Abstract
In this paper we examine the key physical aspects required for a car to ignite Asphalt by driving over the surface, as seen in the highly popular 1985 film "Back to the Future". We calculated the energy transferred through the tyres to the road, and found that the car dissipates around 40 % of the energy required to ignite the road surface. Subsequently, we concluded that to create the fiery visuals as seen in the film the car would have to undergo instantaneous acceleration equivalent to 136 G-force.

Introduction
The highly popular, 1985 film "Back to the future" relies upon the use of time travel for its narrative. In order to travel in time the characters must drive a DMC DeLorean at a speed of 88 mph (39.3 ms$^{-1}$). As the car reaches this threshold it leaves the current time, leaving two flaming streaks on the road extending from the contact points.

In this paper we look to calculate whether it is physically possible for tyres to set fire to the road surface whilst travelling at 39.3 ms$^{-1}$. We will be using the specific scene in which Marty first travels in time, as it allows us to make as little assumptions as possible.

Analysis
From the scene we can see that the initial speed of the car was roughly travelling at 15.6 ms$^{-1}$ before beginning the acceleration to 39.3 ms$^{-1}$. By using Google Maps we can determine that the distance covered during the acceleration is approximately 120 metres in length. Therefore, our initial parameters can be taken as $v_0 = 15.6$ ms$^{-1}$ and $s = 120$m. Using the equation of motion,

$$v_1^2 = v_0^2 + 2as$$

where $v_1$ is the final velocity, $v_0$ is the initial velocity, $a$ is the acceleration and $s$ is the displacement. Using $v_1 = 39.3$ms$^{-1}$ we can rearrange Eq. (1) to calculate acceleration. Assuming the car accelerates linearly, this acceleration is calculated to be 5.42ms$^{-2}$.

By equating the forces acting on the car we can calculate the thrust force $F_T$.

$$F_T = ma + mg\mu$$

Where, $m$ is the mass of the car, $g$ is acceleration due to gravitational forces (9.81 ms$^{-2}$) and $\mu$ is the coefficient of friction between the tyres and the road surface. $\mu$ is assumed to be equal to 0.9 [5].

As we are assuming this scenario involves a standard model DeLorean, we can take the mass to be 1233 kg [1]. Inputting the values into Eq. (2) gives, $F = 17570$ N of frictional force acting
on the car. Dividing by four gives us the fric-
tional force acting on one individual tyre, this
helps us to isolate the system, and gives a force
per tyre of \( F_{\text{tyre}} = 4392 \text{ N} \).

To calculate the energy dissipated by each tyre
we must determine the work done by friction
\( W_{\text{tyre}} \), this energy would be dissipated into the
rod surface as heat.

\[
W_{\text{tyre}} = F_{\text{tyre}}s \quad (3)
\]

Using Eq. 3, an energy dissipation was calcu-
lated as \( W_{\text{tyre}} = 527 \text{ kJ} \).

We are going to assume that the road surface
is constructed from asphalt, as this material is a
common road surface in California, USA, where
the film is set. Asphalt ignites at temperatures
around 673 K [2]. To determine the required
thermal energy that would cause such an ignition
we used the equation for heat capacity,

\[
Q = m_{\text{road}}c\Delta T \quad (4)
\]

where \( Q \) is the heat energy, \( m_{\text{road}} \) is the
mass of the surface layer of the road, \( c \) is the
heat capacity of the road surface, given a value of
0.92 \( \text{kJkg}^{-1}\text{K}^{-1} \), and \( \Delta T \) is the change in tem-
perature required. As we can assume the road
surfaces ambient temperature is around 298 \( K \),
the temperature change is roughly 375 \( K \).

To determine the value for \( m_{\text{road}} \) that will un-
dergo rapid ignition, we can multiply the den-
sity by the surface area of the tyre by a small
depth of 1 cm. The density was taken as 1180
kgm\(^{-3}\) [2] and the surface are of the tyre is cal-
culated as 0.317 m\(^2\) [3]. Thus, we found that
\( Q = 1291 \text{ kJ} \) is the required, near instantaneous,
energy dissipation to cause an ignition of a tyre-
length section of asphalt. Unfortunately, over a
distance of 120 m each tyre only dissipates a to-
total of \( W_{\text{tyre}} = 527 \text{ kJ} \), which is only around 40 \%
of the required thermal energy. And thus whilst
travelling at 39.3 \( \text{ms}^{-1}\) the scene in the film is
physically inaccurate (and not just with regard
to the fire either).

However, if we assume that the ignition is to
occur within one whole tyre rotation due to an
acceleration that occurs after 39.3 \( \text{ms}^{-1}\) due to
the time travel, we can work out the required
speed to cause the ignition.

We subtracted \( W_{\text{tyre}} \) from the value for \( Q \), we
find that \( \Delta W = 764 \text{ kJ} \), this is the change in
work done required over a tyre length of around
1.8 m, which is the circumference of the tyre [3].
By substituting the value for \( \Delta W \), and with \( s =
1.8 \text{ m} \) into Eq. (3) we can determine the change
in force required. This value works out as \( \Delta F =
424. \text{ kN} \).

By subtracting \( F_{\text{tyre}} \) from \( \Delta F \) and substitut-
ing this value into Eq. 2, we can solve for \( a \).
Therefore we can determine the near instantan-
eous acceleration required from 39.3 \( \text{ms}^{-1}\) to
cause ignition of the road surface at the tyre con-
tact points. This gives us an instantaneous ac-
celeration of \( a = 1354 \text{ ms}^{-2} \), which is equivalent
to about a G-force of 138.

Put into context these values would place
Marty McFly in very life threatening condi-
tions, as he would experience higher G-forces
than any human has undergone in a controlled
environment[4] by a factor of approximately
three.

References