.6

Increasing U-Value

- By including a cavity in the wall you can increase the thermal efficacy of the wall.

U-Values

CALCULATION #2

Calculating U-Values

Calculate the U-value for the external wall of a house using the data in Table 16.4.

TABLE 16.4

External render: thickness 19mm Aerated block outer leaf: thickness 100mm Cavity width: 150mm Extruded polystyrene insulation: thickness 100mm Aerated block inner leaf: thickness 100mm Internal plaster: thickness 15mm	***Thermal data of external wall:*** Conductivity of render (k) 0.57 W/mK Conductivity of blockwork (k) 0.18 W/mK Conductivity of insulation (k) 0.025 W/mK Conductivity of plaster (k) 0.18 W/mK Resistance of external surface (R) 0.053 m²K/W Resistance of cavity (R) 0.176 m²K/W Resistance of internal surface (R) 0.123 m²K/W

Draw a sketch of the building element which you are calculating.

STEP 1

External render: thickness 19mm

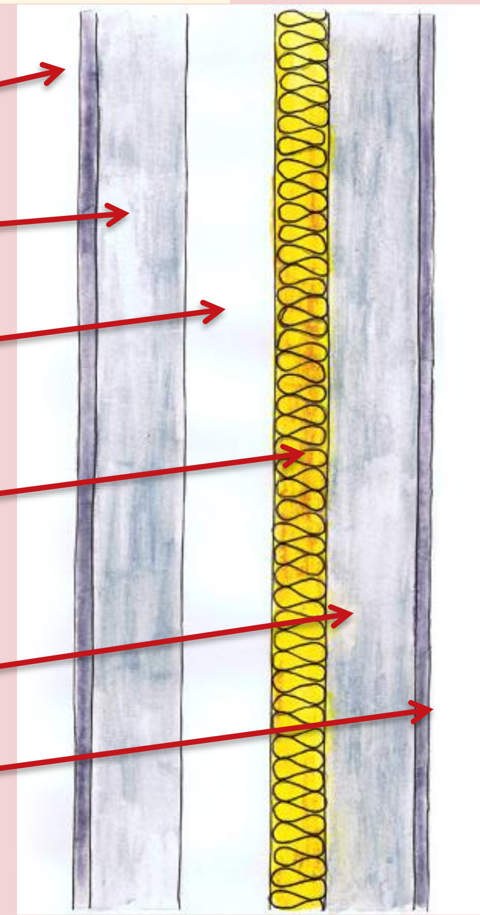
Aerated block outer leaf: thickness 100mm

Cavity width: 150mm

Extruded polystyrene insulation: thickness 100mm

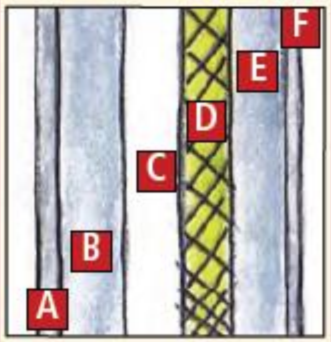
Aerated block inner leaf: thickness 100mm

Internal plaster: thickness 15mm



Draw the table as below.

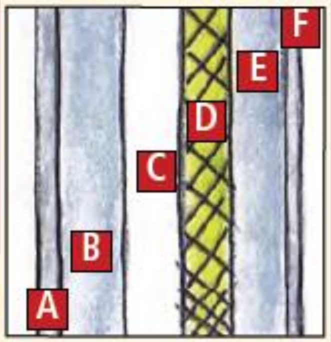
STEP 2



Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
External surface	–		–	0.053
A External render	0.57		0.019	
B Block outer leaf	0.18		0.1	
C Cavity	–		–	0.176
D Insulation	0.025		0.1	
E Block inner leaf	0.18		0.1	
F Internal plaster	0.18		0.015	
Internal surface	–		–	0.123

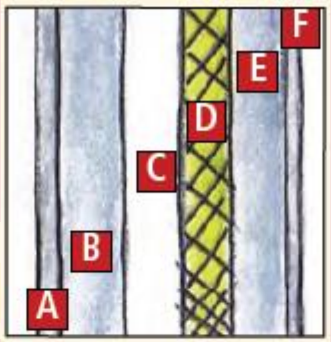
Fill in the resistance values.

STEP 3



Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
External surface	–	–	–	0.053
A External render	0.57	1.754	0.019	0.033
B Block outer leaf	0.18	5.555	0.1	0.555
C Cavity	–	–	–	0.176
D Insulation	0.025	40	0.1	4
E Block inner leaf	0.18	5.555	0.1	0.555
F Internal plaster	0.18	5.555	0.015	0.083
Internal surface	–	–	–	0.123

Add the total resistance.



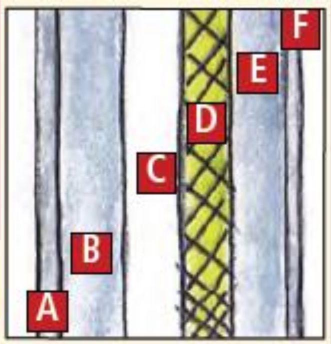
STEP 4

Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
External surface	–	–	–	0.053
A External render	0.57	1.754	0.019	0.033
B Block outer leaf	0.18	5.555	0.1	0.555
C Cavity	–	–	–	0.176
D Insulation	0.025	40	0.1	4
E Block inner leaf	0.18	5.555	0.1	0.555
F Internal plaster	0.18	5.555	0.015	0.083
Internal surface	–	–	–	0.123

Find R^T by adding all values in the resistance column.

$R^T = 5.578$

Draw the table as below.



STEP 5

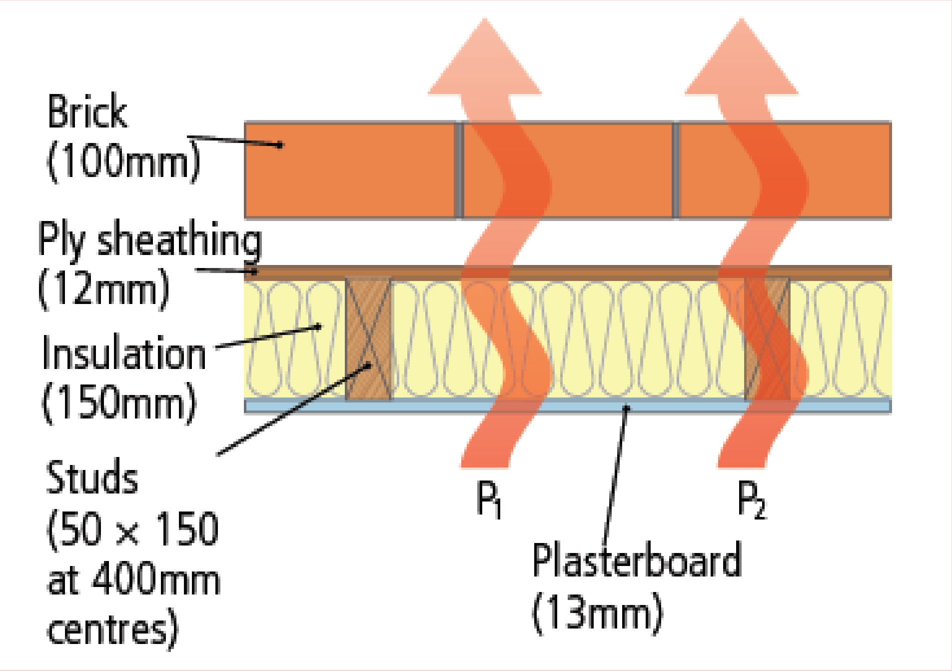
- U-value is found by getting $\frac{1}{R_T}$
- U-value = 0.18 W/m^2K
- This does fit with modern building regulations as per table below.

TABLE 16.1 CURRENT (2011) BUILDING REGULATIONS

Building element	Maximum acceptable U-value (W/m²k)
Roof (pitched with horizontal insulation)	0.16
Roof (pitched with parallel insulation)	0.16
Roof (flat)	0.2
Wall	0.21
Floor	0.21
Window/Door/Rooflight	1.6

Calculating U-Values with two heat paths

- In some building elements there is more than one way for heat to travel.
- For example, in timber frame construction
  - P_1 through the insulation
  - P_2 through the timber stud



U-Values

CALCULATION #3

Calculating U-Values

Calculation

Calculate the U-value for the timber frame wall using the following data:

Brick: thickness 100mm Cavity: thickness 50mm Ply sheathing: thickness 12mm Insulation: thickness 150mm Studs: thickness 150mm Plasterboard: thickness 13mm	***Thermal data of timber frame wall:*** Conductivity of brick (k) 0.77 W/mK Conductivity of ply sheathing (k) 0.13 W/mK Conductivity of insulation (k) 0.024 W/mK Conductivity of studs (k) 0.13 W/mK Conductivity of plasterboard (k) 0.25 W/mK Resistance of external surface (R) 0.053 m^2K/W Resistance of cavity (R) 0.176 m^2K/W Resistance of internal surface (R) 0.123 m^2K/W

Draw a sketch of the building element you are calculating.

STEP 1

Brick: thickness 100mm

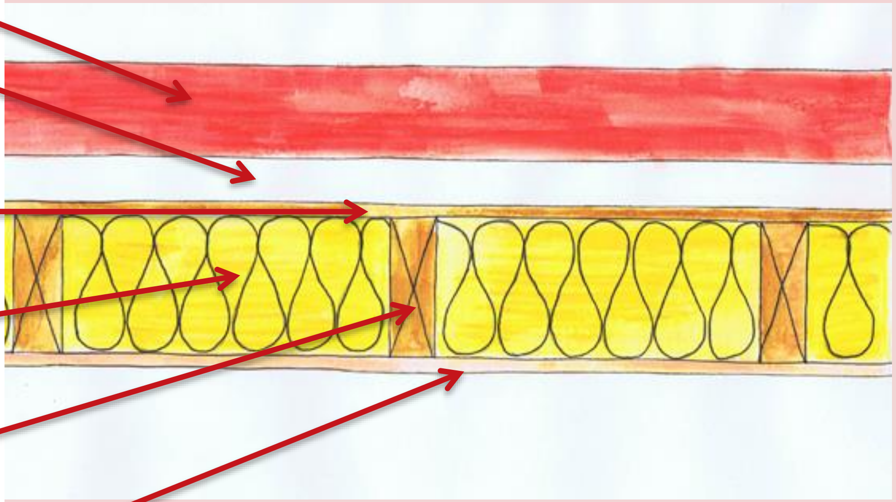
Cavity: thickness 50mm

Ply sheathing: thickness 12mm

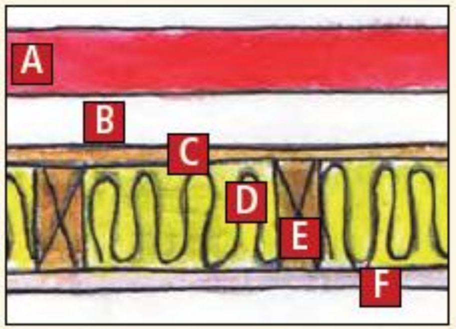
Insulation: thickness 150mm

Studs: thickness 150mm

Plasterboard: thickness 13mm



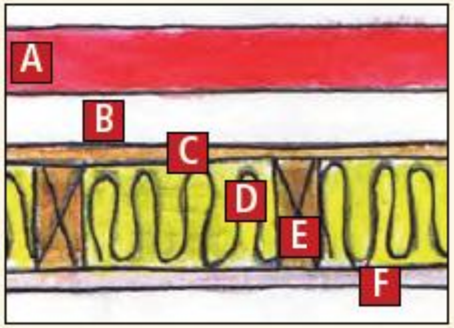
Draw the table as below.



STEP 2

Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
External surface	–	–	–	0.053
A Brick	0.77		0.1	
B Cavity	–	–	–	0.176
C Ply sheathing	0.13		0.012	
D Insulation	0.024		0.150	
E Studs	0.13		0.150	
F Plasterboard	0.25		0.013	
Internal surface	–	–	–	0.123

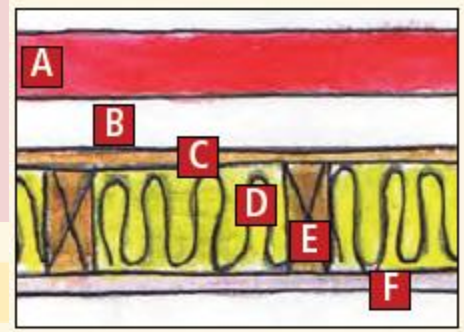
Fill in the resistance values.



STEP 3

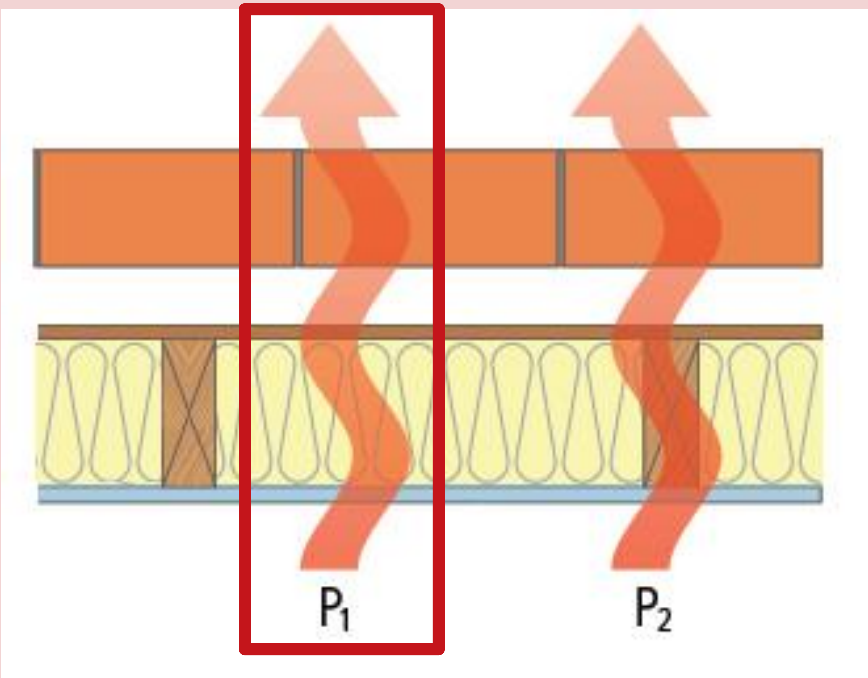
Element	Conductivity $k = \frac{1}{r}$	Resistivity $r = \frac{1}{k}$	Thickness (m)	Resistance $R = r \times T$ $R = \frac{T}{k}$
External surface	–	–	–	0.053
A Brick	0.77	1.3	0.1	0.129
B Cavity	–	–	–	0.176
C Ply sheathing	0.13	7.69	0.012	0.092
D Insulation	0.024	41.67	0.150	6.25
E Studs	0.13	7.69	0.150	1.153
F Plasterboard	0.25	4	0.013	0.052
Internal surface	–	–	–	0.123

Add the total resistance for each path (Path 1).



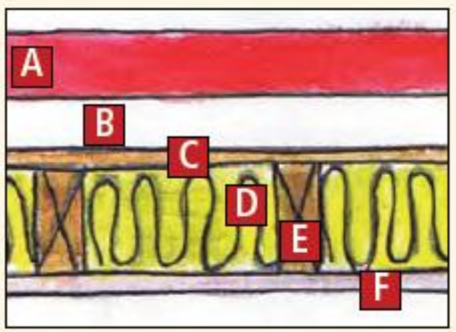
STEP 4

INSULATION PATH (1)	
Element	**Resistance**
External surface	0.053
Brick	0.129
Cavity	0.176
Ply sheathing	0.092
Insulation	6.25
Plasterboard	0.052
Internal surface	0.123



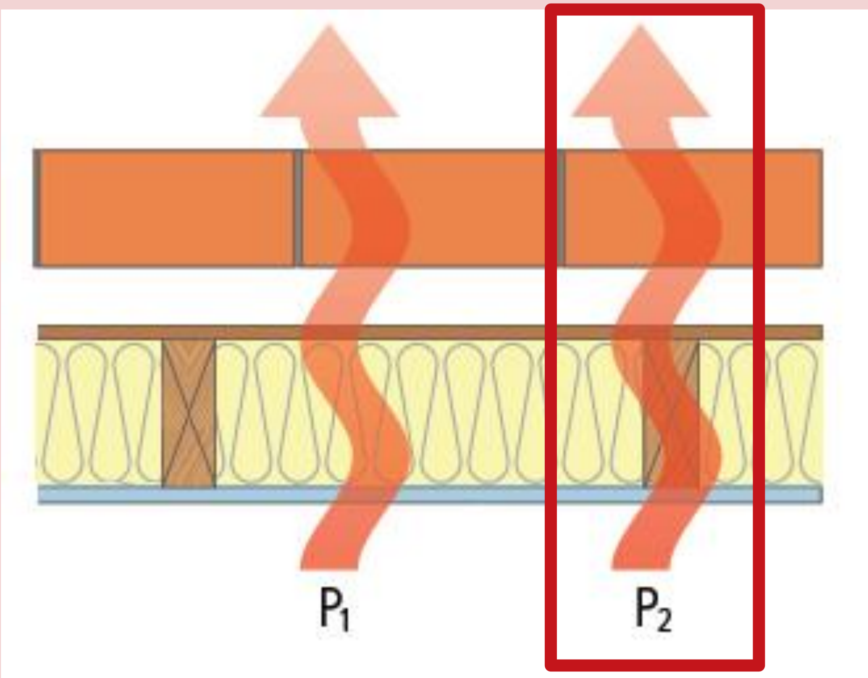
Path (1) $R^T = 6.87\ m^2\ K/W$

Add the total resistance for each path (Path 2).



STEP 4

INSULATION PATH (2)	
Element	**Resistance**
External surface	0.053
Brick	0.129
Cavity	0.176
Ply sheathing	0.092
Studs	1.153
Plasterboard	0.052
Internal surface	0.123



Path (2) $R^T = 1.78\ m^2\ K/W$

To calculate combined upper resistance

STEP 4

$$R_U = \frac{1}{\left[\left(\frac{F_1}{R_1}\right)+\left(\frac{F_2}{R_2}\right)\right]}$$

Where:

F_1 is the fractional area of heat flow through path 1 (the % make-up of the material)

F_2 is the fractional area of heat flow through path 2

R_1 is the total resistance of path 1

R_2 is the total resistance of path 2

To calculate combined upper resistance

STEP 4

$$R_U = \frac{1}{\left[\left(\frac{F_1}{R_1}\right)+\left(\frac{F_2}{R_2}\right)\right]}$$

$$R_U = \frac{1}{\frac{0.875}{6.87}+\frac{0.125}{1.78}}$$

Where:

$F_1 = 0.875$

$F_2 = 0.125$

$R_1 = 6.87$

$R_2 = 1.78$

$$R_U = \frac{1}{0.197}$$

To calculate combined lower resistance

STEP 5

$$R_b = \frac{1}{\frac{F_1}{R_1} + \frac{F_s}{R_s}}$$

Where:

F_1 is the fractional area of heat flow through path 1 (the % make-up of the material)

F_2 is the fractional area of heat flow through path 2

R_1 is the total resistance of insulation

R_2 is the total resistance of studs

To calculate combined upper resistance

STEP 5

$$R_b = \frac{1}{\frac{F_1}{R_1} + \frac{F_S}{R_S}}$$

$$R_b = \frac{1}{\frac{0.875}{6.25} + \frac{0.125}{1.153}}$$

Where:

$F_1 = 0.875$

$F_S = 0.125$

$R_1 = 6.25$

$R_S = 1.153$

$$R_b = \frac{1}{0.248} = 4$$

$R_b = 4m^2K/W$

Feed the bridged value into the table.

STEP 6

Element	Resistance
External surface	0.053
Brick	0.129
Cavity	0.176
Ply sheathing	0.092
Bridged section	4
Plasterboard	0.052
Internal surface	0.123

Total lower resistance (R_L) = 4.62m^2K/W

Using upper and lower resistance in a formula

STEP 7

$$R^T = \frac{R_U + R_L}{2}$$

$$R^T = \frac{5.07 + 4.62}{2}$$

$$R^T = \frac{9.69}{2}$$

$$= 4.845$$

Use the total resistance to find the U-value.

STEP 8

$$\frac{1}{R^T} = \text{U-value}$$

U-value = 0.2W/m^{2}K

Calculating costs

- The heat loss of a building can be calculated when we have:
  - the U-value
  - the area of the building
  - the difference in internal and external temperature
- It we know the fuel type and the price of that fuel, we can also calculate the cost of heat loss.

Calculating Costs

CALCULATION #3

Heat loss formula

STEP 1

Total heat loss = U-value x area x temperature difference

Heat loss is measured in Watts

Total heat loss = 0.1645 x 152 x 11 = 275.044 Watts

1 watt = 1 joule per second, therefore 275.044 watts = 275.044 joules per second

To calculate how much heat is lost per year

STEP 2

- Heating period is:

  (weeks per year) X (days per week) X (hours per day) X (minutes per hour) X (seconds per hour)

  = 41 X 7 X 11 X 60 X 60 = 11365200 seconds

Total number of kilojoules per year calculated

STEP 3

$$= \frac{11365200 \times 275.044}{1000}$$

= 3125930 kJ per year

$$\frac{\text{Total oil}}{\text{calorific value}} = \frac{3125930}{37350} = 83.69 \text{ litres}$$

To find cost per year

STEP 4

- Cost per year is:

  Number of litres X price per litre

  = 83.69 X 0.88

  = €73.65